

## **Principles of Plant Breeding (2 + 1)**

### **Course No-PBG 3.3 (2 + 1)**

#### **Course content :**

##### **Theory :**

- Aims and objectives of Plant Breeding
- Modes of reproduction – Sexual, Asexual, Apomixis and their classification and its significance in plant breeding
- Modes of pollination – Genetic consequences, differences between self and cross pollinated crops
- Methods of breeding – Introduction and acclimatization, Selection (mass selection & Johansson's pure line theory), genetic basis, pure line selection.
- Hybridization – Aims and Objectives, Types of hybridization, Methods of handling segregating generations like Pedigree method, Bulk method, Back cross method and various modified methods.
- Incompatibility and sterility and their utilization in crop improvement
- Heterosis and Inbreeding depression – Various theories of heterosis, Exploitation of hybrid vigour for development of inbred lines, single and double cross hybrids
- Population improvement programmes – Hardy-Weinberg law, Recurrent selection, Synthetic and composite varieties
- Methods of breeding vegetatively propagated crops – Clonal selection, Mutation breeding, Ploidy breeding, Wide hybridization and their significance crop concept in crop improvement.
- Breeding resistance to biotic and abiotic stresses – variability in pathogens and pests, Mechanisms of resistance in plant pathogens and pests.
- Genetic basis of adaptability to unfavourable environments
- Definitions of biometrics, assessment of variability, additive, dominance and epistasis and their differentiation, Genotype x environment interaction and influence on yield/performance, IPR and related issues.

##### **Practical :**

- Study of megasporogenesis and microsporogenesis, Fertilization and life cycle of angiospermic plant
- Plant breeder's kit
- Hybridization techniques and procedures
- Study of male sterility and incompatibility in field plots
- Handling of segregating generations
- Problems on Hardy-Weinberg law
- Back cross methods
- Field layout of experiments, field trials and maintenance of records and registers
- Estimation of heterosis and inbreeding depression, Heritability, GCA and SCA
- Estimation of variability parameters

##### **Reference book –**

1. Plant Breeding – Principles and Methods - B. D. Singh
2. Principles of Plant Breeding – R. W. Allard
3. Essentials of Plant Breeding – Phundan Singh

**Plant breeding** is the applied branch of Botany which deals with the improvement of agricultural crops.

### **What is Plant Breeding ?**

1. Plant breeding means the improvement in the heredity of crop plant and production of new crop varieties which are far better than original / existing one in all aspects.
2. Plant breeding is an art and science of improving the genetic pattern of plants in relation to their economic use.
3. Plant breeding is the art and science of changing and improving the heredity of plant.
4. Plant breeding is the genetic adjustment of plants to the service of man.

Plant breeding, as a science, involve 4 basic principles :

1. Formation of hypothesis,
2. Experimentation,
3. Observation, and
4. Conclusion.

### **Why Plant Breeding is considered as an art and science?**

In early days, when the scientific knowledge was not available, the plant breeder depend upon their skill and judgment in selecting the superior types of varieties. They do not know about

1. Inheritance of character,
2. Role of environment,
3. Basis of variation in plant, etc.

So that time the plant breeding was mainly an art.

As the knowledge of genetics and other related sciences progressed, the plant breeding become less of an art and more of a science. The modern techniques of crop improvement developed on sound scientific basis only after the rediscovery of the Mendelian laws of inheritance. So modern plant breeding is mainly based on these genetic principles. Without this precise knowledge and background, the modern plant breeder can not solve the vast range of problems.

Therefore, at this stage hybridization or crossing is considered as an art, but without the knowledge of genetics this technique of hybridization is not going to play anything in plant breeding. So that, now plant breeding is more a science and less an art.

### **Plant Breeding is an industry**

Plant breeding can be viewed upon as an industry, where improved varieties are produced.

In this industry several units can be seen :

1. The processing Unit
2. The multiplication Unit, and
3. The research and development Unit.

#### **1) In the Processing Unit :**

- The required product is built from some raw materials.
- During this process waste products are removed.
- The raw material is formed by the varieties chosen as parents in breeding programme.
- The genotype removed during the processing from the waste products.
- The few superior genotypes selected – form the end product.

## 2) In the Multiplication Unit :

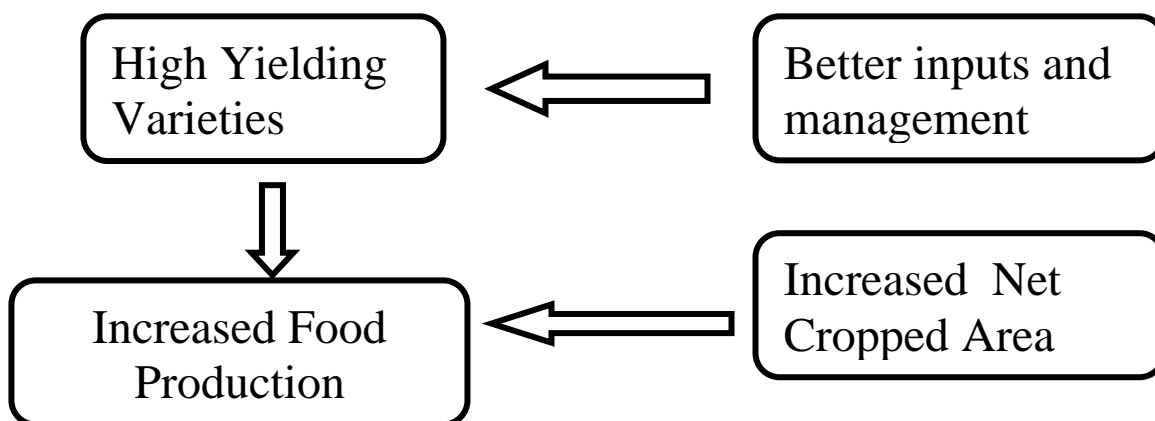
- Take care of this end product, which must be multiplied

## 3) In the Research and Development Unit :

- The research unit comprises all work directed
- As collecting scientific information,
- Improving procedures already in use, or
- Developing new procedures.
- This research can be very practically or more basically oriented

## Importance of Plant Breeding

- The food grain production in India had increased from 54.92 million tonnes (from 99.28 million hectares) in 1949-50 to 241.00 million tonnes in 2010-11.
- This represents an increase of about 438 per cent during a period of 60 years.
- As a result, the nation became almost self-sufficient in food grains.
- But the population in India is growing at an alarming rate of around 2.5 per cent per year. This makes it necessary that the food grain production should also increase at least at the same rate or even at a faster rate in order to improve the nutritional status of the masses.
- Increased quantum and better management of inputs, such as fertilizers, irrigation water, plant protection and cultural practices, and from improved crop varieties (Fig.-1).
- It is doubtful that the net cropped area can be increased indefinitely, but there is still some scope through double and multiple cropping.



**Fig. 1. Factors contributing to increased food production in India**

- Improved input management practices are yet to be fully exploited, and vast tracts of cultivated lands are very poorly managed.
- In future, agricultural production is most likely to increase from providing better environment through management and from crop varieties capable of fully exploiting the environment so provided.
- Better environment alone cannot lead to better yields from inferior varieties beyond a certain limit, the limit being set by the genetic makeup of the variety.
- Improving the environment beyond a certain limit for any variety may adversely affect its performance.

- This point is illustrated by the tall and dwarf varieties of wheat. Tall wheat varieties respond to nitrogen application upto 60 kg/ha, but higher doses of nitrogen reduce yields primarily due to severe lodging.
- Dwarf wheat varieties, on the other hand, give increased yields upto, or even beyond 120 kg nitrogen per hectare.
- It is believed that the genetic makeup of the crop plants is such that it would permit considerable, perhaps endless, changes and improvements.
- Further, the changes brought about in the present varieties probably represent only a small portion of the possibilities.
- Thus continuous favourable changes in the genotype of crop varieties are a must for increasing yields from crop plants.
- Plant breeding deals with this aspect of crop production: ***“It consists of the principles and the methods required for favourably changing the genetic constitution of crop plants suited to human needs than the existing ones.”***
- ***Domestication: “The process of bringing a wild species under human management is referred to as domestication.”***
- *Thus domestication may be regarded as the most basic method of plant breeding.*
- *All other breeding methods become applicable to a plant species only after it has been successfully domesticated.*
- This is likely to give rise to better types than the wild ones.
- Domestication continues till today, and is likely to continue for some time in future.
- This is particularly true in the case of timber trees, medicinal plants, microbes and plants satisfying some special requirements.
- Transfers of specific genes, *e.g.*, for disease resistances, from wild species (or even from unrelated organisms) to cultivated ones may be regarded as domestication of those genes, *i.e.*, of a part of the genome of the concerned species.
- It is likely that man also exerted some selection either knowingly or unknowingly. Movement of man from one area to another brought about the movement of his cultivated plant species.
- *The introduction into an area of new plant species or varieties from other parts of the world is an integral part of plant breeding today.*

### Landmarks in plant breeding

<i>Year</i>	<i>Name of scientist</i>	<i>Outstanding contribution</i>
1717	Thomas Fairchild	Developed first interspecific hybrid between sweet william and carnation species of <i>Dianthus</i> ( <i>Dianthus barbatus</i> x <i>D. caryophyllus</i> ).
1800	Knight, T.A. (English)	First used artificial hybridization in fruit crops.
1840	John Le Couteur (English) and Patric Shirreff (Scottish)	They developed the concept of progeny test and individual plant selection in cereals.
1856	De Vilmorin (French Biologist)	Further elaborated the concept of progeny test and used same in sugarbeet.
1866	Mendel, G.J. (Austria)	Discovered principles of inheritance working with garden pea
1890	Rimpu (Sweden)	First made intergeneric cross between bread wheat ( <i>Triticum eastvum</i> ) and rye ( <i>Secale cereal</i> ), which later on gave birth to <i>Triticale</i> .
1900	DeVries (Holland) Correns (Germany) Tschermak (Austria)	Rediscovered Mendel's laws of inheritance independently.
1900	Nilsson, H. (Swedish)	Further elaborated individual plant selection method.
1903	Johannsen, W.L. (Danish botanist)	Developed the concept of pureline. In 1909 coined the terms genotype and phenotype
1908	Shull, G.H. (US) East, E.M. (US)	Proposed over dominance hypothesis of heterosis independently working with maize.
1908	Hardy, G.H. Weinberg, W.	Developed concept of hardy-Weinberg law in population genetics.
1908	Davenport, C.B.	First proposed dominance hypothesis of heterosis.
1910	Bruce, A.B. Keeble, F. and Pelles, C.	Elaborated the dominance hypothesis of heterosis proposed by Davenport.
1914	Shull, G.H.	First used the term heterosis for hybrid vigour.
1917	Jones, D.F.	Proposed dominance of linked gene hypothesis as explanation for heterosis. He first made double cross in maize and also first used genetic male sterility in the development of maize hybrids.
1919	Hays, H.K. Garber, R.J.	Gave initial idea about recurrent selection. They first suggested use of synthetic varieties for commercial cultivation in maize.
1920	East E.M and Jones, D.F.	Also gave initial idea about recurrent selection.

1921	Sewall Wright (English)	Gave five systems of mating namely random, genetic assortative, phenotypic assortative, genetic disassortative and phenotypic disassortative.
1925	East, E.M. and MangeIsdorf A.J.	First discovered gametophytic system of self incompatibility in <i>Nicotiana sanderae</i>
1926	Vavilov, N.J. (Russian Geneticist)	Identified 8 main centres and 3 sub centres of crop diversity. He also developed concept of parallel series of variation or law of homologous series of variation.
1927	Karpechenko (Russian Geneticist)	First developed intergeneric hybrid between radish and cabbage which had undesirable features of both species.
1928	Stadler. L.J. (US)	First used X-rays for induction of mutations in crop plants.
1935	Nagaharu. U.	Proposed the origin of tetraploid species of <i>Brassica</i> using a triangle which is popularly known as U's triangle.
1936	East, E.M.	Supported overdominance hypothesis of heterosis proposed by East and Shull in 1908.
1937	Harrington, J.B.	Proposed mass pedigree method of breeding which is a modification of pedigree method.
1939	Goulden, C.H.	First suggested the use of single seed descent method for advancing segregating generations of self pollinated crops.
1940	Jenkins. MT.	Described the procedure of recurrent selection.
1944	Stadler, L.J.	Proposed use of gamete selection for improvement of inbreds in maize.
1945	Hull, F.H.	Coined the terms recurrent selection and over-dominance working with maize.
1950	Hughes M B. and Babcock, E.B.	First discovered sporophytic system of self incompatibility in <i>Crepis foetida</i> .
	Gerstel, D.V.	Gerstel discovered the same independently in <i>Parthenium argentatum</i> .
1951	Painter, RH.	Gave three mechanisms, viz, non-preference, antibiosis and tolerance of insect resistance in crop plants.
1952	Jensen, N.F.	First suggested the use of multilines in oats.
1953	Borlaug, N.E.	First outlined the method of developing multilines in wheat.
1953	Mather, K.	Developed the concept of disruptive selection.
1956	Flor, H.H.	First developed the concept of gene for gene hypothesis in flax for flax rust caused by <i>Malampsora lini</i> .
1958	Thoday, J. M.	Further elaborated the concept of disruptive selection.

1963	VanderPlank, J.E	Developed the concept of vertical and horizontal resistance.
1964	Borlaug. N.E.	Developed high yielding semidwarf varieties of wheat which resulted in <b><u>Green Revolution</u></b> .
1965	Grafius, J.E.	First applied Single Seed Descent (SSD) method in oats.
1968	Donald, C.M.	Developed the concept of crop ideotype working with wheat.
1970	Patel, C.T.	Developed <b>world's first</b> cotton hybrid for commercial cultivation in India.
1976	Yuan Long ping <i>et al.</i>	Developed <b>world's first rice hybrid</b> (CMS based) for commercial cultivation in China.
1983	Fraley <i>et al.</i>	Developed <b>first transgenic (genetically engineered) tobacco</b> plant in USA.
1987	Monsanto, USA.	Developed <b>first transgenic cotton</b> plant in USA.
1991	ICRISAT, India	Developed <b>world's first pigeon pea hybrid (ICPH 8 GMS based)</b> for commercial cultivation in India.
1997	Monsanto, USA	<b>First identified terminator gene</b> , which allows germination of seed for one generation only.
1998	Monsanto, USA	Identification of <b>traitor gene</b> , which responds to specific brand of fertilizers and insecticides.
2002	Mahyco - Monsanto	Released three <b>Bt cotton Hybrids</b> (MECH 12, MECH 162 and MECH 184) for cultivation in M.P., A.P., Maharashtra, Gujarat, T.N. and Karnataka.
2005	Govt. of India	Approved cultivation of some Bt cotton hybrids in Punjab, Haryana and Rajasthan.

### **SOME INDIAN PLANT BREEDERS**

In India remarkable contribution has made in the field of crop improvement. The significant contribution of some Indian Plant Breeders is briefly given here.

#### **T. S. VENKATRAMAN**

He was an eminent sugarcane breeder. He transferred thick stem and high sugar contents from Noble cane to North Indian canes. This process is known as Noblization of sugarcane. He developed several varieties of sugarcane having high yields and high sugar content. He was Director of Sugarcane Breeding Institute, Coimbatore.

#### **B. P. PAL**

He was an eminent Plant Breeder, known for his contributions to the breeding of superior diseases resistant N.P. varieties of wheat. He was the **first Director General** of ICAR.

#### **PUSKARNATH**

A famous potato breeder who developed several high yielding varieties of potato. He was the Director of **CPRI, Shimla**.

#### **N. G. P.RAO**

He is an eminent Sorghum Breeder. He developed several high yielding hybrids of grain sorghum. He was Chairman of **ASRB** and Vice-Chancellor of Marathawada Agril. University Parbhani.

#### **K. RAMIAH**

He was a renowned rice breeder. He developed several high yielding varieties of rice when he was the Director of **CRRI, Cuttack**.

#### **K. ATHWAL**

He is a famous pearl millet breeder. He worked in PAU, Ludhiana and developed several superior varieties of Pearl millet.

#### **BOSISEN**

He was an eminent maize breeder. He developed several varieties of maize for Hill region of Uttaranchal. He established the **Vivekanand Parvatiya Krishi Anusandhan Shala** at **Almora, Uttaranchal**. He was the Director of this Institute till his death.

#### **DHARMAPAL SINGH**

He is an eminent Oil-seeds breeder. He released several varieties of Oil-seeds (Rapeseed and Mustard) from Kanpur. He was Vice-Chancellor of G.B.Pant University of Agriculture and Technology, Pantnagar.

#### **C. T. PATEL**

He was a famous Cotton breeder who developed World's First Cotton hybrid in 1970 from Gujarat Agricultural University, Surat Station. He is known as **FATHER of Hybrid Cotton**.

#### **V. SANTHANAM**

He is a famous cotton breeder who developed several high yielding varieties of **Upland cotton** and two varieties of **Egyptians Cotton**. He was the first Project Coordinator for All India Coordinated Cotton Improvement Project and later worked in **FAO** as cotton consultant.

### **THE DISCIPLINES A BREEDER OUGHT TO KNOW**

To be successful, a plant breeder must know all he can about the plants he is working with. Thus he should have an understanding of the following: (1) botany, (2) genetics and cytogenetics, (3) agronomy, (4) plant physiology, (5) plant pathology, (6) entomology, (7) bacteriology, (8) plant biochemistry, and (9) statistics.

#### **1. Botany**

A plant breeder must have a clear understanding of the morphology and the reproduction of plants he aims to improve. He should also be familiar with the taxonomy of these plants.

#### **2. Genetics and Cytogenetics**



The principles of genetics and cytogenetics provide the bases for plant breeding methods. Therefore, a thorough knowledge of these subjects is essential for a rapid and efficient improvement of a crop plant.

### **3. Agronomy**

A good breeder is first a good agronomist. He must be able to raise a good crop in order to select and evaluate his material.

### **4. Plant Physiology**

Adaptation of a variety is determined by its response to environmental factors like heat, cold, drought, salinity etc. Knowledge of the physiological bases of these responses would help the breeder in developing cold, drought or salinity tolerant varieties. In addition, several physiological approaches to breeding for higher yields are being developed.

### **5. Plant Pathology**

Breeding for disease resistance is an important objective of plant breeding. For an effective breeding - for resistance, a sound knowledge of plant diseases and their pathogens is essential.

### **6. Entomology**

Insect pests cause considerable damage to crops. Knowledge of insect pests would be necessary in order to breed insect resistant varieties, and to protect susceptible breeding materials from pest damage.

### **7. Bacteriology**

Legumes have root nodules containing *Rhizobium* sp., which fix atmospheric nitrogen. The efficiency of this system depends upon both the host and *Rhizobium* genotypes. Therefore, in legume improvement a knowledge of *Rhizobium* would be helpful. This aspect of legumes is receiving a great deal of attention these days.

### **8. Plant Biochemistry**

Several types of quality tests are required to determine the quality characteristic of a crop variety. These tests often involve chemical analyses, e.g., protein content, amino acid content etc. Knowledge of biochemistry would be helpful in conducting these tests, and also in developing breeding strategies and selection techniques for such characters.

### **9. Statistics**

For a precise comparison of performances of various entries varieties, a sound knowledge of statistical methods is a must. The breeder must be well-versed in field plot techniques, experimental designs and relevant statistical analyses and tests. The understanding of quantitative inheritance is also based on statistical principles.

### **10. Plant Biotechnology**

Plant biotechnology is fast emerging as an extremely potent tool for crop improvement. This discipline is highly specialized and extremely sophisticated with its own array of terms, concepts and phrases. The breeder must be, at least, familiar with the basics of this discipline to enable him to communicate and interact in a meaningful manner with the experts in the subject so that this powerful tool is exploited in a profitable manner.

- In addition to the above, the breeder must be aware of the present market demands, needs of the farmer and the problems of crop production in the concerned area.

- He should also be able to see into the future to be able to meet the challenges that the farmers may face years later.
- The breeder has to plan several years ahead because it takes at least 12-15 years to develop and release a new variety.
- It is difficult for one person to be a specialist in all the above areas.
- As a result, modern plant breeding is becoming more and more of a team effort. Specialists in genetics, pathology, entomology and agronomy cooperate with the plant breeder in crop improvement.
- The Indian Council of Agricultural Research (ICAR) has formulated its All India Coordinated Crop Improvement Projects on these lines.

## **OBJECTIVES OF PLANT BREEDING**

Plant breeding *aims to improve the characteristic of plants so that they become more desirable agronomically and economically*. Some of the main objectives of plant breeding may be summarized as follows.

### **1. Higher Yields**

Most of the breeding programmes aim at higher crop yields. This is achieved by developing more efficient genotypes, *e.g.*, hybrid varieties of maize (*Z. mays*), sorghum (*S. bicolor*), bajra (*P. glaucum* etc.

### **2. Improved Quality**

The quality of plant produce determines its suitability for various uses. Therefore, quality is an important aspect for plant breeders. Quality characters vary from one crop to another, *e.g.*,

- grain size, colour, milling and baking qualities in wheat (*Triticum aestivum*),
- cooking quality in rice (*Oryza sativa*),
- malting quality in barley (*Hordeum vulgare*,
- size, colour and flavour of fruits,
- keeping quality of vegetables,
- protein content in cereals and legumes,
- lysine content in cereals,
- methionine and tryptophan contents in pulses etc.

### **3. Disease and Insect Resistance**

Resistant varieties offer the cheapest and the most convenient method of disease and insect management. In some cases, they offer the only feasible means of control, *e.g.*, rusts in wheat. Resistant varieties not only increase production but also stabilize it.

### **4. Change in Maturity Duration**

It permits new crop rotations and often extends the crop area. Development of wheat varieties suitable for late planting has permitted rice-wheat rotation. Thus breeding for early maturing crop varieties, or varieties suitable for different dates of planting may be an important objective in many cases.

### **5. Agronomic Characteristics**

Modification of agronomic characteristics, such as, plant height, tillering, branching, erect or trailing habit etc., is often desirable. For example, dwarfness in cereals is generally associated with lodging resistance and fertilizer responsiveness.

**6. Photo-insensitivity**

Development of photo-insensitive and thermo-insensitive wheat, and photo-insensitive rice (*O. sativa*) varieties has permitted their cultivation in new areas. Rice is now cultivated in Punjab, while wheat is a major *rabi* crop in West Bengal.

**7. Synchronous Maturity**

Synchronous maturity is highly desirable in crops where several pickings are necessary e.g mungbean (*Vigna radiate*,) pigeon pea (*Cajanus cajan*), cotton (*Gossypium sp.*), etc.

