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TRAINING IN RURAL POULTRY DEVELOPMENT PROJECT

PRINCIPLES OF POULTRY BREEDING

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POULTRY BREEDING

The objective of the breeding part of this course is to increase the understanding of avian genetics and poultry breeding techniques. This will provide a sound basis for evaluating flock performance and the knowledge necessary to determine the best breeding stock for a particular application.

Table of Contents

INTRODUCTION

Understanding of a course dealing with poultry breeding requires some knowledge of basic genetics. Here it is only possible to present a brief introduction to the genetics of inheritance. In addition in this introductory section we will also compare some aspects of poultry breeding with that of other farm animals.

Genetic inheritance

The science of genetics is concerned with determining the modes of inheritance or the transmission of biological properties from generation to generation. The particulates that determine the modes of inheritance are called genes. The genes or hereditary factors are contained in bodies called chromosomes. The chromosomes are threadlike structures located in the nuclei of microscopic cells which make up the bodies of all higher organisms. Chromosomes exist in every living cell (both autosomal and sex cells) in pairs. Transmission of hereditary characters is only through sex cells. Chromosomes are mainly composed of deoxyribonucleic acid (DNA). The DNA is composed of a linear sequence of basic units or nucleotides. Each nucleotide is made up of a base, a phosphate and a sugar molecule. Each base could be adenine, thymine, guanine or cytosine, and the codes directing everything in an animal depend on the unique arrangement of these bases into DNA.

Genes that determine specific characteristics are segments of DNA molecule. The manipulation of genes is the basis for all breeding programs, and DNA may be considered as building blocks of the genetic foundation of an animal. As the chromosomes exist in pairs the genes also exist in pairs. For example, in chicken there are 38 pairs of autosomal chromosomes and one pair of sex chromosome. On each chromosome there could be thousands of genes. Genes may express themselves in different ways. The way genes express themselves will be clearer if the definition of the following genetic terms is given:

Phenotype The external appearance or some other observable or measurable characteristic of an individual.

Genotype The complete genetic make-up of an individual.

Locus Region on chromosome where a specific gene pair or allelic series is located.

Allele Members of a pair (or series) of different hereditary factors that may occupy a given locus on a specific chromosome and that segregate in formation of gametes. Simply allele is an alternative form of a gene for the same character.

Homozygous Paired genes (alleles) at the same locus on paired chromosomes code for the same characteristic (trait).

Heterozygous Paired genes (alleles) at the same locus on paired chromosomes code for the different characteristics (traits).

Dominant The characteristic (trait) that masks the expression of its paired allele and is expressed in the phenotype.

Recessive The characteristics (trait) that is masked by its paired allele and is not expressed in the phenotype.

Complete Dominance The complete masking of the expression of one paired allele by the other allele.

Incomplete Dominance Partial expression of both paired alleles resulting in a blending of the two traits in phenotype.

Overdominance A genetic situation in which individuals heterozygous for a gene pair (or series) are superior in some manner to any homozygote of the pair or series.

Heterosis The extent to which the progeny of a cross differ from the average of the parental types in a given character. Positive or desirable heterosis is called 'hybrid vigour'. The opposite of heterosis is inbreeding depression.

F_1 The hybrid offspring or first filial generation from a given mating.

Mitosis Cell division in which each chromosome duplicates itself and the daughter cells each have the same number of chromosomes as the parent cell.

Meiosis Cell division during germ cell formation in which chromosome number is reduced with each daughter cell receiving only one member of each chromosome pair.

Poultry breeding compared to other livestock.

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Poultry breeding has achieved a level of practical application that is not even approached in large-animal breeding. Selection and crossbreeding techniques have enabled the production of a laying fowl which will provide up to 300 eggs a year, as against less than 100 from unimproved poultry. Similar improvement in growth rate is observed in a relatively short time. There are several reasons for this fast progress.

Generation interval

Generation interval defined as the average age of parents when their chicks which are going to be used as replacements are hatched is the shortest in chicken than any other livestock. Age at sexual maturity in chickens is about 21 weeks of age and generation interval is as short as one year. This has accelerated developments in poultry breeding.

High reproductive rate

The major reason for fast progress in poultry production through breeding is the high reproductive rate. The female chicken can potentially produce one fertile egg per day with relatively few nonproduction days per year. Embryonic development commences outside of and unattached to the dam's body, allowing continuing ovulation during the incubation period. The incubation period for the fertile chicken egg is only three weeks before hatching. Thus, many more offspring are available from which to select breeding stock than are possible with mammals.

The role of inbreeding and crossbreeding

These unique biological advantages (high reproductive rate, their relatively low cost and short generation interval) of chicken have made it possible to develop inbred lines. Intense inbreeding increases the chance of expression of deleterious recessive genes and perhaps death of chicks. In addition affected animals will be culled, this will reduce the frequency of detrimental genes in the offspring generation. The cost of removing even large number of animals with undesirable genes is relatively small in poultry and the remaining could easily multiply to produce adequate number of replacements.

Sex chromosomes and sex-linked genes.

Birds differ from mammals in certain characteristics associated with inheritance. One of the major differences is the genetics mechanism by which sex of the offspring is determined. In mammals, sex of offspring is determined by the male gametes, but in birds it is determined by the female gametes. Basically this procedure depends on the number of complete sex chromosomes (*Z*) in each tissue cell. In birds there are two complete sex chromosomes in the male but the female possesses only one.

Since all male cells contain a pair of complete sex chromosomes, after meiosis in the testes cells, only sperm cells with a single complete sex chromosome can be produced. On the other hand all female cells contain only a single complete sex chromosome, after meiosis in the ovary cells, one-half of her ova will contain a complete sex chromosome and the other half will contain the incomplete sex chromosome. Ova from 50% of her ovulations containing the complete *Z* sex chromosome, if united with any male sperm cells, will produce male offspring containing both complete *Z* sex chromosomes, one from each parent. Ova from the other 50% of her ovulations not containing the complete sex chromosome, but containing the *W* chromosome, if united with any male sperm cells, will produce female offspring containing a single complete *Z* sex chromosome from the male parent and the incomplete *W* chromosome from the female parent. Thus, in birds, the female determines the sex of the offspring. The opposite is true in mammals, including humans.

Since females have only one complete chromosome, genes carried on that chromosome (sex-linked genes) will occur only on that chromosome while males will carry such genes on both of the chromosomes. Due to this a male chicken can transmit a sex-linked characteristic to his sons and daughters. The female, having only one complete sex chromosome cannot contribute one to her daughters. Therefore, any characteristics carried on the sex chromosome by the female cannot be transmitted to her female offspring. The very fact that only one complete sex chromosome from the male parent is transmitted makes these particular progeny female. Knowledge of these facts has been very important in poultry breeding for the transmission of desired characteristics.

- This is specifically used for sex determination through feather characteristics at the time of hatching. A sex-linked gene responsible for slow feather (*K*) which is dominant to rapid feathering (*k*) is used as a tool in sexing chicks at hatching time. In the rapid feathering chick, the primary and secondary wing feathers are longer than the coverts; although in the slow feathering chick the primaries and coverts are about the same length. For example, a rapid feathering male mated to a slow-feathering female produces slow-feathering male progeny and rapid feathering pullets. This makes it possible to select pullets at hatching time and will be used for egg production. On the other hand the males could be used for broiler production or could be killed a few days after hatching. Other sex-linked characteristics such as feather color could also be used for sex determination in different chicken varieties. For this to work the male parent must be homozygous for the recessive factor and the female parent must show the dominant character.

- Although there are several types of dwarfism in chickens, the sex-linked type is the most common one. It is produced by the sex-linked, recessive gene, *dw*. Birds of normal size carry the sex-linked, dominant gene, *Dw*. This knowledge is sometimes used to produce normal broilers by dwarf females which will have relatively lower maintenance requirement. This is done by mating homozygous Normal males to recessive dwarf females which result in all Normal but carrier progeny. In the production of dwarf commercial layers the recessive dwarf males are used.

- Other groups of sex-linked genes of importance in chicken are genes responsible for barring, here designated by B, located on Z chromosome of certain breeds. This allele reduces pigmentation in the plumage. In the males which carry two barring alleles (BB) the white spot on the head is more pronounced than in females which carry only one (BW). The advantage of using this allele is that once it is introduced into a breed from which all the barring alleles of the gene had been removed from the population by selection, the chicks of each sex are distinguishable at hatch. Using this method; the ability to identify sex does not depend on crosses between different breeds, and is known as auto-sexing. However, breeds based on any of the methods of sex determination did not develop for two reasons: First, vent sexing by the Japanese method is found to be efficient. Secondly, the White Leghorn became the most important parent of most hybrid strains of egg producing birds, and auto-sexing does not work with White Leghorns.

Importance of single genes

In addition to sex-linked genes, other genes which determine feather color, comb type, egg color, broodiness etc. controlled by one or a few number of genes are also important. In the broiler industry, for example, birds with white feather are preferred by producers to colored ones because they result in a 'cleaner' looking carcass. However, consumer preference to feather color depends on tradition and custom.

There are also one or few number of genes with lethal or subvital effect which reduce hatchability or the production of normal chicks.

THE REPRODUCTIVE SYSTEM IN BIRDS

Many anatomical details distinguish birds from mammals and condition their physiology, their biology and pathology. Although the general physiology of birds is similar to mammals, there are some peculiarities with regard to digestion, reproduction, moulting and heat regulation. Here a short account of the reproductive system of the chicken will be given.

In the male, the genital apparatus includes two testicles located within the abdomen, under the first lobe of each kidney. Each testicle excretes the sperm it produces into a very sinuous ductus deferens, which emerges into the cloaca through a papilla (Fig. 1a).

In the female, the genital apparatus has the function of producing and excreting eggs. The single ovary is located within the abdomen under the left kidney. It forms a cluster of variable volume, composed of follicles in various stages of development, ranging from the volume of a pin's head to that of an egg yolk. These follicles are enclosed in a thin membrane traversed by many blood vessels, which open progressively, as the yolk, or vitellus matures (Fig. 1b).

When mature, the vitellus falls into a vast oviduct which comprises five successive parts:
- infundibulum, a wide funnel that receives the vitellus, which remains in it for only a quarter of an hour:
- magnum, which follows it and secretes the white (a stay of 3 hrs);
- isthmus, which produces the two shell membranes (stay of 1 hr);
- uterus, where the shell forms (stay of 24 hrs);
- vagina, which carries the egg to the cloaca to be laid.

Thus the cloaca is an organ common to three apparatuses, digestive, urinary and reproductive, constituting their terminal portion.

