Breeding Programs

This is the eleventh article in a series of brief progress reports on the application of the science of genetics to commercial agriculture.

meaning and significance of heritability in improvement of strains through genetics

Everett R. Dempster

Principles of the science of genetics are becoming of increasing importance with respect to breeding programs designed to improve measurable economic characters, such as egg production.

Improvement by selective breeding—the application of genetic principles—depends upon the degree to which offspring resemble their parents. If there is no correlation—mutual relation of characteristics—between the two generations, selection of superior animals to become parents will not lead to any improvement in the next generation. The greater the resemblance of the progeny to their parents, the less the regression will be from the superior level of the selected group to the average of the parental generation.

The computation of the magnitude of such correlations between parent and offspring is based on Mendelian theory—which holds that inheritance in plants and animals depends on the presence of determining factors, genes, which behave as units in their transmission from parents to offspring.

Heritability

In addition to this theory, certain statistical values are required, which can be computed, from appropriate data, for particular characters and particular herds or flocks. One of the most fundamental of these statistical values is called the heritability.

Heritability to the breeder is as concentration of ore is to the miner. The amount of metal the miner can produce in one year depends upon the amount of ore that can be treated in that year and upon the concentration of metal in the ore. For the breeder, the rate of improvement of some character—such as height or skeletal structure—depends upon the amount of variation in that character among different animals and upon the proportion—which is analogous to the concentration of metal in ore—of their variability that is due to genetic or hereditary causes.

This proportion—called heritability in genetics—has a very simple application to mass, or individual, selection; under certain conditions it is the proportion of the reach of the parent that is realized as gain in the offspring.

As an example, if one generation of swine has an average weight of 200 pounds and the individuals from this generation, which are selected as parents of the next generation, weigh 220 pounds at the same age, a 30% heritability indicates that the expected gain from selection would be about 30% of the 20 pounds parental superiority—or six pounds.

This illustration is an oversimplification because, if selection were based not only on the weight of individuals but also on that of the brothers and sisters—family selection—the gain might be greater; if there were a considerable amount of inbreeding the gain might be less, or there might be a loss. Furthermore, due to different conditions in different seasons there might be a seasonal gain or loss—not carried over to subsequent generations—of much more than six pounds.

The importance of heritability lies more in its application to efficient breeding plans than in the estimation of gains that are likely to be achieved. In general, if heritability is low, maximum progress depends on paying considerable attention to the measurements on relatives—the brothers and sisters—of the prospective parents; if heritability is high, the individual should receive the greater consideration.

This principle may be illustrated with an example in poultry.

The heritability of the production index—hen housed average, or number of eggs produced per original pullet placed in the laying house—is low, only about 5%, while the heritability of body weight is high, at about 50%. If there are five full sisters in a family, however, the corresponding heritabilities of family averages will be about 13.65% for the production index and 75% for the body weight.

The family heritability is thus 2.73 times as great as the individual heritability in the case of egg production, but only 1.50 times as great in the case of body weight. However, the variability of family averages is less than that of individuals. For egg production, the family variability—measured by a statistical constant known as the standard deviation—is 47% of the individual variability. For body weight the comparable figure is 63%.

Thus the gains from family selection as compared to those from individual selection are 128%—2.73 multiplied by 47%—for the production index and 95%—1.50 multiplied by 63%—for body weight. Hence, family selection is more efficient than individual selection where the heritability is high.

In either case, the maximum gains can be achieved by a combination of individual and family selection, with more attention paid to the family average when the heritability is low, and more attention given to the individual when the heritability is high.

The Mendelian theory, in terms of heritability and correlation between relatives, also provides some guidance with respect to managemental practices of breeders.

Calculations on this basis, for example, show that the heritability of sire-family averages—averages of all pullets from a given sire—may be greatly reduced if the progeny of different sires are put in separate pens.

Greater accuracy in the identification of good heredity is achieved if the offspring of individual sires are distributed—either at random or according to some systematic plan—to different pens.

