Sexual Reproduction in Plants

In sexual reproduction, a new individual is produced by the combining of material from two parents. In plants, as in animals, a **sperm** moves towards an **egg**. **Fertilization** occurs when the egg and sperm nuclei (the central part of each cell) unite to start development of the offspring. By repeated cell division, the fertilized egg grows from a single cell into a many-celled **embryo** (a tiny new plant that develops into a seed). All living things that reproduce sexually take some features from each parent. Next year's flowers will resemble this year's flowers because they inherit features from both of their parents.

The **flower** is the structure that makes **sexual reproduction** in flowering plants possible. A wide variety exists in flower appearance, but the function of the flower parts is the same. Their functions are listed below.

The **stamen** – contains the male part of the flower. It produces **pollen**, a yellow powdery substance. Pollen is produced in the top of the stamen, in a structure called the **anther**.

The **pistil** – contains the female part of the flower. The top of the pistil is called the **stigma**. When a pollen grain reaches the pistil, it sticks to the surface of the stigma. The stigma produces a sugar that is used by the pollen to grow a tube. The **pollen tube** "digs" its way down through the style, allowing delivery of the sperm down to the **ovary**. This is the enlarged part of the pistil where the female sex cells (eggs) are produced. The eggs are fertilized by the sperm from the pollen tube. The transfer of the pollen from anther to the stigma is called **pollination**. If allowed to develop without being picked, the ovary dries and splits open to disperse the seeds(s).

The **petals** – of the flower attract insects that carry the pollen from one plant to another. Some plants have no petals and the pollen is carried by the wind. Can you think of any other ways pollen could be transferred from plant to plant?

DEFINITION OF PLANT BREEDING

Plant breeding is the conscious human effort needed to improve and develop new plant varieties in order to satisfy the demand for human food and animal feed. It is a selection made possible by the existence of variability.

Plant breeding is an art or a science designed to bring about better high yielding, disease and insect resistant and adaptable crop genotypes through careful selection. It is an art because it involves the use of human power of observation and vision, i.e. ability to know the right time to carry out breeding operations and ability to know and identify crop genotypes that are, for example

a. Physically resistance to disease and pests

b. Agronomically good

c. Easily cooked by the end users.

It is a science because we know already that plant physical characteristics(P) are controlled or conditioned by genotype(G) and environment(E) both of which can be manipulated by man.

$$P = G + E$$

Plant breeding is a science that relates to the study of genetics, cytology, pathology, entomology, pathology, systematic, statistics, biostatistics, physiology, biochemistry. It is therefore an applied science that involves all science disciplines.

SCOPE OF PLANT BREEDING

Plant breeding involves three major areas (plant introduction, hybridization and selection) that are referred to as conventional breeding methods.

Apart from the above, we have modern plant breeding methods which includes:

a. Plant tissue culture

b. Mutation breeding

c. Plant engineering(biotechnology)

[A] PLANT INTRODUCTION

This is the oldest method/procedure of crop improvement. It involves movement of plants or crop species from one place to another, a conscious movement of crops from one area to new areas and as a result of this, we have centre of origin of crop and centre of diversification. For instance, Cocoa which was from South America was introduced into West Africa. Coconut from the Pacific Island is also common in West Africa. Maize is from Mexico and Pineapple is from Hawaii; Cowpea is from Ethiopia, Soybean is from China (Asia) and Banana is also from Asia.

It is therefore very possible that plant introduction can change the economy of a nation.

QUESTION: How can plant introduction change the economy of your Nation?

[B] HYBRIDIZATION

This is a process of making crosses between two plant parents that are genetically different (diverse, dissimilar, varied, and non-identical). Hybridization is called *controlled pollination*. It is divided into two major parts (a) out-crossing and (b) inbreeding.

OUT CROSSING

This is a relationship between individual plants that are genetically different. Here, two or more traits (characters) are combined in a new individual called **HYBRID**. The individual that are genetically different can be called INBREED LINES. Hybrid is the product from the individual that are genetically dissimilar.

