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Economic Potentials of Poultry Breeding

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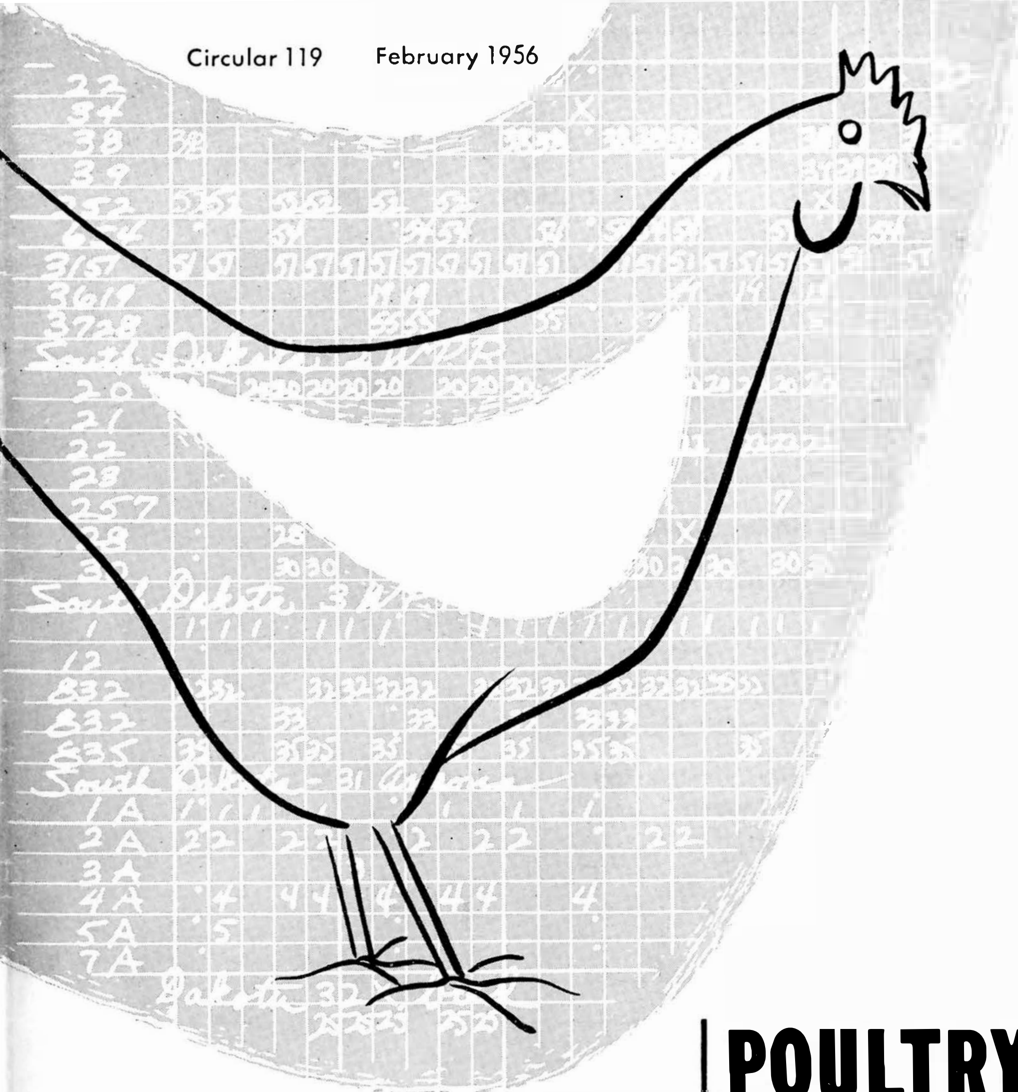

economic potentials of POULTRY BREEDING

POULTRY DEPARTMENT

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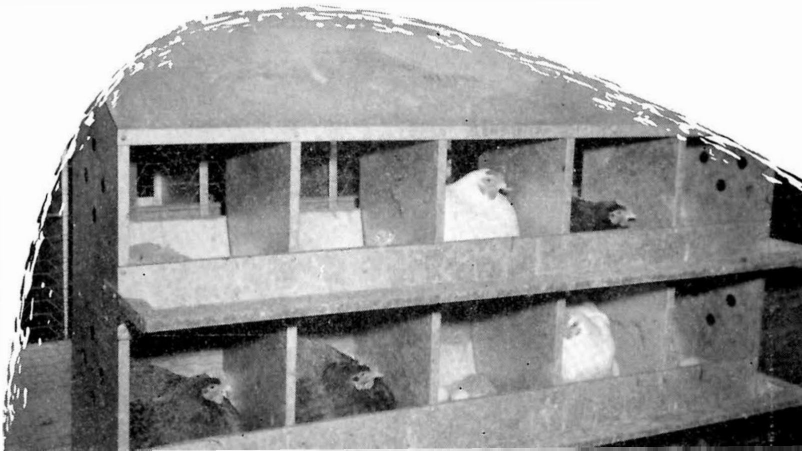

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Economic Potentials of Poultry Breeding

Walter Morgan, Dean Jones, and William Kohlmeyer[1]

Introduction

One of the remarkable agricultural accomplishments of the past 30 years has been the increased productivity of our chickens. Not only has the poultry industry produced hens that would lay more eggs (national average, 1925—112, 1954—183), but the economical production of meat in the form of broiler-fryers has created a new industry in the poultry field.

In attempting to analyze important factors contributing to these advances, it seems that three areas of improvement have been of major importance. Management (particularly as it relates to disease control and sanitation problems), breeding and selection, and improved rations have all contributed significantly to increased productivity. The purpose of this circular is to discuss methods used by geneticists to improve poultry by breeding and selection. In addition to reviewing some of the proven methods which resulted in recognizable improvement, unproven ones are included.

It is our hope that after the poultryman reads this publication some of the unfamiliar terms that confront him can be more clearly understood and their importance evaluated. A glossary is included and may serve as a handy tool for defining technical or semitechnical terms.

It is the goal of the geneticist to make next year's birds better than this year's birds. As previously mentioned, two of the greatest variables affecting the ability to measure any

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changes brought about by breeding or selection are (1) management (particularly as influenced by regularity and climate) and (2) diet of the birds. When genetic changes or changes due to different gene combinations are discussed hereinafter, it will be assumed that the environment, managerial practices, and ration remain constant unless otherwise specified.

Specifically then, what tools does the poultry breeder have available? A proper understanding of the potentials and the limitations concerned will necessitate a short discussion dealing with established genetic principles.

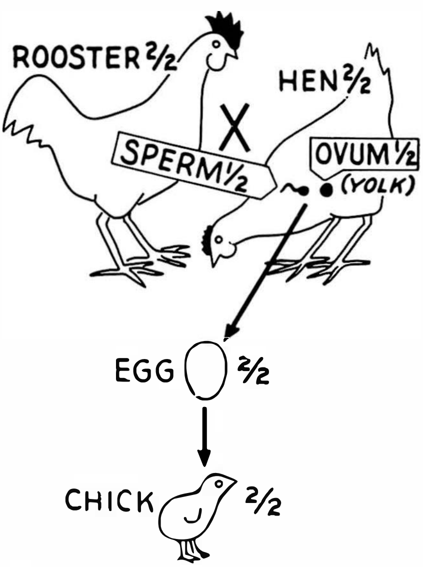
Genetics as a Tool

Genetics is a science dealing with similarities and differences among individuals related by descent, or in terms of the breeder, it is a science dealing with heredity and variation. Heredity is usually thought of as that phase of genetics which concerns itself with the resemblance among individuals related by descent. Variation, on the other hand, deals with the differences among individuals related by descent.

The basis for heredity is found in the cells, which are characteristic of all plants and animals. Within the nucleus of each cell there are a number of pairs of bodies known as the chromosomes along which the genes are arranged in linear order. A gene is a hereditary unit that produces an effect (which is peculiar to itself alone) upon some character of form, structure, or function.