Reproduction in hens is accomplished by the eggs. The egg is made up six parts: embryo, vitellus or yolk, albumin or 'white', the two membranes and the shell. Laying of eggs can occur without the intervention of the cock. For the eggs to be fertile, a cock must have 'straddled' the laying hen. One cock is sufficient for the fertilization of about ten hens.

Laying by the hen occurs, in birds of improved breed, about every 24 hr over longer or shorter periods, separated by resting periods. A good layer, in a tropical country, produces on average 175 eggs per year, and even more if she is very well fed and good conditions of hygiene are ensured. She begins to lay from the age of 5-6 months, but eggs at the beginning of laying are often too small to be incubated.

From practical point of view, it should be noted that hens prefer to lay at particular hours of the day. The hours may vary more or less with climatic conditions and with breed, but on the whole the following data should be remembered:
-only 2% of eggs are laid before 7 hr or after 17 hr (daylight) but more than half (55%) are laid between 9 and 13 hr.

This distribution of laying should be noted, since it is important to remove eggs from the hen houses as quickly as possible, to put them in a place offering good conditions (environmental temperature 12 to 14°C). Removing the eggs as quickly as possible is essential to keep the eggs clean and fresh. Handling eggs properly increases the proportion of chicks that would be obtained from the total number of eggs incubated (i.e. hatchability).

The hen's egg only produces a chick if it has been fertilized, and on condition that it has been kept for 21 days at a temperature of 38 to 39°C. This operation, called incubation, is carried out naturally by the broody hen, or artificially in installations called incubators. At the end of 21 days, the chick formed inside the egg breaks the shell with its beaks, which for this purpose is armed with a very hard point called the egg tooth, which disappears soon after hatching.

DIFFERENCES BETWEEN NATIVE AND EXOTIC BIRDS

Types of indigenous birds in Ethiopia

The local chicken of Ethiopia feeds, manages and houses itself with very little input from its owner. Although their productivity level is rather limited they are relatively better adapted to feed shortage and climatic stress, and they are more disease resistance than any of the exotic breeds. The local chickens compared to the White Leghorn, the most widely used exotic breed in Ethiopia, are better or equal in age at first egg, hatchability, dressing percentage and in percent yolk weight but were poorer in body weight, egg weight and rate of egg production (Teketel, 1986 and Abebe, 1992). However, comparisons between local and exotic chicken were carried out under 'improved' intensive management system which might favor exotic birds. Local chicken are small-bodied and are exclusively raised under traditional management system. The local chickens are not properly described but they are identified by their plumage colors as black, red, white, etc. The variation between indigenous birds in terms of egg and meat production is rather low. Some promising strains which may be considered for future improvement were identified based on limited studies (Teketel, 1986 and Abebe, 1992).

Types of exotic birds

Pure-bred chickens may be identified according to their placement into specific class, breed, variety and/or strain. A class is a group of standard breeds that have developed in certain geographical regions of the world. The four major classes of chicken are American, Asiatic, English and Mediterranean. Distinctive differences among breeds within a class are primarily those of body shape, size, and skin color. Distinctive differences among varieties within a breed are primarily those of feather color, pattern and comb type. A strain is a chicken-breeding stock bearing a given name and produced by a breeder through at least five generations of closed-flock breeding. Distinctive differences among strains are genetic and are selected by the breeder for specific purposes. One of the most common chicken types in Ethiopia, the single comb white Leghorn, is of the Mediterranean class, the Leghorn breed and the White variety. The exotic birds could also be classified based on their utility into meat or egg type. Another way of classifying exotic bird types is as either pure breeds (strains) or commercial crosses.

Pure breeds or pure strains

These are strains which are crossed between themselves to produce commercial crosses that will be used to produce eggs or meat (or both for the mixed breeds).

White Leghorn: White Leghorn is the best layer of white eggs, which are used most often in tropical Africa among the pure poultry strains. Its flesh is meagre and of mediocre quality, so it is only used as an 'egg-laying machine'. The origin of the Leghorn breed is Italy but was selectively bred in the USA for increased laying capacity. The White Leghorn is a strain with great tolerance for tropical climatic condition such as heat and humidity.

White Wayandotte: A hen of American origin, created towards the end of the 19th century, it enjoyed first place in that country before spreading through Europe. Its colour is white, the beak and feet are yellow, the crest is triple and it is heavily feathered. White Wayandotte is a very hardy breed adapting to all climates and of mixed aptitude (dual purpose breed). Thus it is very profitable up to the time of culling, contrary to the Leghorn. The hen's weight varies between 2.5 and 3 kg, and that of the cock between 3 and 4 kg. As it has a great tendency to get fat, it must be severely rationed.

Rhode Island Red (R.I.R.): A breed created in Rhode Island State in the USA from a cross between Asiatic and Mediterranean breeds. This breed occupies one of the very top places both as the pure breed and in commercial crosses. It is a breed well adapted to commercial rearing and to tropical conditions. In addition the cocks are also used to improve native birds through crossbreeding in many parts of Africa. The hen weighs from 2.5 to 3 kg, while the cock may reach 4 kg. It is a dual purpose breed: the hen is very good layer of tinted eggs, while the pullets fatten well and produce good quality flesh. This breed does however have the defect of a high food consumption ratio.

Other examples of pure strains used in tropics are New Hampshire, Light Sussex, Barred Plymouth Rock, Cornish White, etc..

Commercial crosses

Commercial crosses are strains developed by selecting within breeds for several generations and crossing the breeds in different ways. In the naming of the crosses the male strain is the first named. For example, the Shaver starcross 566 is the result of a Rhode Island Red X barred Plymouth Rock cross, where the Rhode Island Red is the male strain (cock) and barred Plymouth Rock the female strain (hen). There are a number of commercial crosses used in Africa for about fifteen years. The choice of the crosses to be imported should depend on the farming conditions, level of technical competence, climate and demand (white or brown eggs, size of pullets, etc.).

Environmental adaptation

Indigenous birds are better adapted to local environment and local feedstuffs, low level of feeding, heat stress and also are more disease resistance than imported breeds. For example, in Bangladesh a native chicken called Deshi, are found to be more productive than exotic birds because of their tremendous ability to survive under stress conditions, resist local diseases and retain their scavenging habits. Of course there are also variations in adaptability within local birds and also within exotic birds. For example, both brown and white strains of laying hens can be productive at high temperature, although white birds tend to be slightly more productive. Moreover, there is more variation between individual birds in egg production under high ambient temperature than under normal temperature. Thus when adaptability is measured as productive adaptability there is variation between birds which suggested that there is a possibility to improve them by selective breeding.

Another reason for the adaptability of native chicken to harsh environmental condition is their small size which means they are more tolerant to high ambient temperature and perhaps have a higher feed conversion efficiency due to their smaller maintenance requirement. There are also major or single genes with relevance to adaptation to tropical environment:

1. Sex-linked dwarf gene, which leads to a drastic reduction in body size. The associated advantages of their small size are their low maintenance requirement, improved persistency, reduced incidence of fat liver haemorrhages, etc.

2. The autosomal major gene responsible for naked neck which reduces feathering intensity by about 20-30 % in heterozygous and by up to 40% in homozygous individuals. This improves the insensible heat loss through exposed body surface and is also associated with the widening of apterial tracts.

3. There is also a single gene responsible for frizzled feather (curled outward near their tips). The presence of this dominant gene assists the thermo-regulation efficiency specifically under hot dry conditions through better circulation of hot air around the body due to their curly feathers.

In case of dwarf and frizzled birds the better adaptation is achieved by reduced heat production, however, in the case of naked neck birds the fasting heat production is reduced but the heat production under ad-libitum feeding is increased. Considering the genetic improvement schemes in developed countries, it is simple to manipulate, and convenient to integrate these genes into breeding programs by establishing paternal lines. The presence of such genes in native birds is not properly studied. However, there are Naked neck birds locally called 'Melata' among native types in Ethiopia. The 'Melata' ecotypes in Ethiopia were found to produce more eggs than the other types (Teketel, 1986).

ECONOMIC TRAITS IN POULTRY

The expression of traits that we discussed in the introductory part of this handout depends on the presence or absence of a gene or a few number of genes. For example, White Leghorn birds with two recessive sex-linked dwarf genes will show dwarfism regardless of the environment or any other situation. Traits that are controlled by one gene or a few number of genes are called qualitative traits. Although qualitative traits are important, many of the traits of high economic importance in farm animals are influenced to a large extent by many genes each with a small effect and the environment. Such traits which are influenced by many genes and the environment together are called quantitative traits. As opposed to qualitative characters where animals could be classified into one or another discrete class variation in quantitative traits is continuous. For these reasons, knowledge of the phenotype of the bird does not give a direct indication of its genetic make-up as would be the case with qualitative characters. Similarly it is not possible to make predictions of expected frequencies of different genotypes in the population as is the case with qualitative traits. Consequently, when thinking of the inheritance of these quantitative characters one has to think not in terms of individual animals and particular mating pairs. Instead one thinks in terms of populations of the animals and the frequency of occurrence of various alleles within the populations.

There are a large number of quantitative traits which influence performance of chicken. In this section the most important ones and their degree of variation and heritability will be discussed. In addition relationship between the economic traits and their meaning will be briefly mentioned. However, first we shall explain some important concepts in animal breeding.

Explanation of some terms

Variation

Almost all living things show considerable variation. Variation among animals in size, growth rate, disease resistance, egg production, etc., has been observed and recorded. This variation is the raw material the breeder has available for flock improvement or selection. The total variation in a particular trait that is observed could be due to:

- the kind of genes the animals carry
- the kind of environment (here including managerial factors) to which the animals are exposed.
- the joint action or interaction of a specific hereditary with a specific environmental influence.

If we consider only the variation that is caused by the genes (the genetic variation), it can be subdivided into:

- Additive genetic variance which is the genetic or hereditary variance dependent upon additive gene effects, i.e. a gene has a given plus or minus effect regardless of which other member of the pair or allelic series may be present.
- Non-additive genetic variance which is the genetic or hereditary variance dependent upon the combination in which the particular gene exists. This includes the genetic variation due to interaction within gene pairs (dominance variance) and due to interaction between non-allelic genes(epistatic variance).

Heritability

Heritability could be calculated as the proportion of the genetic variability to the total phenotypic variation (the sum of the environmental and genetic variation). This gives us heritability in the broader sense. The more common definition of heritability is as the ratio of the additive genetic variance to the total phenotypic variance (i.e. the sum of the additive genetic variance, non-additive genetic variance and the environmental variance). This is called heritability in the narrower sense and is the one which we refer to in the forthcoming discussion. We are usually interested in the additive part of the genetic variance because it the one which can be readily changed by selection.

and body weight. If any two traits are associated with each other due to the sum of environmental and genetic causes we say they have phenotypic correlation.

