PRINCIPLES AND PRACTICES USED IN LIVESTOCK IMPROVEMENT PROGRAMMES IN THE U.S.A.

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SUMMARY

Practical uses of the principles of genetics in livestock improvement in the United States are illustrated by on-the-farm programmes and by central testing station schemes where data on economically important and heritable traits may be collected and records made available for selection of breeding stock. The general effects of mating systems on livestock are summarized and some areas of research which may lead to useful approaches in the genetic improvement of livestock are presented.

A MORE PRECISE TITLE for this paper would be "Some of the principles and some of the practices used in some of the livestock programmes in some parts of the U.S.A." In fact, the major emphasis is to be on one aspect of this subject, namely, on-the-farm recording and selection programmes for pigs and sheep in the state of Wisconsin.

SWINE AND SHEEP ON-THE-FARM RECORDING

The first records were collected in the Wisconsin Swine Selection Cooperative in 1945 and in the Wisconsin Sheep Improvement Program in 1949–50. Each programme has been operated each year since.

Basically, the plan in these programmes was to get farmers to keep a few simple records which it was hoped they would use to help them select their stock for economically important and heritable traits. At the same time, it was recognized that the records would provide demographic-type research information on the farmers' stock. Also, it was hoped that this approach might open up the way for co-operation in the form of farmers undertaking specific research for the University. There were other dividends expected, such as those accruing from the knowledge the farmers would gain about their stock *per se* and in comparison with the stock of others in the programme. This was expected to, and undoubtedly does, serve to stimulate them to seek guidance from extension

personnel on all aspects of their farm enterprise—breeding, feeding and management. Not least among the values of this type of work is the opportunity it presents to give farmers some insight into the science of animal breeding and how it might be used to help develop truly superior livestock. In discussions of this topic, their interest can be more easily aroused because they feel they are a part of a co-operative venture with the University. In addition, it gives one a pedagogical advantage, when talking to farm groups, of being able to draw on illustrative material taken directly from the records with which the farmers are familiar. Another value of this type of work comes from the research problems suggested to the extension and research personnel by their close association with the farmers' individual operations.

The focal point of the programme is the selection index—a convenient device for putting together, in correctly balanced form, the information pertinent to the goals sought, namely, efficient production of what the ultimate consumer needs. There are so many aspects of straightforward genetics, biometry and economics wrapped up in a selection index that it is an excellent point of departure for discussion of important principles in these areas and their use in a livestock improvement programme.

The present index for pigs includes information which attempts to depict transmitting ability for productivity of dam (number of pigs raised per litter), rate of gain (weight at 5 months of age), and carcass quality (percentage lean cuts). The traits used in the index are the number of pigs in the litter at farrowing, the number at 5 months, and the weight of the pig, the length of foreleg and the loin backfat at five months of age.

For lambs efficiency of production is considered in terms of weight-for-age and number of lambs raised by the dam, and fleece yield as reflected by staple length and weight-for-age. For ewes, lamb production and fleece weight are taken into account.

PROCEDURES

The general procedure in these programmes each year is to get in touch with past and potential co-operators in the winter and ask if they wish to be in the programme. If so, they are requested to send in the expected dates of farrowing and lambing.

At birth of their pigs and lambs, they are supposed to fill in litter or ewe record cards with the identification numbers of the pigs and lambs and their sex. Birth weights and any other information they wish to collect can be recorded on the cards but no more is required until the staff gets the "5 months" information for pigs and the "4 months" information for lambs. This is done at a time when the average of the herd or flock is close to these ages. One or two men go to the farm and get the weights, backfats and lengths of leg on the pigs, the weights and staple lengths on the lambs, and, if available, record the weights of the fleeces of the ewes. The record cards are then sent to the writers' office, the records are adjusted and an index is calculated on each animal. A list of top indexing gilts and lambs and low indexing ewes is returned to the farmer with their original records and a covering letter. This letter explains, in simple terms, what was done with the records and suggests how they should be used, namely, sort out enough of the top indexing gilts and ewe lambs for replacement and put these in a separate pen from the remainder of the group. Then, look them over for defects and replace defectives with those next in order on index.

At the end of the year, a printed sheet is sent to each co-operator giving the average index and average performance on each of the traits considered for all of those in the programme that year. The averages of the top-one-fourth and bottom one-fourth of the farms on index and the component traits are also printed on these yardsticks. The averages of the stock of the particular farmer to whom the form is to be sent are also placed in position on these yardsticks. The purpose of this is to make the farmer aware of where his swine and sheep enterprises are in comparison with his peers. If he is not in the top group, it is hoped that this sheet will urge him to consult an extension specialist to learn whether it is likely to be his breeding, feeding, or management programme which needs to be improved. It is pointed out to them that the individual traits and indexes are not readily comparable between herds or flocks for selection purposes, but that the differences between herds and flocks should point up for them the goals they presumably can attain if they follow the best practices in all aspects of their livestock enterprise.