Inasmuch as the chromosomes are paired in each bird (diploid number) and the genes are arranged in a line along each chromosome, the genes are also paired. Genes that are identified by breeding tests and are shown to segregate are assigned symbols which can be employed when explaining methods of inheritance.

Most of us are familiar with the fact that two gametes (the egg from the hen and the sperm from the rooster) are necessary to produce a baby chick. However, contrary to some notions, the rooster does not have any more influence on the type of chick that will result



Each parent has an equal influence on the make-up of the offspring

than does the hen. Each gamete (the egg and the sperm) contains half of the hereditary material which contributes to the make-up of the new chick.

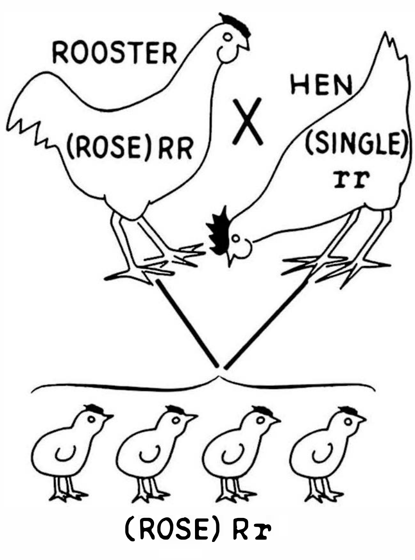
A process known as reduction of chromosome number occurs when the gametes are formed. At reduction division one member of each chromosome pair (which contains one gene of each pair) enters the newly formed gamete. During this process of gamete formation, it is a matter of chance alone whether the member of the chromosome pair entering the germ cell is of maternal or paternal origin. Thus there is a constant reshuffling of the chromosomes and the genes contained thereon in each generation. The two types of chromosomes which we will discuss are the autosomes and the sex-chromosomes; chickens have approximately 38 pairs of autosomes and one pair of sex-chromosomes.

In chickens, the male has two sex-chromosomes which are alike (we will call them XX). The female, however, has only one sex-chromosome which is like the ones found in the male and may or may not have another unlike sex-chromosome. Thus, the male would be represented by XX and the female by either XY or X-. Irrespective of which of the latter types represents the female, it can be seen that the egg is the germ-cell which determines the sex of the baby chick. Genes which are carried on the sex-chromosome are called sex-linked genes. Thus far, they have only been identified on the X chromosome.

The simplest type of inheritance is concerned with dominant and recessive genes which have a 50-50 chance of being passed on to the progeny (offspring). These genes are said to "assort at random" or to have "independent assortment."

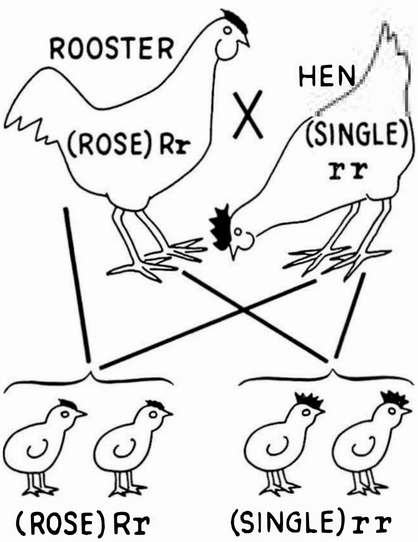
An example of this type inheritance is observed in comb type where rose comb is dominant to single comb. Inasmuch as the autosomes are always paired, there would be two rose comb genes (symbol *RR*) in a bird pure for this characteristic. Similarly, there would be two single comb genes (symbol *rr*) in a single comb bird. Because both genes are alike, in the individuals described, the birds are called homozygotes; they are homozygous for comb type.

Here is what results from a mating of a pure (homozygous) rose comb to a single comb bird.



The progeny would all be rose comb. This test would have commercial importance in a flock of White Wyandottes where the breeder desired to eliminate all birds that gave rise to single comb progeny.

If the mating of rose comb x single comb did not give all rose comb progeny, then the rose comb in question would, of necessity, be impure for rose comb.



Removal of the impure individuals would result in a flock containing only homozygotes which could produce only rose comb progeny. In the examples, the individuals that are *Rr* are heterozygotes or heterozogous for rose comb. The symbols represent the genes. Consequently *RR*, *Rr*, and *rr* are genotypes. *R* is dominant to *r*. The description or appearance of the birds (rose or single) is called phenotype.

The type of inheritance depicted here is simple Mendelian inheritance, and the mating designed to eliminate phenotypic rose comb birds that were genotypically heterozygous is called a testcross. The testcross involves the mating of an unknown individual to the homozygous recessive type (*rr*). From this test, one single comb bird produced by a rose comb bird would prove that the parent is a carrier (*Rr*). To adequately test that an unknown rose comb bird is *RR*, it should produce 12 or more rose comb chicks and none with single combs when mated to a single comb bird.

In most instances variations in feather color, feather structure, skin color, comb type, and pronounced deviations in body structure (such as creepers and dwarfs) are inherited in the simple fashion described for rose comb vs. single comb. They are controlled by a single pair of genes which may be either autosomal or sex-linked. It can be argued that such variations are of economic importance, but they are of considerably less importance than such characters as body size, growth rate, viability, hatchability, and egg production.

A few characters of economic importance, such as white plumage and rate of feathering, are inherited in a simple manner. But the majority are inherited in a more complex fashion. Studies of the inheritance of such important characters as egg production, hatchability, growth rate, body size, viability, and others indicate that they are controlled by many genes. Such characteristics are said to have a multifactorial type of inheritance and are not transmitted in an "all or nothing" manner. But the degree or amount of expression depends upon the number of favorable genes present. Characters resulting from multifactorial genes demonstrate a cumulative effect.

Selection and Breeding

Any discussion of present day poultry breeding methods must concern itself with at least two aspects of poultry breeding. These are: (1) methods of selection and (2) mating systems. It should be realized that the two are not set distinctly apart, but are more-or-less integrated so that there is some method of selection associated with each mating system. Likewise it will become apparent that no one method of selection is normally associated with a specific mating system. However, to facilitate clarity of presentation, the discussion of selection methods and mating systems will appear separately.

Methods of Selection

Individual or Mass Selection

The selection of individuals on the basis of the individual's performance without regard to the performance of ancestors, sibs, or other collateral relatives or progeny is known as mass selection. As such, it is completely effective or satisfactory for simple recessive characters.

Since recessives breed true, the only errors that can creep in here are errors of classification. To illustrate, matings of early feathering birds among themselves yield nothing but early feathering offspring when this character is due to a sex-linked recessive gene.

On the other hand, mass selection is less effective in eliminating undesirable recessives when simple dominant characters are concerned. The Wyandotte breeder knows how futile it is to try to eliminate single comb genes from his stock by mass selection because the birds homozygous for rose comb are indistinguishable from the heterozygotes.

For other economic characters inherited on a multifactorial basis, the amount of improvement that can be expected from mass selection is dependent upon the heritability of the character involved and the extent of the variation (sometimes called "reach") within the stock. Possibilities for improvement with mass selection are good for those characters having high heritability (a high correlation between phenotype and genotype). Important traits such as body weight, rate of growth, and egg weight respond rather rapidly to mass selection.

On the other hand, response to mass selection is much slower and improvement may be limited when dealing with characters having moderate or low heritability such as keel length, breast width, viability, and egg production.

It seems probable that mass selection is much more capable of raising the general level of performance of characters which have moderate to low heritability when little improvement has previously been made with those characters. The ultimate success that can be accomplished will be limited here, again, by the extent of variability within the stock for the selected character. That is, the improvement that can be attributed to heritability will be larger when there is a wide variation for the given character. As the general level of performance is raised, mass selection is relatively less effective.

