Animal Breeding

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GENETICS CONSTITUTION OF POPULATIONS

- **Animal Breeding:** It is a science which uses the principles of population and quantative genetics for the improvement of livestock production.

- **Genetic improvement is valuable because:**

- it is permanent,
- it is cumulative, and
- it is usually highly cost–effective.

- The purpose of animal breeding is not to genetically improve individual animals, but to improve animal populations, to improve future generations of animals.

- There are two basic tools for genetic improvement of populations:
  - A. System of Mating.
  - B. Selection

Strategies for genetic improvement

- **In future**, new strategies for genetic improvement may become available as a result of developments in biotechnology

e.g.

- Gene transfer within or between species,

-Determining a major gene affecting a polygenic trait,

- Marker–assisted selection,

- DNA fingerprinting and

- Sex control.

The science of genetics

- **Genetics** is a science that studies heredity and variation.

- **Heredity** is the transmission of traits from the parents to the offspring via genetic material,

- **Variation** is the occurrence of differences among individuals of the same species.

- The science of genetics can be broadly divided into four major categories:-

1. Transmission genetics (classical genetics, individuals).
2. Molecular genetics (cell, DNA)
3. Population genetics (group of individuals, traits by one or few genes)
4. Quantative genetics (group of individuals, traits by many genes)

The aims of animal breeder

- **The aims of animal breeder:**

1- The first, what is the “best “animal?

Is the best dairy cow:

- The one that gives the most milk or
- The one with the best feet, legs and udder or
- The one combine performance in these traits in some optimal way?

• The answers are decided upon the determination of the direction of genetic change for breeding operations, breeds, and even species.

2- The second question is, how animal populations are improved genetically?

• This question involves genetic principles and animal breeding technology.

The aims of animal breeder

So, the main purposes of animal breeder are:-

1. To select the most desirable animals based on the prediction of genetic merit (Selection)
2. To produce superior genotypes by combination of genes through breeding plans (systems of mating).

- **A population may be defined as:**
- A group of individuals of the same species in a defined location.

- **The gene pool is:**

The summation of genes and genotypes that occur in a population of organisms of the same species

Traits, phenotypes and genotypes

- **A trait:**

  is any observable or measurable characteristic of an individual.

a. Observable traits:

Traits we mention in describing the appearance of an animal.

Example: Coat colour, size, leg set, head shape

b. Measurable traits:

Traits we mention in describing how an animal has performed.

Example: weaning wt., lactation yield, time to run a mile, etc.

- **The phenotype:** is the value taken by a trait, in other words, it is what can be observed or measured.

  Example: Shell colour (white, yellow) calf birth weight (35, 40 kg)

- **The genotype:** represents the genes or the set of genes responsible for a particular trait.

- **P (phenotype) =G (genotype)+ E (environment and management)+GE**

Classes of traits

1. **Fitness traits:** are concerned with features of reproduction and viability.

   Examples: conception rate, litter size, gestation length, fertility, survivalability.

2. **Production traits:** are concerned with features that cover performance of the animal in productive terms.

   Examples: milk yield, growth rate, feed efficiency weaning weight and egg production.

3. **Quality traits:** are all characters which are increasingly important as pressures mount for more acceptable food in health terms.

   Examples: carcass composition, meat quality, egg quality, milk fat percentage.

Classes of traits

4. **Type traits:** are usually features of more aesthetic nature where personal performance is important and the breeder selects for such things.

   Examples: coat color, coat type, udder shape and constructional traits.

5. **Behavioral traits:** are increasingly important for animal welfare

   Example: aggression, docility, cannibalism

- **Economic traits:** are those traits which have monetary value in the production of livestock.

Gene and genotypic frequencies

How do you genetically describe a population?

The answer is to use gene and genotypic frequencies

A gene frequency or allelic frequency or gametic array

Gene frequency: the relative frequency of a particular allele in a population.

fi = (# of copies of the allele i)/(total # of copies of all alleles).

The frequencies of all the alleles at any one locus must add up to unity, or 100 percent.

genotypic frequencies

Genotypic frequency: the relative frequency of a particular genotype in the population.

- *fij* = (# of individuals carrying the genotype *ij*) / (total # of individuals).

•Naturally, the frequencies of all the genotypes together must add up to unity, or 100 percept.

Hardy–Weinberg law:

Hardy is an English mathematician, and Weinberg is a German physician developed in 1908 mathematical models and equations to describe what happens to gene pool of a population under various conditions.

Hardy–Weinberg law states that

In a large random–mating population with no selection, mutation, migration or chance, the gene frequencies and the genotype frequencies are constant from generation to generation and furthermore, there is a simple relationship between the gene frequencies and the genotype frequencies.

