THE RELATIONSHIP OF ENVIRONMENT TO SELECTION

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A character expression is the result of the interworkings of inheritance and environment. Because of this, the possible respective effects of both inheritance and environment should be considered in the selection of breeding stock, especially where the objectives are to develop lines for specific purposes.

Attempts have been made to measure the relative importance of heredity and environment. Wright (1) made a study of the relative effects of heredity and environment on amount of white spotting in two stocks of guinea pigs, one that had been highly inbred and the other an outbred population. In actual units of measurements, the variance due to environment was almost the same in the two stocks, .354 for the inbreds and .372 for the outbreds. The per cent of variance due to environment, however, was markedly different in the two stocks; 97.2 per cent of the variance in the inbred stock was due to environment whereas environment was responsible for only 57.8 per cent of the variance in the outbred stock. Heredity was therefore the cause of only 2.8 per cent of the variance in the inbred stock and for 42.2 per cent of the variance in the outbred stock. The reason for the difference was that the inbreeding had purified the one strain to the point where most of the initial hereditary variability for white spotting had been removed.

Lush, Hetzer and Culbertson (2) in a study of the birth weights of pigs came to the conclusion that only 6 per cent of the variance was due to the heredity of the pigs, whereas 94 per cent was due to environmental factors. The 94 per cent was divided equally between the environment common to litter mates and the environment not common to litter mates.

Bywaters (3) in a study of the 60-day weaning weights of Poland China pigs during the early stages of an inbreeding experiment came to the conclusion that only 18 per cent of the variance was due to heredity. Of the remaining 82 per cent, 40 per cent was attributed to environment common to litter mates and 42 per cent to environment not common to litter mates.

The above mentioned experiments are somewhat disconcerting to those of us who have believed that livestock improvement could be advanced rapidly through selection, especially phenotypic selection.
Some care need be exercised, however, that we do not underestimate the influence of heredity. The above mentioned study of spotting in guinea pigs by Wright, while perhaps somewhat surprising in the amount of variance due to environment, actually provides beautiful evidence of the fact that an individual's inheritance circumscribes the individual's possible attainments and that environment determines how far the individual actually goes toward fulfilling those possibilities. In this case the actual units of measurable variation due to environment were essentially the same in the two stocks. Each stock was therefore not only quite definitely limited as to how far environmental factors might carry the white spotting but each was limited to a rather definite range of variation; in this case the range for both happened to be essentially the same.

In the study by Lush, Hetzer and Culbertson the heredity of the pigs had not had sufficient time to exercise much influence and, furthermore, the heredity of the sow undoubtedly is one of the factors affecting the environment common to litter mates. Bywaters' study of variance in weaning weights of pigs shows that the variance due to heredity had risen from the six per cent found in birth weight to 18 per cent of weaning weight. But of the remaining 82 per cent attributed to environment, 10 per cent is credited to permanent differences between dams. Probably the larger portion of this is due to the dams' heredity.

The above mentioned studies of heredity and environment are all fine attempts to get at some of the fundamentals involved. We the reviewers will, however, do well not to generalize too widely regarding these results because in each case the investigator was working with rather definitely restricted hereditary and environmental bases, as is absolutely necessary in studies of this kind. The comparative effects, however, change as we widen the hereditary base from strain to breed, breed to specie, specie to genus, and so on until we have embraced the whole biological world. As we widen the hereditary base, we soon reach a point where at least certain differences caused by heredity are not to be confused with those caused by environment. In like manner we may widen the environmental base to the point where life is impossible.

Since heredity circumscribes the individual's possible attainments and environment determines how far the individual will go toward fulfilling those attainments, it becomes increasingly important that an environment be provided which will adequately test the heredity of the individuals submitted for selection. The importance of this point in constructive breeding is well emphasized by the work of scientific plant breeders. In wheat, environmental differences such as fertility, moisture,
etc, may cause a modification in the amount of rust. A plant that is
genotypically rust resistant is often severely infected by rust if it has
been infected previously by loose smut. Growing conditions may also
apparently cause considerable change in rust reaction. In 1935 Ceres,
a variety that had been less affected with rust under field conditions than
Marquis in previous years, became heavily rusted. Apparently this was
due to changed growing conditions.

