A STUDY OF FACTORS AFFECTING SURVIVAL FROM BIRTH TO WEANING AND TOTAL WEANING WEIGHT OF THE LITTER IN SWINE

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PRODUCTIVITY in brood sows during the pre-weaning period is measured by fertility, survival of the pigs born, and milk production. All three of these factors contribute to a large extent to the total weaning weight of the respective litters and are of individual economic importance to the hog producer. Therefore, from the breeder’s standpoint, it is important to know to what extent these factors are related to one another or influenced by other factors in order to select effectively for greater productivity in the breeding herds already established or in the development of improved lines.

High survival of the pigs born is an important goal of all swine raisers. Even though improved methods in management and certain methods of breeding have helped to lower the death loss of little pigs the problem is still of major importance. From a study of several herds under varying conditions Kernkamp (1943, 1946) found that the average loss of little pigs during the suckling period was about 25 percent and that the losses were due to more than 35 different diseases, disorders, or conditions. The death rate was highest in pigs up to one to two weeks of age and was reduced as they grew older.

The early experiments in guinea pigs by Wright (1922) and in swine by McPhee et al. (1931) and others have shown that a rapid increase in inbreeding had a deleterious effect upon the vitality of the newborn and thus reduced survival considerably in most instances. They also found that there was a decided decrease in weaning weights of the young as the inbreeding increased. This was reflected in a lower total weaning weight of the litter as inbreeding had decreased the size of the litters. Winters et al. (1943), by the use of a flexible program of inbreeding and rigid selection for all traits connected with vigor, reported an ability to maintain survival and weaning weight at a relatively high level as the inbreeding increased. It is generally

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acknowledged also that crossbreeding increases the vigor of new born pigs which is reflected in higher survival and higher weaning weights.

There is apparently a relationship between size of litter and survival and, according to most reports, a higher percentage of the pigs born die before weaning in the larger litters. Studies of Bywaters (1937) on Poland China hogs, indicate that litter size has little effect on average weaning weight for he found that only three percent of the total variance in the average weaning weights was attributable to the size of the litter. In a report of a study on Large White hogs, Smith and Donald (1937) suggest that there is a relationship between fertility and milk production, the latter increasing with fertility but not to a large enough extent to give each pig in a large litter the same chance as those in the small litter. They concluded (in accordance with other reports) that there was too much variation within the litters to account for much of a relationship between litter size and individual weaning weight. Undoubtedly, the relationship between fertility and milk production is quite variable in itself; for, even though his observations were limited, Donald (1937) was able to demonstrate considerable differences in milk production between sows of the same fertility. Later he (Donald, 1939) showed that the sow's influence on the growth of the pig up to weaning was great enough to cover up the individual pig effects. The influence of milk production on weaning weights is also brought out in the study by Zeller et al. (1937).

Weaver and Bogart (1943), Meyer (1940), and Lüthge (1933) found that there was a greater percentage of pigs raised in litters having a higher average birth weight, but this may have been associated more with size of litter as the smaller litters were composed of larger pigs. Wright (1922) indicated that there might be some physiological interrelation between birth weight, gain, and size of litter. A positive correlation between birth weight and weaning weight in pigs was indicated by Weaver and Bogart (1943) and Lush and Culbertson (1931).

Among the most important effects upon survival are those due to heredity and individuality of the parents. Wright (1922) first brought this out in the inbreeding study with guinea pigs where he found that the average success of the different families in raising their young was not correlated with weight nor with size or frequency of litters. He also found no significant correlation between the percentage born alive and that raised although success or failure in each separately was undoubtedly characteristic of the families. Hodgson (1935) points out that temperament of the sow is extremely important in her rearing ability and he found definite line differences in this respect which were reflected quite unmistakably in the results obtained. Lush et al. (1933), Lush and Molln (1942), Lüthge (1933) and Olbrycht (1943) also re-
ported that individual differences between sows had considerable effect. In an inbreeding study with Chester Whites, Hetzer et al. (1940) found significant differences between individual sires in the number of pigs alive at 28 days and at 70 days even though there were no differences in the size of litters at birth.

In the present study it was proposed to determine what effects inbreeding, size of litter, and birth weight had upon survival of the litter from birth to weaning and upon the total weaning weight of the litter in the hogs used in the Minnesota swine breeding project.