**8. Non-shattering Characteristics**

It would be of great value in a crop like mung where shattering is a major problem in case of many commercial varieties.

**9. Determinate Growth**

Development of varieties with determinate growth is desirable in crops like mungbean, pigeon pea (*Cajanus cajan*), cotton (*Gossypium sp.*), etc.

**10. Dormancy**

In some crops, seeds germinate even before harvesting if there are rains at the time of maturity, e.g., mungbean, barley, Spanish groundnut, etc. A period of dormancy in such cases would check the loss due to germination. In some other cases, however, it may be desirable to remove dormancy.

**11. Varieties for New Seasons**

Traditionally, maize is a *kharif* crop. But scientists are now able to grow maize throughout the year. Similarly, mung is now grown as a summer crop in addition to the main *kharif* crop.

**12. Moisture Stress and Salt Tolerance**

Development of varieties for rainfed areas and for saline soils would be helpful in increasing crop production in India. The major proportion (about 70%) of the cropped area in the country is rainfed. The estimates of salt-affected (saline) soils in the country vary from 7 to 20 million hectares, of which about 2.8 million hectares are alkaline soils. Most of these areas are spread in the states of Uttar Pradesh, Haryana and Punjab.

**13. Elimination of Toxic Substances**

Some crops have toxic substances which must be eliminated to make them safe for consumption. For example, khesari (*Lathyrus sativus*) seeds have a neurotoxin,  $\beta$ -N-oxalylalanine alanine (BOAA) that causes paralysis. Similarly, brassica oil has erucic acid, which is harmful to human health. Removal of such toxic substances would increase the nutritional value of these crops.

## **ACTIVITIES IN PLANT BREEDING**

The desired changes in genotypes of crop species and the consequent benefits to farmers are brought about by a series of interrelated and largely interdependent activities. These activities are as follows:

- (1) Creation of variation,
- (2) Selection,
- (3) Evaluation,
- (4) Multiplication and
- (5) Distribution

**Refer Figure**

### **1. Creation of variation.**

- Genetic variation is a prerequisite for any improvement in a crop. Therefore, in any breeding programme, this is always the first step unless variation preexists.
- Genetic variation can be created by domestication, germplasm collection, plant introduction, hybridization (intervarietal, distant, somatic), mutation, polyploidy, somaclonal variation and genetic engineering.

### **2. Selection**

- The next step consists of identification and isolation of plants having the desirable combinations of characters, and growing their progeny; this is called selection.
- Selection is necessarily based on phenotype.
- The efficiency of this activity determines the success of a breeding program.
- Various breeding methods have been designed to increase the efficacy of selection.
- Selection finally yields an improved line/strain or population.

### **3. Evaluation**

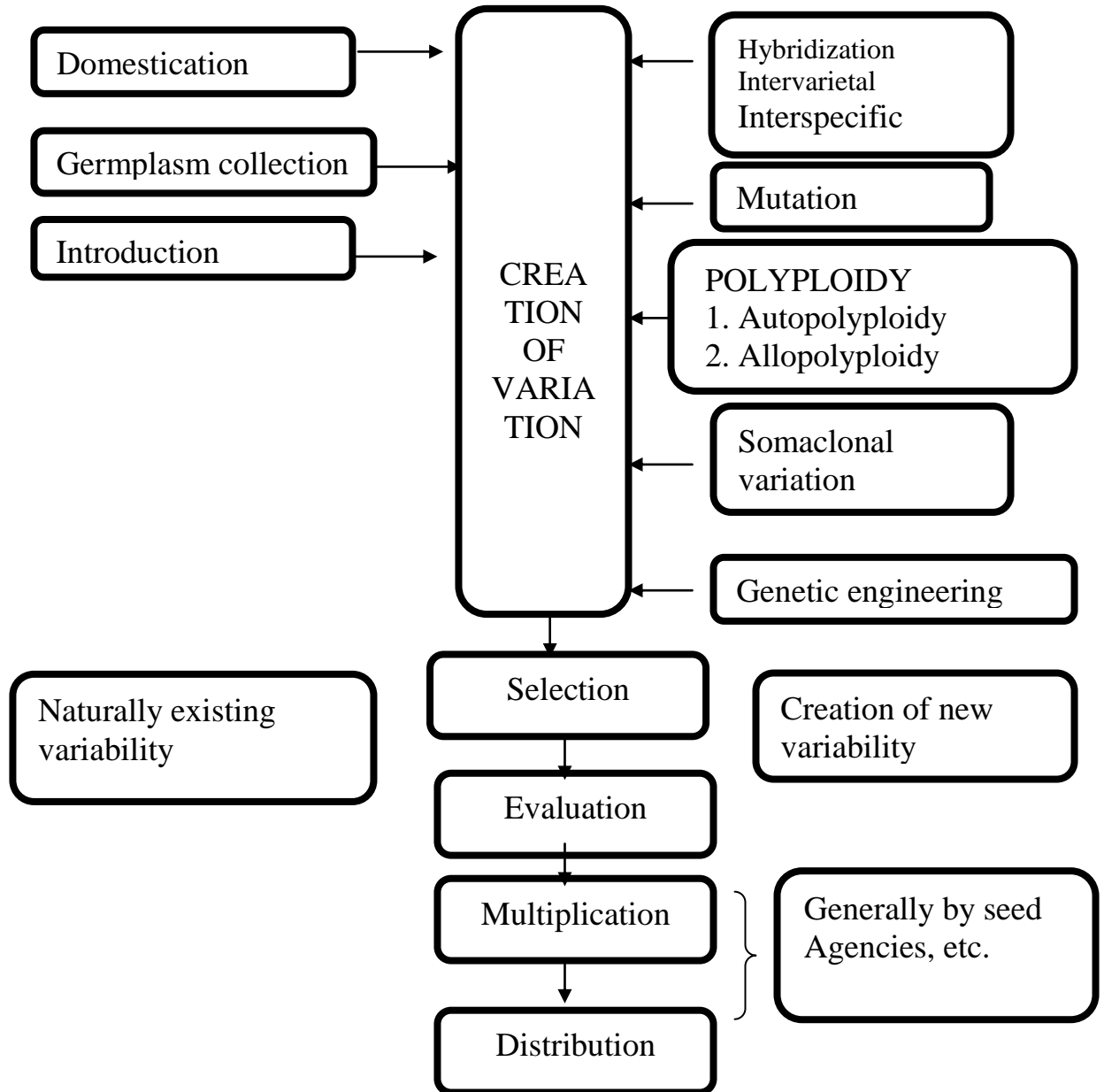
- The newly selected lines/strains/populations are tested for yield and other traits and compared with the existing best varieties called checks.
- Evaluation is a stepwise process, ordinarily conducted at several locations for 3 or more years under the concerned All India Coordinated Crop Improvement Project.
- If the new line/strain/population is superior to the checks, it is released and notified as a new variety and its seed can now be multiplied and, more importantly, certified by a seed certification agency for quality.

### **4. Multiplication**

- This step concerns with a large scale production of certified seed of the released and notified variety.
- Seed production is usually done by seed production agencies in a step-wise manner, and the seed is certified by a seed certification agency.

### **5. Distribution**

- Certified seed is ultimately sold to the farmers who use it for commercial crop cultivation. This activity alone makes it possible to reap the economic benefits from the above activities in form of (1) an enhanced and (2) stable production of (3) superior produce (4) often at a lower cost.



**Fig. 2. Activities in plant breeding.**

## IMPORTANT ACHIEVEMENTS

The important achievements of the plant breeding are as under

### 1. Semi dwarf Wheat and Rice

- One of the most important developments of modern agriculture has been the production of semi dwarf cereal varieties, particularly of wheat and rice.
- The semi dwarf wheat varieties were developed by N.E. Borlaug and his associates at **CIMMYT (International Centre for Wheat and Maize Improvement), Mexico**.
- They used a Japanese variety **Norin-10** as the source of dwarfing genes.
- In 1963, ICAR introduced several dwarf selections from CIMMYT.
- Kalyan Sona and Sonalika were selected from these materials.
- A great majority of the wheat varieties now grown in the country are semi dwarf.
- These semi dwarf wheat varieties are
  - Lodging resistant, Fertilizer responsive, High yielding Resistant to rusts and other major diseases of wheat due to the incorporation of resistance genes in their genotypes.
  - This has greatly increased and stabilized wheat production in the country.
  - These varieties are photo-insensitive and many of them are suitable for late planting.
  - This has enabled cultivation of wheat in nontraditional areas like West Bengal.
- Similarly, the development of semi dwarf rice varieties has revolutionized rice cultivation.
- These varieties were derived from **Dee-geo-woo-gen**, a dwarf, early maturing variety of *japonica* rice from Taiwan.
- **Taichung Native 1 (TN-1)**, developed in Taiwan, and **IR 8**, developed at **IRRI (International Rice Research Institute), Philippines**, were introduced in India in 1966.
- They were extensively grown for few years, but were replaced by superior semi dwarf varieties developed in India, e.g., Jaya, Ratna etc.
- The semi dwarf rice varieties are lodging resistant, fertilizer responsive, high yielding and photo-insensitive.
- Photo-insensitivity has allowed rice cultivation in non-traditional areas like Punjab.
- Even in traditional areas, rice-wheat rotation has become possible only due to these varieties.

### 2. Noblisation of Indian Canes

- Another noteworthy achievement is noblisation of sugarcane.
- The Indian canes, *Saccharum barberi*, were largely grown in North India. They were hardy, but poor in yield and sugar content.
- The tropical noble canes, *Saccharum officinarum* had thicker stem and higher sugar content. But they performed badly in North India primarily due to low winter temperatures in this region.
- C.A. Barber, T.S. Venkataraman and others at the **Sugarcane Breeding Institute (SBI), Coimbatore**, transferred the thicker stem, higher sugar content and other desirable characters from the noble canes to the Indian canes. This is commonly

referred to as **noblisation of Indian canes**.

- They also crossed *Saccharum spontaneum* (vern. kans), a wild species, to transfer disease resistance and other desirable characteristics to the cultivated varieties.
- Several high yielding varieties with high sugar content and well adapted to local climate have resulted from this breeding programme.
- At present, sugarcane breeding all over the world is based on the **noblisation technique**.

### 3. Hybrid varieties

- The development of hybrid varieties of maize, jowar and bajra deserves a special mention.
- A programme to develop hybrid maize began in India over three decades ago in collaboration with Rockefeller and Ford Foundations. Several hybrid varieties have been released since then.
- The Ganga series of hybrids, *e.g.*, Ganga Safed 2, and Deccan, are a few examples.
- Similarly, several hybrids have been released in jowar, *e.g.*, CSH 1, CSH 2, CSH 3, CSH 4, CSH 5, CSH 6, CSH 9, CSH 10, CSH 11 etc.,
- In bajra, *e.g.*, PHB 10, PHB 14, BJ 104 and BK 560.
- More recently, composite varieties are being developed to overcome the difficulties encountered with the hybrid varieties.
- For example, Manjari, Vikram, Sona, Vijay and Kisan are some of the notable maize composite varieties. Some recently released composites are CO 1, NLD, Renuka, Kanchan, and Diara. **The composite varieties often yield as much as the hybrid varieties** and do not have the drawbacks of the latter. More notably, the farmers need not replace the seed every year in the case of composite varieties.

### 4. Hybrid Cotton

- India has achieved the distinction of commercially exploiting heterosis in cotton.
- The **first hybrid variety of cotton** was **H-4** (a hybrid from two *G. hirsutum* strains).
- It was developed by the Gujarat Agricultural University (Surat Station) and released for commercial cultivation in 1970.
- Since then, several other hybrid varieties have been released for cultivation.
- The hybrid varieties are high yielding, and have high ginning outturn and good fiber quality.
- They are becoming increasingly popular with the farmers.
- It is noteworthy that the farmers are more willing to pay the high cost of the hybrid seed produced by hand emasculation and hand pollination.
- Efforts to utilize cytoplasmic male sterility (CMS) for hybrid seed production have been successful and a hybrid based on CMS has been released.
- Hand pollination is essential for seed set on the CMS line.
- The cost of seed production is expected to be reduced to 10% of that incurred by hand emasculation and pollination technique.
- Recently, two hybrid varieties of desi cotton, *viz.*, G. cot. Dh-7 and G-cot. Dh-9, have been released.

## UNDESIRABLE CONSEQUENCES

Crop improvement leads to many desirable changes in crop species, which make these crops more useful to man. However, it also generates some undesirable effects, which include (1) genetic erosion, (2) narrow genetic base and (3) increased susceptibility to previously minor diseases.

### 1. Genetic Erosion

Improvement in the yield of a crop species is accompanied with a reduction in variability among the cultivated varieties of that species.

This reduction is produced by two potent factors:

- Replacement of heterogeneous local varieties by few dominant, more homogeneous improved varieties.
- Use of similar/related varieties as parents in breeding programmes.
- The improved varieties are commonly purelines (self-pollinated species) or hybrids (cross-pollinated species), which are much more homogeneous than the unimproved local and open-pollinated varieties.
- A few improved varieties become predominant and rapidly replace the local varieties leading to a rapid depletion of genetic variability (*genetic erosion*).
- This, in turn, limits the prospects of further improvement in the species since variability is the prerequisite for any modification in the characteristics of a crop species.
- Is it not ironical that successful crop improvement has depleted the very basic resource that is so essential for its continued success?
- *Germplasm collections aim at minimizing the detrimental effects of genetic erosion by collecting and preserving the variability in crops and their related species.*

### 2. Narrow Genetic Base

- Many of the improved varieties have one or more parents in common with each other.
- Many semi dwarf varieties of rice have IR 8 or TN I as one of their parents.
- IR 8 and TN I are related to each other by the common parent Dee-geo-woo-gen, the source of their semi-dwarfing gene.
- The semi-dwarf wheat varieties have *Rht 1*, *Rht 2* or both these genes for reduced height; these genes have been derived from a single wheat variety, Norin 10.
- Thus the improved varieties of a crop species are becoming increasingly similar to each other due to the commonness of one or more parents in their ancestry.
- This has led to the narrowing down of the genetic base of these varieties.
- *Genetic base* refers to **the genetic variability present among the cultivated varieties of a crop species.**
- The narrow genetic base has created *genetic vulnerability*, which refers to the susceptibility of most of the cultivated varieties of a crop species to a disease, insect pest or some other stress due to a similarity in their genotypes.
- An example of genetic vulnerability is the outbreak in epidemic proportions of *Helminthosporium* (now, *Cochliobolus*) leaf blight of maize in the 1970s in U.S.A.
- This occurred due to the extreme susceptibility of most of the commercial hybrids to the leaf blight.
- This susceptibility was produced by the Texas male sterility cytoplasm (**CMS- T**)



present in these hybrids.

- A similar case in India is the susceptibility of early bajra hybrids to downy mildew and ergot. This susceptibility was contributed by the male sterile parent of these hybrids, **Tift 23A** or its dwarf derivative, **Tift 23D2A**.
- But in this case, the susceptibility was due to some nuclear genes and not due to the male sterile cytoplasm itself.
- *Genetic vulnerability can be avoided by using diverse and unrelated parents in breeding programmes, and by using unrelated sources of male sterility, semi-dwarfness etc.*
- Breeders are becoming increasingly aware of this problem and they are making conscious efforts to broaden the genetic base of cultivated varieties of various crop species.

### 3. Increased Susceptibility to Minor Diseases

Another problem has been generated by the lopsided emphasis on breeding for resistance to major diseases and insect pests only. This has resulted in an increased susceptibility to minor diseases. As a result, these diseases have gained in importance and produced severe epidemics.

### Domestication

*“It is the process of bringing wild species under human management is referred as domestication”* The present-day cultivated plants have been derived from wild weedy species. Therefore, the first step in the development of cultivated plants was their domestication.

Domestication of wild species is still being done and is likely to continue for a long time in the future. This is because the human needs are likely to change with time. Consequently, the wild species of little importance today may assume great significance tomorrow. This is particularly true for microorganisms producing antibiotics, involved in nitrogen fixation, and producing other compounds of industrial or medical interest; forest trees producing timber and other commercial products; medicinal plants; and plants fulfilling specific needs.

A notable case of recent domestication is that of several members of Euphorbiaceae producing latex. The latex of these plants may be commercially used for the extraction of petroleum products, including petrol and diesel. Ex- Jojoba, Jetropha, Milkweed species etc

### Selection under Domestication

When different genotypes present in a population reproduce at different rates, it is called **selection**.

**Population** : The group of individuals, which mate or can mate freely with each other. Thus a population consists of individuals of a single species growing in the same locality.

Selection is grouped into two types, on the basis of the agency responsible for it.

- (1) Natural selection
- (2) Artificial selection

**1. Natural Selection** : The selection that occurs due to natural forces like climate, soil, biological factors (e.g., diseases, insect, pests etc.) and other factors of the environment.

- It occurs in natural populations, *i. e.*, wild forms and wild species, and determines

the course of their evolution.

- All the genotypes of the population reproduce, plants become more adapted to the prevailing environment.
- The population retains considerable genetic variability.

## **2. Artificial Selection: Selection is carried out by man according to their need and uses.**

- This type of selection is confined to domesticated species.
- It allows only the selected plants to reproduce, ordinarily makes plants more useful to man.
- Leads to a marked decline in genetic variability in the selected progenies/populations.
- Usually plants become less adapted to the natural environment.
- They have to be grown under carefully managed conditions.
- *Our present-day crops are the products of continued artificial selection.*

### **Important changes that have occurred under domestication**

- *Elimination of or reduction in shattering* of pods, spikes etc. This change has taken place in most of the cultivated species.
- *Elimination of dormancy* has taken place in several crop species. Lack of dormancy has become a problem in crops like barley, wheat, mung, etc.
- *Decrease in toxins* or other undesirable substances has occurred in many crops. The bitter principle of cucurbitaceous plants provides an example of this type.
- *Plant type* has been extensively modified. The cultivated plants show altered tillering, branching, leaf characters. etc.
- In several crop species, there has been a *decrease in plant height*, e.g., cereals, millets. This is often associated with a change from indeterminate to determinate habit.
- In some species, on the other hand, there has been an *increase in plant height* under domestication, e.g., jute, sugarcane, forage grasses etc.
- *Life cycle has become shorter* in case of some plant species. This is particularly so in case of crops like cotton, arhar, etc.
- Most of the crop plants show an *increase in size of their grains or fruits*.
- *Increase in economic yield* is the most noticeable as well as desirable change under domestication. This is self-evident in every crop species.
- In many crop species, *asexual reproduction has been promoted* under domestication, e.g., sugarcane, potato, sweet potato, etc.
- There has been a *preference for polyploidy* under domestication. Many of the domesticated plant species are polyploids, e.g., potato, wheat, sweet potato, tobacco, etc., while diploid plants are present in nature. Thus domestication seems to have favoured polyploidy in these crop species.
- In many species, there has been a *shift in the sex form* of the species. In many dioecious fruit trees, bisexual forms have developed under domestication. Self-incompatibility has also been eliminated in many crop species. *Variability within a variety has drastically decreased* under domestication. The extreme case is that of pureline varieties, which are completely homogeneous genotypically.

## PLANT INTRODUCTION

Plant introduction refers to "transposition of crop plants from the place of their cultivation to such areas where they were never grown earlier."

### TYPES OF PLANT INTRODUCTION

1. Primary or Direct plant introduction
2. Secondary or Indirect plant Introduction

#### **Primary or direct plant introduction:**

- When the introduced variety is well suited to the new environment and it is directly released for commercial cultivation without any change in the original genotype.
- It is less common in countries having well organized crop improvement programmes.
- **EXOTIC VARIETY:** Any foreign variety, which is directly recommended for commercial cultivation, is known as **EXOTIC VARIETY**.
  - e.g. Semi dwarf Wheat – Sonora-64, Lerma Rojo, etc.
  - Semi dwarf Rice – TN-1, IR-8, IR-28, etc.
  - Tomato-Sioux, Soybean – Bragg and Lee, Clark-63, Tobacco- Delcrest & Virginia Gold.

#### **Secondary or indirect plant Introduction:**

- When the introduced variety/material may be subjected to selection to isolate a superior variety. Alternatively, it may be hybridized with local varieties to transfer one or a few characters.
- Introduced material is not used directly as a variety.
- It is much more common than primary plant introduction.
  - e.g.-KalyanSona and Sonalika wheat varieties were selected from the material introduced from CIMMYT, Mexico, -Egyptian cotton variety Sujata was released after selection from the Egyptian variety Karnak.
  - Similarly, new varieties have been developed through selection from the introductions in pearl millet, cowpea, radish, sweet potato and many other crops.

### PURPOSES OF PLANT INTRODUCTION

The main purpose of plant introduction is to improve the plant wealth of the country. The chief objectives of the plant introduction may be grouped as follows :

#### **1) To obtain an entirely new crop plant**

Plant introduction may provide an entirely new crop species and it can be used in agriculture, forestry and industries.

e.g. -Mexican dwarf wheat & rice, maize, potato, tomato, tobacco, soybean, etc.

Further it provides lines with new characters like M.S. lines- Tift 23A in Bajra, TSP – 10R in castor, etc.

#### **2) To serve as a new variety**

Sometimes introductions are released as a superior commercial variety. e.g. Sonora-64, Lerma Rojo in wheat, T.N.-1, IR-8 in rice.

**3) To be used in crop improvement**

Often the introduced material is used in hybridization with local varieties to develop improved varieties.

e.g. Pusa Ruby in Tomato – derived from Meeruty x Sioux- an introduction from USA

Cotton Hybrid –4 – derived from G-67 x American nectariless - an introduction from USA

**4) For Scientific studies**

Collection of plants has been used in studies on biosystematics, evolution and origin of plant species.

**5) For fulfillment of aesthetic interest**

Ornamental plants, shrubs and lawn grasses are introduced to satisfy the finer sensibilities of human kinds. These plants are used for decoration and great value in social life.

**Advantage of Plant Introduction**

1. It provides entirely new crop plants.
2. It may provide superior varieties directly/after selection/hybridization.
3. Introduction and exploration are the only feasible means of collecting germplasm and to protect variability from genetic erosion.
4. It is a very quick and economical method of crop improvement, particularly when the introductions are released as varieties directly or after simple selection.

**Disadvantage of Plant Introduction**

If the introductions are not done very carefully and properly, then there are chances of introducing new weeds, diseases and pests. e.g.