Mammals

In the case of mammals there is an unavoidable reduction in heritability of families-average due to the fact that some dams furnish relatively superior intrauterine—prenatal—and nursing environments to all their offspring and other dams furnish relatively inferior maternal environments to all their offspring.

On the basis of Mendelian theory and heritability estimates, allowance can be made for circumstances of this nature.

Actual improvement programs are likely to be considerably more complicated than the foregoing examples. For instance, several characters must be considered when the parents are selected. The relative weighting—values—given to each is again a problem in heritabilities and correlations.

A slightly different example is presented by the problem as to the age at which a measurement should be made. In the flock of fowl mentioned, the heritability of the part-production-index—to January 1, following the placement of the

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pullets in the laying house—is somewhat greater than the heritability of the production index for the full year.

It is, however, the full production index that is of commercial importance, so use of the part-index may result in slightly lower gains per generation. On the other hand, the time per generation can be cut from two years to one year if the part-index is used in selecting parents. Greater gain per year is thus achieved by the use of the part-index. However, maximum gains are obtained by the proper combination of part-index and full-index selections.

Although proper understanding and use of heritabilities can lead to increased rates of genetic gain, much remains to be learned of a fundamental nature with regard to breeding theory. Thus heritability has two components, a useful component—additive heritability—and a component relatively useless for many breeding programs—nonadditive heritability.

The amount and nature of the nonadditive heritability is a problem of current investigation. Its utilization may require special breeding methods. The success to be expected from the production of hybrids from inbred lines of animals depends to a considerable extent on the special characteristics and magnitude of this component.

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DAIRY

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Manufacturing milk prices, determined more by national than by local supply and demand, are usually higher in the fall and winter than in the spring.

Most dairy enterprises include the raising and sale of some dairy stock. The consideration of how many and what kinds of animals should make up the herd, which animals should be raised for use in the herd, which calves should be sold or destroyed at birth, and which should be raised before selling—all constitute a major part of dairy farm management.

Net stock income is the value of stock produced over the cost of stock bought and the death losses and decline in value of stock in the herd.

Net stock income is not a profit from raising of dairy stock since costs of its production are not considered and would be difficult to segregate from the milk production costs.

Net stock income averaged $50 a cow in San Joaquin Valley dairies in 1947 and 1948.

A dairy farm is an intensive enterprise in California, existing on high-priced land. As in all intensive farming, the capital investment is big, and the operating cost can become very high unless good management practices are applied consistently.

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POULTRY

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0.02 units of inhibitor and produced weight gains of 125 grams in the first test and 148 grams in the second test, was selected as a meal giving good results. It was light yellow in color.

The meal selected for further study as the meal giving poorer results was a fairly dark expeller processed meal. This meal contained 0.05 units of inhibitor and in the first test produced an average of 120 grams of weight on the chicks and in the second test, 132 grams.

If the dark meal had been scorched in the processing, its lysine—an amino acid—should be reduced in availability.

In this confirming test two groups of 15 chicks each were used. The chicks were fed a stock mash for seven days and the experimental diets for 14 days.

The expeller meal was fed for seven days and an average weight gain for the seven chicks of 33 grams was recorded. Seven days later—after 14 days on the diet—the average weight gain was 70 grams. Then 0.2% lysine was added to the meal and the tests repeated. After the first seven days the average weight increase was 32 grams and after 14 days the weight gain was 66 grams.

After the first seven days on the solvent processed meal the chicks showed an average gain of 31 grams. At the end of the second week—14 days on the diet—the average gain was 67 grams. Then, as with the expeller meal, 0.2% lysine was added. After the first week the average gain in weight was 33 grams and at the end of the 14 days, the gain was 68 grams.

No essential difference was observed between the two soybean meals. Supplementing with lysine did not improve the nutritional value of the meals, indicating their lysine content was not extensively damaged during processing.

These studies indicate little or no differences among the eight meals and that all were high quality products.

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