It must be realized, however, that even though mass selection may not be the most efficient type of selection in all cases, it has been the most widely used and remarkable results have been achieved thereby. The potential chick buyer would do well to purchase chicks from a hatcheryman who at least does a thorough job of culling his hatchery flocks. This culling is necessary to hold the performance of offspring at the productive level of the parent stock. It will quite likely result in limited improvement in some characters and fairly rapid improvement in those characters which are highly heritable.

Even more improvement is to be expected in various important economic traits when mass selection on the female side is accompanied by use of males selected on the basis of pedigree, family, and/or progeny performance. These latter types of selection have been shown to be somewhat more efficient than mass selection for the improvement of many traits.

Selection can help eliminate odd-shaped eggs.

Mass selection must not stop with the culling of the flock; it must also be applied to the selection of hatching eggs. Small eggs, eggs of poor shell texture, poorly shaped eggs, and otherwise undesirable eggs should be eliminated. Mass selection for large egg size has been shown to be very effective. While it is not likely that all undesirable egg characteristics will respond rapidly to this method of selection, some improvement should be possible.

Pedigree or Ancestral Selection

The selection of breeding stock on the basis of the performance of its ancestors is known as pedigree or ancestral selection. It is an attempt to evaluate the genotype of the individual on the basis of phenotypic performance of the ancestors.

This type of selection is based on the premise that "like begets like." Unfortunately this is not always true since good egg production of the dam is not necessarily followed by high egg production of her daughters. Likewise, there is no assurance that her sons will transmit genetic factors for high egg production to their daughters. Again the degree of heritability is important. More emphasis may be placed on ancestral performance for characters of high heritability than for characters of moderate or low heritability.

One is justified in attaching more importance to the pedigree or ancestral record when information is available for both maternal and paternal ancestors. Similarly, information for more than one ancestral generation is desirable. The more ancestral information that is available, the less the chances are that a given bird may be carrying concealed factors of an undesirable nature in its genotype.

Too much importance, however, should not be attached to outstanding individuals appearing several generations back in the pedigree. Since the contribution of each ancestor in the pedigree to the individual is on the average cut in half by every intervening generation, an ancestor four generations removed, on the average, would have contributed only about six percent of the bird's genes. The futility of tracing pedigrees beyond the third or fourth generation is readily apparent.

In summary, pedigree selection will usually give general improvement. Like mass selection, improvement will be more rapid in those characters having high heritability, but will often be slow and erratic in those characters having low heritability. Knowledge of more than one ancestral generation will improve the accuracy of selection and rate of improvement. This is not fool proof, however, since knowledge thus gained is knowledge of phenotype rather than of genotype.

Family Selection

The selection of individual breeding birds based on the performance of a family group rather than on an individual's performance is known as family selection. There are two types of family selection.

In one, the sib test, probable genotypic merit of the individual is evaluated on the basis of collateral relatives, particularly the full and half brothers and sisters. If a bird has uniformly good sibs, chances are good that the genotypes of the parents were superior and that the bird itself is likely to have a superior genotype. On the other hand, a bird with average or inferior sibs is likely to have an inferior genotype and be of little breeding worth even though she may have a desirable phenotype.

Another type of family selection evaluates the breeding worth of the individual and attempts to estimate the genotype of the individual on the basis of the performance of the progeny or offspring. This is known as the progeny test. In actual practice, the sib test is also a progeny test for the parents of the sibs.

The value of the progeny test lies in the fact that matings of birds with desirable genotypes are likely to produce superior offspring, irrespective of phenotypes. While it is not likely that a low producing bird will have a superior genotype, a superior genetic constitution is not always found in a highly productive bird.

As might be expected, family selection is more efficient for such things as egg production and for those characters having low or medium heritability than it is for characters of high heritability. As has been noted previously, the estimation of breeding value from phenotypic performance of the individual or of ancestral performance for characters of medium or low heritability may be incorrect. The accuracy of such estimation when based upon family averages is likely to be greatly improved. Thus it should lead to more rapid and steady breeding progress.

In actual practice, family selection is often accompanied by mass selection and/or ancestral selection (the most desirable appearing birds from the best ancestral and sib or progeny tested families are likely to be chosen as breeders). It is, however, necessary that the family be above average before selecting potential breeders.

Chief factors limiting use of the family selection method are: (1) a large amount of record keeping, (2) large scale of operation if real progress is to be made, (3) the failure of those families superior in some economic traits to be superior or even average in others. Consideration of the latter has the effect of greatly reducing the potential breeding population. For the reasons just cited and others, such as facilities required and necessary trapnesting, selection on the basis of family performance is beyond the scope of many small breeders.

Trapnesting records for individual egg production are necessary with a family selection program.

Selection is not an end but merely a means to an end. The production of a superior product is dependent only in part upon a good selection program. Once selection has been completed, the breeder is still faced with the task of deciding how to use those selected birds to yield maximum returns for his time and expenditures. In other words, he must decide upon a mating system that will best make use of the particular birds he has selected for the particular purpose he has in mind.

Mating Systems

In the light of recent knowledge, there is no conclusive evidence to indicate that any one mating system is best for all purposes when factors such as performance, cost of the product, and net return are taken into consideration. A brief discussion of the advantages and limitations for different types of mating systems follows.

Systems Not Requiring Inbred Lines

Outbreeding or Outcrossing. The mating of birds that are unrelated, within a breed or variety, is known as outbreeding or outcrossing. It is a random mating except that individuals related to the extent of half brother-half sister, or closer, or some other degree of relationship previously decided upon by the breeder are not included in the same pen.

This type of mating system is quite often followed by commercial hatcherymen. In actual practice, several so-called "key flocks" are maintained and males used to head the hatchery supply flocks are saved from a different key flock each year. It is thus possible to avoid any high degree of inbreeding and yet no pedigree records need to be maintained.

Outbreeding may also be practiced when selection is made on the basis of a family progeny test rather than mass selection. In this instance, the ancestry of each individual is known and it is easy to insure that outbreeding is practiced by excluding individuals from the mating that have the predetermined degree of relationship. Even though inbreeding is purposely avoided, such matings may not be strictly random since the breeder may follow a policy of mating best to best and poorest to poorest.

Another possibility is that of compensatory matings. Here, birds particularly good with respect to an important economic character are mated to birds that are relatively poor for that character. An example would be to mate hens from a family with good egg production but a slow growth rate to males from a family that was only average in egg production but which had an excellent growth rate.

This type of mating system, when used at the commercial hatchery level where mass selection only is being practiced, produces the following results:

(1) It tends to keep undesirable recessive genes covered up, since unrelated birds are less likely to carry the same undesirable recessive genes.

(2) On the average, it maintains the status quo with respect to breeding value of the flock. Except for chance selection of breeding stock, particularly on the male side, little improvement in the average performance can be expected except that which is associated with mass selection. As was noted previously, the improvement associated with this type of selection is often very slow and erratic. Conversely, an unfortunate choice of

breeding stock can result in a decline in the average level of performance.

(3) Lack of uniformitory of progeny may result. Since continuous outcrossing tends to keep the genetic make-up of the flock in a state of flux, there is no tendency to fix either desirable or undesirable genes. (Such fixation—making the strain homozygous for genes controlling various characters—would be desirable for the retainment of beneficial genes.)

(4) There may be an accumulation of undesirable recessive genes in the stock. Since continuous outcrossing may mask the presence of undesirable recessives, selection against them may not be practiced. Outcrossing also tends to disseminate these undesirable genes throughout the flock. Introduction of new stock from time to time may cover undesirable recessives, but it also may add further detrimental genes to the breeder's stock.