1. **Weeds:** *Argemone mexicana*, *Phylaris minor* (Gehunsa), *Lantana camera* (kuri), water hyacinth, etc. are some of the noxious weeds introduced in India from other countries.
2. **Diseases:** Late blight of potato from Europe, Flag smut of wheat from Australia, Coffee rust and Bunchy top of banana from Ceylon, etc diseases were also introduced in India along with plant materials.
3. **Insects:** Potato tuber moth from Italy, woolly aphis of apple, Fluted scale of citrus and very recently strip virus in groundnut.

**MODE OF REPRODUCTION****Why should we know the mode of reproduction ?**

1. The methods of breeding depends upon the mode of reproduction, such as whether crop is sexually propagated or asexually propagated, whether it is self or cross pollinated and sterility and incompatibility involved in the mechanisms of reproduction.
2. Effect of inbreeding and out breeding depends on mode of reproduction because the genetic structure is different.
3. Genetic constituent/structure of plant and population depends on mode of reproduction.
4. Handling and management of breeding programme may depend on mode of reproduction. e.g., handling of breeding material is easy in maize, while it is difficult in alfalfa.

Therefore, it is essential for plant breeder first to know about mode of reproduction in concern crop to select proper breeding methods.

**Flower** : In crop plants, male and female gametes are produced in specialized structures known as **flower**. The flower contains sexual reproductive organs, therefore, it is essential to know the flower structure. Flower normally consists of four whorls.

Calyx	Calyx and corolla helping and protecting the sexual parts.
Corolla	
Androecium	Androecium and Gynoecium important reproductive whorls of the flower
Gynoecium	

### Types of Flower:

1. **Perfect/ hermaphrodite/ bisexual flowers**: A flower containing both stamens and pistil.
2. **Unisexual flowers** :
  - a. **Staminate** flowers: Contains only stamens.
  - b. **Pistilate** flowers : Contains only pistil
3. **Complete flowers**: Contains all four floral organs like sepals, petals, stamens and pistil. eg. Cotton, Groundnut, tobacco, rape, etc.
4. **Incomplete flowers**: Flowers lack one or more these four organs. eg. Wheat, Barley, Oat, Maize, Sorghum, Bajara, Rice, grasses, etc.

### Crop Species:

**Monoecious**: Male and female flowers are on the same plant eg. Maize, Castor, Coconut, etc.

**Dioecious**: Male and female flowers are on the different plants eg. Papaya, Date palm, Hemp, etc.

The mode of reproduction in crop plants may be broadly grouped into two categories.

1. **Asexual reproduction**
2. **Sexual reproduction**

#### A) Asexual reproduction :

1. Vegetative reproduction :	
I. Natural	II. Artificial
<b>Underground Stem :</b> a) Tuber- Potato b) Bulb- Onion c) Rhizome- Ginger d) Corm- Arwi, Satavari, Safron	a) Stem cutting – Sugarcane, grape, roses b) Layering c) Budding d) Grafing e) Gootee
ii. <b>Sub areial Stem:</b> a. Runner - Mint b. Stolon - Jethimadh c. Suckers - Datepalm	
iii. <b>Bulbils</b> : Bulbils are modified flowers that develop into plant directly without formation of seeds. These are vegetative bodies eg. Garlic	
2. <b>Apomixis</b> : Adventitious embryony, Apospory, Diplospory, Apogamy, Parthenogenesis, etc.	

## **B) Sexual reproduction :**

Sexual reproduction involves fusion of male and female gametes to form a zygote ( i.e. the product of fusion) which develops into an embryo.

There are two principal types of sexual reproduction:

1. Isogamy Sexual reproduction
2. Heterogamy Sexual reproduction

### **I) Isogamy Sexual reproduction :**

In this type of sexual reproduction, male and female gametes are morphologically similar. The fusion of such similar gametes is called isogamy sexual reproduction. It is found in lower plants.

### **II) Heterogamy Sexual reproduction :**

If the gametes of both male and female sex morphologically dissimilar, they are known as heterogametes. The fusion of such dissimilar gametes is known as heterogamy. It is most common in flowering plants.

#### **A). Androecium :**

Androecium (andros = male ) is male reproductive whorl of flower. Its component parts called stamens. Each stamen is consist of three parts –

**a) Filament      b) Connective and      c) Anther.**

Pollen grains are male reproductive bodies developing within the anther.

#### **B). Gynoecium :**

Gynoecium is also known as pistil. It is female reproductive whorl of flower. Its component part is known as carpel. When the pistil is made of only one carpel, such pistil is said to be simple or monocarpellary. When pistil possesses two or more carpels then it is said to be compound or polycarpellary. Each gynoecium consists of three parts : a) Stigma b) Style and c) Ovary.

## **SPOROGENESIS**

The production of microspores and megaspores is known as sporogenesis, and production of male and female gametes from microspores and megaspores are known as micro-gametogenesis and mega-gametogenesis, respectively.

### **Study of Microsporogenesis and Megasporogenesis**

The production of microspores and megaspores is known as sporogenesis, and production of male and female gametes from microspores and megaspores, respectively are known as microgametogenesis and megagametogenesis.

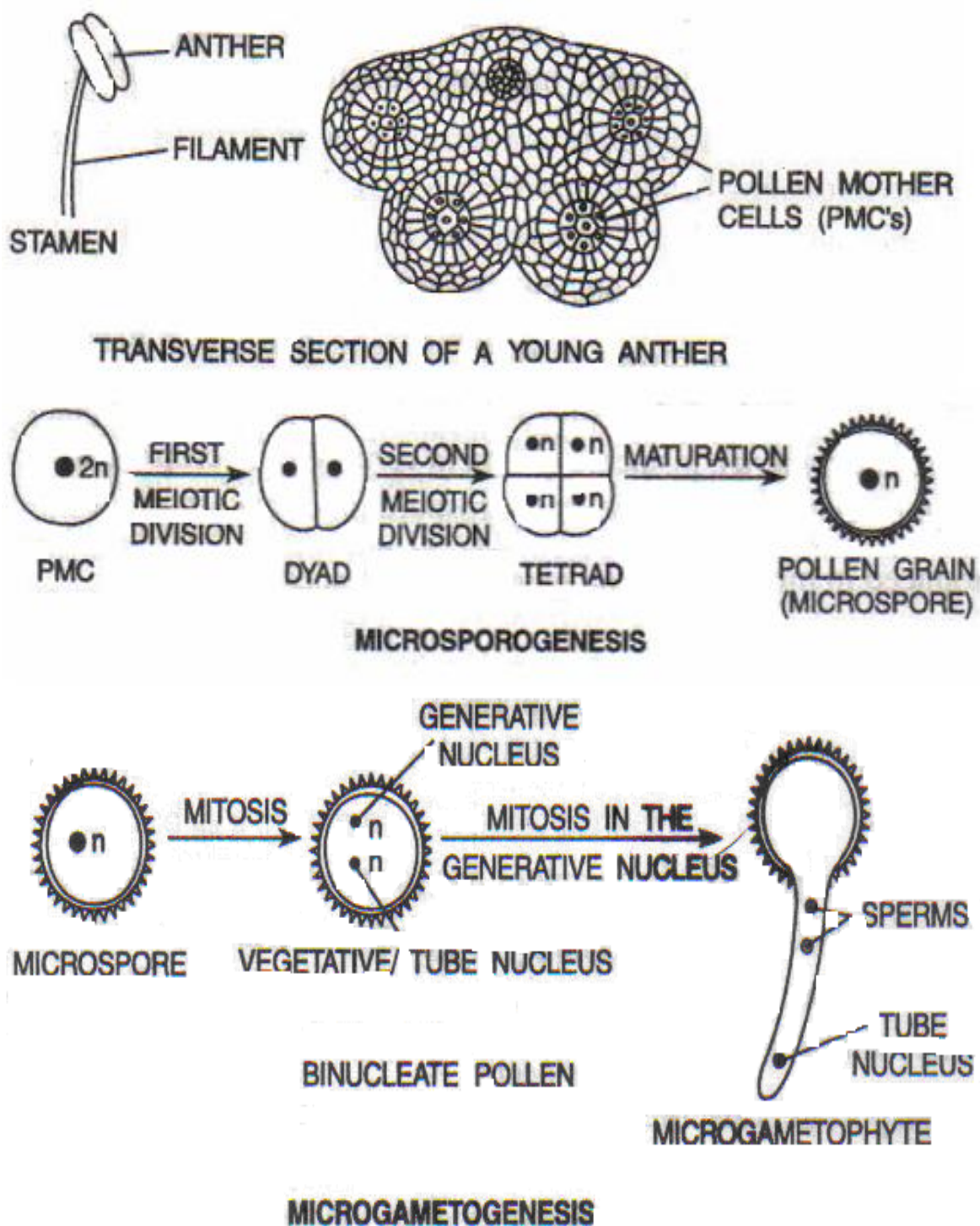
#### **Terminology :**

- **Gamete :** A specialized cell produced by gametogenesis which participates in the process of fertilization is known as gamete.
- **Sporogenesis :** The process of production of microspores (male gametes) and megaspores (female gametes) is known as sporogenesis.
- **Gametogenesis :** The process of production of male and female gametes in the microspores and the megaspores, respectively is known as gametogenesis.

- **Microgametogenesis** : The process of production of male gamete (sperm) is known as microgametogenesis.
- **Megagametogenesis** : The process of production of female gamete (egg cell) is known as megagametogenesis.

**Process of Microsporogenesis and Microgametogenesis :**

- Microspores are produced in anther i.e. microsporangium (**Fig. 2.1**).
- Each anther has four pollen sacs which contain numerous Pollen Mother Cells (PMC). These PMC's are also known as sporogenous tissue or archesporium.
- Each pollen grain undergoes meiosis to produce four haploid cells or microspores.
- The microspores mature into pollen grains by thickening of their wall.
- During the maturation of pollen, the microspore nucleus divides mitotically to produce a *generative nucleus* and a *vegetative nucleus* or *tube nucleus*. This is known as *binucleate pollen grain*.
- The pollens are generally released in this binucleate stage. When the pollen grain reaches the stigma of a flower, it is known as ***pollination***.
- Shortly after pollination, the pollen germinates and the pollen tube enters the stigma and grows through the style.
- The generative nucleus now undergoes a mitotic division to produce two ***male gametes or sperms***.
- The pollen, along with the pollen tube, is known as ***micro gametophyte***.
- The pollen tube finally enters the ovule through a small pore (***micropyle***) and discharges the two sperms into the embryo sac.



**Fig. 2.1 : Process of Microsporogenesis and Microgametogenesis**

**Process of Megasporogenesis and Megagametogenesis :**

- The embryo sac bears the embryo and develops in the ovule. Megaspores are produced in ovules, i.e. megasporangium (Fig. 2.2).
- A single cell in each ovule differentiated into Megaspore Mother Cell (MMC). This MMC undergoes meiosis to produce a row of four haploid megaspores. It is known as linear tetrad.
- Three of the megaspores degenerate leaving one functional megaspore per ovule.
- The nucleus of the functional megaspore divides mitotically to produce four more nuclei. In most of the crop plants, megaspore nucleus undergoes three mitotic divisions to produce eight nuclei in the embryo sac, four at each end.
- The embryo sac increases in size. Then one nucleus from at each end or pole passes



inwards, and the two polar nuclei fuse together somewhere in the middle forming the definitive nucleus.

- Another three nuclei remain at chalaza end or opposite end to form the antipodal cells, which have no definite function so sooner or later they get disorganized.
- They may, however, be nutritive in function. The remaining three polar nuclei at the micropyle end, each surrounded by a very thin wall form the egg apparatus, which consisted of three cells, one is female gamete known as egg cell/ovum/oospore.
- The other two are known as synergids or cooperative cells. They attract pollen tube by secreting some chemicals. One synergid degenerates to provide seat for pollen tube.

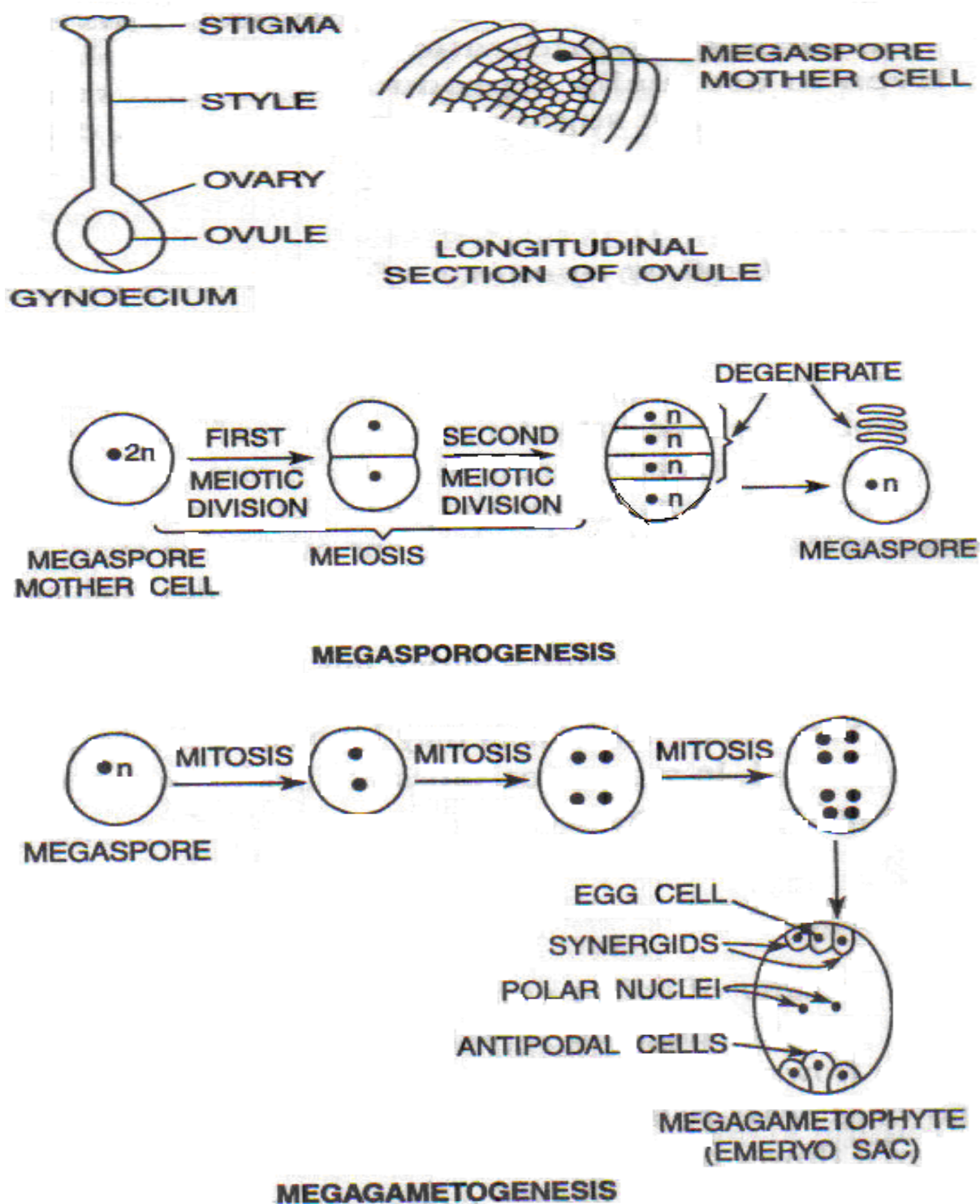


Fig. 2.2 : Process of Megasporogenesis and Megagametogenesis

**Significance of sexual reproduction :**

1. It is possible to combine genes from two parents into a single hybrid plant
2. Recombination among the genes produces large number of genotypes.
3. It is possible to create genetic variation through hybridization.
4. Even in asexual reproducing species, if sexual reproduction occurs, it is used to take the advantage as mentioned above eg. Sugarcane, Potato, Sweet potato etc.

**Significance of vegetative reproduction:**

1. A desirable plant may be used as a variety directly regards less of whether it is homozygous or heterozygous.
2. Identity of the plant can be maintained, even through it is heterozygous in nature.
3. Mutant buds, branches or seedlings, if desirable, can be multiplied and used directly as variety

**MODE OF POLLINATION**

**POLLINATION:** Pollination is defined as the transfer of pollen grains from anther to the stigma is called as pollination.

**Types of pollination: -**

1. Self pollination
2. Cross pollination

**1) Self pollination: -**

It refers to the pollen from an anther may fall on to the stigma of the same flower is called as self-pollination or autogamy.

**2) Cross pollination: -**

It refers to the pollen grains from flower of one plant are transmitted to the stigma of flowers of another plant it is called as cross-pollination or allogamy.

**3) Geitonogamy: -**

When pollen from a flower of one plant falls on the stigmas of other flowers of the same plant. e.g. maize.

**1) SELF POLLINATION: -**

- Development of seed by self-pollination is known as autogamy or self-pollination.
- Autogamy is the closest form of breeding.
- Autogamy leads to homozygosity.
- Such species develop homozygous balance & do not exhibit significant inbreeding depression.
- But in most of these species, self pollination is not compete & cross-pollination may occur up to 5%.
- The degree of cross-pollination in self-pollinated species is affected by several factors. e.g. variety, environmental condition like temperature, humidity & location.

**MECHANISM PROMOTING SELF POLLINATION: -**

There are various mechanisms that promote self-pollination, which are generally more efficient than that cross-pollination.

**Bisexuality:** - Presence of male & female organs in the same flower is known as bisexuality. The presence of bisexual flowers is a must for self-pollination. All the self-pollinated plants have hermaphrodite flowers. The various mechanisms which promote self pollinations are as under

**1) Homogamy: -**

- Maturation of anthers and stigma of a flower at the same time is called as homogamy.
- As rule, homogamy is essential for self-pollination.

**2) Cleistogamy: -**

- When pollination and fertilization occur in unopened flower bud is called as cleistogamy.
- It ensures self-pollination prevents cross-pollination.
- In this case flowers do not open at all this ensures complete self pollination since foreign pollen cannot reach the stigma of a closed flower e.g. wheat, oats, barley and other grasses.

**4) Chasmogamy: -**

- In plants, fertilization after opening of flower is known as chasmogamy.
- It promotes self-pollination.  
e.g. wheat, barley, rice, oats etc.

**5) Position of anthers: -**

- In some species, stigma are surrounded by anthers in such a way that self-pollination is ensured.
- Such situation is found in tomato and brinjal.
- Some legumes, the stamens and stigma are enclosed by the petals.  
e.g. green gram, black gram, soybean, chickpea and pea etc.

**GENETIC CONSEQUENCES OF SELF POLLINATION:**

- Self-pollination leads to a very rapid increase in homozygosity.
- Therefore populations of self-pollinated species are highly homozygous.
- Self-pollinated species do not show inbreeding depression, but may exhibit considerable heterosis.
- Therefore, the aim of breeding methods & develop homozygous varieties.

**2) CROSS POLLINATION:-**

- Development of seed by cross-pollination is called as allogamy.
- In cross pollination species the transfer of pollen from a flower to the stigmas of the others.

***May brought about by***

- 1) Wind (anemophily)
- 2) Water (hydrophily)
- 3) Insects (anemophily)

Many of the crop plants are naturally cross-pollinated. In many species a small amount (up to 5%) of selfing may occur.

**MECHANISM PROMOTING CROSS POLLINATION: -**

There are several mechanisms that facilitate cross-pollination

**I) Dicliny: -**

It refers to unisexual flowers. The flowers are either staminate (male) or pistillate (female).

This is of two types: viz. 1) Monoecy and 2) Dioecy

**1) Monoecy: -**

- Staminate & pistillate flowers occur in the same plant, either in the same inflorescences. e.g. castor, mango, banana, coconut, or in separate inflorescences, e.g. maize.

Other monoecious species are cucurbits, walnut, chestnut, strawberries, rubber, grapes & cassava.

**2) Dioecy: -**

- The male & female flowers are present on different plants, i.e. the plants in such species are either male or female, e.g. papaya, datepalm, hemp, asparagus, & spinach.
- In general the sex governed by a single gene, e.g. asparagus & papaya. There are hermaphrodite plants in condition to male & female plants, & a number of intermediate forms may also occur.

**II) Dichogamy: -**

Stamens and pistils of hermaphrodite flowers may mature at different times. There are of two types

- a) Protogyny – pistils mature before stamens. e.g. bajara
- b) Protandry - stamens mature before pistils.e.g, maize and sugarbeet.

**III) Heterostyly: -**

When styles and filaments in a flower are different length, it is called heterostyly. e.g. linseed.

**IV) Herkogamy: -**

Hindrance to self-pollination due to some physical barriers such as presence of hyaline membrane around the anther is called as herkogamy.eg alfalfa.

**V) Self incompatibility: -**

It refers to the failure of pollen from a flower to fertilize the same flower or other flowers on the same plant.

**OR**

The inability of fertile pollens to fertilize the same flowers is called self-incompatibility.

It prevents self-pollination and cross-pollination.

There are two types of self-incompatibility. 1) Sporophytic and 2) Gamotophytic.

**a) Sporophytic incompatibility: -**

Self-incompatibility is controlled by the genotype of the pollen producing plant is called as sporophytic incompatibility, e.g. cabbage, cauliflower, radish.

**b) Gametophytic incompatibility: -**

Self-incompatibility is controlled by the genetic constitution of pollen is called as gametophytic incompatibility. e.g. potato tomato, rice.

**VI) Male sterility: -**

- It refers to the absence of functional pollen grains in otherwise hermaphrodite flowers is called male sterility.
- Male sterility is not common in natural populations. But it is great value in hybrid seed production.
- It prevents self-pollination and promotes cross-pollination.

**➤ There are three types. Viz. GMS, CMS, CGMS.****a) Cytoplasmic male sterility: -**

The pollen sterility which is controlled by cytoplasmic genes or plasma genes is called as cytoplasmic male sterility. e.g. onion .

**b) Genetic male sterility: -**

The pollen sterility, which is controlled by nuclear genes, is termed as genic or genetic male sterility. e.g. barley , maize, wheat , cotton , sorghum Lucerne, cucurbits, tomato and sugarbeet.

**c) Cytoplasmic genetic male sterility: -**

When pollen sterility, which is controlled by both cytoplasmic and nuclear genes, is known as cytoplasmic genetic male sterility. E,g wheat maize , sorghum , rice, sunflower cotton, tobacco, tomato, onion, sugarbeet , carrot linseed.

**GENETIC COSEQUENCES OF CROSS POLLINATION: -**

- Cross pollination preserves and promotes heterozygosity in a population
- Cross-pollinated species are highly heterozygous.
- The breeding method in such a species aim at improving the crop species without reducing heterozygosity to an appreciable degree.
- Usually, hybrid or synthetic varieties are the aim of breeder wherever the seed production of such varieties is economical feasible.