**Materials and Methods Used**

The data used included those collected from the farrowing and preweaning records from 1937–1944 of the hogs maintained at six of the sub-stations of the Minnesota Agricultural Experiment Station. Only gilt litters farrowed in the spring were used in order to eliminate most of the age and seasonal effects. Altogether, 745 litters composed of 5562 pigs born alive, of which 3918 survived to weaning, were included in the study. These pigs were from 14 inbred lines of which 12 were developed within the Poland China breed, one of them (Minn. No. 1) was developed from a Landrace-Tam-

<table>
<thead>
<tr>
<th>Group</th>
<th>No. of sire groups</th>
<th>No. of litters</th>
<th>No. of pigs born alive per litter</th>
<th>Surviv. %</th>
<th>Birth wt. per pig in each litter</th>
<th>Total 56-day wt. of litter, lbs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cent.</td>
<td>P. C.</td>
<td>All</td>
<td>19</td>
<td>44</td>
<td>64.3</td>
<td>135.8</td>
</tr>
<tr>
<td>W. C.</td>
<td>P. C.</td>
<td>All</td>
<td>44</td>
<td>170</td>
<td>79.7</td>
<td>3.96</td>
</tr>
<tr>
<td>C.</td>
<td>No. 1</td>
<td>214</td>
<td>8.8</td>
<td>71.8</td>
<td>2.80</td>
<td>189.8</td>
</tr>
<tr>
<td>E.</td>
<td>No. 2</td>
<td>4</td>
<td>18.8</td>
<td>99.7</td>
<td>2.67</td>
<td>274.1</td>
</tr>
<tr>
<td>W.</td>
<td>P. C.</td>
<td>All</td>
<td>20</td>
<td>129</td>
<td>61.7</td>
<td>2.74</td>
</tr>
<tr>
<td>S.</td>
<td>No. 3</td>
<td>6</td>
<td>21.5</td>
<td>62.6</td>
<td>2.74</td>
<td>114.0</td>
</tr>
<tr>
<td>E.</td>
<td>No. 1 X P. C.</td>
<td>2</td>
<td>35.5</td>
<td>64.3</td>
<td>2.69</td>
<td>140.1</td>
</tr>
<tr>
<td>P. C.</td>
<td>M</td>
<td>1</td>
<td>75.0</td>
<td>100.0</td>
<td>2.96</td>
<td>276.5</td>
</tr>
<tr>
<td>C.</td>
<td>G</td>
<td>3</td>
<td>55.0</td>
<td>70.0</td>
<td>3.31</td>
<td>275.3</td>
</tr>
<tr>
<td>G.</td>
<td></td>
<td>16</td>
<td>11.1</td>
<td>34.5</td>
<td>3.33</td>
<td>59.3</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>145</td>
<td>745</td>
<td>70.4</td>
<td>2.84</td>
<td>161.4</td>
</tr>
</tbody>
</table>

1 Total No. pigs born alive = 5562. Total No. pigs weaned = 3918.
worth crossbred foundation (Winters et al., 1943), and the other line (Minn. No. 2) is being developed from a Poland China-Yorkshire crossbred foundation. In addition, eight miscellaneous Poland China line-crosses are included. The methods of keeping records, the data collected, feeding and managerial practices, and the breeding program are all described by Winters et al. (1943).

Table 1 gives the mean values of the factors analyzed by different breed and line groups. Survival was determined by the ratio of the number of pigs alive at weaning (56 days of age) to the number born alive in each litter and was expressed in percentage. The inbreeding coefficients for both the dams and their litters were calculated according to Wright’s (1922 b) method.

The litters were grouped by years and by sires, and intra-sire, intra-year regressions calculated from analyses of covariance were used to determine the relationships between the factors referred to above and survival and total weaning weight of the litter. The intra-sire variance and covariance were used in order to eliminate the hereditary effects transmissible by the different boars. The values for survival were transformed from percentage to angles expressed in degrees. These transformations are given in table form by Snedecor (1940) and the advantages and reasons for using transformed values instead of the actual percentages are discussed by him and by Clark and Leonard (1939).

Results and Discussion

Factors influencing survival

The first phase of the study was made to determine the effects of the inbreeding of the dam, the inbreeding of the litter, size of litter at birth, and birth weight of the pigs on survival. These relationships are expressed by

| \( g/b \) | 8.55 | \( g/b \cdot c \) | 12.36 | \( g/b \cdot d \) | 1.61 |
| \( g/c \) | -7.16 | \( g/c \cdot b \) | -12.30 | \( g/c \cdot d \) | -14.86 |
| \( g/d \) | -1.66** | \( g/d \cdot b \) | 1.66** | \( g/d \cdot c \) | 1.69** |
| \( g/h \) | 17.05** | \( g/h \cdot d \) | 15.70** | \( g/b \cdot c d \) | 7.02 |

** Significant at 1 percent level.
simple and partial regressions in table 2. Intra-sire regressions were used in all cases.