Thatcher wheat (4) is a selection from a double cross and combines
field resistance and seedling reaction to certain races of stem rust. Se-
lection for rust resistance was made possible by culturing rust in the
greenhouse and then creating an artificial epidemic of rust in a specially
prepared rust nursery. In other words, this wheat was developed in an
artificial environment similar or even more severe than that under which
it would later grow when exposed to natural rust epidemics. We in the
animal field might well clip a leaf from the plant breeders’ book on this
point. Thatcher wheat was not developed as a hot house plant; perhaps
we might be doing more for the livestock industry if our so-called “seed
stock” were developed and tested under normally favorable commercial
conditions rather than highly pampered ones.

Schollenberger and Clark (5) in a study of the crude protein range
for Marquis wheat grown in Western United States found that the
five year average at Chico, California was 8.9 whereas at Havre, Mont-
tana, it was 17.5. If one were attempting the development of a high
protein wheat for Chico, California, Havre, Montana might not pro-
vide the best testing ground. In like manner the bull or heifer developed
in a darkened box stall, carefully blanketed, knee deep in bedding, and
appetite teased with especially brewed grains is scarcely finding an en-
vironment to test his or her capability of making money under farm or
ranch conditions.

The part that environment plays in shaping the expression of a given
character is well portrayed in the comparative yields of barley varieties
grown in different parts of Minnesota (6). In reviewing this table we
must bear in mind that we are really dealing with restricted environ-
mental differences as compared to those for the country as a whole.

The variations with respect to comparative yields are interesting and
significant: No. 462 is up 44.5 at Waseca but down 25 at Grand Rapids;
Peatland, on the other hand, is down 40 at Waseca and up 43.5 at
Grand Rapids. Manchuria is down 19.9 at University Farm and up
40.1 at Grand Rapids, whereas Glabron is up 60.1 at University Farm
but down 14.9 at Grand Rapids. The above results point clearly to the
fact that the comparative genetic expressions for yield have been modi-
DEVIATIONS OF YIELDS OF SIX PLATS OF THE VARIETIES AT A GIVEN STATION FROM THE SAME VARIETY AT THE OTHER FIVE STATIONS, MINUS THE DIFFERENCE BETWEEN THE AVERAGE YIELDS OF ALL VARIETIES FOR THAT STATION AND THE AVERAGE YIELD OF ALL VARIETIES AT THE OTHER FIVE STATIONS.

(From Immer, Hayes and Powers)

<table>
<thead>
<tr>
<th>Station</th>
<th>Manchuria</th>
<th>Glabron</th>
<th>Svansota</th>
<th>Velvet</th>
<th>Trebi</th>
<th>No. 457</th>
<th>No. 462</th>
<th>Peatland</th>
<th>No. 470</th>
<th>Wisconsin No. 38</th>
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</thead>
<tbody>
<tr>
<td>Univ. Farm</td>
<td>-19.9</td>
<td>60.1</td>
<td>19.1</td>
<td>14.7</td>
<td>-34.8</td>
<td>5.4</td>
<td>-18.3</td>
<td>-14.5</td>
<td>-19.3</td>
<td>7.2</td>
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<td>Waseca</td>
<td>-28.6</td>
<td>-4.0</td>
<td>-8.2</td>
<td>-21.1</td>
<td>24.9</td>
<td>4.5</td>
<td>44.5</td>
<td>-40.0</td>
<td>-10.3</td>
<td>38.9</td>
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<td>Morris</td>
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<td>-17.1</td>
<td>-6.9</td>
<td>-11.3</td>
<td>34.7</td>
<td>-5.2</td>
<td>16.7</td>
<td>9.8</td>
<td>4.8</td>
<td>-14.9</td>
</tr>
<tr>
<td>Crookston</td>
<td>14.3</td>
<td>-30.2</td>
<td>-20.4</td>
<td>4.6</td>
<td>14.3</td>
<td>8.3</td>
<td>8.4</td>
<td>-27.1</td>
<td>24.2</td>
<td>3.5</td>
</tr>
<tr>
<td>Grand Rapids</td>
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<td>-14.9</td>
<td>16.3</td>
<td>29.2</td>
<td>-33.9</td>
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<td>-16.9</td>
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<td>-5.2</td>
<td>-9.2</td>
<td>-26.4</td>
<td>28.2</td>
<td>35.1</td>
<td>-18.1</td>
</tr>
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</table>
fied considerably in the different varieties by environment. In other words, the gene complex of each variety appears to have an optimum environment; and what is equally important, each of the various environments is met by different comparative responses from the different gene complexes.