**3) OFTEN CROSS-POLLINATED SPECIES: -**

- Cross-pollination often exceeds 5% and may reach 30% such a species is known as often cross-pollination. e.g. jawar cotton, arhar , safflower , etc.
- Often hybrid varieties are superior to others.

**DETERMINATION OF THE MODE OF POLLINATION: -**

- 1) The first step – Determine the mode of pollination of species is to examine its flower. Mechanism like dioecy, protogyny, protandry, cleistogamy are easily detected; they clearly indicate the mode of pollination.
- 2) The second step: -
  - Isolate single plants and recording seed set under isolation.
  - Space isolation, i.e individual plants grown at sufficient distance to prevent cross-pollination, is preferable to isolation by bags or cages.
  - Isolation of bags and or cages may create an environment unfavorable for pollination and seed set.
  - Failure of set seed in isolation proves the spaces to be cross-pollinated.

- However, setting of seeds only indicates of self-pollination. Finally, the effect of selfing (inbreeding) on the vigour of plants should be studied. Loss in vigour due to inbreeding is common in cross-pollination, but self-pollinators show to inbreeding depression.

#### **DETERMINATION OF THE AMOUNT OF CROSS POLLINATION**

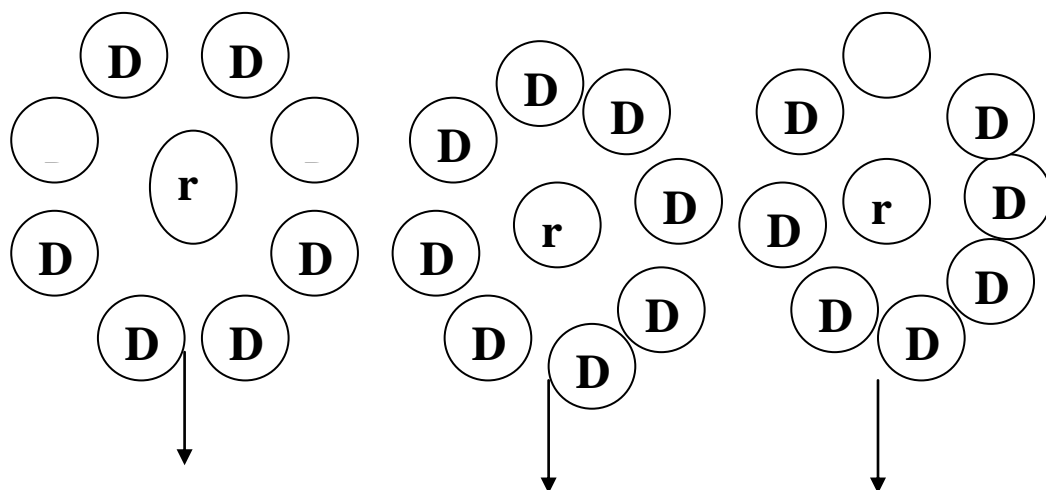
The amount of cross-pollination is determined by planting two strains of the concerned species in a mixed strain.

- 1) One strain is homozygous for a dominant character preferably an easily recognizable seed or seedling character.
- 2) Other strain has the recessive form of the character.
- 3) The two strains are planted in such a manner that each plant of recessive strain is surrounded by plants of the dominant strain to provide abundant pollen.
- 4) The seeds from the plants of only recessive strain are harvested.
- 5) The percentage of seeds carrying the dominant allele represents the percentage of crosspollination in the species.
- 6) The frequency of cross-pollination varies greatly with variety, weather condition. e.g. In a study on safflower, the estimates of out crossing in different varieties grown in the same time at the same location from 0-8.7% similarly, the amount of cross pollination in a single variety grown at a several locations varied from 1.3-9.8%. Therefore such a study should include several varieties of the crop and the study should be conducted at several locations for two more years.

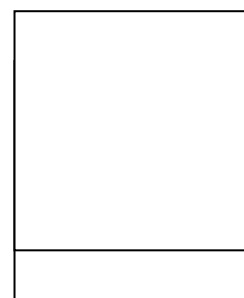
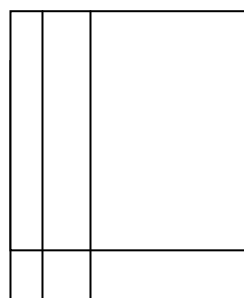
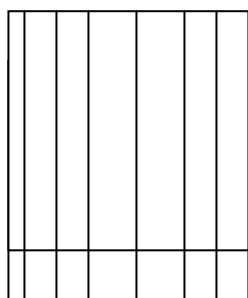
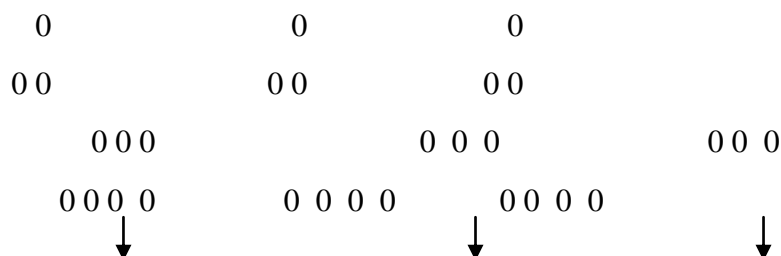
**DETERMINATION OF THE AMOUNT OF CROSS – POLLINATION:**

Crop : Castor Inbred / Varieties:1.VI – 9 Green Stem (Recessive)

2. 48-1 Red Stem (Dominant)



Steps : 1. Sowing : Where, r = VI-9 and D = 48-1



No. of Plants 100    No. of Plants 100    No. of Plants 100

Plot No.1

Plot No.2

Plot No.3

**Recording of Observations:**

Character	Plot No.1	Plot No.2	Plot No.3	Average
Green Stem Plant (Recessive)	55	60	53	-
Red Stem Plant (Dominant)	45	40	47	-
% Cross Pollination	45	40	47	44

The average of cross-pollination is 44 %.

**Significance of pollination: -**

1. Gene action.
2. Genetic constitution
3. Adaptability
4. Genetic purity
5. Transfer of genes

**1. GENE ACTION: -**

In refers to mode of expression of genes for various characters in a population. Gene action is of two types :

- 1) **Additive gene action:** - It is associated with homozygosity and is more in self-pollination species.
- 2) **Non additive gene action or (dominant and epistasis):** - It is associated with heterozygosity and therefore is more cross-pollinated species.

**2. GENETIC CONSTITUTION: -**

The breeding population is of four types viz. heterozygous, homozygous, homogeneous, and heterogeneous.

- 1) **Heterozygous:** - Individuals have dissimilar alleles at the corresponding loci and are pure types.
- 2) **Homozygous:** - Individuals have dissimilar alleles at the corresponding loci and are of pure types. (They do not segregate on selfing)
- 3) **Homogeneous:** - The genetically similar population is known as homogeneous.
- 4) **Heterogeneous:** -
  - Genotypically dissimilar population it is known as heterogeneous.
  - It may again the homozygous or heterozygosity and cross-pollination results in heterozygosity because in breeders have advantageous of homozygosity and outbreeders have advantage of hererozygosity.

**3) ADAPTABILITY:**

It refers to stable performance of a variety over a wide range of environmental conditions.

- The cross pollinating species have better adaptability (Buffering capacity) than self pollinating species, because of more heterozygosity and heterogeneity in the former case.
- The heterozygosity populations have broad genetic base. Such a populations have greater capacity to stabilize productivity over a wide range of changing environments.
- Heterogeneous population gives more stable yields over Similarly; heterozygous individuals such as F1 hybrids are more stable to environmental variations than their homozygous parents.
- Thus mode of pollination plays a key role in varieties adaptability.



**GENETIC PURITY: -**

- Self-pollination maintains the genetic purity of a species and the purity of a variety of a self-pollinating crop can be easily maintained for several years.
- Cross-pollination creates heterozygosity and genetic composition of a cross-pollinating variety change gradually.
- Hence, self-pollination is essential even in cross-pollinated species to maintain the purity in parental lines.

**5) TRANSFER OF GENES:**

Cross-pollination permits transfer of desirable genes from one species to another. Or combining of desirable genes from different sources in to a single genotype is possible through cross-pollination.

**Classification of crop plants based on mode of pollination and mode of reproduction.**

<b>Mode of pollination and reproduction</b>	<b>Example of crops</b>
<b>A. <u>Autogamous species</u></b> <b>1. Seed propagated</b>	Wheat, rice, barley, oats, chickpea, pea, cowpea, lentil, green gram, black gram, soybean, common bean, moth bean, linseed, sesamum, khesari, sunhemp, chillies, brinjal, tomato, okra, peanut. Potato
<b>B. <u>Allogamous species</u></b> <b>1. Seed propagated</b>  <b>2. Vegetatively propagated</b>	Corn, pearl millet, rye, Alfalfa, radish, cabbage, sunflower, sugarbeet, castor, red clover, white clover, safflower, spinach, onion, garlic, turnip, squash, muskmelon, watermelon, cucumber, pumpkin, oilpalm, carrot, coconut, papaya.  Sugarcane, coffee, cocoa, tea, apple, peaches, pears, cherries, grapes, almond, strawberries, pine apple, banana, cashew nut, rubber, sweet potato, etc.
<b>C. Often-allogamous species. (Seed propagated)</b>	Sorghum, cotton, triticale, pigeonpea, Tobacco.

## MALE STERILITY

It is a condition in which pollen grains are non-functional or absence of functional or active pollens. Male sterility is caused by chromosomal aberration, gene action or cytoplasmic influences. It occurs in nature sporadically perhaps due to mutation.

Male sterility is much more useful in plant breeding because

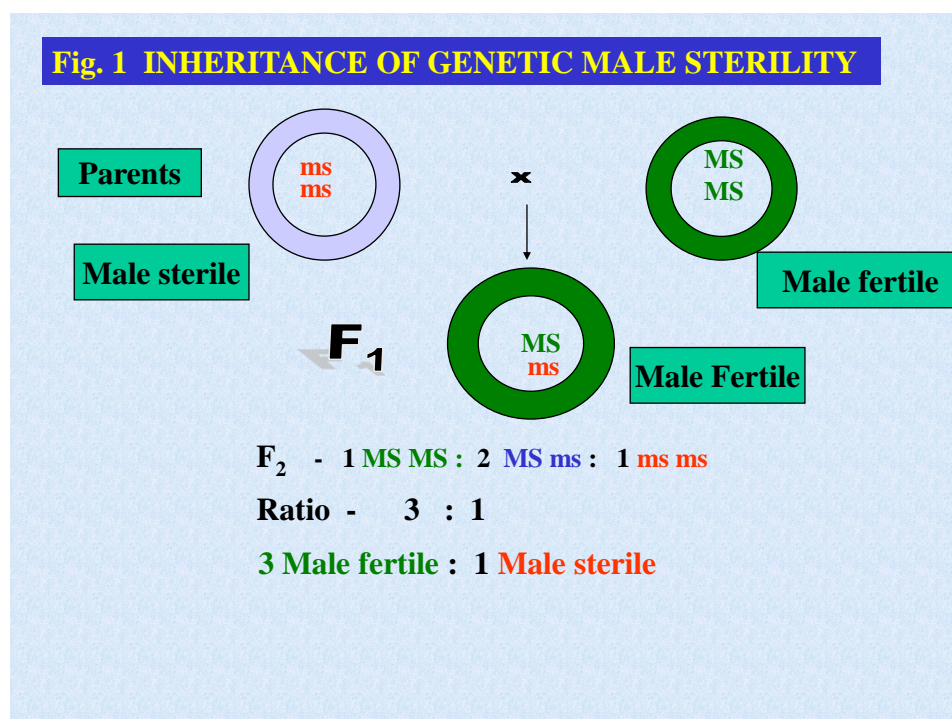
1. It acts as genetic emasculation and facilitates large scale hybrid seed production.
2. It saves the tedious and laborious work of emasculation.

Male sterility is classified into 3 groups.

1. Genetic male sterility
2. Cytoplasmic male sterility
3. Cytoplasmic-genetic male sterility

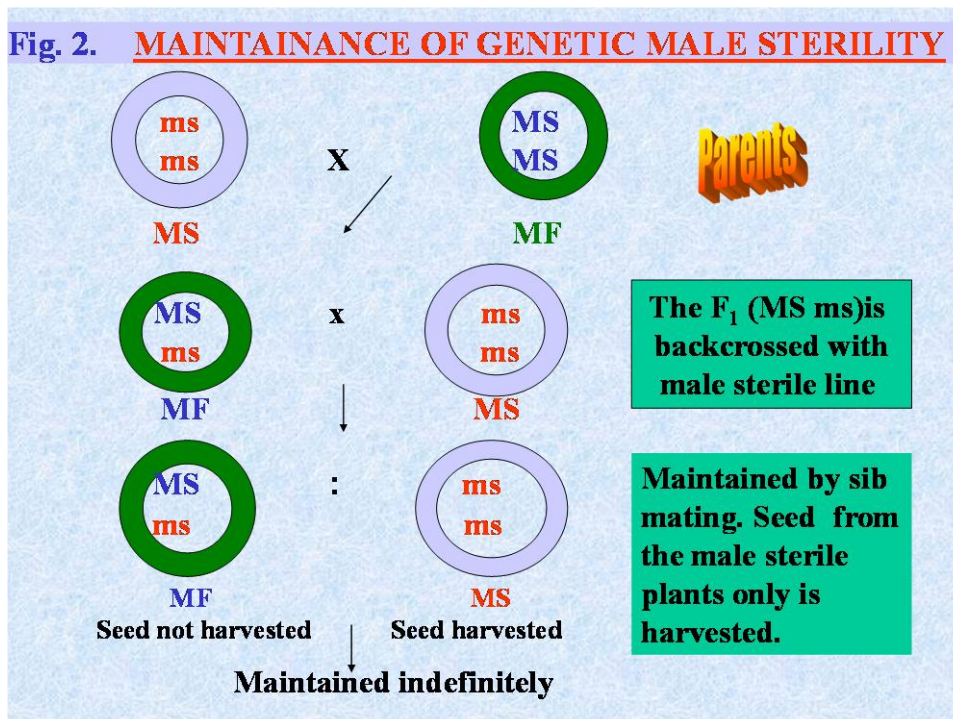
### (I) Genetic Male Sterility :

1. This type of male sterility is governed by single recessive gene “ms”. Therefore, it is monogenic recessive character.
2. The male sterility alleles arise spontaneously or may be artificially induced.
3. The inheritance of male sterility is as illustrated in Fig. 1.



### Maintenance of Genetic Male Sterility (GMS) :

The male sterile line (MS) may be maintained by crossing it with heterozygous male fertile plant. Such a mating produces 1:1 male sterile and male fertile plants as demonstrated in Fig. 2.



### Utilization of Genetic Male Sterility

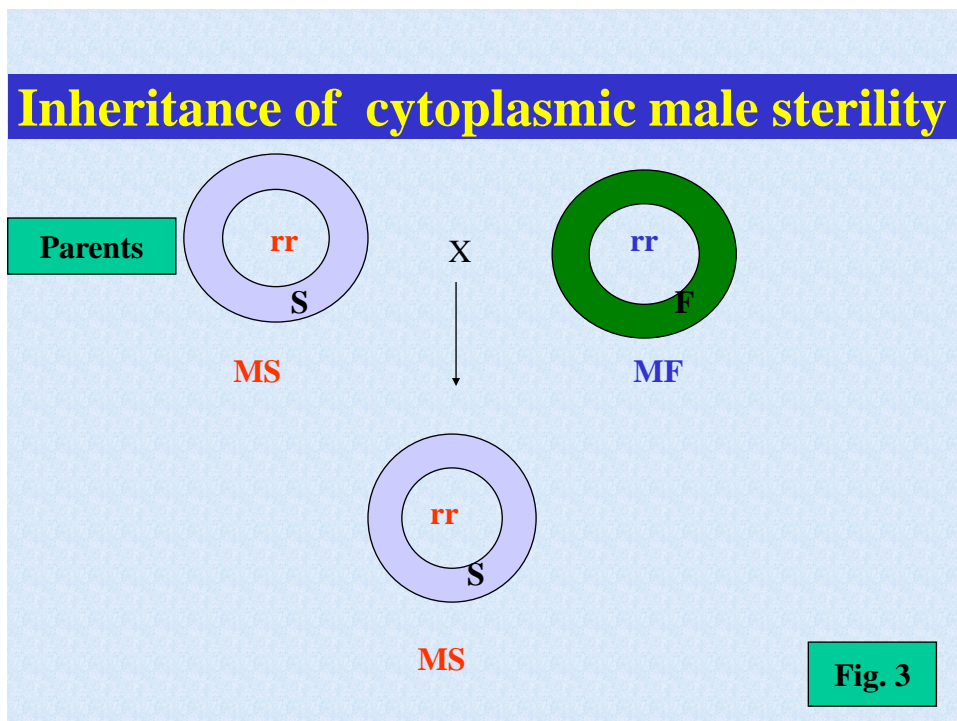
- Genetic male sterility is used for hybrid seed production in the crop like castor and pigeon pea.
- The problem associated with genetic male sterility is that the male sterility population also contains 50% male fertile plants.
- So, in hybrid seed production programme such male fertile plants must be eliminated before flowering and this job is very tedious and laborious.
- If marker gene is available then it becomes easy to identify male fertile plants at seedling stage and can be rogued out.

### (II) CYTOPLASMIC MALE STERILITY

- This type of male sterility depends on cytoplasmic factor.
- Plants carrying particular type of cytoplasm are male sterile.
- Since the cytoplasm of a zygote comes primarily from egg cell, the progeny of such male sterile plants would always be male sterile.

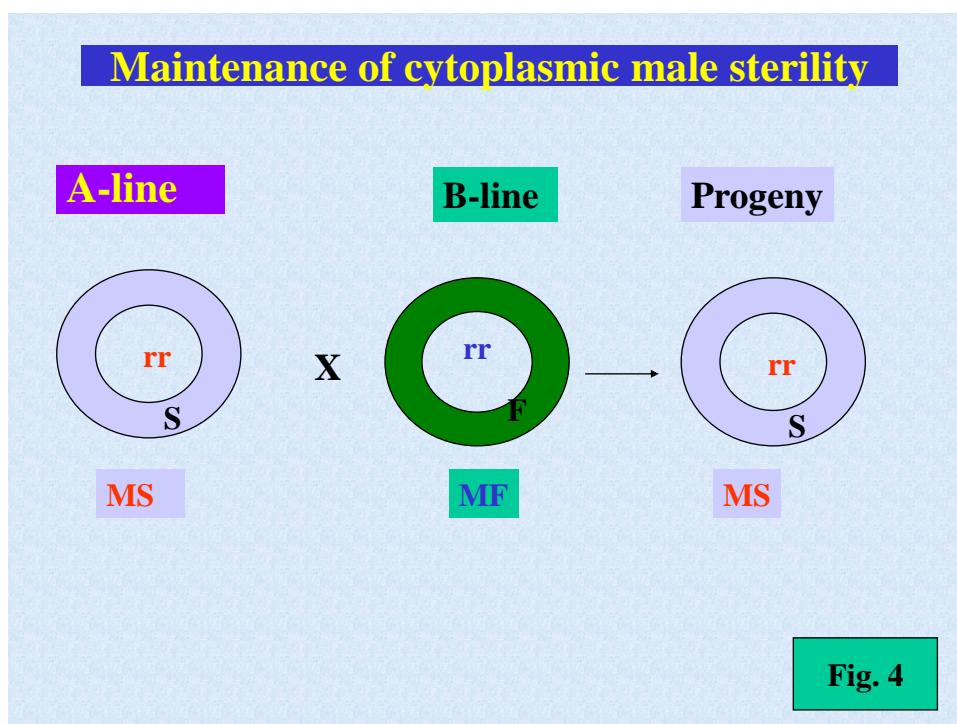
#### Inheritance of cytoplasmic male sterility

- The F<sub>1</sub> produced by the crossing between male sterile and male fertile plants would always be male sterile (Fig. 3), since their entire cytoplasm is derived from the female parent.



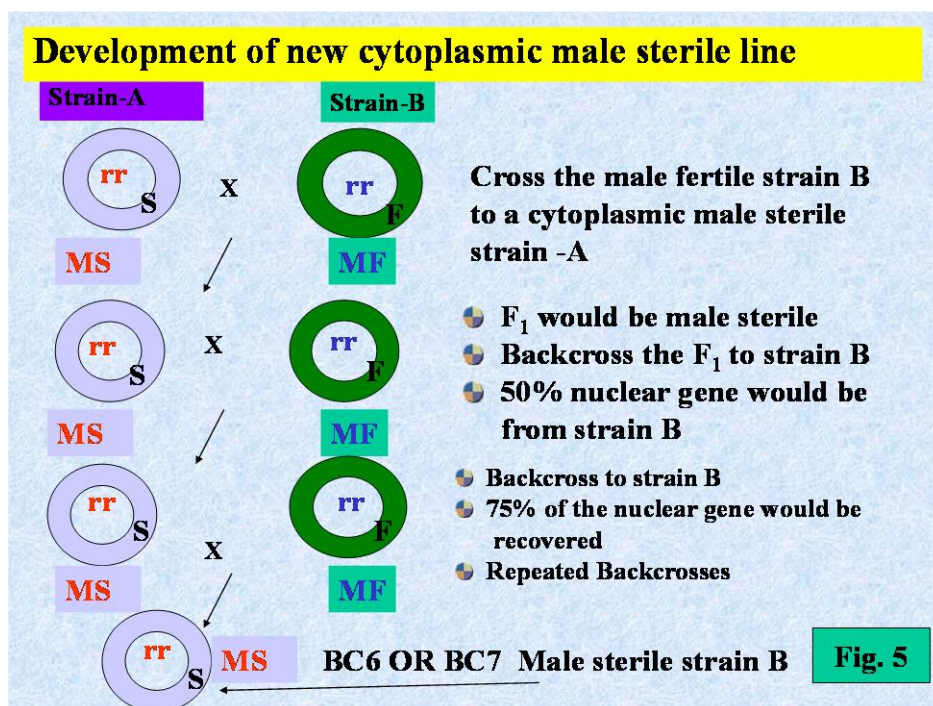
#### Maintenance of cytoplasmic male sterility

- The cytoplasmic male sterile line is maintained (Fig. 4) by crossing it with its male fertile counter part known as maintainer line or B-line as it is used to maintain the male sterile line.
- The male sterile line is known as A-line.