From the above table it is evident that the effects of inbreeding, either of the dams or their litters, on survival are not statistically significant. In addition, these regressions are quite small indicating only slight effects or trends when one considers that the unit increase for inbreeding used to calculate the above regressions is 1.00 or 100 percent. Taking the regression $g/b$ as an example, there was only 8.55 degrees (equivalent to 2.2 percent) increase in survival accompanying 100 percent increase in the inbreeding coefficient or 0.855 degrees (equivalent to 0.02 percent) increase in survival for ten percent increase in inbreeding. However, it is interesting to note that the regressions of survival on inbreeding of the dam are in the positive direction while those of survival on inbreeding of the litter are all negative. This might be explained by the fact that during the entire course of the swine breeding project at Minnesota, considerable emphasis has been placed upon the selection of future breeding stock from litters showing the greatest vitality which has tended to maintain a certain level in survival regardless of the depressing effects of inbreeding in the litters. The above data for the dams are biased in so far as only enough gilts from highest performing litters have been retained for the succeeding generations, and consequently breeding records on all females produced were not available. When considering this fact and the one that the inbreeding increased progressively with each succeeding generation, the positive relationship between inbreeding of the dams and survival definitely indicates that selection for higher survival has been effective. Further evidence for the above fact was found in another study by the authors where they obtained the relatively high heritability estimate for survival of 40.3 percent for the same populations from which these data were drawn (Cummings et al. 1946). Also, a more flexible program of increasing the inbreeding and of selection has been used in this project than that used by other workers who obtained rapid decline in vigor due to inbreeding.

An increase in the size of litter had a depressing effect upon survival. However, its effect was quite small and about the same when inbreeding of the dams and litters was held constant. When the effects of the average birth weight were held constant this relationship was no longer statistically significant indicating that average birth weight was a more important factor than either size of litter or inbreeding.

From the regressions, $g/d.h$, $g/h$ and $g/h.d$ it is seen that the chances for survival were greatest for the heavier pigs at birth regardless of the size of litter even though there was a significant negative correlation between average birth weight and size of litter ($r = -.32$). This indicates a strong physiological interrelationship.
Factors influencing total weaning weight of the litter

The effects of the same factors referred to above on total weaning weight of the litter at 56 days of age are given by intra-sire regressions in Table 3.

Again, neither the inbreeding of the dams nor the inbreeding of the litter had a significant effect upon total weight of the litter at weaning. The regression \( i/c \) was significant at the 5 percent level, but apparently the effects of \( c \) included more than those associated with just inbreeding of the litter. This relationship does not hold up for this regression was no longer significant when the effects of the inbreeding of the dam and the size of the litter were held constant. Again selection for total weaning weight has been some

**Table 3. Within Group Simple and Partial Regressions:**

<table>
<thead>
<tr>
<th>Simple regressions</th>
<th>Partial regressions</th>
<th>Partial regressions</th>
<th>Partial regressions</th>
</tr>
</thead>
<tbody>
<tr>
<td>( i/b = 98.35 )</td>
<td>( i/b.c = 57.71 )</td>
<td>( i/b.d = 33.17 )</td>
<td>( i/b.cd = 8.44 )</td>
</tr>
<tr>
<td>( i/c = -155.12^* )</td>
<td>( i/c.b = -131.14 )</td>
<td>( i/c.d = -84.49 )</td>
<td>( i/c.bd = -81.04^* )</td>
</tr>
<tr>
<td>( i/d = 15.64^** )</td>
<td>( i/d.b = 15.57^** )</td>
<td>( i/d.c = 15.49^** )</td>
<td>( i/d.cb = 15.48^** )</td>
</tr>
<tr>
<td>( i/g = 1.97^** )</td>
<td>( i/g.d = 2.32^** )</td>
<td>( i/g.h = 2.07^** )</td>
<td>( i/g.dh = 2.24^** )</td>
</tr>
<tr>
<td>( i/h = 18.41^** )</td>
<td>( i/h.d = 51.02^** )</td>
<td>( i/h.g = -16.93^** )</td>
<td>( i/h.dg = 15.90^** )</td>
</tr>
</tbody>
</table>

* Significant at 5% level.
** Significant at 1% level.

what effective, but not to the same extent as that for survival, since the depressing effects of the inbreeding of the dam have not been as great as those of the inbreeding of the litter. The reasons for this are probably the same as were discussed in regard to the relationships between inbreeding and survival. However, there was a trend for some depressing effect of inbreeding on total litter weight at weaning.