Regardless of the cause of association there could be negative or positive correlation between two traits. An example of negative genetic correlation in chickens is that between body weight on the one hand and egg production and hatchability of the eggs on the other hand. The breeder of broilers when selecting for increased body weight should also take into account the possible reduction in egg production and hatchability of the eggs. One way to take such negative effects into account could be by using procedures like selection index where birds are selected for important traits simultaneously.

Egg production traits

Several analyses of economic data have been made in an attempt to identify characters of importance for egg production. Apparently egg mass alone can account for up to 90 per cent of the variation in economic return. Other characters which have some, if minor effect, are body weight, feed efficiency, viability and shell quality. To these traits, must be added the fertility and hatchability of eggs. It is logical to consider these in the same order as the life sequence of the chicken.

Fertility and hatchability

Besides the effects of nutrition, management system and egg storage, fertility of eggs is influenced by genetic factors. Genetic analyses which have been reported indicate, as might be expected, that the heritability of fertility as a compound character is low, probably of the order of 0.05. Thus its improvement by selection would be difficult. Fertility of eggs is influenced by the whole of the reproductive physiology of both the male and the female domestic fowls. In addition it is also influenced by social ranking of the birds in the flock and mating behaviour of the flock. Furthermore data collected from birds which are flock mated may be very different from data collected on pair mated or artificially inseminated birds.

It is obvious that any single gene having a large detrimental effect on fertility could be relatively easily eliminated from a population due to natural selection alone, unless there is some opposing advantageous pleiotropic effect. Apparently, in the pleiotropic category is the dominant autosomal gene for rose comb found in the White Wayandotte breed. Whilst dominant for comb morphology, the gene is simultaneously recessive for reduced fertility. It has been conclusively shown that the gene's effect in the homozygous rose-combed male is to reduce the sperm's fertilising ability but not to reduce the viability of embryos derived from matings involving such males. Although both hatchability and fertility are considered here as quantitative traits it must be recalled that they are also influenced by up to 30 single detrimental genes.

It is extremely difficult to distinguish between low fertilisation rate and a high incidence of early embryonic death, so that fertility and hatchability of fertile eggs are frequently considered together as hatchability of eggs set. There are several known major genes which cause embryo abnormalities and death. These particular genes can be easily eliminated if they have no advantage of the heterozygotes which would tend to maintain stable polymorphism.

Considering the complex nature of the fertility traits it is not surprising that reported estimates of heritability of hatchability of fertile eggs and of all eggs set have been about 0-0.15. It must be stressed that hatchability is not an easy trait to measure, partly because of the considerable variation between eggs in the time required in the incubator for the chicks to hatch.

Egg production

The number of eggs produced in a certain time interval, e.g. a year, is generally used as a measure of the production capacity of a hen under specified environmental conditions, but sometimes that total weight of the eggs is used. However, since egg number and the average weight of eggs are negatively correlated it is preferable to regard them as separate traits.

There are three commonly accepted ways of expressing the egg-production of a group of birds: survivor production, hen day production and hen housed production.

- Survivor production is the number of eggs per bird for those birds which survive the recording period.
- Hen-day production is total number of eggs laid by the flock in a given period divided by the product of the number of days and the number of hens alive on each of these days. This measure, like the previous one, does not include any measure of viability.
- Hen-housed production, is a combination of egg production and viability, being the total number of eggs laid divided by the number of birds housed at the start of the recording period multiplied by the number of days that the birds were actually in lay.

All three measures can be combined with sexual maturity if needed. As an example let us express egg production in three ways given the following information:-

- total egg production = 50000
- number of layers at the start of the recording period = 189
- number of layers at the end of the recording period = 175
- the number of production days = 362

The calculations are made as follows:

- Survivor production = 50000/ 175 = 285.7 eggs per bird
- Hen-day production = 50000/ 175 x 362 = 0.789 eggs per bird per day or 79 percent daily production, assuming all the birds died towards the end of the period at the same time.
- Hen-housed production = 50000/ 189 x 362 = 0.73 per bird per day or 73 percent hen housed production.

The common practice was earlier to record the egg production for each bird during a period of one year. However, there is a shift towards measuring egg production up to say 500 days of age of the bird; this method has several advantages and it is now the main technique used by most testing stations and breeding entities with some variation in the final age. When measuring egg production up to say 500 days of age the effect of age at sexual maturity is automatically included, and the records of groups with different hatching dates can be directly compared. This is not the case when birds are compared based on one-year's production.

In order to reduce the generation interval and increase the rate of selection it is common to use part-period records in the breeding work. The genetic correlation's between the part-period and full productions are fairly high and normally fall between 0.7 and 0.8. This is no general rule, however. The correlation's are true only within populations and the genetic and phenotypic correlation should be estimated for each breeding project or population. Selection on early part-records in some strains may have the effect of altering a former positive correlation so that the total egg production remains unchanged. There is evidence that this has happened in some populations selected on early part-year record. The solution appears to be, either to select on a longer record and so increase the generation interval or to work out prediction equations which take the correlation into account.

Egg production level of birds depends on five "components" traits. These "components" are:
(1) Age at sexual maturity, i.e. age at first egg. The younger the bird when she begins to produce eggs, the greater her egg production will be during her laying year. However, this takes on a negative value, because eggs laid by younger birds are smaller than those laid by older birds. Feed-control and light-control programs are used to prevent early egg production. Under otherwise equal conditions, early maturing birds lay more eggs than late-maturing ones. The heritability of this trait is estimated to be 0.15-0.45.
(2) Laying intensity: This character is manifested by the ability of the bird to lay at a rapid rate. Since chickens lay their eggs in clutches - that is, they lay an egg on each of several consecutive days before they miss a day - clutch size (length) is an important genetic factor. When a hen is producing at the rate of 80% (percentage hen-day production in a given period), she must lay one egg on 4 out of every 5 days. Some birds have been known to lay eggs for 200 consecutive days before missing a day.
(3) Broodiness: The manifestation of broodiness depends on the hormone prolactin, and is highly heritable. However, indigenous birds go broody after laying about 12 eggs. Although

it is a highly heritable trait, environmental conditions such as having communal nest boxes in poultry house increase the incidence of broodiness. The following measures may be used for preventing broodiness:-secretion of oestrogen, putting broody birds into wire-floored pens with free ventilation, adequate feeding and increasing the lighting period.

(4) Incidence of pauses: Pauses longer than 2 or 3 days between clutches have a phenomenal bearing on the total number of eggs laid during the production period. These long pauses are usually the result of some types of stresses but they are also genetically influenced.

(5) Laying persistency: This is mainly measured towards the end of the laying period. Normally hens start to moult when they are 16-20 months old; some moult slowly and others rapidly, some continue laying while moulting, but most stop laying. Hens that start moulting late in the season are on the average better producers than those that start early, and these differences are partly genetically determined. Moulting, however, is postponed by a gradual increase in the number of daylight hours, and is no great problem in modern management with its refined light/dark programmes.

When total egg production is measured from the commencement of laying, persistency has a greater influence on the records obtained than when the yield is measured from a certain age. When egg production is measured up to 500 days of age early maturity is then more important.

Hens generally reach their highest egg yield in the first laying year. The egg production in the second year is, on an average, only 70-80 per cent of the production in the first year, and the third year's production is 70-80 percent of the second year's production. In large scale intensive systems hens are usually kept for egg production for one laying year only, or at the most for two years.

The heritability of part-records of hen-day egg production has been estimated to be 0.20-0.30; and that for the production for a complete laying year, or to about 500 days of age, is very similar. The heritability of hen-housed production to 500 days is much lower, being only

0.05-0.10, which reflects the influence of mortality on this trait. Traits associated with viability have usually low heritability value.

Egg size

Egg size, which is nearly always measured as weight, is at its lowest at the commencement of the laying period, but it increases steadily for about seven or eight months, after which there is only slight increase, if any at all, for the rest of the laying period. In general, the first egg laid in a series, following a pause, is somewhat larger than the subsequent eggs. When a hen has reached her maximum egg size in the first laying year, approximately the same size is maintained in the second year. In the later years, however, egg size decreases with increasing age. Normal egg size varies considerably between breeds, strains and inbred lines. The rate of increase during the first laying period is very similar irrespective of the egg size when laying commences. This increase is approximately 6 g per dozen eggs per week.

For selling purposes, most countries grade eggs in some way by weight. The two most common practices are either to classify eggs into arbitrarily designated weight-grades and sell them by number at different prices for different weight-grades, or similarly to assign eggs to weight-grades and sell by weight at a price which is differential depending on the weight-grade of egg making up the weight sold. Either of these practices results in a reducing price advantage for increasing egg size as the basic size goes up. At the top of the scale an increase in egg size above the weight of the top grade has no economic advantage. In selection, the rate of economic return will decline with increasing egg size and there is an upper threshold above which an additional increase in egg size is not economically worthwhile. Also, as market requirements usually involve a proportion of eggs falling into each of the weight grades, there is obviously an intermediate optimum egg size. This optimum depends on the economic differentials between the weight-grades and the average price per egg. The selection aims for egg size can therefore be stated only in respect of specific market requirements. It also has to be remembered that egg size has a biological optimum. There are hatching problems associated with both tails of the size distribution.

Ethiopian Institute of Agricultural
Research Centre

As previously mentioned the heritability for number of eggs are moderately high, 0.20-0.30. The heritability of egg size is still higher or, about 0.50. These two traits have as a rule a negative genetic relationship to each other, a fact that makes simultaneous improvement for both difficult. One best way to circumvent this difficulty is by trait-wise selection in different lines for several generations followed by crossing. This seems to be a good method for producing layers with good egg production capacity and optimal egg size.

Several selection experiments for both large and small egg sizes have been made in several countries. Changes in egg size have usually been followed by changes in the same direction in body weight which indicates that egg size and body weight are positively genetically correlated. Inbreeding has generally caused some reduction in egg size though most of the reduction can usually be explained as a correlated response to the reduction in body weight which is also a usual consequence of inbreeding.

Environmental factors, including nutrition, light pattern, temperature and ventilation, particularly during rearing, can influence egg size to a considerable extent. However, the extent of the direct effect of environment on egg size as compared with the indirect effects through body size and sexual maturity are not known. The interrelationships of these three traits are complex. Within breeds, there are positive genetic and environmental correlation between any two of the three traits. The exceptions are the negative environmental correlation between body weight and sexual maturity and possibly that between sexual maturity and egg size. The genetic correlation between egg size and egg number is negative but the environmental correlation is positive, combined selection for these traits is not easy.