Therefore outbreeding cannot be recommended as a mating system at the commercial hatchery level if better than average performance is desired. A continuous grading program should be more effective with respect to average level of performance and uniformity of results.

Outbreeding may be an effective method of improving general level of performance at the breeder level where pedigree selection or, preferably, selection on the basis of family or progeny test records is made. However, even at this level, there are certain limitations. A strictly random type of mating at the breeder level would probably result in the maximum amount of genetic variability. On the other hand, it is not very effective as a means of fixing desirable genes and probably is not the most rapid approach to top performance levels for selected characters.

This type of mating could be effectively used in progeny testing males inasmuch as it gives a fairer estimate of the breeding worth of the male than a nonrandomized mating would. Thus a more accurate estimate of the male's genotype should, in time, lead to relatively rapid improvement.

The practice of mating best to best in an outcrossing program is effective in obtaining a rapid extension of the range of performance particularly at the upper levels. Thus the best birds of each succeeding generation will probably exceed the performance of the best birds of the preceeding generation, even though the average performance tends to lag behind.

This type of mating quite often would be desirable for characters such as growth rate and egg production where maximum performance is desired. For certain other characters, however, such as egg size and in some cases body size, where either extreme is undesirable, the mating of unlike individuals produces a middle expression of the economic character more desirable than either extreme.

In a sense this is a case of mating best to poorest. It has the effect of raising the lower limit of performance as well as lowering the upper limit of performance. Such a practice may temporarily achieve a uniformity of performance regarded as desirable by some. But the mating of best to poorest has no place in a progressive breeding program where the ultimate goal is other than a median expression of an economic character.

A commercial hatcheryman having a working arrangement with a poultry breeder who uses outcrossing as a mating system should attempt to find which of these three types of outcrossing is practiced by that breeder.

Eggs or chicks from progeny-tested males (tested by a random mating) mated to the best females will usually be more expensive but may well be worth the extra cost. If such are not available, eggs or chicks from a mating of best to best should, on the average, be superior to stock obtained from random matings.

The use of stock from a mating of best to poorest individuals can hardly be recommended for improving the hatcheryman's supply flocks. While such stock might perform very well itself, it would be heterozygous for some of its good characters and would not make good breeding stock because it would not breed true for those characters.

Grading. Grading or upgrading, as it is sometimes known, involves the introduction of males of superior breeding, to be mated with successive generations of breeding hens. This procedure is followed until the offspring approach very closely the quality of the superior birds purchased.

In the most extreme form, purebred males of good quality are mated to nondescript or mongrel hens for several successive generations. It has been shown that flocks of mongrel fowl can be rapidly improved with respect to type, color, and egg production through the use of standardbred cockerels.

Probably the reasons that this particular type of grading has not been generally adopted for the improvement of farm flocks are because the initial cost of purebred chicks is not high and chickens reproduce rapidly. Thus cost and supply are not limiting factors as they are in larger forms of livestock.

The mating of superior males of a breed or variety to relatively unimproved purebred females of the same breed or variety is a less extreme form of grading. This method is used primarily by the chick multipliers or commercial hatcherymen who have in the past produced the bulk of the commercial egg production stock. These multipliers return either yearly or at more or less regular intervals to the same poultry breeder. From him they buy breeding males from superior stock that are then used on hatchery supply flocks upon which mass selection has usually been practiced.

The chief advantages of this system of mating are that it provides a relatively large amount of improvement for a low cost and it provides a satisfactory means of distribution of desirable germ plasm accumulated by the good breeders. The fear that returning to the same breeder for males in succeeding years will be detrimental does not seem to be justified.

The main limitations of this mating system are: (1) that it requires continuous introduction of stock or eggs from an outside source with attendant disease hazards, and (2) progress in improvement is limited by the quality of the breeding stock used for grading purposes.

Of course there is also the possibility that the stock being used for grading, while excellent in most respects, is inferior in some important economic character such as egg size or rate of growth, and its continued use might introduce undesirable characters in the graded stock.

In summary, grading probably provides the maximum improvement with the minimum cost. It is perhaps the most efficient method available for dispersion of desirable genes accumulated by outstanding breeders. It should be equally effective as a mating system for either meat or egg production.

Closed Flock System. Another type of mating system is the closed flock system whereby a flock is reproduced entirely from its own members. In addition to being more-or-less a distinctive mating system in its own right, it may involve the use of other mating systems such as outbreeding, inbreeding, or linebreeding at the commercial breeder level. At the level of the commercial hatcheryman, upgrading as well as mild inbreeding may occur.

Since stocks are usually not pedigreed, any linebreeding that might occur would be largely accidental in nature. It would be difficult, if not impossible, to maintain strictly outbred matings at this level. Successful avoidance of inbreeding would be largely influenced by the number of males involved; small flocks would normally reach a higher degree of inbreeding sooner than would large flocks.

For the specialized breeder, this system would seem to have considerable merit. By closing his flock to the introduction of outside genes he might concentrate the desirable genes in his stock while eliminating the undesirable ones by proper selection methods.

The method chosen by the specialized breeder to do this may vary from breeder to breeder. It will likely involve some inbreeding and linebreeding combined at times with random mating within the flock. If no undesirable genes become fixed during this process, eventually it should be possible to increase the frequency of desirable genes in the flock while largely eliminating the undesirable ones.

If some undesirable characteristic becomes fixed, it may be necessary to cross the closed flock with another flock (preferably a closed flock) which carries the desired characteristic. This would be followed by closing the flock once more and repeating the selection process. It might be necessary to repeat this process a number of times for important economic traits. But in the end the breeder should have a flock relatively pure for most of the genes controlling the desirable economic characters.

Hatcherymen can take advantage of the improvement made by specialized breeders who use the closed flock system by returning to them year after year for cockerels to head their supply flocks.

When a hatcheryman returns to the same breeder annually, there is a gradual increase in the concentration of desirable factors in his breeding stock and at the same time he establishes a type of closed flock breeding system. In the course of time, the quality of his hatchery supply flocks will closely approach the quality of the flocks of the specialized breeders. This return to the same specialized breeder for superior males each year might be thought of as a type of upgrading.

A variation of this system is sometimes used at the supply-flock level. In this system, stock is originally purchased from a specialized breeder for the flock owner. Then instead of purchasing chicks or eggs to provide males for further breed improvement each year, the flock owner uses stock only from his flock with no introduction of outside stock. Thus in most cases the only selection possible under this system is physical appearance.

It is quite obvious that this method would only be desirable if the original stock had been of superior quality. Even so, it has the disadvantage of not allowing the flock owner or hatcheryman to take advantage of the additional improvements the specialized breeder may be making in his strain.

From the standpoint of the chick buyer, an important advantage of obtaining chicks from such a mating system should be their uniformity of performance. This does not mean that they would be uniformly good for all characteristics. For some they might be uniformly bad due to insufficient attention on the part of the breeder for that particular character. In addition, the repeatability of performance from year to year should be quite consistent.

When the performance is poor with this type of breeding system and the poor performance cannot be ascribed to poor management or poor environmental conditions, the chick buyer should consider the possibility of buying his chicks elsewhere because sudden dramatic improvements are unlikely.

Crossbreeding. The practice of mating purebred sires of one breed to purebred dams of another breed is known as crossbreeding. It has long been used as a breeding method in an effort to obtain a considerable amount of hybrid vigor.

Crosses between breeds will usually be expected to show more hybrid vigor than strain crosses. This is because it seems less likely that the same undesirable genes would be fixed in two breeds than in two strains of the same breed.

Unfortunately, theoretical results are not always realized in actual practice. While it is possible to show that in most crosses some hybrid vigor is obtained by crossbreeding, little or no heterosis is apparent in others. In some cases the crossbred offspring may actually be inferior to either one or both of the parental breeds. In others crossbreeding may result in a marked increase in performance with respect to certain economic characters and in no stimulation at all with respect to other traits.