RESULTS

What about the annual averages for the traits considered? Using all the data collected each year, there are large and rather steady increases in numbers of pigs farrowed and raised per litter and in the pig weights at 5 months of age. Similar large and steady increases have occurred in lamb weights, percentage of twins born per ewe, but not in fleece weight. The increase in number of pigs farrowed and weaned has been 2.5 over the past 19 years of the programme (0.13 pigs per year). This represents an increase of 29% and 38%, respectively, over the initial levels. A comparable figure for 5-month pig weight is an increase of 41 lb (2.2 lb per year), or a 31% increase over this period of time. The increase in 4-month weight of lambs has been 17 lb (1.1 lb per year), or a 28% increase for the 16-year period. For the percentage of lambs born as twins, there is an increase of 23% (1.4% per year).

These upward trends in performance are reminiscent of some data presented by Lush (1951) when reviewing "Genetics and Animal Breeding" at the celebration of the fiftieth anniversary of the rediscovery of Mendel's work. He showed how production per animal had changed during the preceding years for many traits recorded in several different countries. For a twenty-year period of time, mostly just prior to the time covered by the records, the percentage change over the initial production level was between 5% and 20% for butterfat production and test, fleece weight, and for thickness of backfat and belly, feed units per unit gain and average daily gain in pigs. Lush concludes that "it is my opinion that a large part of these truly astonishing changes made in animal productivity over the last 20 to 50 years is genetic."

In the case of the swine and sheep on-the-farm results, there is no satisfactory objective evidence that the changes observed were a result of the use of the selection index by the farmers or, in fact, the use of any part of the records as a basis for deciding on herd and flock replacements. Information is available on the extent to which the animals recommended on index were kept for replacements as well as figures on the actual selection differentials and on regressions of offspring on parent. These figures give evidence that some genetic progress has

TABLE 1: MEANS AND INTRA HERD-YEAR STANDARD DEVIATIONS, GILT SELECTION DIFFERENTIALS AND HERITABILITIES (Wisconsin Swine Selection Cooperative, 1953–58)

Trait	Mean	Stand. Dev.	Selection Differential Abs.	Standardized	Heritability
Number farrowed	9.0	2.1	0.7	0.3	0.14
Number, 5 mon.	7.1	2.0	0.8	0.4	0.12
Pig weight, 5 mon. (lb)	141	23	11	0.5	0.20
Litter weight, 5 mon. (lb)	1,003	268	171	0.6	0.12
Pig index	95	17	10	0.6	0.26

occurred and that even more would have occurred if the recommendations had been followed strictly.

Table 1 gives the means, intra herd-year standard deviations, selection differentials and heritability estimates based on daughter-dam regressions in the swine data. The selection intensities in the gilts were 0.25 which should allow for a selection differential of 1.28 standard deviations. The observed selection differential on pig index was about one-half of this.

Because of this difference between "potential" and realized selection differentials, it is of interest to note the frequency with which the gilts were taken from the list of top indexing gilts recommended. If this list is restricted to the same number of gilts as those actually kept for replacement, it is found that 70% of the replacements made from the herd came from this list. The other 30% which remained in the herd, but with lower indexes than the recommended, did not appear to have been selected because of superiority on any of the traits on which information was available on the record cards. On the contrary, those selected but not recommended were animals which, on the average, came from dams producing 0.63 pigs less at farrowing than those recommended and not selected; they were also inferior by 0.85 in numbers of pigs reared and 15 lb in weight of individual pigs and 157 lb in weight of litter at 5 months of age.

The reasons for not using those which were recommended are not clear. Infertility and other abnormalities may have played a role, but it is unlikely that these factors accounted for the major part of those culled from the recommended list. Weight on a given day, and age at a given time were not, at least, a consistent basis for culling

from this list. It is likely that type and details of conformation were major factors in these decisions. These data do not provide information on this point. Whatever the reasons were for this substitution of lower indexing gilts, it is clear that rather large potential improvement for economically important traits was sacrificed thereby.

The actual changes observed in the index and its component traits were obviously much larger than those expected on genetic grounds in the context of the observed gilt selection differentials and heritabilities and estimated generation interval. For index and for 5-month pig weight, the observed changes were 2 to 2½ times larger and for numbers farrowed and weaned close to 5 times larger than those expected on the basis of gilt selection using the minimum generation interval of one year. The extent to which sire selection, environmental changes and fluctuating samples of breeding groups, of herds, and even of animals within herds have influenced the data year by year has not been determined. It is, of course, also uncertain as to whether or not a selection differential for a given trait was the result of direct selection for that trait or due to phenotypic association of it with others on which selection was actually based.