### Utilization in plant breeding

- The  $F_1$  of cytoplasmic male sterile line is always male sterile, therefore, it cannot be utilized for grain crops where seed is the economic part.
- It is useful for ornamental or vegetatively propagated crops where vegetative part is of economic value.

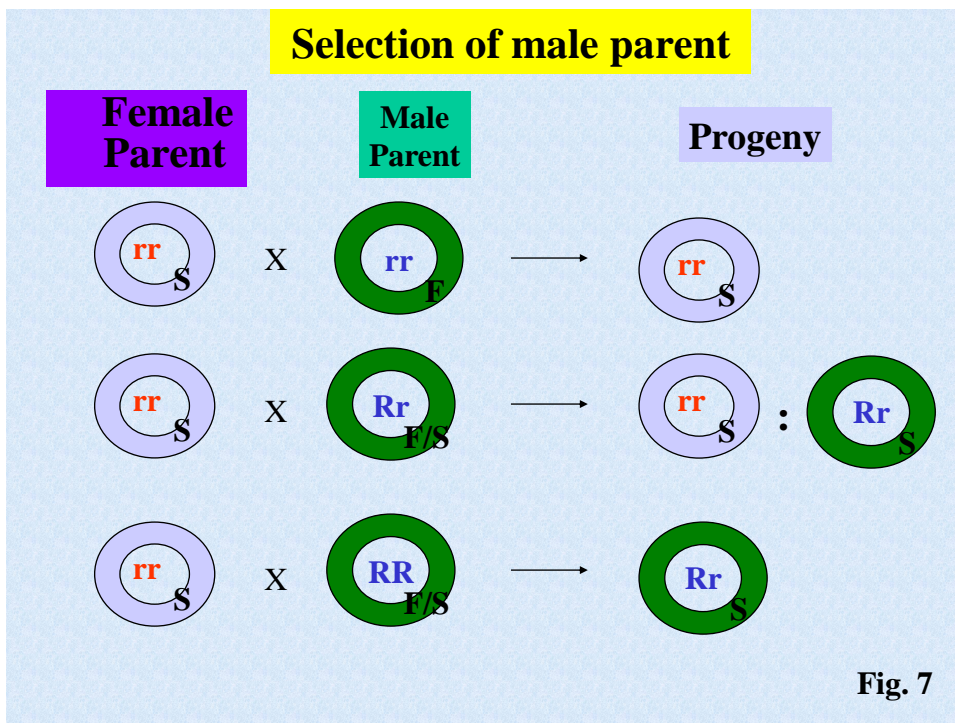


### (III) CYTOPLASMIC-GENETIC MALE STERILITY

- In this type of sterility both genetic as well as cytoplasmic factor are involved.
- This is a case of cytoplasmic male sterility where the nuclear genes are available for restoring the fertility (Restorer gene) in male sterile line.
- A gene, usually dominant, which effectively overcomes the effect of male sterile cytoplasm on pollen sterility, is known as restorer gene.
- Here, fertility restorer gene 'R' is dominant and restores the male fertility in the  $F_1$  hybrid.
- Therefore, the cytoplasmic male sterility is converted into cytoplasmic-genetic male sterility.
- This type of male sterility is available in maize, sorghum, bajra, sunflower, rice, onion and wheat.
- The plants would be male sterile in the presence of male sterile cytoplasm if the nuclear genotype is 'rr' but would be male fertile if the genotype is 'Rr' or 'RR'.
- New male sterile lines may be developed as demonstrated in Fig. 5.
- But the condition is that the nuclear genotype **of the recurrent strain must be 'rr', otherwise fertility will be restored.**

#### Maintenance of Cytoplasmic Genetic Male Sterility

- Fertile counterpart (B line) is used to maintain cytoplasmic male sterility (A line) (Fig. 4).
- This fertile counterpart is also called maintainer line or B-line, just identical to line-A.



#### Origin of male sterile cytoplasm :

1. Spontaneous mutation
  - Mutant cytoplasm have been isolated in crops like maize, bajra and sunflower
2. Interspecific hybridization
  - In wheat male sterile cytoplasm have been derived from *Triticum timopheevii* or *Aegilops caudata*
3. Induction thru Ethidium Bromide
  - Ethidium Bromide is a potent mutagen for cytoplasmic genes
  - Generally seed treatment is applied

#### Limitation of Cytoplasmic Genetic Male Sterility :

1. Undesirable effects of cytoplasm
  - a. Example – Texas cytoplasm of wheat (CMS-T) is highly susceptible to Helminthosporium blight
  - b. Tifton cytoplasm (Tift 23A) of bajra is highly susceptible of downey mildew
2. Unsatisfactory fertility restoration
3. Unsatisfactory pollination
4. Modifier genes overcome the effect of male sterility
5. Environmental effects overcome the male sterility

## SELF INCOMPATIBILITY

Its mechanism in which pollen grains of the flowers are not in position to fertilize the same flower or the other flower of the same plant.

- Self incompatible pollen grains fail to germinate on the stigma
- If some pollen grains do germinate, pollen tubes fail to enter the stigma
- If pollen tube enters into style but they grow too slowly to effect fertilization before the flower drops
- Some time fertilization is effected but the embryo degenerates at very early stage
- Self incompatibility is a biochemical reaction but the precise nature is not clearly understood
- Lewis (1954) classified the self incompatibility as under
  1. Heteromorphic system
  2. Homomorphic system – 2 types
    - a) Gametophytic control
    - b) Sporophytic control

### Homomorphic Incompatibility

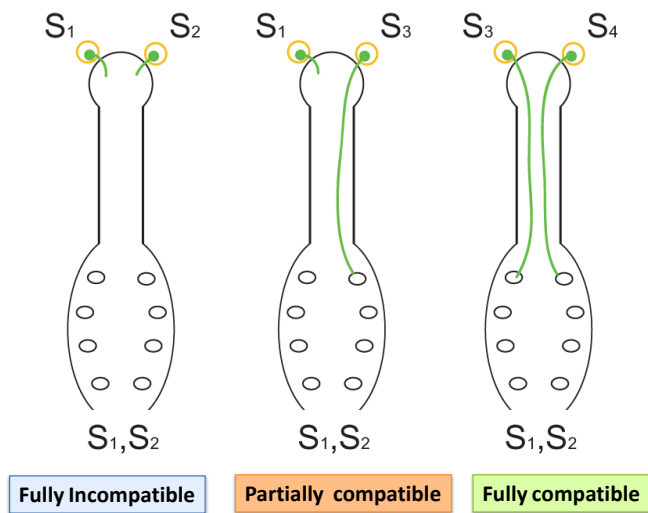
- Incompatibility reaction is not associated with the morphological differences of flower
- Two types – Sporophytic and Gametophytic
  - **Sporophytic** : Incompatibility reaction of pollen may be controlled by the genotypes of the plant on which it is produced. **Example** – Radish, diploid brassica crops
  - **Gametophytic** : Incompatibility reaction of pollen may be controlled by its own genotypes. **Example** – Pineapple, Ryegrass, diploid coffee, diploid clovers

### Gametophytic System

- Gametophytic system described by East and Mangelsdorf (1925) in *Nicotiana glauca*
- Incompatibility reaction of the pollen is determined by its own genotypes
- Incompatibility reaction of the pollen does not depend upon the genotype of the plant on which it is produced
- It is governed by single gene having multiple alleles (Example : *Nicotiana glauca*, *Lycopersicon*, *Solanum*, *Petunia*)
- Gametophytic incompatibility can be suppressed or sometimes eliminated by means of polyploidy induction, irradiation with x-rays and gamma rays
- In some species (*Phalaris*) it is governed by two loci (S & Z), while in sugarbeet and papaver three loci are involved
- In above cases polyploidy does not affect the incompatibility reaction but here pollen tube grows slowly in the style containing same S allele as in the pollen and due to slow growth it fails to effect fertilization
- In a single gene system there are three types of matings
  1. Fully incompatible – S<sub>1</sub>S<sub>2</sub> x S<sub>1</sub>S<sub>2</sub>
  2. Fully compatible – S<sub>1</sub>S<sub>2</sub> x S<sub>3</sub>S<sub>4</sub>
  3. Partially compatible – S<sub>1</sub>S<sub>2</sub> x S<sub>2</sub>S<sub>3</sub>



### Gametophytic system

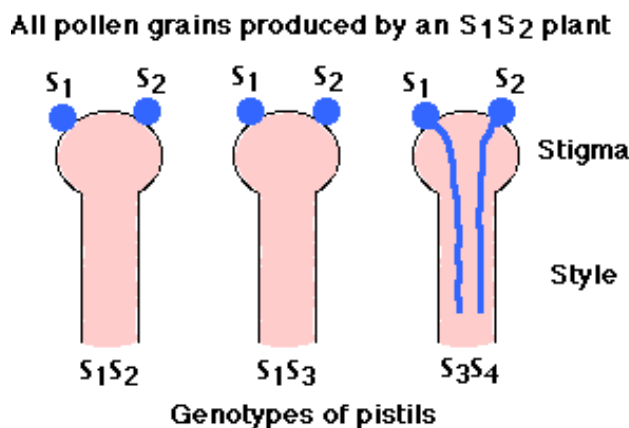


### Sporophytic System

1. The sporophytic system described by Hughes and Babcock (1950) in *Crepsis foetida*
2. Incompatibility reaction of the pollen is determined by the genotype of the plant on which it is produced
3. Incompatibility reaction of the pollen does not depend on its own genotypes
4. It is governed by a single gene having multiple alleles (> 30 alleles are known in *Brassica oleracea*)
5. The number of S alleles is large in the gametophytic than the sporophytic system
6. S alleles also exhibit dominance and codominance
7. Key characteristics –
  - Frequent reciprocal differences are noticed
  - Incompatibility can occur with the female parent
  - A family consists of three incompatibility groups
8. Polygenes (modifying genes) are known to increase as well as decrease the activities of S alleles in both systems



## Sporophytic system



### Mechanisms of self incompatibility

1. Pollen and stigma interaction
2. Pollen tube and style interaction
3. Pollen tube and ovule interaction

### Relevance of self incompatibility

1. Hybrid seed production
  - Two self incompatible but cross compatible lines are interplanted
  - Self incompatible lines are interplanted with self compatible

### Hybrid seed production problems associated with Self incompatibility system

1. Productions and maintenance of parental lines by hand pollination is tedious and costly
2. Raises the cost of hybrid seed
3. Continuous selfing/inbreeding also responsible for depression of self incompatibility
4. Extreme environmental factors overcome the effect of SI & which is responsible for high proportion of self seed (> 30 %)
5. Bees are often like to remain stay within parental lines when they are morphologically different, which also increase the proportion of self seed
6. Transfer of S – allele from one variety to another variety is tedious & complicated

### Elimination of self incompatibility

1. Doubling the chromosomes numbers
2. Isolation of self fertile ( $S_f$ ) mutants

### How to overcome self incompatibility

1. Bud pollination
2. Surgical techniques
3. End of season pollination
4. High temperature

5. Irradiation
6. Grafting
7. Double pollination
8. Other techniques
  - Treatment of flower with carbon monoxide
  - Application of electrical potential differences
  - Phytohormone treatment
  - Treatment of some protein synthesis inhibitors
  - Steel brush pollination

## **BREEDING METHODS**

### **1. For self pollinated crops**

- a. Mass selection
  - b. Pureline selection
  - c. Pedigree method
  - d. Bulk method
  - e. Backcross method
  - f. Other approaches
- } For segregating population
1. Multiline varieties
  2. Population approach
  3. Diallel selective mating scheme
- Production of homozygous lines thru anther culture

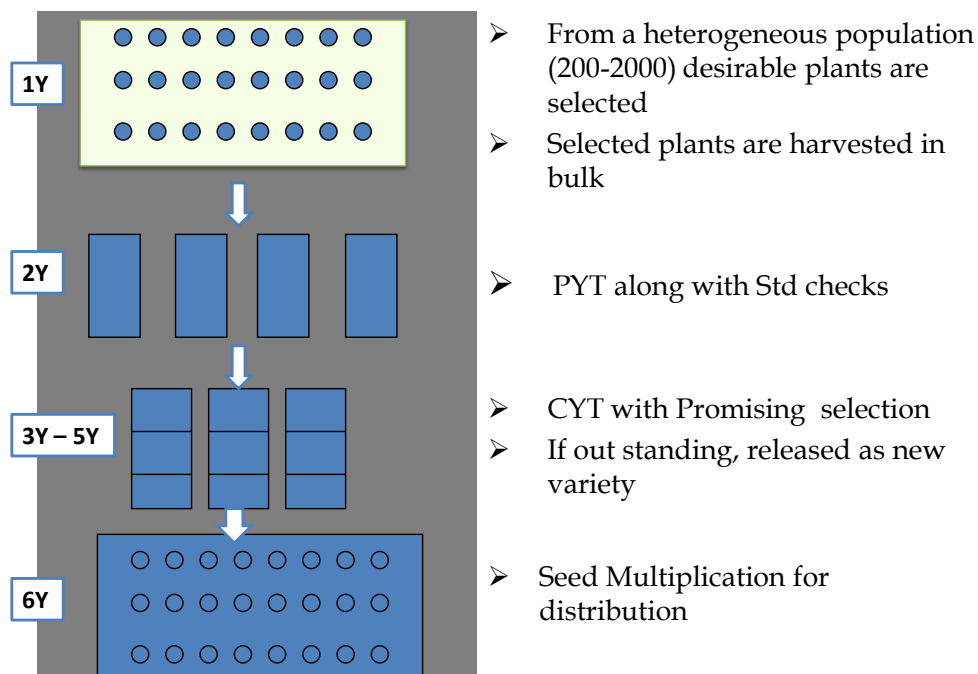
### **2. For cross pollinated crop**

- a. Mass selection
- b. Population approaches
  - i. Simple recurrent selection
  - ii. Recurrent selection for General Combining Ability (RSGCA)
  - iii. Recurrent selection for Specific Combining Ability (RSSCA)
  - iv. Reciprocal Recurrent Selection (RRS)

## **MASS SELECTION**

- In mass selection, large numbers of plants with similar phenotypes are selected and their seeds are mixed to gather to constitute the new variety
- Selections of plants is based on easily observable characteristics (Morphological characters)

## General Procedure of Mass Selection



### Merits of mass selection

1. Variety developed thru mass selection having a wider adaptability
2. Extensive and prolonged yield trials are not required
3. Mass selection retain considerable genetic variability
4. It is less demanding method

### Demerits of mass selection

1. Varieties developed thru mass selection is not highly uniform
2. Improvement thru mass selection is generally less than pure line selection
3. Due to absence of progeny test we can't judge that selected plant is homozygous or heterozygous
4. Varieties developed thru mass selections are difficult to identify in seed certification programme
5. This method utilizing the variability present in the population, it does not create any new variation

## PURELINE SELECTION

- Its progeny of single self fertilized homozygous individuals of a self pollinated crop
- Also known as individual plant selection
- In this methods large numbers of plants are selected based morphological characters and are harvested separately and each progeny of them are evaluated individually

### Characteristics of Pureline

- All plants within a pureline having a similar genotypes

- The variation within a pureline is entirely due to environmental and non heritable
- Pureline become genetically variable with time

### **Uses of Pureline**

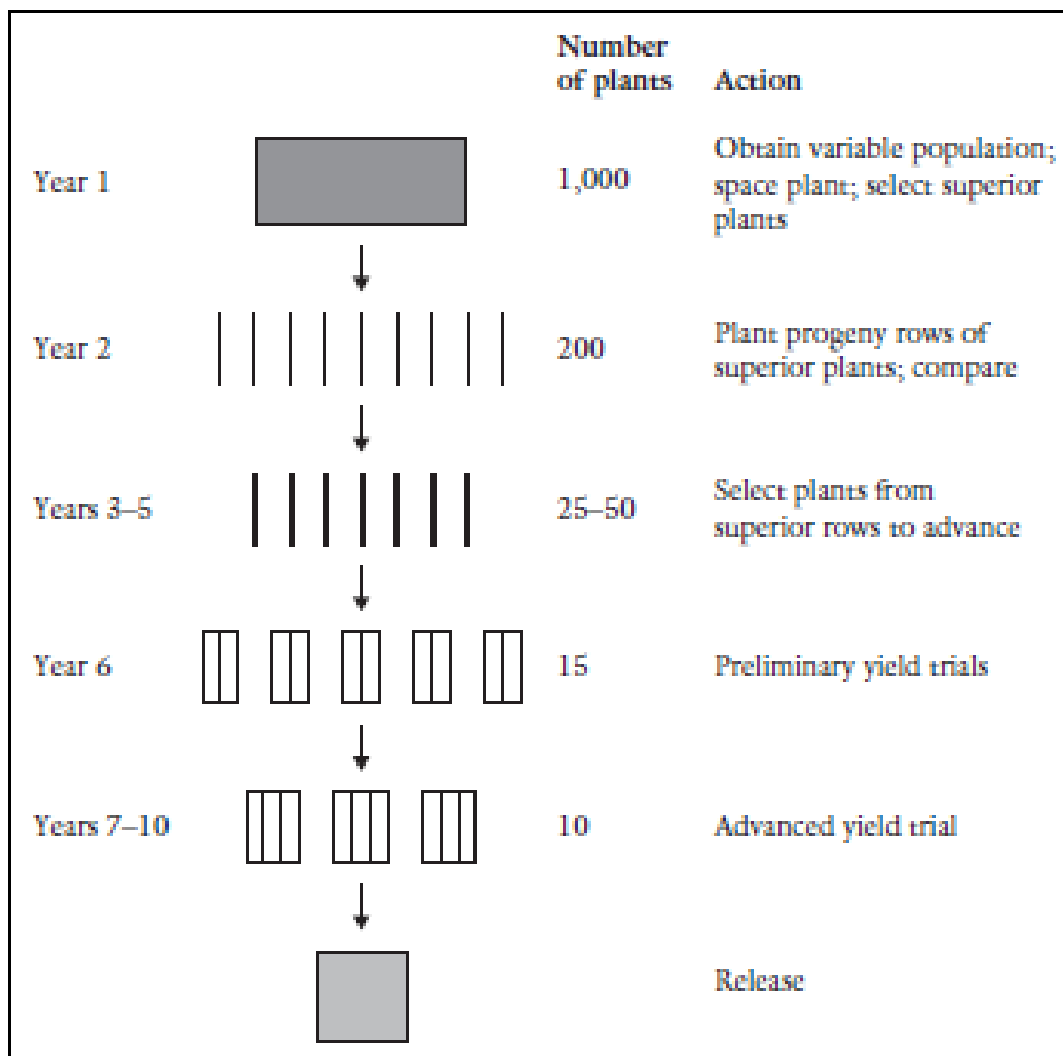
- As a variety
- As a parents in hybridization programme
- In studies of mutation
- Other scientific studies

### **History of pureline**

- Pureline theory or Vilmorin Isolation Principles
- Vilmorin Isolation Principle is the basis for progeny test

### **Applications of Pureline**

- Improvement of local varieties
- Improvements of old pureline varieties
- Selection for a new characteristic in a pureline
- Selection in the segregating generations from the crosses



## PURELINE SELECTION METHOD

### Advantages of pureline selection

1. This method provide maximum possible improvement in original variety
2. Variety developed thru pureline selection is extremely uniform, so it is more liked by farmers and consumers
3. Due to extreme uniformity, variety is easily identified in seed certification programme

### Disadvantages of pureline selection

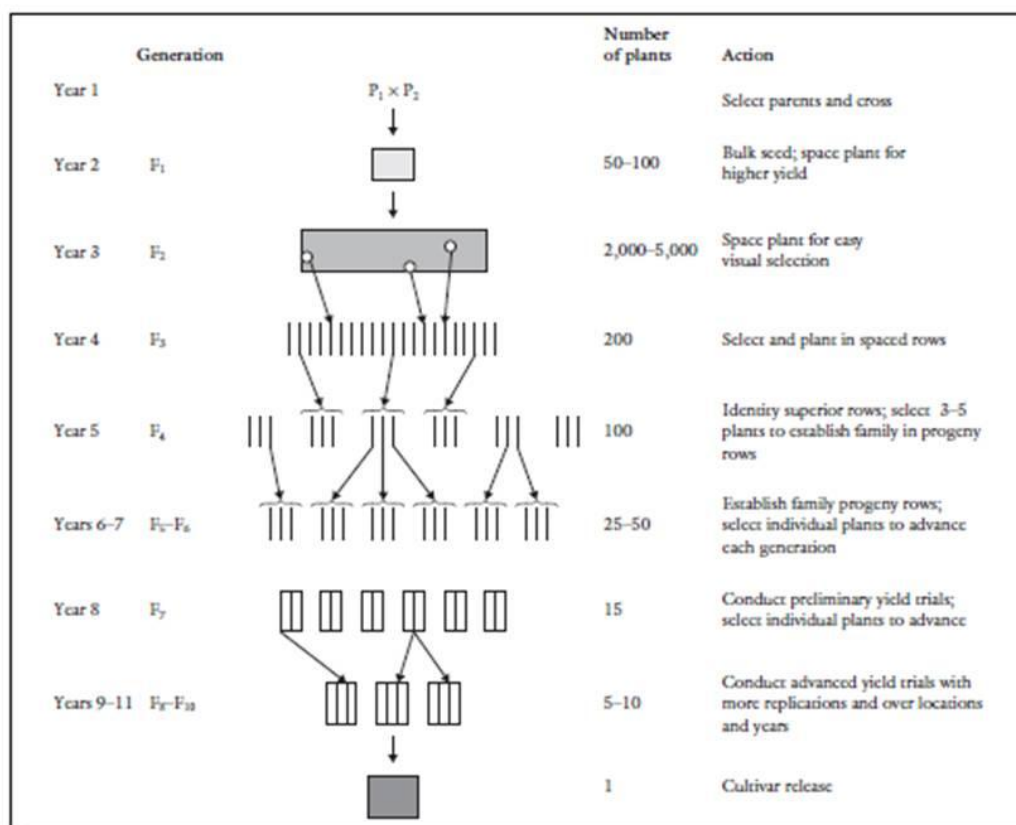
1. Variety developed thru pureline selection do not have wider adaptation and stability
2. It require more time, labour, space and other resources than mass selection
3. The upper limit of improvement is depend upon the genetic variation present in original population
4. Breeder has to devote more time for development of new variety thru pureline method

## PEDIGREE METHOD

- In pedigree method, individual plants are selected from  $F_2$  and subsequent generations and their progenies are tested
- In this method, the relationship between parents and offspring are recorded and that record is known as PEDIGREE RECORD
- Pedigree record gives an idea about individual parent, grand-parent and grand-grand parent information
- Important key traits are also maintained in pedigree record
- Only promising progenies should be included in the record
- The record must be accurate