There are three types of hybrid:

a. Single Cross (2 way) hybrid - AA x BB = AB

b. Three(3) way hybrid - AA x BB x CC = AB x CC

c. Double hybrid - (AA x BB) x (CC x DD) which is a product of two single hybrids.

A condition whereby the hybrid obtained from a cross is better than or superior to either of the two parents that are used in the cross is called **HYBRID VIGOUR**. Hybrid vigour is also referred to as **HETEROSIS**.

INBREEDING

This is a relationship among individuals that have common ancestors i.e. relationship among individuals that are genetically similar. It is a way of making crosses between individuals that are related by **'DESCENT'**. Note that Outcrossing increases the proportion of heterozygosity whereas Inbreeding increases homozygosity.

Consider a cross between a tall(TT) and a short(tt) plant parent

Tt

tt

TT

F_1

Gametes T t

Tt

Tt

F_1 selfed gives the F_2

TT, Tt, Tt and tt are the F_2 gametes

At the F_1 generation, the proportion of heterozygosity is 100%. However, when you advance the generation heterozygosity becomes ½ and homozygosity is increased to 50% also. At the F_2 generation, the proportion of both heterozygosity and homozygosity is 50-50. Also in the F_3 generation, heterozygosity is 25% and homozygosity is 75%.

	HETEROZYGOSITY	**HOMOZYGOSITY**
F_1	100	0
F_2	50	50
F_3	25	75
F_4	12.5	87.5
F_5	6.25	93.75
F_6	3.125	96.875
F_7	1.56	98.435

As you advance the generations heterozygosity decreases whereas homozygosity increases. The proportion of homozygosity or heterozygosity allow breeders to know what it is called **COEFFICIENT OF INBREEDING** (Q) which measures the probability that 2 pairs of gene at a locus are descendants of a common ancestor. It is a measure of increases in homozygosity.

$$\text{Inbreeding Coefficient} = \left(\frac{2^m - 1}{2^m}\right)^n \quad \text{OR} \quad [1 - ½^m]^n$$

Where n = Number of gene pairs and m = Number of generations of selfing

Worked Example 1

If Q =?, n = 2 and m = 3

$$\text{Inbreeding Coefficient} = \left(\frac{2^3 - 1}{2^3}\right)^n$$

$$= \left(\frac{7}{8}\right)^2 = 49/64 = 0.77 = 77\%$$

Example 2 Find n when m is 2 and Q is 56.3%

Inbred lines are obtained from cross pollinated crops that are self pollinated after some generations of inbreeding i.e. they are lines that are self pollinated over a long generation. Consequently, after a long generation of inbreeding genotypic uniformity becomes greater than when it was at the initial population. A line that is obtained after some generations of inbreeding among cross pollinated population can be an inbred line. It is obtained from crossers that are self pollinating e.g. maize

Note: Inbreeds are never better than their parents, whereas hybrids are better than their respective parents. Therefore a hybrid is obtained by performing inbreeding on crossers that genetically differs for a number of generations. A pure line is the progeny of a single individual obtained by selfing or it is a product of self -fertilized homozygous individual because it is obtained from a selfer. Members of pure line individuals do not necessarily have the same genotype but their genetic uniformity is greater than what obtains in the progeny of cross fertilization.

CONSEQUENCES OF INBREEDING

1. Inbreeding increases homozygosity
2. It leads to reduction in quality of traits under consideration
3. It leads to production of inbred lines
4. It leads to exposure of deleterious recessive genes (albinism/old disease)
5. It leads to sterility of the ovary in plants
6. It leads to yellowing, stunting
7. It also leads to susceptibility to disease in plants.

[C] SELECTION: Means making a choice and it is done in plant breeding to allow individual plants to propagate themselves. Selection is possible only if there is variability and this suggests that variability makes selection possible and easy because bad characters can easily be seen and eliminated. One can equally select crop genotypes that are high yielding, disease resistance or agronomically good among others and then introduce or use them in hybridization with other crops from different environments.