Viability

Viability implies resistance to any of a very large number of potential causes of death. Among such causes are both "genetic defects" and infections disease. It is reasonable to assume that "genetic defects" have a wide range of severity, which relates to the ease with which they can be detected. "Genetic defects" in the present context, can be divided into those that cause anatomical abnormality which generally reduces bird performance and those that cause fairly major metabolic disturbance necessitating major changes in the diet, or other aspects of the environment, if the bird is to survive or perform satisfactorily. The breeder is generally not concerned about the grosser genetic defects, since there are relatively easily eliminated from the strains he uses. More interest and effort is applied to selecting strains which are resistant to infectious disease. Several studies have shown that selection for reduced incidence of "genetic defects" and genetic resistance to infectious disease can be effective, but the studies also showed conclusively that resistance to one pathogenic organism does not necessarily or usually imply resistance to another one. Therefore, it would be necessary to select strains specifically for resistance to all diseases they are likely to encounter. This would be an enormous task, made more difficult by the problems of maintaining regular and standard exposure to the disease and of avoiding the transfer of passive immunity so that exposure shall have an equal chance of affecting all individuals. It has up till now generally been agreed that, where alternative effective vaccination, or elimination by slaughter programmes, are available, selection for resistance to specific diseases is not worthwhile. However, the situation would be different should one be in a position to select for disease resistance in general or at least for resistance to groups of diseases.

In the near future it may prove feasible to combine genetic methods and management techniques for increasing survival in general as well as to specific disease. In the case of Marek's disease the combined use of vaccinations and resistant strains seem to be an attractive alternative to vaccinations alone. Native birds may have a higher level of viability under scavenging or extensive management conditions when compared to imported commercial strains. However, in Ethiopia under floor management conditions the mortality rate of local birds was reported to be higher than exotic birds. The reason for the lowered survival rate of native birds could be lack of adaptation to indoor management system.

Body weight and feed consumption traits

The importance of body weight in laying chickens is connected more with its relation to feed consumption, sexual maturity and egg weight than with its direct effect on economic return. In countries with a well developed broiler industry the value of the carcass of the hen at the end of the first laying year is very low and the carcasses more or less create a disposal problem, so that the smaller the bird the better. The relationships with other traits however, cause considerable problems in deciding the weight of the bird to be selected. Genetically and environmentally, within strains the relationship between body weight and feed consumption, sexual maturity and egg weight are all positive; but between body weight and egg production the genetic correlation is negative and the environmental one is positive. Therefore, what is desirable on economic grounds is antagonistic to the direction of selection for body weight. On the one hand, reduced food consumption and increased egg production will be obtained by a lower body weight; on the other, earlier maturity, greater egg weight and higher carcass value will be derived from a larger body weight. The use of selection index or the creation of specialized strains for crossing are therefore probably necessary for optimum result.

Table 1. Approximate range of heritability estimates for egg production traits.

Hen-day egg production in the first laying year (no. of eggs):	
Part time record, 3 or 4 months lay	0.20-0.30
One year from date of first egg, or to 500 days of age	0.20-0.35
Hen housed egg production one year from date of first egg, or to 500 days	0.05-0.10
Age at sexual maturity (age first egg)	0.15-0.45
Egg-size (representative samples of eggs from each hen)	0.40-0.60
Egg-shape	0.25-0.50
Shell colour (within a population with brown eggs)	0.30-0.90
Thickness of shell	0.25-0.60
Colour of yolk (on standardised ration)	0.10-0.40
Firmness of albumen	0.10-0.70
Frequency of blood and meat spots	0.10-0.50
Fertility	0.00-0.05
Hatchability	0.10-0.15
Viability	0.01-0.15

The heritability of adult body weight at a certain age is fairly high, ranging between 0.2 and 0.8. It is known, however, that there are genetic differences in the shape of the growth curve, so that selection based on single measurement of body weight could have a differential effect on the whole growth pattern, depending upon the age at which the measurement is made. For instance, selection for increased weight at point of lay might result in a bird which grew rapidly up to that age but put on little weight thereafter, whereas similar selection for body weight at the end of the laying year might result in a bird which grew more rapidly throughout its life. The former result may be desirable for a laying bird, since rapid growth to point of lay will advance maturity and increase egg size; whilst slow and late growth keeps feed consumption to a minimum. Still another alternative is to select on the basis of body weight at both the beginning and the end of the laying year. This has two complications.

- Firstly female body weights taken between 17 and 22 weeks of age are probably an unreliable indication of differences in mature body weight, because the birds' reproductive organs are developing rapidly at this time and much of the variation in body weight merely reflect a variation in the maturity of the sexual organs.
- Secondly selection based on body weight at the end of the laying year leads to a longer generation interval. If selection for body weight is to be practiced selection on the basis of a single body weight measurement taken between 22 and 32 weeks of age is probably to be preferred.

Feed consumption is closely correlated to body weight. It has, however, been shown that there are still genetic differences in feed consumption after body weight differences have been accounted for. The main problem involved in directly selecting for feed consumption is the difficulty and cost of accurately recording feed intake.

Feed efficiency can be defined in many ways. One is the Feed Conversion Ratio (FCR) defined as:

TFC/TEP= FCR, where TFC stands for Total Feed Consumption and TEP for Total egg mass production.

Research results have showed that about 80 percent of the individual variation n FCR is explained by variation in body weight, body weight gain and egg mass production. The remaining part of the variation, the residual feed consumption (RFC), can be computed on an individual level as the difference between recorded and expected FCR and used in selection. This trait gives probably a more effective response in feed efficiency than ordinary selection indexes based on body weight and egg production. The heritability estimate of RFC in chicken is about 0.2.

Egg quality characters

These characters have become of increasing importance in recent years, as marketing outlets have placed greater emphasis on the sale of quality products. The main quality traits are:- egg shape, shell quality and colour, albumen quality, blood and meat spots, and yolk quality. The economic importance varies with the method of market payment in different countries. Egg shape, shell quality and blood and meat spots are probably of major importance, since they have a direct effect on the return obtainable for an egg. In some parts of the world shell colour is also economically important, since higher prices can be obtained for brown eggs than for white.

Egg-shape: This trait is of particular importance to packers and transporters because of its influence on the proportion of broken and cracked eggs. A typical range in shapes would be from almost a perfect sphere to regular ovoid and pear shaped eggs. An objective assessment which has been used to measure egg shape experimentally is given by an index measuring (Breadth/Length) x 100.

An index of 74 is considered optimal and a variation between 72 and 76 as satisfactory. It can be seen that the narrower or longer the egg the lower the index. Though the index is somewhat limited in that only two variables of shape are included, these two are largely responsible for determining the suitability of shape for the type of containers at present used for moving eggs.

Seasonal variations in shape have been reported, as has variation between eggs within a clutch from the same hen. Reports on the heritability are few but vary widely in their estimates. Some workers have found heritabilities of 0.10-0.30. Information concerning the correlation between egg shape and other production traits is limited. The estimates reported are a positive genetic correlation (+0.4) and a negative environmental correlation (-0.3) with egg size. All other estimates with other traits have proved to be very small and therefore are considered to be of little consequence.

Shell quality: This trait is important because it influences market value through resistance to cracking and because of its effects on hatchability. Though it has not been proven, it seems likely that the optimum shell quality for the two purposes may not be the same. The factors which contribute to shell quality and strength are shell thickness, porosity of the shell, membrane thickness, the mineral content of the shell and the protein matrix. There is considerable difficulty in defining, and hence in measuring, shell strength. The final objective is to produce eggs which do not crack under field conditions. The incidence of broken and cracked eggs in packing stations usually range from 6 to 8 percent, so it is extremely difficult to obtain correlations other than zero or very small correlations, between strength measurements, shell characters and the proportion of eggs cracked under commercial conditions. There is a high negative correlation between shell thickness and the proportion of cracks; but other shell characters are also influencing shell strength.

Shell colour: Shell colour of eggs depends on the pigment ooporphyrin, which is deposited mainly on the outer surface of the shell. The pigment is related to haemoglobin of the blood. Even white eggs contain small amounts of ooporphyrin. In the early part of the laying year more pigment is deposited on the egg shell than towards the end of the year.

Until recently, measurement of shell colour has depended on the subjective comparison of eggs with a standard colour range of eggs which could be numbered for subsequent quantitative analysis of the data. However, at least two instruments which estimate reflectivity of the shell are now available for measuring shell colour. Several hundred eggs an hour can be measured with these instruments.

Shell colour varies considerably between breeds. Some breeds, such as the Barnevelder, Maran and Orpington, produce eggs with a deep brown shell colour, whereas the eggs of the Rhode Island Red and Sussex are less pigmented and more reddish brown, and those of the White Leghorn are largely pure white. Shell colour is considered to be a quantitative character and heritability estimates are variable, ranging from 0.3 to over 0.9.

Some South American breeds produce eggs with blue or green shell colour and the blue colour depends on an autosomal dominant gene. The green colour is assumed to be due to a mixture of brown and blue pigment.

Albumen Quality: The albumen in the egg can be divided physically into four layers. Surrounding the yolk is a layer of thick albumen, which extends in a thread to both poles of the egg and is called the chalazae and chaliziferous layer. Next is the layer of inner thin albumen, followed by a deep layer of thick albumen. Finally there is a further layer of outer thin albumen which is found just under the inner shell membrane. The consumer considers a desirable egg to be one which when broken out stands firm with a relatively high proportion of thick albumen. An egg which has a spreading "watery" white is not considered desirable. It may be caused due to

- the strain of bird,
- certain respiratory diseases,
- seasonal effects, particularly the temperature to which the birds are subjected, and
- poor egg storage conditions.

Albumen quality has been measured in several ways: for instance, the viscosity has been measured as well as the weight of albumen, an index of the height and width of thick albumen and the area of thick albumen. The commonest measurement is the height (in millimetres) of the albumen at the periphery of the yolk. This can be measured by breaking the egg onto a flat surface and measuring the height with a tripod micrometer. This albumen height is often expressed in Haugh units, which is a simple correction of height for the effect of egg size. It has been found that the regression of albumen height on egg size varies considerably between breeds and strain, and therefore the regression estimate used to calculate Haugh units may be misleading for comparisons of albumen quality between breeds or strains. All estimation of albumen quality should be made at a standard time, optimally one day after the egg was laid, so that comparisons are not confused by differential storage-time effects.