In general, crossbreeding has resulted in higher hatchability, faster growth, more efficient gains, and better chick livability. For these reasons, the hybrid vigor resulting from breed crossing has been utilized extensively and is of considerable value to those raising broilers.

There is, however, no clear-cut evidence that crossbreds can be used most profitably for egg production. As in the case of strain crossing, some crosses seem to perform much better than others. In many cases crossbreds have not exceeded the better parent with respect to egg production, and in a few instances where they were superior, their superiority was relatively slight.

Table 1. The Number of Broody Periods of Purebreds and Crossbreds*

Breed or Cross	Year 1951	1953	1954
Purebreds			
White Leghorn (W.L.)	0	—	0
New Hampshire (N.H.)	4	5	0
Crossbreds			
N.H. x W.L.		—	42
White Plymouth Rock (W.P.R.) x W.L.	31		—
W.P.R. x N.H.	34	33	—
Barred Plymouth Rock (B.P.R.) x W.P.R.		—	28
Rhode Island Red (R.I.R.) x B.P.R.		11	—

*Fifty-five hens were in each pen for an 11-month period.

The crossbreds frequently show a much higher incidence of broodiness than either parental strain. This probably accounts for the fact that few crossbreds thus far tested have been better egg producers than the better purebred parent.

Evidence concerning adult livability is somewhat limited, but present data do not seem to indicate that hybrid vigor results in lower adult mortality.

In summary, it appears that the success or failure of crossbreeding as a means of obtaining heterosis depends not only upon what breeds enter the cross but also upon what strains within those breeds are used.

Strain Crossing. Closing a flock to the introduction of outside stock results in the formation of an interbreeding population in the breed or variety known as a strain. In the process of formation of the strain, any or all types of selection mentioned earlier may be practiced, and one or more mating systems may be involved. As a result, certain genes, either good or bad, tend to become fixed, and the strain becomes relatively uniform for those characters controlled by the fixed, or homozygous, genes.

Mating two strains of different origin is known as strain crossing. It was formerly thought that a cross between strains within a breed or variety would not result in much heterosis unless the strains were highly inbred. However recent evidence indicates that crosses involving highly productive strains that were only slightly inbred resulted in heterosis with respect to hatchability, age at sexual maturity, egg production, egg weight, and body size.

This does not mean that one can cross strains haphazardly and still expect superior results in all cases.

Table 2. Adult Deaths of Purebreds and Crosses*

BREED OR CROSS	Year and Location 1951C†	1951E‡	1952C	1952E	1953E
Purebreds					
White Plymouth Rocks (W.P.R.)	10	8	—	—	—
New Hampshires (N.H.)	8	11	11	10	11
White Leghorns (W.L.)	----	—	9	10	—
Crosses					
W.P.R. inbred males x N.H.hens	7	4	9	8	11
N.H. males x W.P.R. inbred hens	7	5	—	—	—
W.P.R. inbred males x W.L. hens	----	—	11	11	—
W.P.R. males x N.H. hens	----	—	—	—	11

*The numbers represent birds that died during an 11-month period. Each pen started with 55 pullets.
†C represents tests conducted at the Cottonwood substation.
‡E represents tests conducted at the Eureka substation.

In fact, if a number of strain crosses were made, three possibilities might be expected: (1) a few would be very good, (2) a large number would be equal or only slightly better than the average of the two parental strains and not quite so good as the better parental strain, and (3) a few might be inferior to either parental strain.

There is hope that as more strain crosses are made, some will be identified that will give even greater hybrid vigor than those thus far tested. Unfortunately, there seems to be no way of predicting in advance those strains which will "nick" or combine well when put together in a cross.

If sufficient heterosis can be obtained by strain crossing of relatively noninbred productive strains, it may be possible to provide chicks of high productive potentiality to the farmer at a relatively low cost. This is because it would be unnecessary to go through the long and costly process of developing and maintaining relatively nonproductive inbred lines for crossing purposes.

Strain crossing also avoids some of the disadvantages such as undesirable skin color, undesirable feather color, and, sometimes, a high incidence of broodiness, which are associated with some breed crosses.

As mentioned previously, the chief disadvantage of this mating system is the failure of some strain crosses to show any heterosis. A second disadvantage is that two strains of the same breed or variety must be maintained. To some extent this limits the amount of breeding work that can be carried on with either or both parental strains. A third disadvantage, common to strain crossing as well as other forms of crossing, is that the cross must be repeated year after year since use of cross strain birds as breeders results in a second generation showing considerable lack of uniformity.

Linebreeding. A special type of inbreeding in which there is a continued mating of the flock back to the decendants of some particular ancestor is called linebreeding. The purpose of this is to increase the number of times the given ancestor appears in the pedigree and thereby increase the contribution of that ancestor to the inheritance of the flock as a whole.

When the admired ancestor is more than a few generations removed from the present flock, linebreeding is not a very effective means of increasing productivity since that ancestor's contribution is halved with each succeeding generation. Here the fixation of type, both good and bad, would probably occur at a slower rate than with intense inbreeding.

Systems Involving Inbred Lines

Inbreeding. The mating of relatives, called inbreeding, is another mating system that has been used in an attempt to improve the economic qualities of the fowl. Inbreeding may be carried on at different levels. The mating of brother x sister or half brother x half sister is a much more intense form of inbreeding than matings between cousins or grandaughter x grandsire. As such, the mating of brother x sister would be much more effective than the mating of cousins in reducing genetic variability within the stock.

The fixation of characters, with consequent reduction of variability, is one of the chief purposes of inbreeding. Unfortunately, bad as well as good characteristics may sometimes become fixed despite careful selection practices.

Even with rigorous selection, it has thus far been impossible to fix enough of the desirable genes in any inbred line to raise the productive level for economically valuable traits above that which can be attained by other systems of breeding. Therefore, it appears extremely unlikely that inbred lines will themselves provide the end product. Because of their homozygosity for certain desirable characters, they may be used to good advantage for subsequent crossing, thus supplying the means to an end —more productive poultry.

As we have already seen, less intense forms of inbreeding may be used in the closed flock type mating system to concentrate or fix desirable genes in the stock. This may be accomplished to a large extent when mild inbreeding is carried out without the reduction in vigor, strength, and general hardiness that often accompanies the more intense forms of inbreeding. However, the degree or rate of fixation is also lessened with mild inbreeding.

Topcrossing. Mating inbred males with females which are not inbred is called topcrossing. Although this method of utilizing inbred lines has not been widely used to date, results obtained at this station indicate that this method of mating may have considerable promise. Undoubtedly, just as with strain and breed crossing, some topcrosses may result in little hybrid vigor whereas others may result in a considerable amount. In a relatively short period of time it would be possible to test a large number of such crosses and discard all but the most promising ones.

Theoretically the top cross hybrids should have some decided advantages over crossbreds or strain crosses. Since the males used would in all probability be rather highly inbred, the genetic contribution of any one inbred male to his offspring would not be greatly different from that of any other inbred male of the same line. This should result in greater uniformity in the progeny of a topcross mating than from breed or strain crossing.

Another advantage would be the high repeatability of performance of the topcross progeny as compared to crossbred or strain cross progeny. This results from the fact that many genes controlling economic characteristics would be homozygous or fixed in the inbred lines, whereas relatively few might be fixed in the noninbreds. Consequently, the continuous reshuffling of the genes of the noninbreds with each new generation would result in considerable performance fluctuation from year to year.

The topcross hybrid has an advantage over the conventional four-way cross hybrid which is produced by crossing four inbred lines, since it utilizes one inbred line instead of four. It should therefore be cheaper to produce because it is necessary to maintin only one costly inbred line rather than four. This lowered production cost might offset any differences in uniformity or repeatability of performance if, indeed, any existed.