### Ways of keeping Pedigree record

Generation	Number
F1	200H125
F2	200H125-3, 200H125-7, 200H125-8
F3	200H125-3-3, 200H125-7-3, 200H125-7, 200H125-8-2
F4	200H125-7-3-2, 200H125-7-5
F5	200H125-7-3-2-2, 200H125-7-3-2-7, 200H125-7-5-6
F6	200H125-7-3-2-2-2, 200H125-7-3-2-7-3
F7	200H125-7-3-2-2-2 (B), 200H125-7-3-2-7-3 (B)



**Merits of Pedigree methods**

1. Provide maximum opportunity to breeder to utilize his skill
2. Method is well suited for improvement of characters which can be easily identified and simply inherited
3. Transgressive segregation for yield and other attributes can be recovered
4. Requires less time than bulk method for development of new variety
5. Information about inheritance about qualitative characters will be available
6. Plants/progenies with visible defects are easily eliminated in early stage of breeding

**Demerits of pedigree method**

1. Maintenance of accurate pedigree record is tedious job
2. Selection has to be carried out between as well as within a large number of progenies in every generation
3. Success of this method depends upon the skill of the breeder
4. Selection for yield in F<sub>2</sub> and F<sub>3</sub> is ineffective

**Applications of pedigree method**

1. Combinations breeding
2. Transgressive breeding

**Selection approaches in pedigree method –**

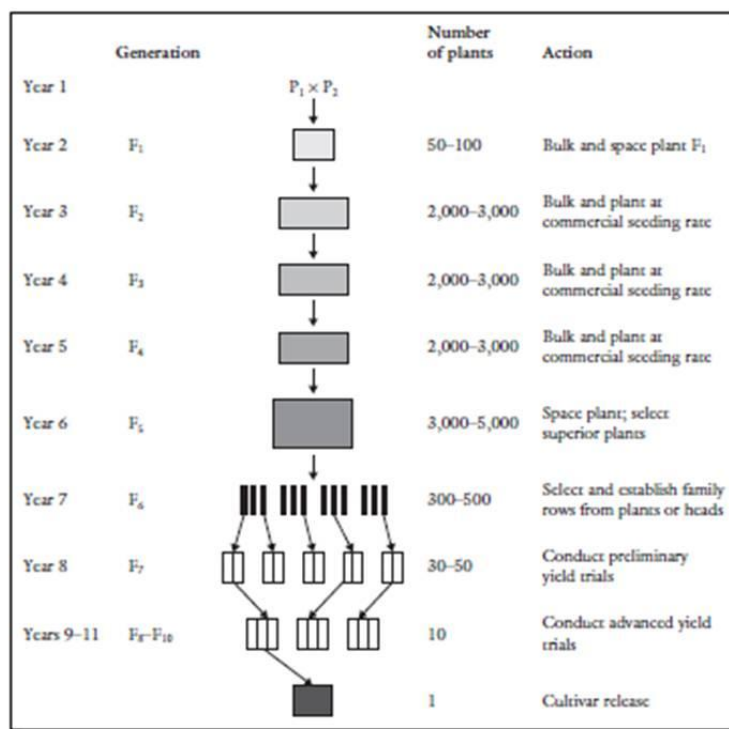
1. Contiguous control
  - In contiguous control check variety is planted after every two rows of F<sub>3</sub> progenies. This ensures that each F<sub>3</sub> progeny is located next to control variety and here the yield of F<sub>3</sub> progenies are expressed as per cent of that of the control variety.
2. Moving average
  - In this method, F<sub>3</sub> progenies are planted in random order and no check variety is included in the trial. The yield of the F<sub>3</sub> progenies is expressed as per cent of average yield of seven F<sub>3</sub> progenies i.e. F<sub>3</sub> progeny and nearest three progenies on either side.
3. Off season crops –
  - a) Wheat, Oat & Barley – Wellington (TN)
  - b) Rice – Cuttak
  - c) Maize – Dholi (Bihar)

## BULK METHOD

- This method first time used by Nilson-Ehle in 1908
- F<sub>2</sub> and subsequent generations are harvested in bulk
- Duration of bulking vary from 6 to 30 or more years depend upon the objective of the breeding program

### Applications of bulk method

1. Isolation of homozygous lines
  - F<sub>7</sub> - > 98 % homozygosity achieved by the population
  - Different RILS available in F<sub>7</sub>
2. Waiting for the opportunity for selection
  - Selection require specific type of environment
  - Artificial selection by creating specific type of environment
3. Opportunity for the natural selection
  - a. F<sub>2</sub> to F<sub>6</sub> – generation exposing to different environments
  - b. Potential genotypes survive in the population



### Bulk Method

### Merits of Bulk method

1. Its simple, convenient and inexpensive method
2. Artificial or natural epiphytotic eliminates the undesirable types and increase the frequency of desirable types
3. Natural selection increase the frequency of desirable types in the population
4. Breeder has to pay little attention from F<sub>2</sub> to F<sub>6</sub> (in bulking period)
5. No need to kept pedigree record, which can save the time and labour
6. Due to large population and more number of natural selection cycles frequency of getting of trasgressive segregants are much higher than pedigree method
7. Thru artificial selection increased the frequency of desirable types



- This method is suitable to study the survival of genes and genotypes in the population

### Demerits of Bulk method

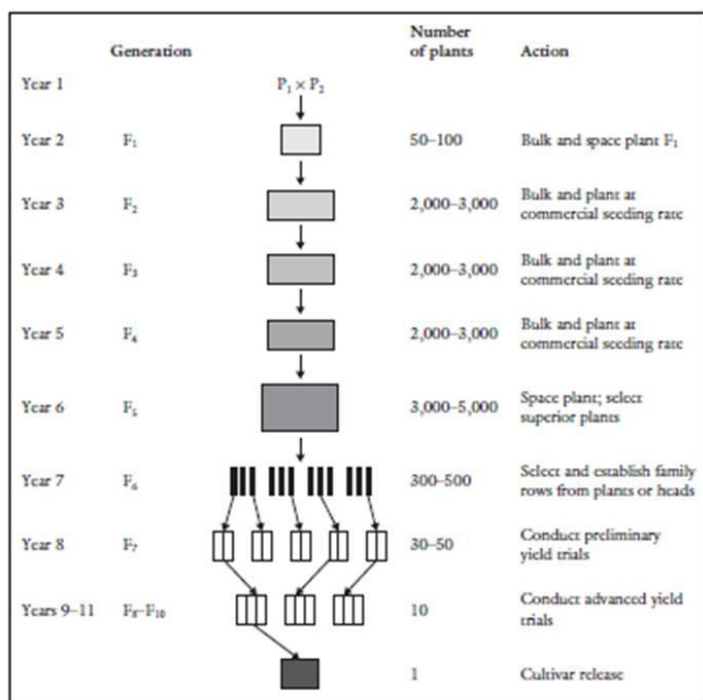
- This method takes longer time to develop new variety
- In short term bulk, natural selection has a little effect on the genetic composition of the population
- This method provides little opportunity to the breeder to utilize his skill
- A large number of progenies have to be selected at the end of the bulking period
- Information on the inheritance of the character cannot be obtained
- In some cases at least natural selection may act against the agronomically desirable types

### SINGLE SEED DESCENT METHOD

- It is a modification of Bulk Method
- Chief objectives of SSD method is rapidly advancing the generation of the crosses
- F<sub>2</sub> to F<sub>6</sub> generations are grown without any sort of selection and without considering the vigour of individual plant
- 2-3 generation may be raised using green house and off season nurseries facility

### Important features of SSD

- Lack of selection (natural or artificial till F<sub>5</sub> or F<sub>6</sub>, when the population is reasonable homozygous)
- Raising of F<sub>3</sub> and later generations from bulk of one seed from each F<sub>2</sub> and the subsequent generation plant in order to ensure that each F<sub>2</sub> plant is equally represented in the end population
- Popularity of this method is due to Speed and economy



**Single Seed Descent Method**

**Merits of single seed descent method**

1. Advances the generation with the maximum possible speed in a conventional breeding method
2. Required very little space, effort and labour
3. Makes the best use of green house and off -season nursery facility
4. Ensures that the plant retain in the end population are the random sample from the F<sub>2</sub> population

**Limitation of single seed descent method**

1. This method does not permit any forms of selection (natural or artificial) in the segregating generations
2. In each successive generation population size become progressively smaller due to poor germination and death of plants due to pest and disease problem

**BACKCROSS METHOD**

- The between hybrid (F<sub>1</sub>) with either of its parents is known as **backcross**
  - For transferred of simply inherited character
- **Test cross** – The cross between F<sub>1</sub> and its homozygous recurrent parent
  - For the detection of linkage analysis

**Requirements of the Backcross program**

- A suitable recurrent parent which are lacking in one or two characteristics
- A suitable donor parent, which have the character in a highly intense form
- The character to be transferred must have high heritability
- Sufficient number of backcrosses should be made to transfer a specific character

**Applications of backcross method**

1. Intervarietal transfer of simply inherited characters
2. Intervarietal transfer of quantitative characters
3. Interspecific transfer of simply inherited characters
4. Transfer of cytoplasm
5. Transgressive segregation
6. Production of isogenic lines
7. Germplasm conversion

**Merits of Back cross method**

1. The outcome of the backcross method is known beforehand
2. Extensive yield trial is not required
3. Backcross program is not dependent upon environment (Offseason nurseries and green house facilitates can be used to fasten the breeding program)
4. Much smaller population are needed
5. Easily overcome the specific defects of the variety without affecting its performance and adaptability
6. It may be modified so that easily get transgressive segregants

### **Demerits of Backcross method**

1. The newly developed variety generally cannot be superior to the recurrent parent except for the character that is transferred
2. Sometimes undesirable closely linked gene may also transferred along with desirable gene
3. Hybridization has to be done for each backcross
4. By the time back program improve the recurrent parent, there may be chance of replacement of existing variety by other high yielding varieties

### **Genetic consequences of repeated backcrossing**

1. Repeated backcrossing leads to homozygosity at the same rate as selfing
2. The genotype of the backcross progeny becomes similar to that of recurrent parent
3. There would be opportunity in each backcross generation for crossing over to occur between the genes being transferred and the genes tightly linked with it. When genes are tightly linked, large backcross population would have to be grown to obtain desirable recombinant type.

### **Achievements of backcross method**

1. The backcross method has been extensively used for the transfer of disease resistance to popular- widely adapted varieties
2. This is illustrated by the popular wheat variety Kalayan Sona, which became susceptible to leaf rust
3. Rust resistance has been transferred to Kalayan Sona from several diverse sources, e.g., Robin, K1, Bluebird, Tobari, Frecor, HS19, etc. using the backcross method
4. Three multiline varieties, viz., KSML3, MLKS11 and KML7406, have been released for cultivation as a result of the above
5. Another example is provided by the hybrid bajra varieties in India. The male sterile line Tift 23A was highly susceptible to downy mildew leading to a high susceptibility of the hybrids. Tift23A was used in backcross programmes with resistant lines from India and Africa to develop downy mildew resistant male sterile lines, such as MS521, MS541A, MS570A, etc. which are now being used for producing downy mildew resistant hybrids
6. Characters other than disease resistance have been transferred by the backcross method
7. Good examples of this types are available in cotton. *G. herbaceum* varieties Vijay, Digvijay and Kalyan are some of the cotton varieties developed by the backcross method

## MULTILINE VARIETIES

- Multiline varieties are the mixture of several isogenic lines having similar agronomic characteristics but having different genes for disease resistance.
- The idea of multiline varieties was given by Jensen in 1952 for cereals
- In 1954, Borlaug suggested that several purelines with different resistance genes should be developed thru backcross programme using one recurrent parent
- Separate backcross programme is run for each donar parent using one common recurrent parent. In the end number of isogenic lines developed.
- Equal amount of seed from each isogenic lines are mixed to produce a multiline variety
- The breeder should keep several isogenic lines with different resistance genes in store for future use

### Merits of multiline varieties

- All the isogenic lines are identical to the recurrent parent in different agronomic characteristics. Therefore the disadvantage of pureline mixture are not present in multiline varieties
- Only one or two lines become susceptible at a time for the particular pathogen, so the loss to the cultivar is relatively low
- The further spread of disease is more slower
- Only small portion of the field is affected by a particular pathogen, so the yield loss is less

### Demerits of multiline varieties

- The farmer has to change the seeds of multiline variety every few years depending upon the change in races of the pathogen
- There is possibility that a new race (super race) may attack all the lines of multiline variety.

### Achievements –

Several rust resistance multilines in wheat developed based on this concept using different resistance genes like

- KSML-3 (mixture of 8 isogenic lines, which possesses different rust resistance genes)
- MLKS-11 (mixture of 8 isogenic lines)
- KML-7406 (mixture of 9 isogenic lines)

## RECURRENT SELECTION

- The idea of recurrent selection was proposed by Hayes and Garber in 1919
- The basic idea of recurrent selection is to isolate superior inbreds from the population
- The recurrent selections are four different types – Simple Recurrent Selection, Recurrent selection for General Combining Ability (RSGCA), Recurrent Selection for Specific Combining Ability (RSSCA) and Reciprocal Recurrent Selection (RRS)

### Simple Recurrent Selection

- Recurrent selection is effective in increasing the frequency of desirable genes of various traits in the population
- It also increase yielding ability of the population

**Recurrent selection for General Combining Ability (RSGCA)**

- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior GCA

**Recurrent selection for Specific Combining Ability (RSGCA)**

- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior SCA

**Reciprocal Recurrent Selection (RRS)**

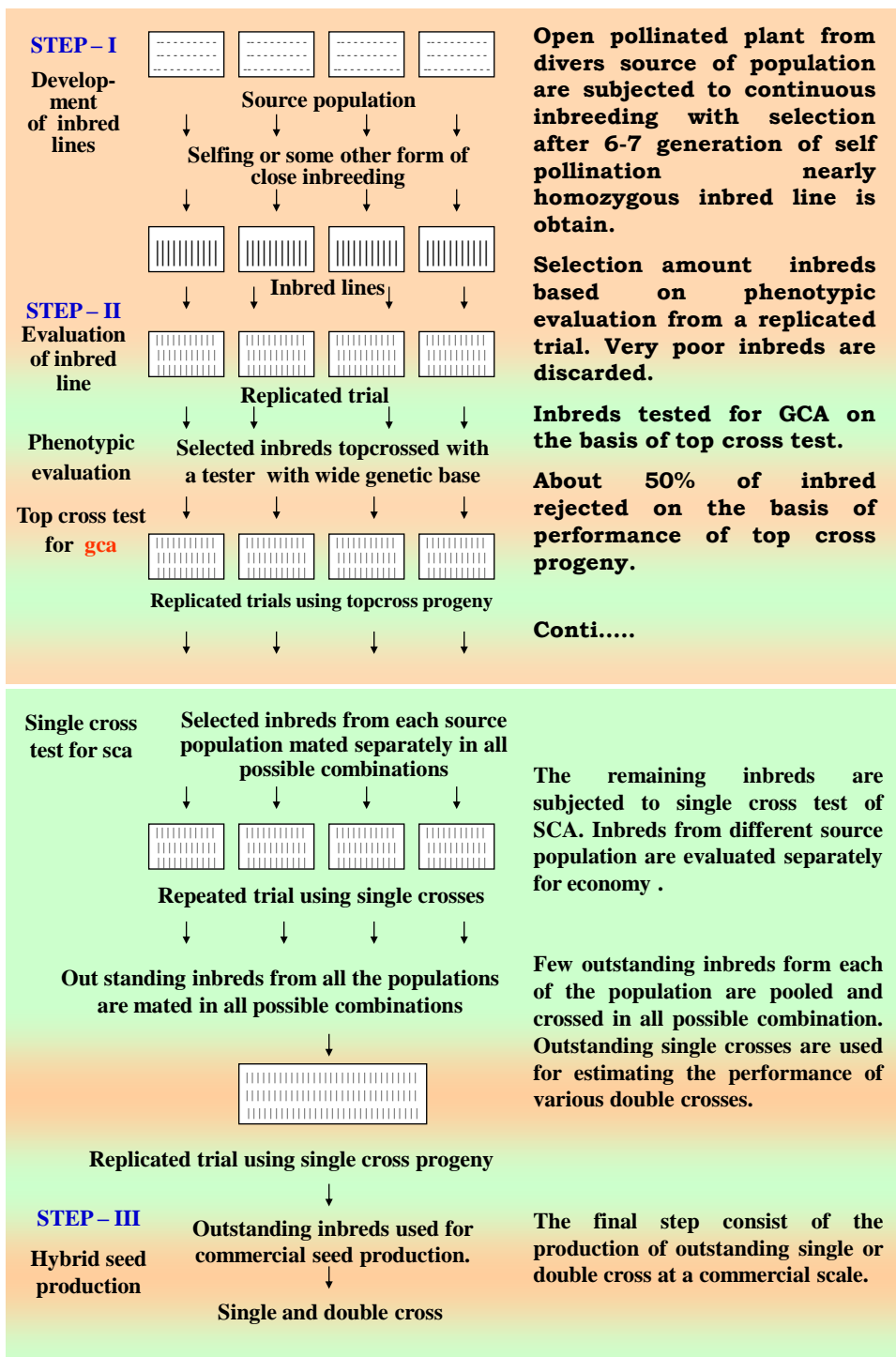
- It may be used to improve the yielding ability and the agronomic characteristics of the population
- It also increase the frequency of genes of superior GCA and SCA

**HYBRID VARIETY**

- **Hybrid** varieties are the first generation ( $F_1$ ) from crosses between two pure-line, inbred, pollinated varieties, clones or other population that are genetically dissimilar
- Most of the commercial hybrid varieties are  $F_1$  from two or more pure lines or inbred
- An **inbred** is a nearly homozygous line obtained by continuous inbreeding of a cross-pollinated species. It is maintained by close inbreeding, preferably by self-pollination
- Hybrid varieties were first commercially exploited in maize
- It is believed that hybrid varieties, on an average, gives yield increase of about 30-50%.
- The utilization of cytoplasmic-genetic male sterility is one of the significant landmarks in the development of hybrid varieties
- CGMS system used for hybrid seed productions in crops like –
  - Rice
  - Wheat
  - Bajra
  - Sorghum
  - Cotton
- GMS system used for hybrid seed productions in crops like –
  - Chilli
  - Brinjal
  - Tomato
  - Okra
  - Cotton

**The operation involved in the production of hybrid varieties in such a case are :**

- Development of inbred lines
- Evolution of inbreds
- Production of hybrid seed



### Merits of hybrid variety

- Hybrid varieties exploit both GCA and SCA component of heterosis. Thus they utilize heterosis to the greatest possible extent
- The produce from hybrid, particular single cross, varieties is more uniform as compared to that from open pollinated, synthetic or composite varieties
- They can produce both in cross and self pollinated crops species
- Hybrid varieties are maintained in the form of their parental inbreds, which are grown in isolation and subjected to selfing
- In many self pollinated crops, hybrid varieties yield 25-30% more than the pureline varieties

**Demerits of hybrid variety**

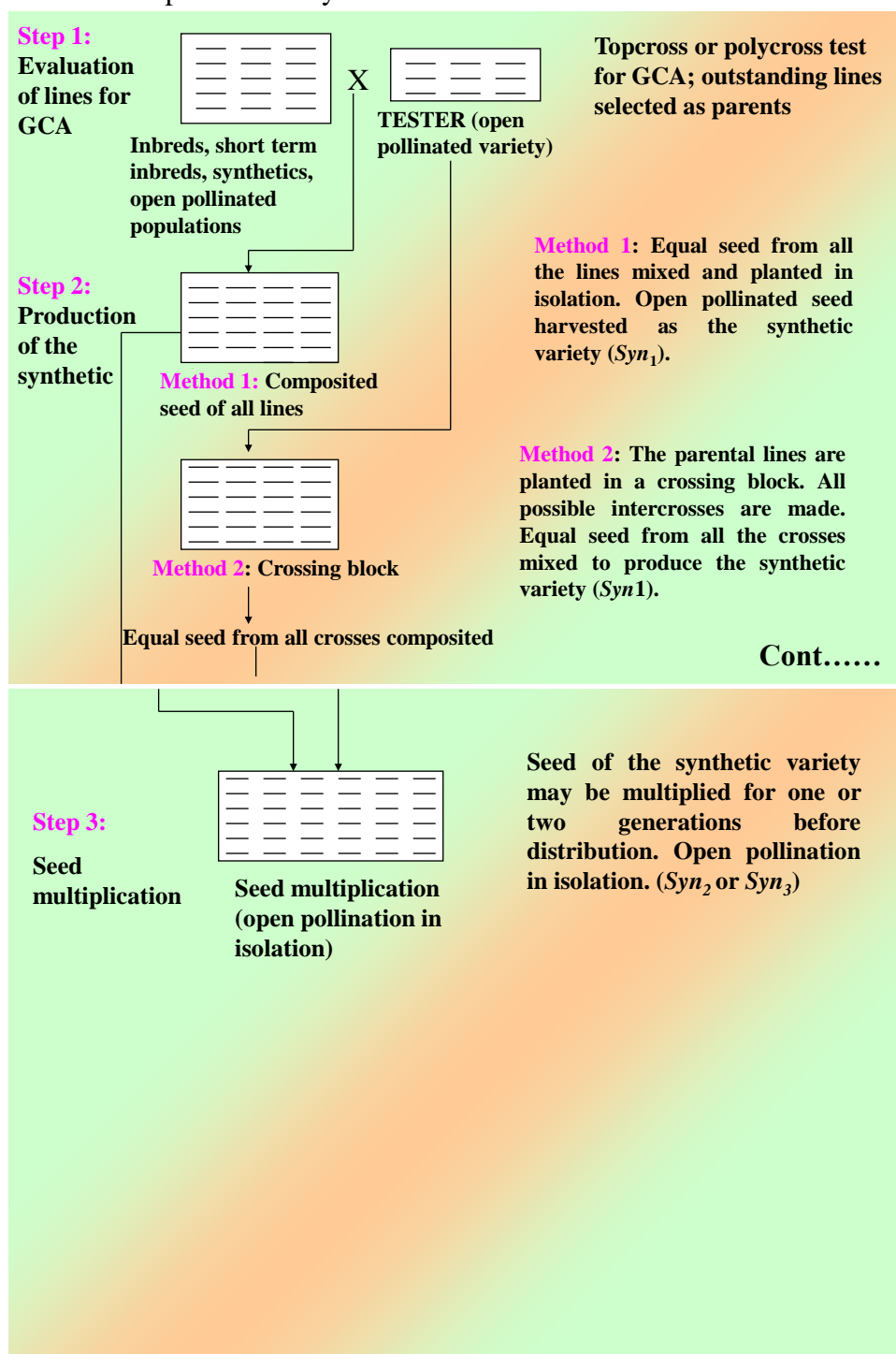
- Farmer has to use new hybrid seed every year
- Hybrid seed production requires considerable technical skill
- The exploitation of full potential of hybrid varieties
- The large scale production of hybrid seed depends on easy emasculation of the female parent and on adequate pollen dispersal from the male parent
- In most cross-pollinated species, the requirements of isolation are rigidity and ordinarily, difficulty to fulfill expect on large farms

## SYNTHETIC VARIETY

- Synthetic variety consists of all possible crosses among a number of lines that combine well with each other.
- The lines that make up a synthetic varieties may be inbred lines, clones, open pollinated varieties or other populations tested for GCA or for combining ability with other.