The heritability estimates of various albumen quality estimates are variable, and depend on the method of analysis and strain or breed. The estimates range from 0.1 to 0.7, depending on strain, and success has been reported in selecting for strains with differing amounts of thick albumen. Correlation with other production characters indicate both positive and negative phenotypic and genetic relationships with egg production, and consistently positive correlations with egg weight.

Yolk characters: The colour of the yolk appears to have some consumer appeal, deep yellow yolks being preferred. Since the yolk colour can be almost completely determined by certain harmless additives in the ration, this trait is of little direct interest to the geneticist. An estimate of heritability of colour under a standard nutritional regime is 0.15. Probably of greater importance is, the heritability of yolk weight has been found to be in the range of 0.10 and 0.4. Genetic and phenotypic correlation's between yolk weight and egg weight have been estimated as positive and high (0.58 to 0.82). But there are part-whole correlations; more important are the high negative genetic (-1.0) and phenotypic (-0.4) correlations between yolk weight/egg weight ratio and egg weight. This suggests that selection for increased egg weight would result in a lower proportion of yolk in the egg.

Blood and meat spots: Approximately 1-2 per cent of all eggs candled are found to contain blood or meat spots, which usually appear in the border between the yolk and the albumen. Earlier it was considered that meat spots were degenerated stages of blood spots, which arise as intrafollicular haemorrhages. It is now known that blood and meat spots are of separate origin, and that meat spots originate from lesions in the mucosa of the oviduct. Meat spots show fluorescence in ultraviolet light but blood spots do not. The size of the inclusions and the colour (red to white) of the meat spots vary. After a relatively heavy haemorrhage a large part of the albumen may be stained by blood. For experimental purposes, the number of inclusions are counted in eggs which have been broken out and the inclusions can also be scored for size by visual assessment. Blood spots are more frequent than meat spots, and eggs containing either type are removed commercially by candling.

Meat production traits

Until the 1930s, even in those countries with modern poultry production systems, chicken meat for human consumption was largely derived from old hens which had completed their laying life or from surplus cockerels from egg-producing or dual-purpose breeds. From the 1930s in America and much later in Europe, special strains and "hybrids" were developed for meat and broiler production, other than those developed for egg production. Broiler chickens were developed first as pure breeds and then as two and three way cross "hybrids". The relatively high efficiency of these "hybrids" specially for meat production has severely depressed the economic value of the carcass of the laying hen to the point where it is frequently regarded as an offal problem. The characters of major importance in the development of broiler chickens are growth rate, feed efficiency rate, mortality, feathering, skin colour and carcass quality. To these traits, which refer to the performance of the broiler chick itself, should be added the reproductive performance, particularly hatchable egg production of the female parent.

The negative genetic correlation between egg production, body size and growth rate, which has already been mentioned, makes the task of simultaneously improving these three traits in one strain extremely difficult. The more effective method is developing two strains. The female parent strains (usually a two-way cross) which is specifically developed for hatchable egg production is based on an index of egg production and progeny growth rate. On the other hand the male parent strains is specifically developed for growth rate and carcass quality of the progeny. The final cross is obtained after mating the male strain with female strain. In a situation in which the genetic variance is largely additive (i.e. heritability is high) the crossing may have no advantage. On the other hand because of the hybrid vigour frequently demonstrable for egg production, a typical fitness trait, it is proving more successful than selection for all traits within a single population.

Growth rate

During more than 30 generations, intense selection for increased body weight has been performed in meat-type chickens. This has resulted in a very rapid growth rate and today's broiler is almost twice as heavy at the same age as the "old" meat type chicken strains. In spite of this enormous increase in growth rate, the additive genetic variance does not seem to have been diminished to any great extent. Heritabilities in the range of 0.3-0.6 are frequently reported.

The market requirements for body weight at slaughter vary considerably. For example, in Sweden it is common practise to slaughter the birds at five weeks of age whereas six to eight weeks are normal ages in USA and England. In many parts of African, including Ethiopia, the preference could be for relatively older broilers suitable for prolonged cooking.

There is evidence that there are genetic differences in growth rate between hybrids, which implies that the optimum age and weight at slaughter may vary between hybrids. Changes in the weight ranking of different hybrids may be critical in the present age ranges. Under these circumstances, it is preferable to decide the required weight for slaughter and select for the shortest time to reach that weight, rather than to select for increased weight at a particular age. Another problem which arises is that the weight differential between sexes increases as the mean weight of both sexes increases. There is evidence that the genetic correlation for weight between the two sexes is not equal to 1.0. Thus there is a need to select for a decreased differential weight between the sexes at the same time as for increased weight of both sexes. This would necessitate the use of a selection index involving the genetic parameters for growth in the two sexes separately and the genetic correlation between them.

There is a high phenotypic correlation between the weight of day-old chicks and the weight of the eggs from which they hatch. An effect of egg weight on chick-weight has been found up to ten weeks of age; but the proportion of variation accounted for by this and other maternal effects is usually small.

The efficiency in broiler production is due to the fact that faster-growing animals are more efficient in reaching a fixed market weight. The increased efficiency is due the length of time involved in production, and thus the overall cost of maintenance is reduced.

Feed efficiency and feed consumption

An increased growth rate does not necessarily mean a better feed efficiency. Several investigations report very low genetic correlations between feed efficiency and weight gain. It is shown that much of the gain in weight is attributable to a correlated response in appetite and that much of the genetic variation in gain is coupled to differences in feed intake. Heritabilities for daily feed intake vary between 0.1 and 0.6 with a mean of about 0.3. The genetic correlations between daily feed intake and daily gain were very high, varying between 0.5 and 1.0 whereas the corresponding correlation with feed efficiency fell into the interval of 0.2 to 0.5.

Viability

While the genetic variation for growth rate is still high there is nevertheless a risk to reach a selection plateau in broiler breeding because natural selection is likely to work against the artificial one. Fertility is negatively associated to body size and fatness and the artificial selection has laid little emphasis on reproduction. Low egg production and large sized eggs are other problems faced by broiler breeders. Some of these difficulties, however, can be countered with by management, e.g. keeping the dam lines or crosses on a restricted diet, or by selection on a sub-optimal feed environment. As a result of the fast growth rate and consequently heavy birds at a very young age, sudden deaths due to heart failure have started to occur among seemingly healthy chickens at an appreciable frequency. Leg weakness has also turned up as a viability problem for the same reason. Total mortality amounts to about one percent unit a week or slightly less. Most of the deaths are due to the above-mentioned causes and not to ordinary poultry diseases, which are controlled by vaccination and medication programmes in addition to the normal passive immunization via the hen's egg.

Carcass quality

Carcass quality is extremely difficult to define objectively. Three traits are worth special mentioning.

- Firstly, the eviscerated weight can easily be measured. It is closely related both phenotypically and genetically to live-weight. The heritability of eviscerated weight is as high as for liver-weight but measures more directly the amount of meat on a carcass.
- Secondly, the shape of the breast muscles over the keel bone has been considered in several investigations as a measure of carcass quality. The measurement most commonly used has been breast angle; but other combinations of breast width, cross sectional breast area and body depth have also been used. The breast muscles should be wide and deep, so that there is no projection of the keel bone above the surrounding tissues. The heritability of breast angle at eight weeks of age has been estimated at 0.4, and the genetic and phenotypic correlations with live weight are about 0.3 and 0.4, respectively.
- Thirdly, breast blisters or keel bursae are commonly found in broilers, their type and frequency are influenced both by genetics and management. They make the largest single cause of down grading of carcasses in processing plants. The incidence of breast blisters in a strain increases with increase in weight, and the correlation between incidence and the weight of individual birds in the flock is high. The incidence is higher in males than females, even after correction for weight differences. The heritability of breast blisters has been estimated at 0.2. Any management factor which predisposes to poor bone formation, such as low calcium in the diet or a shortage of vitamin D, also predisposes to a high incidence of breast blisters. Birds with poor bone formation tend to perch on the ground more frequently and this causes irritation of the tissues over the keel bone.

Another cause of breast blisters is leg weakness, a condition which thus affects both death rate and carcass quality.

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A main problem in broiler breeding is the increasing amount of abdominal fat. This fat adds to the body weight and is mainly discarded at slaughter thus diminishing economic return both from the growth period and from the carcasses. Recent findings show that it is possible to reduce abdominal fat either by direct selection against fat content or by indirect selection by means of improving feed efficiency. Selection for growth rate has thus proved inefficient in improving feed efficiency as mentioned above but selection for body composition should probably improve feed efficiency as well.

Feather and skin characters

Three aspects of feathering are important in the production of meat chickens.

- The first which is essential, is that the chicks should feather rapidly. A rapid feathering chick has better ability to regulate temperature than a slow feathering one. Rapid feathering gives superior resistance to various types of infections and better survival.
- Secondly slow feathering, result in comparatively bare areas of skin, which increases the incidence of breast blisters and scarring of the skin. This in turn means a higher proportion of down-graded and poor quality carcasses in the processing plant.
- Thirdly, white feathers are preferred to coloured ones. Remains of dark coloured pin feathers on the carcass detract from its value. The usual method of avoiding these detrimental features is to produce hybrids from parents, at least one of which should be homozygous for the dominant white gene which partly inhibits black pigment formation. Unfortunately, strains of birds homozygous for the recessive white gene are not entirely devoid of pigment. In this type of bird, the pin feathers may be more or less pigmented and the pigmented spots often appear in the skin on the breast of the chicks. The pigment deposition increases gradually during the first few weeks after hatching and, though it decreases later, it may still be evident when the broilers are processed. Generally, the pigment deposition is more marked in female than in male chicks. These problems do not arise with fast feathering dominant white chicks.

Most of the breeds from which broiler strains have been developed were yellow skinned, and for the majority of markets for which broilers are produced this character is satisfactory. In some markets, however, where the consumer has generally associated yellow skin with the carcass of an old laying hen, the preference is for a white skinned broiler. Strains of broilers carrying the white skin gene have now been developed by intercrossing the yellow skinned broiler strains with breeds that have white skin, such as the Light Sussex. This is then followed by subsequent selection for growth rate and white skin for several generations after the F_1. Such localised consumer market requirements can be a considerable brake on progress in more important economic characters such as growth rate.

A further skin colour defect to be avoided is that of black or blue melanin pigmentation, generally on the shanks. Such pigmentation, previously rather common in broiler strains, is much disliked by processors and packers and has been strongly selected against by breeders. Few if any broiler strains now have any melanin pigmentation of the skin.