The simple and partial regressions of total weaning weight of the litter on size of litter at birth are all positive and highly significant; and in this study, there was 20.26 pounds increase in the total 56 day weight of the litter for each additional live pig at birth when the effects of survival and birth weight were eliminated. This relationship is to be expected if there was little association between litter size and average weaning weight as reported by other workers.

An increase in survival increased total weaning weight of the litter. These
regressions were highly significant and changed very little when the effects of size of litter and birth weight were eliminated.

Total weaning weight of the litter was increased 15.9 pounds with an increase of one pound in the average birth weight when size of litter and survival are held constant. However, when only the effects of survival were eliminated an increase of one pound in the average birth weight decreased the total weaning weight 16.9 pounds. This last regression is difficult to interpret in relation to the others; but it is probably due to the fact that the heavier pigs at birth were in the smaller litters since there was a significant negative regression of average birth weight on litter size (coef. = -.057). When size of litter at birth was the only other factor held constant the regression of total weaning weight on average birth weight was very large (r/d.h = 51.02) indicating a very strong influence due to birth weight alone.

It is apparent in both phases of this study that, so far as the offspring themselves are concerned, birth weight had the greatest effect upon both survival and total weaning weight of the litter. This fact and the one that there was a strong relationship between survival and total weaning weight indicate that, with the pigs farrowed during the course of the project so far, vitality and growth impulse were apparently interrelated and both were capable of being expressed during prenatal development as well as after birth. This physiological relationship may be explained further as such.

The basis for vitality has been established at a very early stage in each pig's development—probably at the time of fertilization for undoubtedly it is genetic in origin. Vitality or vigor is then manifested in one respect by greater growth and physiological development during the embryonic and fetal periods and finally results in the birth of a heavier pig which has the ability to continue to be vigorous and grow rapidly during the nursing period if the proper environment is provided. The results of the above study would indicate that the basic causes for growth impulse and vitality are certainly closely associated or the same. It need be taken into account, however, that there are a number of complicating effects, such as uterine environment (including size of the litter and position in-utero) and environmental conditions after birth, which will alter this relationship considerably in some instances even though a good basis for growth and survival has already been established.

The authors fully realize that the data presented are somewhat biased inasmuch as they represent a highly selected population in which only the most vigorous individuals were saved for breeders. Nevertheless, the relationships between the factors studied are descriptive of the inbred lines of swine being developed in the Minnesota swine breeding project. Some of the results, especially the effects of inbreeding on vigor, are not what would be expected
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on the basis of most previous inbreeding experiments in swine.

The effects of inbreeding on vigor are interesting and significant in this study since there was not a rapid decline in vigor as inbreeding progressed when using a flexible system and rigid selection. In the case of survival there was practically no decline. Miss King (1918, 1919) actually improved the fertility and size in rats by selection even when using a fixed and rapid system of inbreeding. Therefore, these results, too, are encouraging for they demonstrate the possibility of maintaining many of the elements of vigor when developing inbred lines of livestock with the genetic purity so desirable in breeding animals.

Summary and Conclusions

Data from 745 gilt litters composed of 5562 pigs born alive and of which 3918 pigs survived to weaning were utilized to study the effects of inbreeding, size of litter, and birth weight upon survival and total weaning weight of the litter. These litters included 12 Poland China inbred lines, one Minnesota No. 1 line, one Minnesota No. 2 line, and eight miscellaneous line-crosses.

Neither the inbreeding of the dam nor the inbreeding of the litter had a significant effect upon survival of the pigs from birth to weaning or upon the total weaning weight of the litter.

With the hogs used in this study, it has been shown that selection has been effective in holding survival at a relatively high level for inbred stock in spite of the depressing effects generally associated with inbreeding. Selection was also somewhat effective insofar as total litter weaning weight is concerned but not to as great an extent as for survival.

An increase in the size of the litter at birth reduced the chances for survival; the effects, however, were small. An increase of one pig in the size of litter increased the total weaning weight of the litter on the average by 0.26 pounds, when birth weight and survival were held constant.

Average birth weight of the litter had the greatest effect upon both survival and total weaning weight of the litter. An increase of one pound in average birth weight increased total weaning weight 15.9 pounds.

An increase in survival increased the total weaning weight of the litter.

The analysis of these data indicates a strong interrelationship between vitality and growth impulse both of which were capable of being expressed before birth as well as afterwards. However, the maternal influence has not been separated.

Literature Cited