The operations involved in the production of synthetic varieties are illustrated as below.

1. Evaluation of lines for GCA
2. Production of synthetic varieties
3. Multiplication of synthetic varieties





**Merits of Synthetic variety**

- The farmer can use the grain produced from synthetic variety as seed to raise the next crop.
- In variable environment, synthetic variety is likely to do better than hybrid varieties.
- The cost of synthetics varieties is relatively lower than that of hybrid varieties.
- Seed production of varieties is a more skilled operation than that of synthetic varieties.
- Synthetic varieties are good reservoir of genetic variability.
- There is good evidence that the performance of synthetic varieties can be considerably improved through population improvement without appreciably reducing variability.

**Demerits of Synthetic variety**

- The performance of synthetic varieties is usually lower than that of the single or double cross hybrids.
- The performance of synthetic varieties is adversely affected by lines with relatively poorer GCA.
- Synthetic varieties can be produced and maintain only in the cross pollinated crop

<b>Synthetic variety</b>	<b>Composite variety</b>
1) Synthetic variety produced by crossing in all possible combination a number of lines that combines well with each other	1) That is produced by open pollination among a number of outstanding stains
2) It exploit only GCA test	2) Without test of GCA and SCA
3) Improvement is better in synthetic variety in comparison to composite variety	3) Improvement is lesser in comparison to synthetic variety



## BREEDING FOR DISEASE RESISTANCE

- **Disease-** Disease is an abnormal condition produced by an organism, e.g., fungi, bacteria, viruses, nematodes and insects
- **Pathotype:** A strain of pathogen virulent toward a specific resistance gene in the host (similar in meaning to physiological race, but not the same)
- **Host:** The plant affected by a disease
- **Pathogen:** The organism that produces the disease
- **Pathogenicity:** Ability of the pathogen to infect the host and produce disease. It is genetically controlled.
- **Resistance:** The ability of the host to prevent the pathogen from producing disease
- Different crops are attacked to different degrees by the different kinds of pathogens, but it may be emphasized that all the crop species are attacked by them
- For example
  - Cereals suffer from epidemics of air-borne fungi
  - Solanaceous crops are infected severely by viruses
  - Cotton is damaged by many insects
- In the order of their importance (based on the damage caused by them), the pathogens may be listed as : **Fungi > bacteria > viruses > nematodes = insects**

## LOSSES DUE TO DISEASES

- Diseases reduce total biomass (dry matter) production by the crop in one or more of the following ways:
  - Killing of plants,
  - Killing of branches,
  - General stunting,
  - Damage to the leaf tissues
  - Damage to the reproductive organs including fruits and seeds

## MECHANISM / MODES OF DISEASE RESISTANCE :

### DISEASE ESCAPE:

The freedom of susceptible host plant varieties from a disease due purely to the environmental factors. Disease escape occurs primarily by avoiding contact, but unfavorable weather conditions may prevent infection. It may be achieved by

1. Early varieties: Early varieties often escape a disease since they mature before the disease epidemic occurs, e.g., early groundnut varieties generally escape 'tikka' disease and early potato varieties may escape late blight.
2. Changed date of planting: A changed date of planting may successfully avoid a pathogen. For example, virus-free seed potato is produced by sowing the crop in October instead of November, the normal planting time. The October-planted crop escapes aphid infestation and, consequently, virus infection since during October-January the aphid population is very low.
3. Change in the site of planting:  
In case of soil borne fungi, e.g., root rots, wilts etc., and other soil-borne disease, it is highly effective to change the site of planting.

4. Use of resistant root stocks:

Resistant root stocks to soil borne diseases have been successfully used in many fruit trees to grow otherwise susceptible, but desirable, varieties.

5. Balanced application of NPK:

A balanced application of NPK is of some usefulness as potassium is known to enhance the ability of a host to resist diseases, while N is known to increase succulence and susceptibility.

6. Control of the disease carrier:

Some diseases, particularly viral diseases, are transmitted by insects; the control of insect vector in such cases is extremely useful in controlling the disease. The control of yellow mosaic in mung bean (*V. radiata*) is based on the control of white fly, the vector for the yellow mosaic virus.

## 2. DISEASE RESISTANCE

- Host varieties are classified as susceptible or resistant according to their response to the concerned pathogen. The disease resistance reactions of the hosts to the various pathogens may be grouped into the following types:
  - Susceptible,
  - Immune,
  - Resistant and
  - Tolerant.

### Susceptible Reaction

- Disease development is profuse and is presumably not checked by the genotype of host. The susceptible reaction is classifiable in relative terms only, that is, in relation to the reactions of other host varieties available and the prevailing environment.
- Wheat variety Agra Local is generally taken as the susceptible standard in scoring of wheat rusts (all the three rusts).

### Immune Reaction

- When the host does not show the symptoms of a disease, it is known as immune reaction.
- Immunity may result from the **prevention of pathogen to reach the appropriate parts** of the host, e.g., exclusion of the spores of ovary infecting fungi by closed flowering habit of wheat and barley.
- But more generally, it is produced by **hypersensitive reaction** of the host, usually, immediately after the infection has occurred.
- In **hypersensitive reaction**, a group of host cells around the point of infection dies. This severely restricts the establishment of pathogen and eliminates its reproduction. Thus in immune reaction, the rate of reproductions of the pathogen is zero, ( $r = 0$ ).

### Resistance

- Resistance denotes less disease development in a genotype than that in the susceptible variety and is a relative attribute.

- Infection and establishment do take place, but growth of the pathogen in the host tissue is restricted. This results in smaller spots or pustules than in the susceptible variety.
- Generally, the rate of reproduction is considerably reduced, which limits the spread of disease. In case of resistance disease symptoms do develop and the rate of reproduction is never zero, i.e.,  $r > 0$ , but it is sufficiently lower than 1 (1 is the rate of reproduction on the susceptible variety) to be useful.
- The inhibitions of growth of pathogens are believed to be nutritional in nature, and in some cases chemical growth inhibitors may be involved.

### **Tolerance**

- Tolerance implies that the host is attacked by the pathogen in the same manner as the susceptible variety, but there is little or no loss in biomass production or yield.
- Generally, tolerance is difficult to measure since it is confounded with partial resistance-and disease escape.
- To estimate tolerance, the loss in yield or some other trait of several host varieties having the same amount of disease, e.g., leaf area' covered by the disease etc., is compared.
- Virologists use the term tolerance to denote a lack of symptoms even in the presence of the virus. The lack of symptoms, however, may be strain-specific, and it does not necessarily mean a tolerance in terms of damage caused by the disease.
- Plant breeders inevitably select for tolerance whenever yield is the basis for selection.

### **VERTICAL AND HORIZONTAL RESISTANCE**

The terms vertical and horizontal resistance were introduced by Vander Plank and are widely used :

#### **1. Vertical Resistance**

- It is also known as race-specific, pathotype-specific or simply specific resistance.
- Vertical resistance is generally determined by major genes.
- It is characterized by pathotype-specificity.
- Pathotype-specificity: The host carrying a gene for vertical resistance is attacked by only that pathotype, which is virulent towards that resistance gene. To all other pathotypes, the host will be resistant.
- Thus an avirulent pathotype will produce an immune response, i.e.,  $r = 0$  or close to 0, but the virulent pathotype will lead to the susceptible reaction, that is,  $r = 1$ .
- Immune or susceptible response in the case of vertical resistance depends on the presence of virulent pathotype.
- When the virulent pathotype becomes frequent epidemics are common in the case of vertical resistance

#### **2. Horizontal Resistance**

- It is also known as race-nonspecific, pathotype-nonspecific, and partial or general resistance.
- Horizontal resistance is generally controlled by polygenes and is pathotype-nonspecific. That is why it is also known as 'general resistance'.

- Reproduction rate of the pathogen is never zero, but it is less than one, *i. e.*,  $r > 0$  but  $< 1$ .
- ***Horizontal resistance does not prevent the development of symptoms of the disease, but it slows down the rate of spread of the disease in the population.***
- Polygenes governing horizontal resistance (HR) operate on gene-for-gene basis in a way similar to the oligogenes of vertical resistance (VR), but often this is not evident due to the small effects of the individual genes and due to the small interaction (resistance x virulence) effects.
- It is very difficult to separate HR from VR.
- Further, HR may not always be more stable than VR.

Resistance	Vertical	Horizontal
<b>Pathotype- specificity</b>	Specific	Nonspecific
<b>Nature of gene action</b>	Oligogenic	Polygenic; rarely oligogenic
<b>Response to pathogen</b>	Usually, hypersensitive	Resistant response
<b>Phenotypic expression</b>	Qualitative	Quantitative
<b>Stage of expression</b>	Seedling to maturity	Expression increases as plant matures
<b>Selection and evaluation</b>	Relatively easy	Relatively difficult
<b>Risk of 'boom and bust'</b>	Present (rarely durable)	Absent (durable)
<b>Suitable for</b>	1. Annuals but not perennials	Both annuals and perennials
<b>1. Host</b>		
<b>2. Pathogen</b>	2. Immobile pathogens,	All pathogens
<b>Need for specific deployment of resistant varieties</b>	Critical for success with mobile pathogens	None
<b>Need for other control measures</b>	Likely	Much less likely
<b>Host-pathogen interaction</b>	Present	Absent
<b>Commonly used, but not strict synonyms</b>	Major gene, race-specific, seedling, monogenic, differential specific, pathotype-specific, races specific resistance	Polygenic, race nonspecific, pathotype-nonspecific, mature plant, adult plant, field, uniform resistance
<b>Efficiency</b>	Highly efficient against specific race	Variable, but operates against all race

## MECHANISM OF DISEASE RESISTANCE

The various mechanisms of disease resistance are as follows:

- (1) Mechanical
- (2) Hypersensitivity
- (3) Nutritional

### (1) Mechanical

- Certain mechanical and/or anatomical features of the host may prevent infection. For example, closed flowering habit of wheat and barley prevents infection by the spores of ovary infecting fungi.

### (2) Hypersensitivity

- Immune reaction is due to the hypersensitive reaction of the host
- This mechanism is found in case of biotrophic organisms or obligate parasites

- Immediately after infection, several host cells surrounding the point of infection die. This leads to death of the pathogen or at least prevents its spore production

### (3) Nutritional

- The reduction in growth and in spore production is generally supposed to be due to an unfavourable physiological conditions within the host
- Most likely, a resistant host does not fulfill the nutritional requirements of the pathogen and thereby limits its growth and reproduction
- However, a more precise information is not available on this aspect

### (4) Antibiosis

- These kinds of resistance reaction are because of presence of some toxic substances ex. Phenolic or polyphenolic components are responsible for it.

### Gene-For-Gene- hypothesis/relationship

- The gene-for-gene relationship between a host and its pathogen was postulated by Flor in 1951 on linseed rust.
- Subsequent studies have shown that the gene-for-gene relationship holds true in most of the cases studied extensively, and is now widely accepted.
- It has been found that for every resistance gene present in the host, the pathogen has a gene for virulence. Susceptible reaction would result only when the pathogen is able to match all the resistance genes present in the host with appropriate virulence genes. If one or more resistance genes are not matched by the pathogen with the appropriate virulence genes, resistance reaction is the result.
- In most of the pathogen, virulence is recessive to avirulence.
- *The gene-for-gene relationship is the consequence of specific interactions between the products of genes governing host resistance, and those, conditioning pathogenecity*

### SOURCES OF DISEASE RESISTANCE

Resistance to diseases may be obtained from the

- A known variety
- Germplasm collection
- Related species
- Mutations
- Somaclonal variation
- Unrelated organisms

### METHODS OF BREEDING FOR DISEASE RESISTANCE

The following breeding methods have been commonly used:

- Selection
- Introduction
- Mutation
- Hybridization
- Somaclonal variation
- Genetic engineering

## TESTING OF DISEASE RESISTANCE

Three types of fungal diseases

1. Soil-borne diseases
2. Air-borne diseases
3. Seed-borne diseases
4. Insect transmitted diseases

**Soil borne diseases** – Here fungal pathogens are survived inside the soil. **Example** – Root rot, wilt and damping off. Screenings of such diseases are to be carried out with the help of sick plot techniques.

**Air-borne diseases** - Here fungal pathogens are transfer along with wind. Example – Rust, smut, mildews, blights and leaf spots etc. Screenings of such diseases are to be carried out with the help of infector row techniques. In wheat for rust screening highly susceptible agra local variety is used.

**Seed borne diseases** – In seed borne diseases fungal pathogens are survived inside the seed. Example – smut, bunt etc. Here disease screening carried out after providing sufficient inoculums load to the seeds. Some time spore suspension prepared in water or dry spore directly dusted on seeds and then open field or artificial screening is carried out.

**Insect transmitted diseases** – Most of viral diseases they are transmitted by insect vector. Example – Leaf Curl Viral diseases in chilli transmitted by white fly, Groundnut bud necrosis virus in chilli is transmitted by thrips & okra yellow vein mosaic virus transmitted by white fly. So for screening insect transmitted diseases infector row/spreader row techniques are used. Artificial screening in glass house condition is also carried out by releasing virulent vector.

## BENEFITS OF BREEDING DISEASE AND INSECT RESISTANCE

- It is difficult to quantify the financial benefits which have resulted from the use of resistant varieties, but some potentially important pests and diseases have been rendered economically unimportant solely because resistant varieties have been widely grown.
- Resistant varieties reduce pest damage at all levels of infestation.
- Do not cost more to grow in terms of time and labour than susceptible varieties.
- Generally non-toxic to man, live- stock and wildlife.
- Do not pollute the environment.
- Plant breeding for pest and disease resistance is a slow and expensive process and it has often taken 10-15 years to develop agronomically acceptable varieties, even when sources of resistance were readily available.
- The development and manufacture of new pesticides can take even longer, and cost much more, than the breeding of a new variety.
- Resistant varieties can generally be maintained at a very small extra cost, whereas new supplies of pesticides have to be manufactured each year.



## **DRAWBACK/LIMITATION OF BREEDING DISEASE & INSECT RESISTANCE**

- Failure of resistant varieties after sometime
- Appearance of new pathogen and races (super race)
- Resistant varieties usually give only a partial control

## **BREEDING FOR INSECT RESISTANCE**

Why insect resistance is more important

- Major proportion of crop losses is due to insect
- Wide range of insect-pests (Sucking and chewing type)
- Polyphagous in nature
- Extensive pesticide application creates problems like
  - Increases the cost of production of crops,
  - Reduces the population of natural enemies (predators and parasites) of insect pests
  - Leads to the development of pesticide-resistant races of insects
  - Pollutes the environment (the most tragic and horrifying example is the Bhopal Gas Tragedy of December, 1984)

Insect pests may be grouped into two classes **on the basis of their mode of feeding:**

- 1) **Sucking pests:** suck the cell sap, *e.g.* aphids, jassids, thrips, white fly, mites etc.
- 2) **Tissue feeders:** feed on the various plant parts, *e.g.*, stem or shoot borer, root borer, fruit borer, leaf hoppers, weevils, beetles etc.

Above both the types of insects reduce the quality as well as the quantity of crop yields.

### **Direct damages**

- 1) Reduced plant growth or stunting,
- 2) Damage to leaf, stem, branch, flower buds, flower, vegetative buds, fruits and seeds
- 3) Premature defoliation of leaves,
- 4) Wilting of plants.

### **Indirect damage**

- Many insects *e.g.*, aphids, mites, white fly etc. transmit plant viruses, *i.e.*, serve as vectors of pathogens. Further, injuries caused by insects make the plants more vulnerable to attacks by fungal and bacterial pathogens.

## **DEGREE OF INSECT RESISTANCE**

The degree of insect resistance grouped into the following FIVE categories:

(1) Immunity (2) High resistance (3) Low resistance (4) Susceptibility

- 1) **Immunity:** A host-insect relationship in which the insect will not consume the plant under any conditions.
- 2) **High Level of Resistance:** The host plant possesses such traits that result in a small level of damage by a specific insect under a given environment.
- 3) **Low Level of Resistance / Partial Resistance:** The level of resistance is such that the host suffers less than average damage by an insect. The average damage is assessed on the basis of a number of varieties of the crop in question.

- 4) **Susceptible Response:** The level of damage or infestation is average or more than average.
- 5) **High Susceptible Response:** The level of damage or infestation is much more than the average for the crop.

## MECHANISMS OF INSECT RESISTANCE OR TYPES OF INSECT RESISTANCE

Insect resistance is grouped into four categories:

- 1) Non-preference,
- 2) Antibiosis
- 3) Tolerance
- 4) Avoidance

Insect resistance may exhibit one, more often, two or more of these mechanisms

### 1. Non-preference:

- Host varieties exhibiting this type of resistance are unattractive or unsuitable for colonization, oviposition or both by an insect pest.
- This type of resistance is also termed as *non-acceptance* and *antixenosis*.
- In some cases, the expression is so strong that the insects walk-off the resistant plants, *e.g.*, aphid resistance in raspberry.
- In some cases the insects do not walk-off the resistant plants, but they feed for a comparatively shorter period and are generally restless on the resistant plants as compared to on susceptible ones, *e.g.*, aphid resistance in sugarbeet.
- Non-preference involves various morphological and biochemical features of host plants.

### 2. Antibiosis:

- *Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and or reproduction of the insect pest.*
- *In severe cases, it may even lead to the death of the insect pest.*
- Antibiosis may involve morphological, physiological or biochemical features of the host plant.

### 3. Tolerance:

- An insect tolerant variety *is attacked by the insect pest to the same degree as a susceptible variety. But at the same level of infestation, a tolerant variety produces a larger yield than a susceptible variety.*
- In some cases, tolerant varieties show greater recovery from pest damage than do susceptible varieties, *e.g.*, in the case of shoot borer in sorghum.
- In other cases, tolerance may be due to **the ability of host to suffer less damage by the pest**, *e.g.*, aphid tolerance in sugarbeet and *Brassica* sp., and greenbugs tolerance in cereals.

### 4. Avoidance:

- *Pest avoidance* is the same as disease escape.
- It is often as, or even more, effective as true resistance in protecting a crop from insect pest damage.
- Most cases of insect avoidance result from the host plants being at a much less susceptible, developmental stage when the pest population is at its peak.
- For example, early maturing cotton varieties escape pink bollworm infestation, which occurs late in the season.

- The crop may be grown in a season when the pest population is very low, *e.g.*, seed-plot technique in potato to avoid aphid infestation.

## NATURE OF INSECT RESISTANCE

Insect resistance may involve

- 1) Morphological features
- 2) Physiological features
- 3) Biochemical features of the host plant

### Morphological Features:

A number of morphological factors, *e.g.*, hairiness, colour, thickness and toughness of tissues etc., are known to confer insect resistance.

- **Hairiness:** Hairiness of leaves is associated with resistance to many insect pests, *e.g.*, in cereals to cereal leaf beetle, in cotton to jassids and in turnip to turnip aphid.
- **Colour of Plant:** Plant colour may contribute to non-preference in some cases. For example, red cabbage and red-leaved Brussels's sprouts are less favoured than green varieties by butterflies and certain other lepidoptera for oviposition. Similarly, bollworms prefer green cotton plants to red ones.
- **Thickness and Toughness of Plant Tissues:** Thick and tough plant tissues present mechanical obstruction to feeding and oviposition and thereby lead to non-preference as well as antibiosis. For example, thick leaf lamina in cotton contributes to jassid resistance, while solid stem leads to a resistance to wheat stem sawfly.
- Similarly, thick and tough rind of cotton boll makes it difficult for the bollworm larvae to bore holes and enter the bolls.

### Other Characters:

- **Narrow-lobed and leathery leaves:** *Gossypium arboreum* varieties with **narrow-lobed and leathery leaves** are more resistant to jassids than are those with broad-lobed and succulent leaves.
- **Longer pedicels:** Cotton varieties with **longer pedicels** are more resistant to bollworms than those with shorter ones. A longer pedicel makes the movement of larvae from one boll to another more difficult.
- **Leaves of nectariless:** cotton varieties are devoid of nectar glands; as a result, they are visited by insects less frequently than are the normal plants.