Singlecrossing. Mating two inbred lines which are not closely related is known as singlecrossing. An inbred line of poultry results when close relatives (first cousins or closer) are mated for at least four generations. The poultry constituting this line must be so related that the mating of any pair within the line would result in progeny which have an amount of inbreeding exceeding that obtained from three successive generations of full brother-sister matings.

We refer to a line as being inbred when it has a coefficient of inbreeding of at least 50 percent. The inbred lines used for crossing have no common ancestor in the four immediately preceding generations.

Unfortunately, from the standpoint of economical maintenance, our inbred lines at this station (and probably this would apply to all inbred lines) do not perform as well as noninbred stocks or the hybrid offspring which the inbreds produce. The production cost of singlecrosses is very high because the line producing the eggs is below average in performance. Consequently, we have not tested the relative performance of singlecrosses.

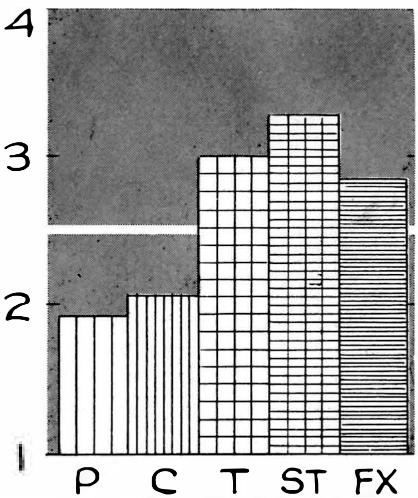
Singlecross Topcrossing. Mating singlecross males to purebred females is called singlecross topcrossing. Here, two inbred lines are necessary to produce the singlecross sons. However, in contrast to many of the males from inbred lines, these singlecross males will normally demonstrate a reproductive performance equal to or superior to purebreds.

In addition, preliminary tests have indicated that the single-cross topcrosses have outperformed other mating types at this station. From the breeder's standpoint they are

Table 3. Fertility and Hatchability of Eggs From Singlecross Topcross Matings Compared With Some Inbred Lines (1953)

BREED OR CROSS	% Eggs Fertile	% Fertile Eggs Producing Chicks	% Chicks From All Eggs Set
Singlecross Topcrosses			
(SD-1 x SD-11) x W.P.R.	95.5	83.2	79.5
(SD-1 x SD-11) x N.H.	92.7	84.2	78.1
(SD-4 x SD-11) x B.P.R.	88.0	86.0	75.7
(SD-11 x SD-1) x N.H.	95.0	90.3	85.8
(SD-11 x SD-4) x W.P.R.	95.6	81.9	78.3
Inbred Lines			
SD-1	56.1	50.7	28.4
SD-4	57.6	51.1	29.4
SD-11	61.4	68.2	41.9

easier to produce than the incrosses because it is only necessary to maintain two inbred lines.



Eggs per hen housed—purebred, crossbred, topcross, singlecross topcross, four-way cross. Top performance is 4.

Incrossing or Incrossbreeding. Crossing inbred lines for the production of hybrid chicks is known as incrossing or incrossbreeding. When the singlecross hybrid is mated to a third inbred line, a three-way cross hybrid is produced. If, as is the more common practice, two singlecrosses are mated together, a double or a four-way cross hybrid is produced. This is a common method used in producing many of the commercial hybrids now being offered for sale.

When all of the inbred lines used in producing the hybrid are of the same breed or variety, an incross hybrid is produced. But if inbred lines of two, three, or four breeds or varieties are used, the resulting hybrid is known as an incrossbred.

Generally the procedure has been to cross inbred lines from several breeds. The reason for this is that it has been supposed that more hybrid vigor would be obtained by crossing inbred lines of relatively diverse origin than by crossing inbred lines developed within a breed or variety. Presumably, lines developed within the breed would have more similarity than lines between breeds, thus giving less stimulation or heterosis when crossed.

There is no question but that the

crossing of inbred lines results in a considerable amount of heterosis and that the progeny produced excel their inbred parents by a comfortable margin. This would be expected, since the inbred parents are not likely to be very productive.

There is some question as to whether these hybrids are superior to superior birds that are produced by other breeding methods. Sufficient data have not yet been accumulated to answer this question. Tests indicate that some hybrids have been outstanding in performance whereas others have been only mediocre. This is to be expected and it seems probable that as more combinations of inbred lines are made and tested, it may be possible to produce hybrids which are far superior to any of those now in existence.

Inbred lines used in producing the hybrids are relatively homozygous and undergo little change in genetic makeup from year to year. Thus, the uniformity of progeny and the repeatability of results from year to year my be two of their most important advantages.

Because of the lack of homozygosity of stocks of chickens bred by other methods, there may be considerable lack of uniformity of progeny. Also there may be considerable variability of results due to important genetic segregation occurring from year to year in random bred flocks. Thus good results in one year are not always repeated the following year even though the same source of stock is used.

Uniformity of results and repeatability of performance from year to year may justify in the producer's mind the increased cost of hybrid chicks, even though marked superiority over the best egg producing strains is not evident. It could also be argued that the cost of producing quality purebred chicks which equal the performance of hybrids might be nearly as high as the cost of producing the hybrid chicks.

Less information is available at our station concerning the use of heavy breed hybrids for meat production. But it is clearly evident that, theoretically, hybrids have the same advantages for broiler production as for commercial egg production.

Their chief disadvantage in this phase of production would be the higher chick production cost which might make it difficult to produce a broiler chick at a competitive price.

Potentially Useful System

Reciprocal Recurrent Selection. A recently proposed type of breeding and selection system is reciprocal recurrent selection. It theoretically offers considerable promise. It may be especially useful to breeders whose stocks have apparently reached a leveling off point as a result of the application of older selection and breeding methods. This leveling off point, beyond which there seems to be little hope for further improvement, is commonly referred to as a "plateau."

Reciprocal recurrent selection is a method devised to make maximum use of heterosis. The commercial product to be offered for sale is a cross between strains or breeds.

Table 4. Comparison in Egg-Laying Performance of 4-Way Cross Hybrids With Other Birds at the Various Substations

TYPE OF BREEDING AND YEAR	Substation Where Test Was Conducted	Hen-Housed Egg Production Difference*	Hen-Day Percentage Difference†	Rating‡
Purebred				
1953	Cottonwood	—36.8	—6.0	4
1953	Eureka	—37.3	—10.6	4
1954	Eureka	+13.3	+2.8	2
1954	Highmore	—31.4	—12.3	4
Crossbred				
1953	Cottonwood	+32.8	+7.0	1
1953	Eureka	—1.0	—0.6	3
1954	Eureka	—15.8	—4.5	3
1954	Highmore	+0.2	+5.4	3
1955	Cottonwood	—14.1	—2.3	4
1955	Eureka	—6.8	—4.9	4
1955	Highmore	—9.8	—3.6	4
Topcross				
1953	Eureka	+13.7	+5.1	2
1955	Highmore	+1.6	—1.4	2
Singlecross Topcross				
1954	Highmore	+20.6	+4.5	1
1955	Cottonwood	+16.0	+1.8	1
1955	Cottonwood	+9.1	+3.7	2
Four-Way Cross				
1953	Cottonwood	+2.8	—1.1	2
1953	Cottonwood	+1.1	+0.1	3
1953	Eureka	+24.5	+6.1	1
1954	Eureka	+52.5	+8.9	1
1954	Highmore	+10.7	+2.5	2
1955	Cottonwood	—11.0	—3.2	3
1955	Eureka	+16.3	+2.2	1
1955	Eureka	—6.1	—1.4	3
1955	Highmore	—6.9	—2.7	3
Commercial Hybrid				
1954	Eureka	—50.0	—7.3	4
1955	Eureka	—3.4	+4.1	2
1955	Highmore	+15.2	+7.6	1

*Difference between the average number of eggs laid by the 4-way cross pen and the average for all pens at that substation during that year. Based upon the number of birds housed.