The results in the sheep improvement programme are comparable to those for pigs in the sense that only a fraction of the large gains in weight and twinning can be assigned to the selection practised in the ewe lambs. Likewise, the two programmes are comparable in that there are wide discrepancies between "potential" and realized genetic gains and apparently for the same general reasons, namely, failure to make full use of the selection index or its component traits in deciding on flock replacements.

As pointed out earlier, one of the benefits to be derived from programmes of this kind is in the research information provided directly as a by-product of the data collected on the farmers' own stock and as a result of a co-operative arrangement whereby the farmer actually tests specific stock for the experiment station.

In the Wisconsin programmes both kinds of research have been carried on. The following are studies based on the data made available by co-operators in these swine and sheep programmes: performance of the progeny of

inbred and linecross experiment station boars compared with those of non-inbred, non-linecross boars bred to comparable sows in two-sire herds (Durham *et. al.*, 1952; Bradford *et al.*, 1958); development of lamb and ewe selection indexes and ewe life time performance index (Karam *et al.*, 1953; Felts *et al.*, 1957; Felts, 1958; Knothe and Chapman, unpubl.); analysis of kind and amount of selection practised in pigs and construction of pig selection indexes (Bernard *et al.*, 1954; Robison *et al.*, 1960); comparison of different breeds of swine and of straightbreds with crossbreds (Bradford *et al.*, 1953a); study of the effects of different dates of spring farrowing on pig performance (Bradford *et al.*, 1953b); measures of relative merit of lambs from different breed crosses (Neville *et. al.*, 1958; Bailey *et al.*, 1961a, b).

This approach to research has not only made it possible to do experimental work which the facilities of the experiment station could not accommodate, but has also given a wider sampling of genetic stock and environmental conditions and hence a broader and practical background for recommendations based on this research. It should, however, be pointed out that this approach to research is not a substitute for but a helpful adjunct to carefully controlled experimentation in quantitative animal breeding. The latter has to be done with animals owned by the research institution and under the complete control of the research worker. These approaches are complementary not alternative.

The programmes which have been described are only two of a large number recommended for improvement of livestock throughout the United States. They do, however, point to some of the principles which may be applied and illustrate some of the useful purposes programmes of this kind can serve.

DAIRY AND BEEF CATTLE ON-THE-FARM RECORDING

Dairy and beef cattle on-the-farm testing programmes of national significance are those sponsored by the National Cooperative Dairy Herd Improvement Association, its counterpart identified with the Purebred Dairy Cattle Association, and the Performance Registry International. The first of these programmes was started in the United States under a different name in 1906 and was patterned

on the plan of the Danish cow testing associations which originated in the previous decade. The second of the above is merely an adaptation of the first, conducted under the auspices of breed registry associations. The third was organized in 1955 as a testing and certification scheme for co-ordinating the beef cattle improvement programmes of the different States and of the provinces of Canada.

Each of these programmes has as its major feature the recording of information on what are considered economically important traits. The availability of this information to the breeders provides a basis for selecting stock.

CENTRAL TESTING STATIONS

The problem of estimating the genetic differences which exist between animals from different herds and flocks and the need for comparative record information collected by an agency independent of the owners of the animals have led to a number of central livestock performance testing stations in the U.S.

The general procedure for central testing stations is similar for different species and in different localities with many variations on the main theme. The attempt is, of course, to bring the animals to the centre early enough in life so as to allow previous environmental effects to be minimized in estimating performance at the station. An effort is made to provide uniformity of treatment of the animals at the station at any one time, between testing periods, and, in some cases, between testing stations. More detailed information, under close supervision, is likely to be taken on animals at the stations than on the farms on such things as growth rate, efficiency of feed utilization, conformation scores, and carcass yield. One other function some of these centres has performed is to instruct the breeders in the principles involved in estimating genetic differences between animals in economically important traits.

The relatively small proportion of males used in the breeding herd or flock and, hence, the large selection differential possible, makes it extremely important to evaluate the transmitting ability of males accurately. This may be done for certain traits by on-the-farm recording but, in most cases, the farmer wants to spread the base

from which he gets his male replacements. This may be to avoid inbreeding or to give him wider choice in his selections. In these cases, the need for central testing station facilities for performance or progeny testing is evident. As a rule, the value of testing many males and turning the generations rapidly means that primary emphasis should be placed on performance testing. For traits which cannot be measured or cannot be estimated accurately on the live animal, and for final evaluation of males thought to be superior on individual performance, the sib and progeny test should provide the necessary information.