Assumptions of the Hardy–Weinberg law (Equilibrium conditions):

1. The population is sufficiently large meaning that sampling errors or chance or drift are negligible.

2. Mating within the population occurs at random.

3. There is no selective advantage for any genotype i.e. no no differential reproduction.

4. The population is closed i.e. no immigration nor emigration.

5. There is no mutation from one allelic state to another.

Applications and uses of the Hardy–Weinberg law

1. To track and predict how gene frequencies will be transmitted from generation to generation given a specific set of assumptions.

2. It represents an idealized situation (which might be difficult to be happened). So, real situation can be compared to the ideal.

The divergence from the equilibrium tells you how the population is changing (note that it doesn’t say why).

Applications and uses of the Hardy–Weinberg law

3. The Hardy–Weinberg principle can be also used to estimate specific allele frequencies such as recessive genetic disorders (diseases).

A practical use of the Hardy–Weinberg equation can be seen in analysis of genetic diseases example: cystic fiberosis, phenylketonurea (PKU) and albinism.

Many genetic diseases are recessive so their expression is only exhibited by individuals who are homozygous.

Genotype	Phenotype
AA	Normal
Aa	Normal
aa	Disease expressed

Applications and uses of the Hardy–Weinberg law

4. Estimation of heterozygote frequency or carriers of recessive:

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The frequency of a recessive phenotype usually can be determined by counting such individual in a sample of the population. Their frequency in a population is represented by **q2**, provided that mating has been at random and all Hardy–Weinberg conditions have been met in the previous generation.

If Hardy–Weinberg equilibrium can be assumed, the frequency of heterozygote among all individuals, including homozygotes is given by **2pq**.

Qualitative and Quantitative traits

Qualitative and Quantitative traits

- The basic principle of breeding is that, the larger the number of traits included in a breeding programme, the slower is the rate of progress in any one of them.

- The main challenge to the breeder is to decide on a priority order for required characters, to keep the list short.

Qualitative and Quantitative traits

	Qualitative or Subjective or Simply–inherited traits	Quantitative or Objective or Polygenic traits
Inheritance	Controlled by *a few genes*	Controlled by *many genes*
Phenotype	Tend to be categorical or qualitative in expression. Examples: Coat color (e.g. red or black), presence of horns (horned or polled)	Quantitative or continuous in expression described in numbers. Examples: Growth rate, milk yield, fleece weight (kg)

Genotypes	Genotype of the individuals is described by *identifying genes or gene combinations*. Example: Red horned cattle = bbpp, red polled cattle = bbPP or bbPp.	Genotype of the individuals is described by the "*net effect*" of the many genes affecting the trait (animal performance or breeding value). Example: Breeding value of a cow for milk yield = +600 kg
Environment	Very little or no effect (a black cow remains black in all environments).	affected by environment (when a cow is fed less, she produces less milk).
Economic importance	Generally *less important*.	*Most important as* It determine the profitability.

Example	- Coat colour - Presence of horns - Blood type - Conformation traits - Structural soundness - Comb shape - Aggressiveness	- Milk yield and composition - Birth weight - Weaning weight - Fleece weight - Efficiency of feed conversion - Disease resistance. - Time to run a given distance

Variations in economic traits in farm animals

- **Phenotypic variation:** refers to observable or measurable differences in individuals for a particular trait.
- It is the raw materials with which the animal breeder must work.

- If there were no variations among individuals, there would be no need to select or cull animals for breeding purposes.

- An understanding of the phenotypic expression of genes is the fundamental basis for improvement of livestock through breeding.
- Genes express themselves phenotypically in two ways:
  A. Additive gene action.   **B.** Non-additive gene action.

Additive gene action	Non-additive gene action
Def.: It means that the phenotypic effect of one gene adds to the phenotypic effect of its own allele or other genes.	**Def.:** The phenotypic effect of one gene doesn't necessarily add to the phenotypic effect of the other but members of allelic pairs may interact to give a certain phenotypic effect (dominance and over-dominance), or two entirely separate pairs of genes may interact with each other to produce a particular phenotype (epistasis).
-They are stable and regularly passed from one generation to the next.	- They are not stable and are not regularly passed from one generation to the next.

-Traits determined mostly by additive will be medium to high heritable.	-Traits affected mostly by non-additive gene action will usually be lowly heritable.
- Polygenic traits determined by additive genes action will be affected very little by crossbreeding or inbreeding	- Traits affected mostly by non-additive gene action will be improved by crossbreeding (hybrid vigour) and will show a decline when inbreeding is practiced.
- Additive gene action does not produce hybrid vigour	- Non-additive genes are responsible for producing hybrid vigour.
Example: Carcass quality and quantity	Example: Fertility and liveability

Additive and non- additive gene action

N.B:

- If the trait is low to medium in its degree of heritability and shows improvement when crossbreeding is practiced, this indicates it is probably affected by both additive and non-additive genes action.
- Example: Weaning weight in beef cattle.