However, bad genotypes are left unselected. Therefore, selection acts on existing variability but it does not create variability.

Types of Selection

[A] MASS SELECTION. This is a selection based on the phenotypic value of a plant (Phenotype = Genotype + Environment). If the genotype is good and stable with little or no environmental effect, the genotype of an individual will be nearly equal its phenotype. It means that if a plant comes from a good parental background, environment may have little or no effect on it. Therefore for mass selection to be effective in a breeding programme environmental effect must be small.

Under mass selection harvested seeds or plants are bulked together (composited) without progeny testing. The objective here is to improve the general performance of the population by selecting and bulking superior genotypes. If the environment is good or favourable phenotype will be fantastic and there will be no change in genotype.

$$H = V_G/V_P = V_G/(V_G+V_E)$$

Thus, if V_E is very small or very close to zero, $H = V_G/V_P = 1 = 100\%$

Thus mass selection depends on the following:

1. Heritability of the character that we want to measure
2. The number of the genotypes selected (sample size)
3. Genotype by environment (GxE) interaction
4. Gene effect (either additive or dominant)

Sample size must be very large to avoid inbreeding especially when dealing with open pollinated crops because inbreeding depression leads to reduced vigour and yield. If the G x E interaction is high, phenotype is affected as a result of reduced heritability.

There are two types of heritability, we have *broad- sense*(H_B) and *narrow- sense*(H_N). The higher is the narrow-sense heritability the higher is the proportion of the characters that is transmitted from the parent to the offspring because it is additive portion (H_N)of the gene that is normally transmitted from one generation to another. This narrow-sense heritability is called the breeding value.

Problems of mass selection

1. Effect environment make mass selection ineffective
2. Until segregation occurs in later generation it is not possible to know whether your genotype is homozygote or heterozygote

$$\delta^2_P = \delta^2_g + \delta^2_e$$

$$= \delta^2_g + \delta^2_{gxe} + \delta^2_e \quad \text{because } P = G + E \text{ and thus,}$$

$$H_B = \delta^2 g/\delta^2 p = \delta^2_g/(\delta^2_g + \delta^2_{gxe} + \delta^2_e)$$

Example 1

If $\delta^2 e = 10$, $\delta^2 g = 5$ $H_B =$ 5/15 = 33%

Example 2

If $\delta^2 e = 20$, $\delta^2 g = 5$ H_B = 5/25 = 1/5 = 10%

Advanced Formula

Where r = Number of replications = 3 , n = sample size = 6 , $\delta^2 e = 20$, $\delta^2 g = 5$ $\delta^2 ge = 15$

$$HB = \frac{\delta^2 g}{\delta^2 g + (\delta^2 e / r \times n) + (\delta^2 ge / r)}$$

$$HB = \frac{5}{5 + (10/18) + (15/3)}$$

$$= 5/(5 + 0.7 + 5) = 5/10.7 = 0.49 = 49\%$$

NOTE: When number of replicates increases environmental error decreases and heritability estimate increases

Example

If r = no. of rep. = 8 , n = sample size = 4

H_B = 5/(5 +0.3 +3.75) = 5/9.05 = 0.55 = 55%

NOTE: Stability of variety means general good performance of variety across environments. Adaptability means good performance of variety in one location e.g. Abeokuta. If G x E is large, heritability will be low. When there is no different in the performance of genotypes in different environments, it means there is no G x E interaction.

[B] PURE LINE SELECTION

Pure line selection is a random selection of large number of single plants from original populations that are genetically diverse. Note that selection here is based on individual plants. It is the selected individual plants that becomes new varieties after given consideration to particular characteristics such as seed size, earliness, plant type, diseases resistance e.t.c If the original population is not diverse enough variability can not be created. For variability to be created therefore, we can make crosses or introduced new plants from another region.

Through pure line selection, homozygote plant populations can be obtained from single superior individuals. Thus, pure line selection is a breeding method used to develop grain crops like rice, barley, wheat, oat and a few selfers such as cowpea, soybean and tomato.