The extent to which the central testing station approach can portray accurately the useful genetic differences between animals depends on the success in providing uniformity of treatment for the animals under test, the degree to which previous environmental effects carry over into the test period results, and whether the differences in response of genetically similar animals to station conditions agree with what their differences would have been under farm conditions. Progeny test records on multiple-sire farms of males selected under test station conditions would be most helpful in evaluating the efficacy of the central station approach to evaluating transmitting ability. Artificial insemination could, of course, provide larger numbers of test progeny from wider genetic and environmental bases as well as lead to greater use of sires proven to be genetically superior. This approach has been wisely exploited by dairy cattle breeders and similar approaches are starting to be made in beef cattle and swine.

MATING SYSTEMS

The genetic principles involved in the use of different mating systems have been clearly outlined for many years. The actual effects of inbreeding and crossbreeding in the various classes of livestock are becoming well documented. The effects of these mating systems in different species are in general quite similar in terms of the relative influences on general classes of traits even though they vary in absolute magnitudes.

In general, inbreeding has marked depressing effects on, and crossing gives heterosis for, traits related to re-

production and postnatal survival for which heritabilities tend to be low. For characters related to growth and economy of gain, which are medium in heritability, the effects are, as a rule, less marked, while for more highly heritable characters, such as carcass traits, the effects appear to be minor.

The use of heterosis from crossbreeding is extensively and effectively used in the U.S.A. In some cases the production of market stock from the first cross is the goal. In other cases systematic schemes such as crisscrossing and rotational crossing of several breeds are carried out.

Intensive inbreeding, linecrossing (crossing unrelated inbred lines), and topcrossing (using inbred or linecross males on unrelated non-inbred females), have played an important role in large-scale commercial poultry breeding and "hybrid" hog enterprises in the U.S., but in most animal breeding programmes these systems are not used because of the difficulty and cost of producing and maintaining inbred stock. Linebreeding (maintaining high relationship to a desirable ancestor without intensive inbreeding) has, on the other hand, played an important role in the breeding plans of stock in many herds and flocks.

THE FUTURE

What of the future? Hopefully, livestock breeders will make fuller and correct use of the presently available devices for on-the-farm recording and selecting, of central testing stations, of artificial insemination, and of systematic mating plans. Hopefully, also, animal breeding research and extension personnel will develop more effective programmes for livestock improvement and will provide the necessary advisory, supervisory and inspirational leadership for these programmes to succeed. Most farmers cannot be expected to have the genetic, statistical and economic information basic to these programmes and hence they need help in formulating them, in understanding their implications, and in carrying them out. One does not automatically take and use records and if doing so competes for time on other important aspects of one's life, there is often need for outside inspirational leadership to ensure that the information is collected and used. The importance of this aspect of these improvement programmes cannot be overemphasized.

Genetic improvement by selection will not result unless herd and flock records are systematically kept and wisely used over long periods of time.

What bearing may research in genetics and animal breeding have on future plans for improvement of livestock? This is not known, of course, but there are many areas of research which may well have an important bearing in the field of livestock improvement.

Much work is being done in such areas as:

(1) Mathematical deductions as to the likely consequences of various systems of mating and selection procedures. Will some novel approaches to genetic improvement of livestock emerge from imaginative studies in biometrical and population genetics?

(2) The relative effectiveness of different methods of selection and of different mating systems. Are present conclusions on the relative effectiveness of different selection methods and mating systems going to be acceptable in the light of results from livestock and laboratory animal experiments designed specifically to test these?

(3) Computer simulation studies on problems of population genetics. Will these results lead to major modification of some of the arguments based on population genetics theory as it relates to animal breeding?

(4) The genetic and environmental associations between traits expressed at all stages of development. Are the heritabilities of some of these traits (especially those expressed early in life) and their genetic or environmental correlations with those of economic importance, high enough that individually or in combination they may be useful aids to selection by indicating genotype for, or pointing to environmental effects on, the important traits?

(5) The effects of specific environments in changing the extent to which genetic differences are expressed. Is the role of some environmental factors which may either obscure or reveal useful genetic variability being overlooked?

(6) The role of certain genes in their influence on the genetic expression of other genes which are identified with traits of economic importance. May certain genes

be introduced into the genotype of the animals to reveal genetic variability which is otherwise obscured?

(7) Identification of blood traits which are primarily dependent on the action of individual genes. Will these studies indicate enough useful pleiotropism of these more readily identifiable genes to warrant their use in selecting for economically important traits?

(8) The production of genetic variability by irradiation and other mutagenic agents. Will there be enough desirable genetic material produced by these means to allow it to be utilized effectively in selection or mating system programmes?

Surely out of these and other researches will come information which can be useful as tools for more rapid improvement of livestock.

It is only to be hoped that present beliefs and approaches to the genetic improvement of livestock are not so firmly ingrained that there is failure to recognize and utilize novel approaches which science will provide or perhaps has already provided in unfamiliar contexts.

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