- As some traits may be affected by both types of gene action and because selection and mating procedures are different for additive and non-additive types of gene expression, it is important to know which type affects a certain trait.

Additive and non- additive gene action

Types of phenotypic expression of genes

Characteristics	Types of phenotypic expression of genes		
	Additive	Non–additive	Both additive and non- additive
Heritability	High	Low	Medium
Amount of hybrid vigour	None	Considerable	Some
Inbreeding depression	None	Considerable	Some
Example:	Carcass quality and quantity	Fertility and liveability	Weaning weight in beef cattle (Quantative traits)

Causes of phenotypic variation in farm animals

- The total phenotypic variation for traits in farm animals is due to heredity, environment, and the interaction of both.

- The basic equation is this:
- P = G + E + GE

- Phenotypic variation = Genetic variation +Environment variation + Interaction of G and E
- $\sigma^2P = \sigma^2G + \sigma^2E + \sigma^2GE$

- Genetic variance = 25% of the phenotypic variance.

- Environmental variance+ Covariance between heredity and environment = 75% of the phenotypic variance.

Phenotypic variation in farm animals

- **The σ^2G and σ^2E parts can be divided further into:**

I) Genetic variation (σ^2G):

1. Additive genetic effects (σ^2A).
2. Non–additive genetic effects(σ^2NA).

   a. Dominance effects (σ^2D) b. Epistasis effects (σ^2I)

II) Environmental variation(σ^2E):

1. Permanent environmental effects (σ^2EP),
2. Temporary environmental effects (σ^2ET).

A. Genetic variation (σ^2G)

- Genes not genotypes are transmitted to the progeny because only one gene from the pair at each locus of the parent goes to gamete.

- Genotype of an individual is fixed at conception and those carring a mutation, remains the same for the entire life.

- Differences among genotypes constitute the genetic variation present in a species at any time. However, the transmission of genetic variation from one generation to the next is of considerable importance to the breeder because his goal is to increase the favourable and reduce the unfavourable genotypes.

Genetic variation (σ^2G)

- **Causes of genetic variation during transmission of genes can be attributed to many sources:**

1. Recombination of genes.
2. Gene interactions.
3. Mutation.
4. Chromosome aberrations.
5. Chromosome number changes.

B. Environmental variation (σ^2E)

- Environment includes all such factors as disease, nutrient supply, temperature effects, accidents, and others which the individual may encounter from time of conception until its death.

Two components of environmental variations:

A. Permanent environmental effects:

Typical permanent effects would be inter-herd differences such as different feeding regimes, housing, milking facilities and techniques, care of heifers and dry cows, and disease especially chronic mastitis and reproductive problems.

B. Temporary environmental effects:

Temporary environmental effects are those that last for only relatively short periods of time and are subject to frequent change.

Example: Removing the horns of cattle, Docking the tails of the sheep, clipping of hair in horses and notching of ears.

Environmental variation (σ^2E)

- Although different environments allow different degrees of expression for the same genotype, the environment effects (either permanent or temporary environment) does not transmitted to future generations and does not directly alter the hereditary makeup of the animal.

Phenotypic variations due to environment are important because:

1. They are not transmitted from parents to their offspring.
2. They overshadow variations due to heredity.
3. The proper environment is necessary for an individual to reach its genetic potential.

C. Genotype x Environment Interaction (σ^2GE)

- **It means**: one environment permits the expression of the genetic characters in a breed, while another does not.

- The environment can have a direct effect on the phenotype for example, through nutrition, disease incidence and management but can not have a direct effect on the genotype.

- The genotype can only be indirectly affected by the environment through altering gene and genotype frequency so that certain types are selected as parents for the next generation and others are ignored.

Are the genotype responds differently (interacts) in different environments? ($\sigma^2 GE$)

1. "Hardiness" of sheep for mountain and hill conditions adversely affected if ram-breeding flocks that supply them are located on good low-land conditions?

2. Selection of beef bulls by performance testing for growth under intensive concentrate feed conditions. Are their progeny will grow well on pasture ?

3. Selection for high egg production in poultry kept in cages produce birds will lay well on deep litter or free range?

4. Selection for growth in cattle in temperate climate produces offspring that performs well in the tropics?

C. Genotype x Environment Interaction (σ^2GE)

- The general simplified conclusion from a great deal of work is that for genetic reasons it is best to select and breed animals in the environments in which they have to perform.

We must also recognized well that:

I. The best possible inheritance will not result in a superior herd or flock unless the proper environment is also applied so that the animals can attain the limit set by their inheritance.

II. Nevertheless, the best possible environment will not develop a superior herd or flock unless the proper inheritance is also present in animals.

Thank you