METHOD OF PURE LINE SELECTION

After plant introduction, selected plants are grown in progeny rows for easy observation. This is called progeny testing. Peculiar characteristics of interest are carefully observed and further selections are made for best lines, whereas the off-types (bad) lines are discarded. One can introduce disease *epiphytotics* or other aids to selection for easy elimination of undesirable plant types. Also, plants can be observed in different environments. The longer the period of observation the better is this type of selection. At the tail end, intensive observation and drastic reduction in number of lines is made to reduce cost. Thereafter, we have to isolate the best lines that were selected. The remaining lines after elimination are put in replicated trials to compare them with a commercially popular variety called "check" in relation to yield ability and distinct agronomic performance. Best lines are finally identified within 2 to 3 yeas.

Note that number of lines that are retained under mass selection is relatively larger than what obtains under pure line selection.

Inbreeding Coefficient

This is referred to as the proportion of homozygosity after a given number of generations of inbreeding.

If, for example the the number of generation of inbreeding(m) is 3 and the number of pairs of gene involved(n) is 2

Inbreeding Coefficient (Q) is given as = $[(2^m-1)/2^m]^n = [(2^3 - 1)/ 2^3]^2$

$= [7/82]^2$

$= (0.875)^2$

$= 0.766$

WHAT WILL BE THE VALUE OF Q IF M=2 AND N=2?

Progress from Selection:

This is the same as predicted gain, gain from selection or genetic advance. It is a measure of success during a selection process.

It is given as $Gs = K\ \delta\ H_B$ where

K = Selection differential (a constant) which can be calculated by knowing the difference between the mean of an original population(X_1) and the mean of a selected population(X_2) i.e. $K = X_1 - X_2$. The higher is the proportion of population retained; the lower is the "K" value. Theoretically, "K" values for 1,2,5,10,20,30% retained populations are 2.64,42,2.06,1.76,1.40,1.16, respectively.

Delta (δ) is phenotypic standard deviation of selected population usually at 5% selection.

H_B represents the broad-sense heritability. Low H_B value means little or no gain from selection.

CONSIDER THE FOLLOWING WORKED EXAMPLE:

Days to first flowering in cowpea is the trait to be considered.

Day	**Flowering days**
1	30
2	29
3	35
4	25
5	40
6	30
7	21

8	30
9	40
10*	31

*

Mean days to first flower in TEN (10) plants = 30+29+35+25+40+30+21+30+40+31

$\sum x = 311$

Therefore, **mean of original population** X_1 is 311/10 = 31.1

Variance $\delta^2 = \{\sum x^2 - [(\sum x)^2)/n]\}/9$

$(\sum x)^2 = 96721$ i.e. $(311)^2$ and $(\sum x)^2/n = (\sum x)^2/10 = 96721/10 = 9672.1$

$\sum x^2 = 9993$, n= 10 and n-1 = 9

X	30	29	35	25	40	30	21	30	40	31
X^2	900	841	1225	625	1600	900	441	900	1600	961

Thus, genetic variance ($\delta^2 g$) = [9993.0 – 9672.1]/9 = 320.9/9 = 35.67

IF THREE (3) plants with shortest days were selected from the population, population

Mean of selected population X_2 = (20+25+21)/3 = 25

Thus, K = $X_1 - X_2$ = 31.1- 25.0 = 6.1

Assuming that error variance ($\delta^2 e$) = 10.2, and the calculated genetic $\delta^2 g$ = 35.67

The phenotypic variance ($\delta^2 p$) will be $\delta^2 g + \delta^2 e$ = 35.67 + 10.2 = 45.87

Therefore, the phenotypic standard deviation $= \sqrt{\delta^2 p} = \delta p = 6.77$

Consequently, $H_B = \delta^2 g / \delta^2 p = 36.67/45.87 = 79.94\ \%$

Since $Gs = K\delta H_B$

$Gs = 6.1 \times 6.77 \times 0.7994 = 33.04$ days because Gs is expressed in the unit of the trait that is being measured.