If we accept the above, it does appear that we American animal husbandmen have been more or less begging the question when in response to the farmer's common inquiry as to which is the best breed we reply, "They all have their good points and their bad ones; merely select the good ones from whatever breed you wish." In this type of reply, which has been very common, we have either begged the question or frankly admitted that the breeds have not been differentiated so far as economic characters are concerned. And if this is correct, the farmer is justified in retaliating with the question, "In that case what justification is there for the effort to keep the breeds distinct?" We are then faced with the old adage, "You cannot have your cake and eat it too."

For my part, I lean more to the British viewpoint that the breeds do differ genetically not only in superficial characters but in those that are of economic importance. It is difficult for me to visualize how the breeds could help differing genetically after having been developed under different environments and after having been kept fairly well separated through the years. Nevertheless, the farmer's question raised above is difficult to answer for two reasons: first, because of the genetic variability within the breeds and second, because we have never conducted any comprehensive field trials comparable to those conducted by students of agronomy and soils.

That environment is an important factor affecting genetic expression and thereby having an important effect on selection is borne out by that classical study of Eckles (7) in which he compared the milk and fat production of the same cows when placed under satisfactory farm conditions and when placed under official test conditions. The 41 cows, representing four breeds, produced an average of 8,395 pounds of milk and 343 pounds of fat under ordinary conditions, but under official test conditions this was raised to 14,331 pounds of milk and 564 pounds of fat. Under the environment of official test conditions the production of these cows was raised in milk and fat production 70.7 and 64.9 percent, respectively. The development of the prize winning block animal under artificial environment is comparable to the development of high milk records under official test. In the light of our previous review of wheat and barley breeding trials, are we justified in assuming that the cow which produces the most under the artificial environment of of-
ficial testing will necessarily produce the most under ordinary farm conditions? In like manner, are we justified in assuming that the grand champion baby beef of next week would have been the best, let alone the most profitable, had the lot of them been reared under feed lot conditions?

Still a further though in this direction: We in America have generally accepted the European breeds of livestock as being perfectly suited to all our conditions. Have we been justified in this generalization? Might it not be possible to develop breeds, or at least strains, better adapted to various American environmental conditions and needs?

In the foregoing an attempt has been made to bring out the following points:

1. Environment may greatly modify the character expression of a given gene complex.

2. This, however, does not mean that heredity is of no importance or is even of minor importance, for inheritance circumscribes the individual's possibilities. It does mean, however, that the environment under which the individual was developed should be given due consideration in appraisal of the individual.

3. Since environment is an important factor affecting the character expression of a given gene complex, it would appear wise to develop our strains or breeds under experimental conditions similar to those under which we expect them to function when in the hands of the commercial producer. It is under these conditions that selection will be most effective.

4. It is not unlikely that we are even defeating our purpose in attempting the development of improved strains for farmers within the breeds by proving them under the extremely artificial conditions that prevail in either the development of high butterfat production records or show yard champions.

**Literature Cited**


SOME OBSERVATIONS ON THE RESPONSE OF PUREBRED BOS TAURUS AND BOS INDICUS CATTLE AND THEIR CROSSBRED TYPES TO CERTAIN CONDITIONS OF THE ENVIRONMENT

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In various parts of the Gulf Coast region of the United States attempts are being made to combine through breeding the recognized resistant qualities of Brahman cattle to tropical and sub-tropical conditions with the superior beef-producing qualities of our major beef breeds.

These attempts represent rather wide species crosses of the Bos taurus and Bos indicus cattle. The author (2) had previously reported observations made in Brazil indicating a species difference in the manner in which Bos taurus and Bos indicus cattle respond to high external temperatures and humidity. Regan and Richardson (1) at California have shown that there exists breed differences within the Bos taurus species to withstand high temperatures and humidities.

At the Iberia Livestock Experiment Farm, Jeanerette, Louisiana the U. S. Department of Agriculture initiated studies to determine the degree of resistance of Bos taurus and Bos indicus cattle and their crossbred types to some of the more important climatic factors.

EXPERIMENTAL METHODS

In the studies at Jeanerette, Aberdeen Angus cows were used as representatives of the Bos taurus species and Guzerat cows as representatives of Bos indicus or Brahman species. The crossbred types were F1 and F2 backcrosses of Aberdeen Angus X Guzerat matings.