SELECTION AND CULLING

Selection

Selection is the process of deciding which animals in a generation will be allowed to become parents of the next generation and how many progeny they will be permitted to leave. Selection is of two types,

- Natural selection is a type of selection where natural factors influence the ability of an individual to survive and produce offspring for future generation.
- Artificial selection is a type of selection where man decides the animals that should be parents of the next generation.

Artificial selection is the most important method of producing animals which serve human needs. It is therefore important to know what factors affect selection efficiency. The effectiveness or rate of improvement in performance from selection during a generation, in the simplest possible situation, is dependent on two primary factors. These are the amount of selection pressure applied and the heritability of the trait.

Amount of selection pressure applied

The selection pressure applied to a population depends upon the difference between the mean performance of the birds selected for breeding and the mean of the whole population. This difference between the flock average and that of individuals used for breeding is known as the selection differential.

In general terms the larger the selection differential the more is the progress that can be expected in the selection process. A number of factors may affect the size of the selection differential, amongst these are the number of birds that need to be kept for replacement purposes. In populations that have a high mortality rate and/or are increasing in size, more birds should be saved. Therefore the selection differential will be less than in populations which have low mortality and do not need to increase in size. The selection differential for males is always greater than for females because few of them need to be saved for breeding purposes. In poultry where there is a higher reproduction rate, the selection pressure can be much higher than for mammals.

Heritability

The amount of progress that can be made in the selection process is also directly proportional to the heritability (h^2) of the trait. Selection for a trait that has a low heritability, such as egg production in chickens (5-10%) will result in little progress being made. On the other hand, selection for a trait that is highly heritable such as body weight in broilers (60%), should result in rapid progress being made in the mean performance of the flock. If the heritability of a trait is high a large proportion of the superiority of the parent will be retained in the offspring, as is shown in the following example:-

Rate of gain in the broilers:

Heritability of rate of gain	60% or 0.6
Flock average of rate of gain	35 g a day
Rate of gain of cockerels saved for breeding	50 g a day
Rate of gain of hens saved for breeding	40 g a day

Expected genetic gain $= h^2 \times$ selection differential

$$= 0.6 \times [\ (50 + 40)/2 - 35\ ]\ g$$
$$= 0.6 \times (45-35)\ g$$
$$= 0.6 \times 10\ g$$
$$= 6\ g$$

Therefore the average expected gain of offspring = 35 g + 6 g = 41 g.
This is the average progress per generation, if we want to know the amount of progress per year we have to divide this figure by the generation interval. If the generation interval is somehow shortened to about half a year instead of one-year, then the genetic progress per year could be doubled.

Information for selection

In order to improve animals through breeding the first thing that we should do is to set the breeding objectives. That is the breeder must define the objectives which could include, for example, rate of egg production, egg weight etc. Once this is done the next step is to develop selection criteria which meets these objectives. The next step is to plan means of identifying animals that meet the breeders requirement. Identifying individuals which are genetically superior than others in certain economically important quantitative traits is rather difficult. Identification of superior birds is particularly difficult if the trait is sex-limited, as is the case of egg production. How can you select cocks for traits associated with egg production? The answer of course is by using information derived from the egg laying ability of their female relatives. Thus the breeder has several sources of information that he may use for identifying birds with superior performance.

Individual selection

Selection based on an individual performance is called individual selection or performance testing. When calculating individuals breeding worth or breeding value, its record should be compared against its contemporaries (i.e. birds which were hatched at the same time, fed and managed in a similar way, etc.). Fast progress towards the breeding objective could be achieved if the heritability of the trait is high. In poultry traits such as growth rate, egg weight, feather and skin characters etc. can be evaluated directly from the performance of the individual animal, if suitable performance records are being kept. Here we should distinguish individual selection from mass selection where records on animals are not kept but immediate decision either to select or cull a bird based on certain observed criteria are made. Mass selection will be dealt with under the heading culling. The difference between mass selection and individual selection is that mass selection does not involve any record keeping.

Individual selection was used to a great extent to improve productivity of poultry. However, there are many situations where individual selection may not be appropriate:-

- Egg production and quality traits which are only observed in females;
- For traits with low heritability, individual merit is a poor indicator of breeding value;

In such situations other source of information should be used.

Pedigree selection

Pedigree selection could be practised if the record of the parents of a bird along with their performance is available. We use pedigree performance to estimate the breeding value of an animal when we do not have adequate information on the merit of the animal itself. Pedigree information in determining an individuals genetic worth is valuable because each individual receives half of its genes from each parent. Generally pedigree selection is of limited use in poultry breeding than say in dairy cattle breeding.

Progeny selection

When a performance record of a progeny is used to predicted the breeding worth of either or both parents we call this progeny testing. In fact progeny testing is a more powerful test of the breeding qualities of potential breeders. Progeny selection is a long and expensive process, since the egg-producing ability of offspring of a given mating cannot be determined until many months after the actual matings are made. The progeny must be identified and many records of their actual performance must be made. When the breeder may be interested in 8 to 10 separate characteristics of the breeding stock, the record-keeping task for progeny testing is immense. However, the outstanding proven sires and dams discovered by this procedure will make possible genetic improvement more rapid than with other less rigid means of selection. In some cases, as for broiler growth, the testing period may not be excessively long, and the outstanding matings can be chosen in a fairly short time. For egg production, a partial-year production has been used successfully to predict full-year production records, thus shortening the selection process to some degree.

the second generation. The techniques will work if the traits selected for are positively correlated. If the traits are negatively correlated the progress made in the first generation will be partially reversed in the second. The tandem method of selection is the least efficient of the 3 methods available.

Independent culling level

With this method the breeder lays down a minimum standard for several traits. Each bird to be used for breeding must achieve all of these standards, if not, it will be culled. This technique is commonly used in traditional and pedigree breeding. For example, the following standards might be laid down for a broiler hen (Table 2).

Table 2. Criteria that could be used for selecting egg laying hens by the independent culling method.

	Weight at 8wks age (kg)	Age at 1st egg (days)	Mean weight of 1st 20 eggs (g)	Eggs produced during 1st 50 days of laying
Standard	1.8	140	50	25
Bird 1	1.7	135	55	30
Bird 2	1.9	133	48	32
Bird 3	1.9	141	51	26

With the given 'standard', 'bird 1' would be rejected for breeding because it was too light at eight weeks of age and 'bird 2' would be rejected because it produced eggs that were too small. This would result in the two birds being rejected even though they are above the required standard in all the other traits therefore would have probably been desirable parents of the next generation. On the other hand 'bird 3' which is just above the standard for all traits will be selected for breeding. Thus although the independent culling method is superior to the tandem method in that it allows for selection of more than one trait at a time, it is seriously flawed as a selection technique.

The selection index

In this method a numerical value is given to each potential parent for each of the traits regarded as important. These numerical values are summarized and a total score arrived at for each bird. The birds with the highest numerical values are the ones saved for breeding purposes. The influence that each trait has on the final index is determined by how much importance that trait is given in relation to other traits. The amount of importance given depends on its relative economic value, upon its heritability and the genetic correlation between the traits.

In poultry breeding the calculation of a selection index is very complex process. It is usually impracticable, except in very large establishments for an individual breeder to calculate appropriate heritability and correlation figures for his own flock. However, in unselected populations of poultry average published figures of heritability estimates can be used initially although these may become unreliable once selection proceeds. Selection may reduce heritability estimates and genetic correlation may change greatly with time. The large-scale breeder will therefore automatically verify these at predetermined intervals.

The problem of weight for economic worth is even more difficult because values may change from year to year or from market to market. For example, premiums paid for large eggs may mean that egg size should get a high economic weighting. An even more complex problem of deciding economic value occurs when the breeder is selecting for traits, some of which are important to him directly and some of which are important to his clients. For example, the grower of broiler chickens is interested in growth rate, food conversion and carcass quality. He is not interested in fertility and hatchability. To be a financial success the breeder has to produce enough chicks for sale, but to obtain repeat orders his stock must satisfy the grower. It is very complex problem to solve, especially when some of the traits are negatively correlated. However, some of the complication is avoided by selecting different lines for different traits and crossing them to obtain the final commercial hybrid.

Culling

A great deal of improvement in poultry flocks has been the result of widely applied mass selection practices, particularly in the elimination of such undesirable individuals as unthrifty chicks or pullets, slow growers, poor layers, and those that detract from a reasonable uniform appearance of flocks. However, mass selection, based on phenotypic performance, may be effective through the low to medium range of a given quantitative trait and quite ineffective in the upper range.

Mass selection or culling of poor producers is not usually practiced in highly productive flocks such as those owned by breeding companies where a more sophisticated selection information and methods are used. Culling which involves identifying and removing nonlaying and low producing hens from a flock is an indirect method of applying breeding knowledge to the production of poultry stock. It has been shown that through identification and elimination of the weak, the poultry producer can be assured of economically sound production stock and at the same time be quite sure of retaining birds with superior genetic background.

Culling should take place throughout the year. When chicks are started, all obviously weak birds should be culled. As the flock get older, runty and slow-growing pullets should be eliminated. When the flock is put into the laying house, slow-maturing birds should be removed. During the laying year, flock owners should remove the sick, lame, or injured birds. Generally speaking, heavy culling should not be necessary during the first eight to nine months of lay. However, if egg production slumps badly, it may be desirable to locate the cause and remedy it. The degree of culling is relatively high in small poultry flocks particularly if they are kept for a second or third production year. In Ethiopia commercial laying flocks may be kept for a number of years before they are disposed off say due to lack of foreign currency to import new ones. In this situation culling could have a great role. On the other hand, extensive culling in a large commercial laying flocks may not be practical or economical. At the same time such flocks will be uniformly good egg producers.

In general, there are four reasons for culling:-

1) Salvage the poor producer before the bird becomes too emaciated for market or before she dies.
2) Increase the efficiency of production, which is reflected as a higher percent production of the flock. This also reduces the amount of feed required to produce a dozen eggs, thus giving the producer a more favorable egg-feed ratio.
3) Increase the amount of floor and feeder space available for the good producers, with a resulting increase in efficiency of space and labour required.
4) Control spread of disease.

When a hen is examined to determine whether to "cull" her or "keep" her in the laying flock, there are five things you want to know about the individual:

- Ability to lay. Body capacity, stamina, general health, and alert appearance. This may be determined before production begins or anytime during the first production year.
- Present production. This may be determined at any season of the year to distinguish between those birds that are laying and those that are resting at the time of handling.
- Indication of past performance. These characteristics are usually not apparent in the pullet that has just started to lay, since it depends upon the length of time a bird has been in production. However, these can and should be used for measuring the worth of a bird any time after she starts laying.