†Difference in the rate of lay between the 4-way cross pen and the average for all pens at that substation during that year.

‡Relative egg-production rating. There were four pens at each substation, so the possibilities are 1, 2, 3, or 4.

Thus the parent stock used to perpetuate the pure strain is selected on the basis of the performance of its progeny (when crossed with the other strain or breed with which it will be crossed when producing the chicks). The objective is to locate individuals within a strain which are superior with respect to combining ability and will thus produce a maximum amount of hybrid vigor when crossed with representatives of the other strain.

The birds within the strain which have shown maximum combining ability are mated to perpetuate the pure strain for each of the separate purebreds. This procedure should tend to sort out and fix within each strain those genes that are responsible for the observed heterosis.

To be most effective, this method of breeding must be preceded by a strain or breed crossing program to locate the most desirable strain for use. Selection of two strains showing little heterosis when crossed would result in slow progress for the early generations.

It is essentially a sire testing program and the breeder has a choice of two things. In one he must be prepared to discard a large number of pure strain females (which do not produce superior progeny while cross-strain performance of the males is being tested). His other choice is to be content with the considerable time interval between generations for improvement. Perhaps, as is often the case with any new idea, its chief disadvantage is that it is yet untested.

From the standpoint of the commercial poultryman, this method may in time result in the production of poultry with the uniformity and repeatability of hybrids. From the breeder's standpoint, it also has the advantage that a program can be carried out with little or no increase in the amount of facilities required for progeny testing.

It should also be unnecessary to test as many combinations of lines with this system as would be necessary with a program involving inbreeding and hybridization. With reciprocal recurrent selection only two lines would be developed for each desired cross. Like the hybrid producer, the breeder would have a monopoly on his product. He would maintain the original lines and only the cross resulting from them would be offered for sale to hatcheries.

Possibilities

It is difficult to generalize, either in terms of dollars and cents or operating efficiencies, as to what methods of selection and mating would be most profitable, because there is a tremendous variation in potentials between each farm. A trapnesting program is usually considered esential to a successful poultry improvement breeding program.

Factors that will help guide an individual to the most satisfactory approaches include: (1) size of physical plant—housing facilities available on the farm, (2) number of small pens that can be used for individual matings, and (3) training of the operator, which would include skill in applying techniques and interpreting results as well as familiarity with the work of other researchers. (An example of technique is the practice of artificial insemination, which involves collecting semen as well as inseminating and is sometimes necessary in the development of inbred lines.)

The majority of experimental reports indicate that, under comparable environmental conditions, the birds produced from crosses with inbred lines included in their ancestry perform better (in terms of production) than those without inbreds. One of the proposed explanations for this is that progeny from the inbreds perform more uniformly than do the others.

Another factor, which could apply to any mating type involving nonrelated parents, is heterosis. Several detailed treatises have been developed to suggest explanations for the phenomenon of heterosis. Two possible explanations involve: (1) a complementary action of genes when present in the heterozygous state and (2) the covering of the effects of deleterious recessive genes when favorable dominant genes are introduced from an unrelated mate.

Frequently producers of hatching eggs refer to themselves as poultry breeders when, in reality, they are "multipliers." Unless a poultryman conducts his own breeding program, which might involve practices such as those included in this circular, he does the industry an injustice to refer to his enterprize as a breeding unit.

There is prestige associated with the term "poultry breeder" and rightly so. The "multipliers" contribute considerably to the poultry industry by obtaining breeding stock from outstanding breeders each year or two and reproducing it in much greater quantity than the individual breeder could possibly attain. The currently popular allotting of franchises to hatcherymen is indicative of the poultry industry's need and desire for flock multipliers.

Commercial breeders who use only crosses for their sale chicks make it mandatory for customers and multipliers to return each year for stock. Present results indicate that the crosses mentioned under mating types are at their end point, or perform at their optimum, when those practices are followed.

As two examples: (1) The crossbred performs better after the first generation crossing of two purebreds than would subsequent crossings of the crossbreds among themselves. (2) When incrossbreds, involving two generations of crossing and four inbred lines, are produced, they have better reproductive performances than do later generations which could be produced by mating the incrossbred females to incrossbred males.

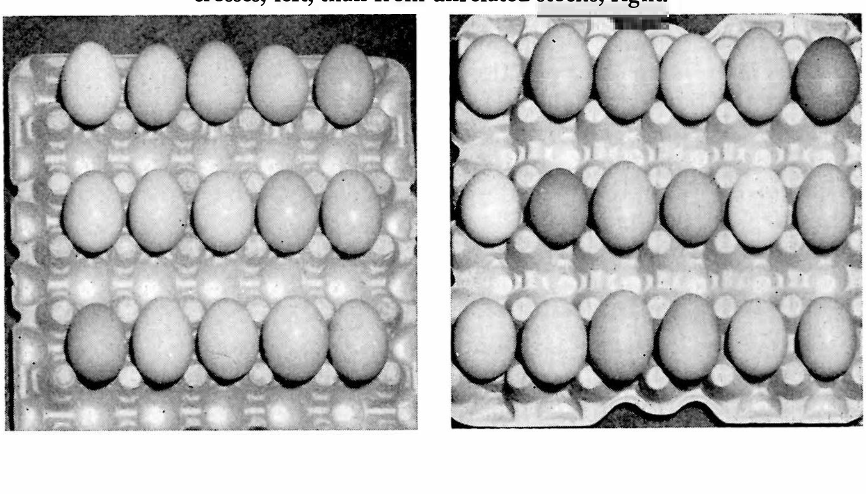
Again, the main advantages seem to be that maximum heterosis is realized at these mating end points and the groups of birds are more uniform. Later matings of the crossbreds give rise to greater variation which in turn results in a number of poor performers in subsequent generations.

Another guide for the poultry breeder, when he is evaluating the possible selection and mating systems, is the particular need that exists in his flock. When the commercial chick which he is producing is slow in reaching sexual maturity, these are questions that arise: "Is this a character of high heritability; that is, can I expect to achieve early sexual maturity by making the bird homozygous for a gene controlling this phenotype?" "Could I expect to improve sexual maturity by crossing my strain with another breed or strain?"

Each of these questions requires separate answers which can best be found in research articles or textbooks dealing with poultry genetics and poultry breeding. In actual experimentation no single gene has been identified for early sexual maturity, which means that this character can not become fixed merely by the simultaneous presence of two like genes at one locus. Other traits which follow the same pattern of inheritance are adult body size, hatchability, and number of eggs laid.

On the other hand, all of these

Greater uniformity is usually found within the inbred lines and controlled crosses, left, than from unrelated stocks, right.



traits do show heterosis. Consequently, in answer to the second question, it would be expected that age at sexual maturity could be reduced by crossing the strain with another.

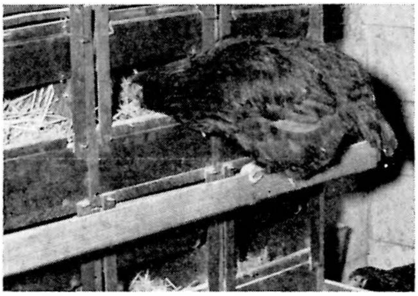
In the light of current findings, poultry breeders might rightfully ask, "What might we set as immediate or eventual performance objectives?" As recently as 1953, D. C. Warren, in *Practical Poultry Breeding*, recognized that the following goals have been individually reached:

- 90% hatchability of all eggs set
- 100% chick livability to twelve weeks of age
- 95% adult livability during the first laying year
- 300 eggs per surviving hen

He suggested that these goals could be reached collectively in one genotype (in one group of birds).