Table 3: Comparison of the characteristics of a layer and nonlayer

Character	Good producer	Poor producer
Head	Clear-cut, rugged, alert, fine quality	Coarse, phlegmatic musculine, "beefy"
Face	Bright red, clean cut, rather thin	Yellowish tint, puffiness
Eye	Full, round, prominent	Dull, defects
Comb & wattles	Large, full, smooth, hard,	Limb, dried, shrunken,

	waxy, bright red, glossy	cold, dull, shrivelled, scaly
Skin	Soft, loose, velvety	Thick, underlaid with fat
Abdomen	Full, soft, pliable, flexible, enlarged	Contracted, hard, fleshy
Pubic bones	Thin, pliable, spread apart, elastic	Blunt, rigid, thick, close together, stiff (two fingers apart)
Keel	Spread apart from pubic bones	Close to pubic bones (3 fingers from pubic bones)
Vent	Large, smooth, moist, dilated, pliable, bleached	Shrunken, puckered, dry, hard, yellow or flesh colored
Eye ring	Bleached, white	Yellow
Ear lobe	White	Yellowish
Beak	Bleached	Yellow
Shanks	Bleached, flattened	Yellow, round
Feathers	Worn, soiled, trim, frayed	Smooth, clean, not worn sleek, glossy
Molting	Late, rapid	Early, slow
Temperament	Active, alert, easy to handle, good appetite	Less active & alert, more difficult to handle, eats less
Health	Good	Diseased
Body capacity	Large, increased	Small, decreased
Legs	Strong, straight	Weak, crooked, crippled

- Rate of production. The number of eggs laid in a given length of time is important; the higher the rate of production, the more valuable the hen.

- Health and vitality. The ability of the birds to withstand the strain of egg production may be determined anytime before or after the egg-laying period.

Comparative characteristics of a good producing hen and a poor producing hen are summarized in Table 3.

When planning to cull or select birds in a laying flock, look over the entire flock before handling any of the birds to get an overall picture. Note the health and vitality of the bird before you pick it up. Then look at the gross structure of the individual, her posture, body shape, and general appearance. The most important traits that should be looked-upon are: handling qualities, head, pigmentation, molt, and the breed characteristics. Although each individual bird is handled, and evaluated, final decision should be based upon the comparison of the bird to the flock average.

Male selection

The selection of males for breeding purposes is equally as important as the selection of the females, since the male contributes to the offspring in the same proportion as the female. In selecting the male for breeding, follow the same points of consideration that are followed in selecting the female, the only difference being that you cannot use such characteristics of production as pigmentation and pubic-bone spread. Note the appearance and evaluate the male's vigor and health. Select a bird that is "large" and has good body capacity and posture. His legs should be strong and straight and they should be relatively rich in pigment. The bird should be alert and active, have a strong head and a broad yellow beak. His feathers should be tight and well-groomed. He should have a wide straight breast bone that carries well back to the abdomen. This type of phenotypic selection generally reflects the physical well-being of an individual bird and may be applied to males that have been genetically selected for the desired egg production characteristics, based on family (progeny, sib, pedigree) performance records.

BREEDING SYSTEMS

Once the decision is made on the birds which should be parents of the next generation, the next step is to decide which individual cock should be mated with which individual hen. The systems of mating between the cock and hen could be categorized as follows based on the relationship between the cock and the hen:

Inbreeding

Inbreeding is a system in which the mates are more closely related than average members of the breed or population being intermated. In general with inbreeding the mates are chosen to have a common ancestral background (pedigree) or relationship. This increases the degree of homozygosity and decreases heterozygosity. These are some of the implications of inbreeding.

- First inbreeding tends to "uncover" undesirable recessive genes, that is, lethal or semilethal. If an undesirable gene is in the population at a very low frequency, the probability of its expression is small. Mating of relatives that have an ancestor carrying the gene, however, will dramatically increase the frequency of the expression.
- Second, inbreeding reduces genetic variation within an inbred line. That means of the variation that exist in that line the heritable part is reduced in proportion to the level of inbreeding.
- A third consequence of inbreeding is a phenomenon called inbreeding depression. Inbreeding depression is the decrease in the average performance of individuals in the population resulting from increased homozygosity of genes with sublethal and deleterious effects.

The intensity of inbreeding usually observed in poultry is rather high compared to other livestock. Three or more generation of brother-sister or son-mother or father-daughter matings or sufficient generations of less intense inbreeding to produce a genetically stable stock are practised in poultry to develop a number of inbred lines. Highly inbred lines are desired by some breeders because their characteristics are believed to be firmly established. Similarly progeny obtained from crossing of two inbred lines are generally uniform in genotype and consequently more uniform in their performance than are those from random mating populations. This uniformity is useful in poultry production where all birds are expected to reach market weight at the same time or start and stop producing eggs at the same time. The other advantage of uniformity is that all poultry management procedures are built around flock average.

The fact that inbreeding concentrates both favorable and unfavorable characteristics has also advantages, since it may reveal weaknesses in a line, which then may be eliminated while selecting for only those desired traits to ultimately incorporated in the commercial production bird. However, the inbred lines are not used for production but they are crossed with other inbred lines to produce the so called commercial hybrids.

Outbreeding

Outbreeding is a general term applied to any breeding system in which animals mated are less closely related than the average of the population from which they come. It includes

- mating of unrelated animals within breeds (purebreeding),
- grading up to a so-called superior breed (up-grading),
- crossing of inbred lines,
- mating of animals of different breeds (crossbreeding), and
- the more extreme crosses between animals of different species (species hybridization), such as the mating of the jack with the mare to produce the mule.

The general objective of outbreeding is to exploit heterosis which is particularly important with traits of a low heritability. The heritability of hen housed average egg production by laying birds is about 5% which means of the total variability in egg production between hens, 5% results from the effects of additive genes. The remaining 95% results from a combination of environmental and non-additive genetic effects. Here we will only deal with crossbreeding and crossing of lines or strains and recurrent selection as they are the most common breeding systems in poultry.

Crossbreeding

Crossbreeding is crossing of individuals of different breeds, for example, White Leghorn and Rhode Island Red. The main reasons for crossbreeding are to increase genetic variation in the population and to encourage the exhibition of hybrid vigor in the offspring generation. The effect of the latter will be seen immediately in the progeny while that of the former will mean increased genetic progress after selection. In addition combining better performance of two or more breeds will also be possible. Breed crosses are more common in developing broiler stock than in layer stock.

Crossing of lines or strains

Commercial hybrid birds are produced by crossing highly inbred lines. Adapted hybrids usually out-yield the best strains primarily due to heterosis or hybrid vigor. When a particular strain in a cross nearly always gives a good result, the strain is said to have "general combining ability". In other cases, strains are useful only when crossed with another specific strain. These specific strains are said to have "specific combining ability". To come up with one or more well performing crosses poultry breeding companies develop several inbred lines and test crosses them in different ways. This is because some strains combine well only when used as the male parent, and others must be used as the female parent to do well.

In poultry there are also other systems of mating which are practiced in combination with selection. In such systems the inbred lines are formed by the direct process of selection than by simple inbreeding. Furthermore, both general and specific combining ability would be selected for simultaneously.

Recurrent selection: This is a system where a highly inbred line-presumably homozygous at most loci is selected as a tester, and a number of strains are crossed with it and their progeny evaluated. The strain giving the best progeny is subsequently intermated to increase their number.

Reciprocal recurrent selection is a system where birds of two strains are reciprocally crossed and the progeny are tested for performance. The start is made from two populations, preferably two already known to give some heterosis when crossed. These two populations, whose combining ability is to be improved, will be referred to as lines A and B. Crosses are made reciprocally, a number of A males being mated to B females, and a number of B males to A females. The crossbred progeny are then measured for the character to be improved and the parents are judged from the performance of their progeny. The best parents are selected and the rest discarded, together with the crossbred progeny, which are used only to test the combining ability of the parents. The selected individuals must then be remated, to members of their own line, to produce the next generation of parents to be tested. These are crossed again as before and the cycle repeated. Deliberate inbreeding is avoided because random changes of gene frequencies are not desired. Reciprocal recurrent selection is based on one year for the selection of additive genetic values and in the second year on heterosis. Generally both recurrent selection to an inbred tester and reciprocal recurrent selection should lead to improved cross performance whether it is the result of overdominance, epistasis, or only additive effects. The short generation interval and the high reproductive rate of poultry has enabled the extensive use of such systems compared to that of other farm animals.

SCAVENGER POULTRY PRODUCTION

Compared to the intensive poultry management system, the traditional system still accounts for over 99% of the poultry meat and egg production in Ethiopia. Before considering areas of possible improvement a brief description of the characteristics of the traditional husbandry is given:

- free-ranging during the day, the poultry are usually gathered at night into a basic shelter to avoid losses through predators;
- feeding limited to what the poultry can find by themselves insects, seeds, kitchen wastes. Sometimes a supplement is given by man, but this supplement is always small and covers only a small part of the nutritional needs;
- very poor productivity due to the fact that the hens do not lay much, that the growth of broilers is slow and that losses are considerable before they are ready for the table;

Ethiopian Institute of Agricultural

- it is rarely the eggs which are consumed, but rather the chickens which are sought for their taste, their relatively dry flesh being well adapted to the prolonged cooking.

However, the traditional Ethiopian sauce known as "doro wot" is, appreciated if prepared using small-sized eggs from local chicken. Similarly cake-makers also prefer eggs from local birds to that of intensively managed exotic birds.

Areas of possible improvement

Improvement in the productivity of scavenging birds can be achieved in a number of ways:

1) the use of more productive birds
2) the provision of supplementary food
3) the provision of better management including disease control.

Although effective improvement could only be possible if the combination of all three is practiced, here we will consider only the first point.

Improvement of the traditional poultry production through breeding could be done in the following ways:-

1) breed replacement: By distributing exotic male and female birds to interested farmers.
2) Crossing native birds with exotic ones: This could simple be achieved by distributing exotic cockerels for crossbreeding with native birds.
3) Selection within the native birds: This is improvement of local birds through selection.

The first option is the most risky one. The survival of exotic birds under tropical scavenging management condition is going to be low and the cost of such introduction could turn out to be expensive. For example, introduction of White Leghorns and Rhode Island Red hens and cockerels into villages in Uganda was not successful. The females ceased laying within a short time under range conditions. White Leghorns were found to be unacceptable to the small scale farmers because they were easily seen and killed by kites. Thus importation of exotic birds is not usually recommended unless there is a significant improvement in disease control, management and nutrition. The choice of breeds, strains or crosses that may be considered for introduction should meet the following criteria:

- hardiness: this is the aptitude to tolerate the environmental conditions (climate, handling, watering, feeding) without an excessive drop in production;
- different aptitudes according to the type of husbandry;

  aptitude for egg production,

  aptitude for meat production,

  mixed aptitudes: production of eggs and meat; this might be preferred because the cocks could be used for meat production and the hens for the production of both eggs and meat.
- high productivity: seeking maximal performances in meat and laying;
- low feed consumption;
- some degree of broodiness in layers as there is limited access for artificial incubators;
- product quality as good for the meat (a firm flesh close to that of bush chicken) as for the eggs (shell strength, egg size, quality of white, yolk colour etc.).

The second option could be implemented cheaply by gradual release of genetically improved males of exotic stock to be mated with local females of small village farmer's. Already experience in some countries like Nigeria has shown that the first crosses between the local and exotic could be as productive as the imported ones. The advantage of this option is that the local birds with tremendous ability of surviving under stress conditions could be combined with the high productivity of exotic birds. However, the kind of breed to be imported has to be carefully selected. The adaptability of the crossbred birds might be high if exotic birds with single genes like dwarf, naked neck and frizzle gene are used for crossbreeding. If such program is going to be carried out unwanted cocks should be slaughtered.

The third option aims at improving local birds through selection. A notable example is the scheme for improving the Deshi (local) bird in Bangladesh. The following procedure might be followed to have a successful local bird improvement program:-

1) first the best ecotypes in the country should identified.

2) started a breed development program for the selected genotypes.
3) distribute selected cockerels for village farmers which meet certain criteria. The criteria may include that the farmers are willing and able to improve their management and they should also be willing to slaughter all unwanted males.

For any of the options to be fruitful the present extensive management system has to be changed to some kind of semi-intensive system.

SOME PRACTICAL ISSUES IN BREEDING

Sexing

In laying strains determination of sex at hatching is important so that the males could be identified and slaughter on the hatching day. We have already discussed that the presence of sex-linked single genes facilitate identification of sexes at the time of hatching. However, sometimes the strains that we use may be the so-called non-autosexable that is they do not have sex-linked genes incorporated. This requires the presence of a 'sexer' who establishes the sex from the appearance of the cloaca. ---

Mating systems

There are three mating systems commonly used in commercial poultry breeding, namely are artificial insemination, pen mating and flock mating.

Artificial insemination

This is a situation where the males are kept separate from the females and at weekly or biweekly intervals mated by artificial insemination. Artificial insemination offers many advantages to the poultry breeder to assure specific matings at specific time. However, it involves a lot of labor and time. Artificial insemination is used commercially for turkey breeding because turkeys do not produce high enough fertility when mated naturally. In chicken artificial insemination is used only in experimental flock.

Pen mating

In pen mating, a small flock of 10-20 females are naturally mated to single male in a pen containing trap nest. Each female is usually wing banded for identification. The hen is trapped in the nest after laying an egg and must be removed by a caretaker who records her wingband number on the fertile egg. This allows each offspring to be identified as to its parents, which is necessary when its performance is later evaluated. Pen mating is used by the chicken breeder for test-crossing great grandparent pedigree lines where they are selected for inbreeding based on performance of offspring from these test crosses. One problem with pen mating is that flock fertility may be low due to preferential mating by the single male.

Flock mating

In flock mating, a number of males are present in a large flock of females at a ratio of one male to 10-20 females, depending on the size and age of the hens. Here trap nesting is unnecessary, since the breeders have already been selected for propagation of an inbred line and mating is random. Flock mating usually provides better flock fertility than pen mating because of more males and some male competition, which results in most females being mated. Flock fertility of 90% can be expected with the flock mating system, which requires about ten days for 20 hens to be mated by a single male. Flock mating is used for breeding to multiply selected grandparent family lines and in crossing inbred parent lines.

Techniques for measuring egg production on individual basis

Recording the egg production of individual hens is essential particularly if one is planning improvement of productivity level through selection. There are a number of ways to obtain the level of production of a laying hen.

Trap nesting

Trap-nests differ from regular nests in that they are provided with trap doors by which birds shut themselves in when they enter. Then the attendant records her identification and lets her out. Birds are identified by either wingband or legband. The shortcomings of this method are that it is labor intensive if done seven days a week, and each week in the year. However, studies have shown that a satisfactory measure of the egg-producing ability of a hen is possible by trap-nesting three days a week as well.

Examining the birds

If cost of constructing trap nests is expensive the egg-producing ability of a hen could also be measured by examining hens early in the morning, and those which are to lay on that day can be detected by feeling the egg in the shell gland. By going through this procedure on three successive days each week a fair estimate of the egg production level of hens could be obtained.

In recent years particularly in developed countries the use of laying cages, the development of computers and electronic recording systems, recording egg production level of hens are automated. However, in countries like Ethiopia where labor cost is relatively cheap trap-nesting and careful examination of the birds early in the morning may serve the purpose.

Organization of poultry breeding in developed countries

Commercial poultry production in most parts of the developing world is based on exotic stocks imported from temperate breeds. The exotic commercial stocks used widely today are hybrids bred by commercial poultry breeding organisations in Western Countries. Here a short account of the breeding techniques adopted by commercial poultry breeding organisations are given. The common breeding work involved in producing and improving hybrids may be split under three headings:

Developing new strains for crossing

From the base population new strains are produced by conventional selection procedures. The strains are being produced both for their own performance and to improve the performance of the cross. A strain's own performance may be little indication of its performance in the cross. However, in general, those populations that have the highest performance as pure-breeds produce the highest performing crosses. Most commercial breeders use closed flock selection to develop and improve their strains while a few use inbreeding and reciprocal recurrent selection. When closed flock selection results in 'plateaued' populations, new genetic material may be incorporated and selection continued. Another point to note is that in poultry, there are several characters of economic importance in the final cross. Breeders achieve this by selecting for different traits in different strains and combining them in the final product.

Cross testing of the strains

Once the different strains are developed, they should be cross tested in different combination to identify the crosses with best performance level. Cross testing is extremely laborious and expensive. For example 5 basic strains would involve 20 two-way, 100 three-way and 380 four-way crosses. Cross testing also raises the problem of the environment in which testing should be done. Crosses are generally tested in a variety of environments in different locations so as to provide a reliable measure of performance of different genotypes.

Multiplication of the crosses with best performance

The next step in the breeding programme is to disseminate the improved stock to as many producers as possible.

The basic setup of "crossing inbred lines" may be diagrammed showing a relatively simple theoretical example utilizing four great grandparents (GGP) pure pedigree lines, each selected primarily for say a single desired characteristic (Fig 2). Each grandparent (GP) line is inbred for several generations and selected for desired characteristics prior to crossing offspring (parents) with another similarly inbred and selected line. These inbred grandparent lines are referred to as multiplication flocks because large numbers of progeny are being propagated, grown, and inbred over several generations. This will result in many individuals with identical, homozygous desirable traits to be used as parents (P) in the final hybrid cross. In order to identify which of many possible lines will successfully transmit desired selected characteristics to offspring, test crossing of the various lines, reciprocally alternating males and females, is employed with a relatively small sample of birds before lines are expanded. When two lines are identified by test crossing to produce uniformly outstanding offspring, these lines are then each reproduced by inbreeding as great grandparent or grandparent stock for eventual cross mating of selected lines for production of commercial strain cross chicks. This final mating of parents stock is done at local hatcheries throughout the world. Parent stock is obtained as chicks from primary poultry breeders and grown to sexual maturity at local hatcheries prior to mating.

Pedigree flocks

(Pure Lines)	# 1	Male Line # 2	# 3	Female Line # 4
GGP Mate:	male x female	male x female	male x female	male x female
Chicks,GP	male+female	male + female	male + female	male + female
Grow:				
Multiplication:		male x female		male x female
Chicks, P		male + female		male + female
Grow:				
Mate:		male x female		
Chicks, hybrid cross:		male + female		
Grow:				
		Commercial Meat chicken		

or Egg-laying pullet

Fig. 2. Basic setup of "crossing inbred lines" used in commercial poultry breeding.

The male line is that inbred family from which the male parent stock is selected for the final cross. The female line is that inbred family from which the female parent stock is selected for the final cross. Male family lines necessarily contain females of the same genetic strain for use in inbreeding, but only the males are selected and utilized for the final hybrid cross. Likewise, female family lines necessarily contain males of the same genetic strain for use in inbreeding, but only the females are selected and utilized for the final hybrid cross.

Trend in poultry breeding in developing countries.

Compared to other livestock a tremendous increase in poultry production based on imported exotic breeds in developed countries has been observed. Many developing countries also import feed, medicament and the management techniques.

Import oriented

The exotic commercial stocks used widely for intensive poultry production today are hybrids bred by commercial poultry breeding organisations in western countries. They are introduced to countries that require it either as day olds, parents or in very few instances as grand-parents. The advantages of such importations is that birds with high genetic potential could be used. However, there are several disadvantages of these importations:-

1. Annual importation of commercial hybrids requires expending foreign currency.
2. There are risks of introduction of exotic diseases into the country.
3. The imported stocks which were developed to perform under certain level of nutrition and management in developed countries may not perform as well in tropical countries.

Furthermore, stock suitable for environments with high temperature or other stresses may differ from those developed in temperate areas. This generally means there is a possibility of genotype-environment interaction. Genotype-environment interaction is a situation in which the magnitude of genetic differences for any trait is influenced by the environment where the measurements are made, e.g. breeds of poultry that produce well under intensive management may not be genetically superior to other breeds under village conditions.

National poultry breeding

To overcome some of the disadvantages listed above, development of breeding stock locally may be seen as an option. However, a number of factors should be considered before embarking upon such an independent poultry breeding program.

1. The size of the local market should be considerably large to justify such a program.
2. There should be adequate capital and trained manpower.
3. There should be adequate physical facilities and a long-term commitment by the people who are going to run such program.

The key question that should be answered before starting an independent poultry breeding program is: Can the same quality of parents be produced cheaper from a local breeding scheme than from imported grand parents? Generally a new and independent breeding program in countries like Ethiopia could be a complex process. It may need the involvement of governments to finance such program at least at the initial stage. Careful assessment of the demand for poultry meat and egg is required before establishing independent breeding programs. After such careful assessment initially the project should work closely with a successful breeding company aboard to avoid possible pitfalls.

The other important point that should be considered when planning poultry improvement through breeding is the improvement of native chicken.

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