Although these predictions seem ambitious in some respects, it must be realized that they are not very inclusive. Size of egg, quality of egg, and carcass appearance are a few of the many important marketing factors not included. It will be interesting to review these goals 30 years from now; will they be raised or lowered?

So far as the present status of poultry breeding is concerned, we are critically appraising old and new methods of selection, of systems of mating, and of available stocks. In particular, many crosses are being made which involve our new inbred lines. Some of the inbred lines which have already indicated that they are superior in their combining ability or "nicking" ability have been released from experiment stations. (South Dakota - 11, a Rhode Island Red developed at this station, is an example.)



South Dakota—11 hen

In conclusion, poultry breeders still find it necessary to prove by contest records and customer satisfaction, that their product should be preferred above that of their competitors. This is a healthy situation. Some of the underlying bases for progressing toward this end have been outlined and discussed. Final choice or rejection of practices suggested here can only be determined by the individual concerned.

Definitions of Terms Used

Allele—Each gene has one or more partner genes (alleles). The alleles are each located in the same relative position on paired chromosomes. In many instances one gene is said to be dominant to its allele; or contrarywise, the second gene is recessive to its dominant allele.

Autosomes—All chromosomes except the sex-chromosomes.

Backcross—The mating of a bird to a mate of the same type or breed as one of the bird's parents.

Cell—Basic unit concerned with the formation of all body tissues and fluids. The two main types are somatic cells and germinal cells.

Character—A term referring to a feature (often to a body form or function) which is frequently used to describe inherited factors.

Chromosomes—Long strands of microscopic materials which are interwoven in the cell nucleus. The genes are arranged in linear fashion on the chromosomes.

Coefficient of Inbreeding—The degree to which an individual, or group of individuals, has been inbred. Usually reported in terms of percentage. Theoretically, it is the percentage of gene-pairs which have become fixed in a homozygous state.

Combining Ability—Good combining ability is the ability of a stock to cross with another stock, or stocks, and produce superior offspring. Crosses of a stock with poor combining ability would produce progeny which was not superior.

Complementary Genes—Genes which result in a different effect when together than when acting independently by themselves.

Crossbreds—Chickens resulting from the mating of one purebred to a different purebred.

Dam—Mother.

Diallel Crosses—The individual mating of more than one male to the same two or more females.

Diploid—Double number of chromosomes. The chromosomes are paired. Cells or individuals with the diploid number have two sets of haploids. All chickens have diploid chromosomes.

Dominant—A condition which permits the appearance of a character, even if there is only one dominant gene present. Normally used in reference to alleles.

Epistasis—The ability of a gene to behave as a dominant towards another gene, or genes which are not alleles. It masks the appearance which would have resulted from other genes.

Fertility—The result when a sperm unites with an egg. It is a necessary forerunner to all baby chicks. All eggs which hatch must be fertile, but all eggs which are fertile will not always hatch. (An exception to this rule has been discovered recently in turkeys where a small percentage of embryos, or poults, develop from unfertilized eggs.)

Fix—Herein used to represent the establishment of a true-breeding or homozygous type.

Gamete—A reproductive cell. It contains the haploid number of chromosomes.

Gene—A unit of inheritance. Genes are linearly located on chromosomes. Each gene occupies a specific tiny locus on the chromosome and influences or controls a specific phenotypic character of the chicken. For convenience, genes are assigned symbols (i.e. *R* for rose comb).

Genetics—The study of inheritance. It attempts to explain similarities or differences between parent and offspring.

Genetic Variability—That portion of the total observed variation which is due to the effects of genes.

Genotype—The type of genes which an individual prossesses.

Germinal Cell—Reproductive cell or gamete.

Haploid—Single set of chromosomes which is normally found in each sperm and unfertilized egg.

Heritability—Degree to which a trait is inherited. The fraction of the total variation that is accounted for by genetic differences. (The factors with high heritability are more easily established in a flock by breeding methods than are those of low heritability.)

Heterosis—Hybrid vigor found in the offspring of unrelated parents.

Heterozygote—A zygote, or individual, containing two unlike genes (or two unlike alleles). The heterozygote cannot "breed true" for the character for which it is heterozygous.

Heterozygous—Containing two unlike alleles.

Homologous—Each somatic cell has diploid chromosomes; that is, the chromosomes are present in pairs. The members of a pair of diploid chromosomes are said to be homologous to each other.

Homozygote—A zygote containing two like alleles for a given trait. It will breed true for the character when mated to similar homozygotes.

Homozygous—Containing two like alleles.

Hybrid—The offspring of two unlike and usually unrelated parents. In poultry breeding the term has become associated more specifically with offspring from parental stocks that have been inbred.

Hybrid Vigor—A desired vigor often observed in the offspring of two unlike parents wherein the progeny preformance exceeds that of both parents.

Inbred Line—A group of chickens which has been subjected to an inbreeding program for at least four generations. The birds have a coefficient of inbreeding of at least 50 percent.

Inbreed—To mate related parents. The most intense methods for inbreeding chickens are to mate: (1) brothers with sisters and (2) parents with offspring.

Incomplete Dominance—A condition which exists when the appearance of the heterozygote is different than the homozygotes.

Incross—Progeny from crosses of inbred lines within a given breed.

Incrossbred—Progeny from crosses of inbred lines of different breeds or varieties.

Lethal—A condition causing death.

Locus—A position on a chromosome where a given gene is located.

Maternal—Pertaining to the dam, or mother.

Mendelian Inheritance—A type of inheritance explainable by the laws established from the genetic studies of Gregor Mendel.

Microscopic—Too small for the naked eye to see but visible with magnification (i.e. under a microscope).

Multifactorial—Controlled by multiple factors.

Multiple Factors—A trait is controlled by mutiple factors when there are several pairs of genes responsible for the expression of the trait.

Mutation—An abnormal condition resulting from some genetic change.

Nick—A term used to express good combining ability.

Nucleus—The center. In cells, the nucleus is a center part which can be identified microscopically; it contains the chromosomes.

Paternal—Pertaining to the sire, or father.

Pedigree Record—A continuous record of the ancestors.

Phenotype—Type of appearance. What the individual looks like. Phenotype is normally controlled by an interaction of the genotype and the environment.

Progeny—Offspring. Sons and daughters.

Progeny Test—Evaluation of the breeding worth of parental stock by the performance of its offspring.

Purebred—A recognized breed which has presumably not been crossed with a different breed.

Random Mating—A mating in which there is no preferential mating excercised by the poultryman.

Recessive—The term applied to a gene which is not expressed in the phenotype unless it is homozygous. A recessive gene has a dominant allele, or mate.

Reciprocal Cross—A breed or variety cross involving mates of the opposite sex. For example, when Red males are mated to Leghorn females, the reciprocal cross woud be Leghorn males mated to Red females.

Recurrent Selection—The selection of breeder stock on the basis of the performance of crossbred progeny produced by testing against a tester stock. The breeder stock and tester stock are maintained independently, with testing continued each year.

Sex-Linked Trait—A character carried on the sex chromosome.

Sex-Linked Cross—A cross between individuals carrying different sex-linked alleles in such a way that the character shown by one sex appears in the offsring of the opposite sex only. An example of this type cross is the mating of barred females with non-barred males; the male offspring are barred, the females are non-barred. This type of inheritance is sometimes referred to as criss-cross inheritance.

Sibs—Sisters and brothers.

Sibship Mating—Mating of sister with brother. Preferred mating type used in inbreeding programs.

Sib-Test—A test which evaluates the breeding worth of an individual by the performance of its brothers and sisters.

Sire—Father.

Somatic Cells—Body cells, as contrasted to germinal cells. Body tissues (i.e. muscle, bone, glands) are composed of somatic cells.

Sperm—The reproductive cell produced by the male.

Viability—The ability to live.

Zygote—The new individual formed when the gametes, or reproductive cells, unite at fertilization.

Mating Systems