### Physiological features

Some of the physiological factors like osmotic concentration of cell sap, various exudates may be associated with insect resistance

- In some of the solanum species secrete gummy exudates in which aphids and some beetles get trapped.
- In cotton high osmotic concentration of cell sap is associated with jassid tolerance

### Biochemical features

Some of biochemical features like presence of some form of chemical are imparting resistance for certain insect-pests like

- A high concentration of gossypol (phenolics component) which is responsible for sucking pest as well as bollworm resistance
- In rice high silica content is responsible for shoot borer tolerance
- In maize high DIMBOA content is responsible for corn borer tolerance
- In tomato high ethanol component is highly toxic to tomato fruit worm

**Distant Hybridization :** It is the cross between two different individuals belonging to the two different species or genus. Interspecific and intergeneric crosses are known as distant cross or wide cross

- 1) **Intervarietal hybridization** – It is cross between two different individuals belonging to the same species. Example : In wheat a cross between Kalyansona and Sonalika.
- 2) **Interspecific hybridization** – It is cross between two different individuals belonging to the two different species. Example : In okra a cross between *Abelmoschus esculentus* and *Abelmoschus manihot*
- 3) **Intergeneric hybridization** – It is cross between two different individuals belonging to the two different genus. Example – Tritical & Raphanobrassica
- 4) **Introgressive hybridization** – The process of transfer of specific gene from wild species to cultivated species is called as Introgressive hybridization

Distant hybridization also known as wide crosses because taxonomically they are more distantly related than varieties of the same species

### History of distant hybridization

- **Thomas fairchild (1717)** : The first distant hybrid was the cross between carnation x sweet willian
- **Karpechenko (1928)** : prepared Raphanobrassica
- **Rimpau (1890)** : prepared Triticale by crossing Wheat & Rye

### Barriers to the production of distant hybrids

1. Failure of zygote formation
  - Dry stigma surface
  - Bigger pollen size
  - Thick stigma layer
  - Pollen tube burst inside the style Example –Datura
  - Longer style – Maize x *Tripsacum*
  - Slow pollen tube growth in polyploid individuals (Diploid x Polyploid – slow)
2. Failure of zygote development
  - Fertilization do take place and zygote formation is taken place
  - Lethal genes
  - Genotypic disharmony between two parental genome
  - Chromosome elimination
    - *Nicotiana* x *Hordeum* & *Triticum aestivum* x *Hordeum bulbosum*
  - Incompatible cytoplasm
  - Endosperm abortion
3. Failure of hybrid seedling development
  - Lethal gene
  - Genetic imbalance
  - Cytoplasmic incompatibility

### Techniques for the production of the distant hybrids

- Use of moisture or fluid of other stigma
- Double pollination

- Mixed pollination (mix cultivated and wild plant pollen)
- Used of short style lines as a female
- Cutting of style
- Polyploidization –
  - *B. oleracea* x *B. campestris* (diploid level fail to cross)
- Ploidy level difference (High F & Low M)
- Doubling of the chromosome number of interspecific hybrid
- Use of bridge species
  - *A. ventricose* x *T. turgidum* ---- F1 x *T. aestivum*
- Use of growth regulator like IAA, 2 4-D, NAA
- Embryo rescue

### Applications of distant hybridization in crop improvement

- Creation of new crop species
- For development of alien addition line
  - **Alien addition line** carries one chromosome pair from a different species in addition to normal diploid chromosome of the parent species
  - If instead of pair only one chromosome complement is additional than it is alien addition monosome
  - Example : Wheat, Oat, Tobacco
  - The purpose of alien addition line is to transfer of disease resistance line
    - Tobacco mosaic resistance
  - Little agriculture importance
- For development of alien substitution line
  - **Alien substitution line** carries one chromosome pair from a different species in place of one chromosome pair of the recipient species
  - Alien addition monosome
  - Example : Wheat, Oat, Tobacco, Cotton
  - The purpose of alien addition line is to transfer of disease resistance line
    - Tobacco mosaic resistance
  - It has more undesirable side effects than alien addition line
  - Both above types lines are developed by backcross method
- Transfer of small chromosome segment
- Disease resistance
  - Okra YVMV : **A. manihot**
- Wider adaptation
  - Wheat and Rice crop rotation
  - Heat and cold tolerance
- Quality improvement
  - Cotton fibre strength improved by using *G. hirsutum*
- Yield
- Transfer of cytoplasm
  - *G. harkensii*
  - *A. caudata*
  - *T. timopheevii*
- Utilization as new crop varieties
  - Varalaxmi is an interspecific hybrid

- Development of new crop species
  - Triticale, Raphanobrassica

**Limitation of Distant hybridization**

- Incompatible crosses
- F1 sterility
- Problem in creating new crop species
- Lack of homology between the chromosome of the parent species
- Undesirable linkages
- Lack of flowering in F1
- Dormancy

## HETEROISIS AND INBREEDING DEPRESSION

The heterosis term was given by Shull in 1914. The heterosis is may be definid as the superiority of an F1 hybrid over both its parents in terms of yield or some other characteristics.

**Types of heterosis** – 3 types

1. Superiority of F1 over mid parental value is known as **heterosis or average Heterosis**
  - Heterosis (%) =  $[(F1 - MP)/MP] \times 100$ 
    - F1 : F1 mean
    - MP : mid parental value
  
2. Superiority of F1 over better parental value is known as **heterobeltiosis**
  - Heterobeltiosis (%) =  $[(F1 - BP)/BP] \times 100$ 
    - F1 : F1 mean
    - MP : mid parental value
  
3. Superiority of F1 over standard check or commercial variety is known as **economic or standard heterosis**. This type of heterosis has commercial importance
  - Standard Heterosis (%) =  $[(F1 - SC)/SC] \times 100$ 
    - F1 : F1 mean
    - SC : mean value of standard check

### Hybrid Vigour

- It is used as the synonym of the heterosis
- Hybrid vigour only indicating the superiority of hybrids over their parents, whereas heterosis describe both superiority as well as inferiority

### Luxuriance

- Luxuriance is the increased vigour and size of interspecific hybrid
- The main difference between luxuriance and heterosis is in the reproductive ability of the hybrids
- Hybrids is with increased fertility, whereas the luxuriance is expressed by interspecific hybrids that may be sterile or poorly fertile

### Genetic bases of Heterosis and Inbreeding depression

- Two hypothesis
  1. Dominance hypothesis
  2. Over dominance hypothesis

### Dominance hypothesis

- Hypothesis was proposed by Davenport (1908)
- Later on it was expanded by Bruce, Keeble and Pellew (1910)
- As per this hypothesis at each locus the dominant allele has favorable effect, while recessive allele has unfavorable effects
- In heterozygous state the deleterious effect of recessive alleles are masked by their dominant alleles.
- So, the heterosis is resulting due to the masking effect of recessive allele by dominant allele, whereas inbreeding depression produced by harmful effect of recessive alleles, which become homozygous due to inbreeding

### **Over dominance hypothesis**

- Hypothesis was proposed by East and Shull (1908)
- Also known as single gene heterosis, super dominance, cumulative action of divergent alleles or stimulation of divergent alleles
- As per this hypothesis, heterozygote's (Aa) at some the loci are superior to both the homozygotes (AA & aa)
- Heterozygosity is the essential and cause of heterosis, while homozygosity resulting from inbreeding produced inbreeding depression

### **Inbreeding**

- Mating between individuals related by descent or ancestry is known as inbreeding or
- Example - Mating between closely related individuals like brother sister mating or sib mating

**Inbreeding depression** – The severe reduction or loss in vigour and fertility due to inbreeding is known as inbreeding depression

- Concept of inbreeding depression was given by East and Shull (1909)
- Marriages between individuals related by ancestry are restricted in early times in Hindu society
- Inbreeding depression is more common in cross pollinated crop
- The chief effect of inbreeding is increase in homozygosity in the progeny

### **Effects of inbreeding**

- Appearance of lethal and sub lethal alleles
  - Lethal – leading to death
  - Sub lethal and sub vital – reduce survival and reproduction rate
  - Example – rootless seedling, defects in flower structure, chlorophyll deficiency
- Reduction in vigour
- Reduction in reproductive ability
- Separation of the population into distinct lines
- Increase in homozygosity
- Reduction in yield

### **Degree of inbreeding depression**

1. High inbreeding depression
  - Alfalfa, carrot
  - Selfing produced lethal characteristics
  - > 25 % yield reduction
2. Moderate inbreeding depression
  - Maize, Jowar, Bajra
  - Proportion of lethal characteristics are relatively very low
3. Low inbreeding depression
  - Onion, cucurbits, sunflower, rye
  - Smaller proportion of lethal characteristics
4. No inbreeding depression
  - Self pollinated crops
  - Showing homozygous balance



## MUTATION BREEDING

**Mutation** – It is a sudden heritable change in the characteristics of an organism is called mutation

### Types of mutation

1. **Gene mutation/Point mutation** – Mutation produced by the changes in the base sequences of the gene is called gene or point mutation
  - Changes in the base sequences taken place as a result of deletion, duplication or transversion
2. **Chromosomal mutation** - Mutation produced by changes in the chromosome structure as well as number is termed as chromosomal mutation
3. **Cytoplasmic mutation** – When the mutant character shows cytoplasmic or extranuclear inheritance it is known as cytoplasmic inheritance
4. **Bud mutation/Somatic mutation** - The mutation occur in buds or somatic tissues is called bud mutation or somatic mutation. Bud mutation or somatic mutation is used for propagation purpose

### History

- The term mutation was introduced by **Hugo de Vries** in 1900
- In earlier days short legged sheep was discovered by English farmer in breed named **Ancon**
- Mutagenic action of X-rays was discovered by Muller in 1927 in *Drosophilla* and for that he was awarded with Noble prize in 1946

**Spontaneous mutation** – Mutation occur in natural population (without any treatment) at a low rate is known as spontaneous mutation

- It occurs at the rate of  $1 \times 10^{-6}$

**Induced mutation** – If mutation induced artificially with certain physical or chemical agents such mutation is called as induced mutation.

- The agents which used for induction of mutation is called as **mutagen** and the used of induced mutation for crop improvement is called as **mutation breeding**

### Characteristics of Mutation

- Mutations which are observed mostly recessive: It is not observed in the same generation as it is concealed by other dominant gene i.e. heterozygous condition. It take time to express and hence get chance to adjust.
- Mutations may have pleiotropic effects: Means it may be affecting more than one character.
- Most of the mutations are deleterious: Because particular genotype is adjusted to particular environment and it is disturbed their survival is disturbed. So, it is deleterious.
- Mutations are random: Means result cannot be predicted. May occur in any gene.
- Mutations are recurrent: That is the same mutation may occur again and again.
- Micro mutations are difficult to identify.
- Variability produced through mutation is same that occur in nature.

### Effects of Mutation

Four types of effects of mutation

1. **Lethal** – Lethal mutation kill each and every individuals carries it.
  - There effects can not be studied because they are nor surviving in the nature
2. **Sublethal and subvital** – Sublethal and subvital mutation reduced the viability but they do not kill all the individual carrying them
  - Sublethal kill more than 50 % individuals
  - Subvital kill less than 50 % individuals
  - Most of all mutation are lethal, sublethal and subvital types
3. **Vital** – Vital mutation does not kill as well as reduced the viability

### Classification of mutagen

1. **Physical mutagens :**
  - A. **Ionising radiations :**
    - a) Particulate radiation –  $\alpha$  rays,  $\beta$  rays, fast neutrons and thermal neutrons
    - b) Non particulate radiation – X-rays, Y-rays
  - B. **Non-ionising radiations :** ultraviolet radiation (UV)
2. **Chemical mutagens :**
  - A. **Alkylating agents :** EMS (Ethylmethane sulphonate), MMS (Methylmethane sulphonate), EI (Ethylene imine)
  - B. **Acridine dyes :** Ethidium bromide, acridine yellow, acridine orange
  - C. **Base analogues :** 5 –bromouracil, 5-cholorouracil
  - D. **Others :** Nitrous acid, hydroxyl amine, sodium azide

### Parts of the plants to be treated

- Seeds – mostly used
- Pollen grains – rarely used
  - Collection of lage ammount is difficult
  - Survival rate is very less
  - Hand pollination of treated pollen is also difficult
- Vegetative propagules – used mainly in case of asexully propagated crops

### Dose of mutation

An optimum dose which produced the maximum frequency of mutations and causes minimum amount of killing (LD50)

### Applications of mutation breeding

1. When breeder does not having any source of variability at time for creation of new variability breeder using this tool
2. It is useful for the improving the specific characteristics of a well adapted high yielding varieties
3. Mutation breeding is useful in improving various quantitative characters
4. Intraspecific and interspecific hybrid is treated with mutagen for increasing the genetic variability

### Limitations of mutation breeding

1. The frequency of desirable mutations are very low i.e 0.1 of total mutation
2. The breeder has to screen large populations to select desirable mutations

3. Desirable mutations are commonly associated with undesirable side effects due to other mutation or chromosomal aberrations
4. Most of the mutations are recessive, so they are not easily detected unless they comes into homozygous stage

#### **Achievements of mutation breeding**

<b>Crop</b>	<b>Variety</b>	<b>Mutant</b>
Tomato	S12	X-rays
Tomato	Pusa Lal Meevuti	30 krd gamma rays
Pea	Stral-art	15krd X-rays
Pea	Navy pea bean	X-rays

#### **Ideotype Breeding Ideotype Concept**

- The term ideotype was introduced by Donald (1968).
- **Ideotype:** "a biological model, which is expected to perform or behave in a predictable manner within a defined environment."
- **A crop ideotype:** "It is a plant model, which is expected to yield a greater quantity or quality of grain, oil or other useful product when developed as a cultivar."
- It may also be called as "model plant type", "ideal model plant type" or "ideal plant type."
- **Ideotype breeding:** "It is a method of crop improvement which is used to enhance genetic yield potential through genetic manipulation of individual plant character."
- Major crops for which ideotype have been developed are wheat, rice, maize, sorghum, pearl millet, barley and mustard.

### **Identification of traits for Analysis:**

The various traits of crop plant that limit growth and yield can be grouped into the following 4 classes

#### **1. Morphological & anatomical traits:**

These are most commonly used by breeders as they are easily identified and measured and are stable. For example, plant height, leaf size, etc.

#### **2. Compositional traits:**

Such traits concern the concentration of specific biochemical in plant tissue and organs. For example, levels of proline, ABA, protein, etc.

#### **3. Process rate traits:**

Process rates that limit growth & yield related to photosynthesis, respiration. e.g. photoperiodic response, etc.

#### **4. Process Control Traits:**

Examples of such limits are activities of Calvin cycle, nitrate, reductase. etc

### **Merits of Ideotypes breeding**

1. Ideotype breeding is an effective method of enhancing yield through manipulation of various morphological and physiological crop characters. Thus it exploits both morphological and physiological variation.
2. In this method, values of various morphological and physiological traits are specified and each character or trait contributes towards enhanced yield.
3. Ideotype breeding involves experts from the disciplines of plant breeding, physiology, biochemistry, entomology and plant pathology. Each specialist contributes in the development of model plants for traits related to his field.
4. Ideotype breeding is an effective method of breaking yield barriers through the use of genetically controlled physiological variation for various characters contributing towards higher yield.
5. Ideotype breeding provides solution to several problems at a time like disease, insect and lodging resistance, maturity duration, yield and quality by combining desirable genes for these traits from different source into a single genotype.
6. It is an efficient method of developing cultivars for specific situation or environment.

### **Demerits of Ideotypes breeding**

1. Incorporation of several desirable morphological and physiological and disease resistance traits from different source into single genotypes is a difficult task. Sometimes, combining of some characters is not possible due to tight linkage between desirable and undesirable characters. Presence of such linkage hinders the progress of ideotype breeding.
2. Ideotype breeding is a slow method of cultivar development, because combining together of various morphological and physiological features from different sources takes more time than traditional breeding where improvement is made in yield and one or two other characters.
3. Ideotype breeding is not a substitute for traditional or conventional breeding. It is a supplement to the former.
4. Ideotype is a moving object which changes with change in knowledge, new requirements national policy, etc. Thus new ideotype have to be evolved to meet the changing and increasing demands of economic products.

### **CLONAL SELECTION AND HYBRIDIZATION**

- Sexual reproduction – Due to segregation and recombination progeny differ from their parents in genotypes and phenotypes
- Example – Sexual propagated crops
- Asexual reproduction – Progeny remain same in genotype and phenotype b'cos progeny derived from vegetative cell/somatic cell
- Example – Banana, potato, sweet potato, turmeric

### **Characteristics of asexually propagated crops**

- Majority of them are perennial
- Reduced flowering and seedset
- They are invariably cross-pollinated
- They are highly heterozygous and show severe inbreeding depression
- They are polyploid in nature (S. cane, potato, sweet potato)
- Many of them are interspecific hybrids (Banana, Sugarcane)
- The crop consist of large number of clones

### **Clone**

- A group of plants produced from a single plant through asexual reproduction is known as clone
- Characteristics of clone :
  1. All the individuals belonging to a single clone are identical in genotypes
  2. The phenotypic variation within a clone is due to environment only
  3. The phenotype of clone is due to effect of G X E

4. Theoretically clones are immortal
5. Clones are highly heterozygous and show the loss in vigour due to inbreeding

### Genetic variation within a clone

#### 1) Mutation

- Somatic mutation/bud mutation is commonly occur in asexually propagated crops at the rate of  $1 \times 10^{-6}$  P. Here only dominant mutation can express its effects in next generation.

#### 2) Mechanical mixture

- It produced the genetic variation in the same manner as pureline

#### 3) Sexual reproduction

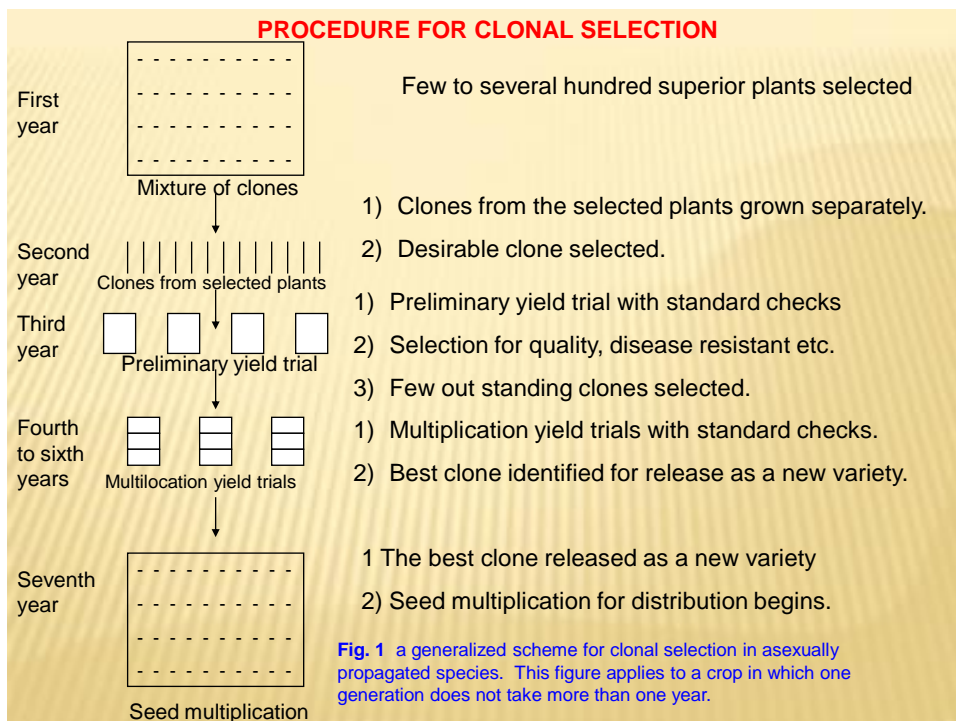
- Sexual reproduction followed by segregation and recombination

### Difference:

Particulars	Clone	Pureline	Inbred
Mode of pollination	Cross pollination	Self pollination	Cross pollination
Mode of reproduction	Asexual	Sexual	Sexual
Genetic makeup	Heterozygous	Homozygous	Heterozygous
Obtained through	Asexual reproduction	Natural self pollination	Inbreeding/sib mating
Maintained through	Asexual reproduction	Natural self pollination	Artificial self pollination
All the plants in a single entity	Identical	Identical	Almost identical
Used directly as a variety	Yes	Yes	No
Genetic makeup within an entity	Heterozygous	Homozygous	Almost homozygous
Organism where found	Plants	Plants	Plants, Animals

### Clonal Degeneration

- The loss in vigour and productivity of clones with time is known as clonal degeneration
- The clonal degeration is taken place due to
  1. Mutation – recurrent in nature, Example in Potato – bolter mutation @  $10^{-3}$
  2. Viral diseases
  3. Bacterial diseases



### Merits of clonal selection

1. It is the only method of selection applicable to clonal crops. It avoids inbreeding depression, and preserves the gene combinations present in the clones.
2. Clonal selection, without any substantial modification, can be combined with hybridization to generate the variability necessary for selection.
3. The selection scheme is useful in maintaining the purity of clones.

### Demerits of clonal selection

1. This selection method utilizes the natural variability already present in the population; it has not been devised to generate variability.
2. Sexual reproduction is a prerequisite for the creation of variability through hybridization.

### Problems in the breeding asexually propagated crops

- Reduced flowering and fertility
  - Polyploid crop
  - Complex interspecific hybridity
  - Cytoplasmic male sterility
- Difficulties in genetic analysis
- Perennial life cycle

### Achievement of clonal selection

- **Clonal selection** – Varieties developed are
  - Kufri Red potato is a clonal selection from Darjeeling Red Round
  - Kufri safed potato variety is a selection from phulwa
  - Bombay green banana is a bud selection from dwarf cavendish
- **Hybridization** – Varieties developed by hybridization followed by clonal selections
  - Kufri alankar, Kufri kuber, Kufri sindhuri, Kufri kundun, Kufri jyoti
  - CO 1148, CO 1158, COS 510, CO 975, COS 109, CO 541

- **Biometry or Biometrics** : It is the science that deals with the applications of the statistical procedure for the study of biological problems
- Biometrical techniques are useful to the plant breeder in four different ways
  - **For the assessment of genetic variability**
    - Range, variance, standard deviation, coefficient of variation, standard error, D2 statistics, Meteroglyph analysis
  - **In the selection of elite genotypes**
    - Correlation and path analysis
    - Discriminant function analysis
  - **For the choice of parents and breeding procedure**
    - Diallel and Partial diallel analysis
    - Line x Tester analysis
    - Generation mean analysis
    - Triallel, Quadriallel, Biparental cross, TTC
  - **For the determination of varietal adaptation**
    - Stability analysis

**Phenotypic variability** – it is an observable variation present in a population is called phenotypic variability

$$P = G \times E$$

**Genotypic variation/Genotypic variance** – It is due to genotypic differences among individuals within population. It is mainly important to the plant breeder. Fisher (1918) divided genotypic variance into three components

1. **Additive variance** – The component of variance arise by taking difference between two homozygote is referred as additive variance
2. **Dominance variance** – The deviation of heterozygote from the average of the two homozygote is referred as dominance variance. It is also called as Intra-allelic interaction
3. **Epistatic variance** – The deviations arises as a consequences of interallelic interaction is called epistatic variances. It also include additive x additive, additive x dominance and dominance x dominance interaction

**Heritability** – It is the ratio of genotypic variance to total variance is referred as heritability

$$\text{Heritability (H)} = V_g/V_p,$$

$$\text{where } V_p = (V_g + V_e)$$

$$V_p = \text{Phenotypic variance}$$

$$V_g = \text{Genotypic variance}$$

$$V_e = \text{Environmental variance}$$

They are two types

**Broad sense heritability** : Its ratio of genotypic variance to total variance

- Its estimates are valid when homozygous lines are studied
- It is less useful in plant breeding

**Narrow sense heritability** – it is the ratio of additive variance to total variance

When we are dealing with segregating generations, it is estimated

It is more useful in plant breeding

**Heritability estimates are useful for the plant breeder because**

- Based on heritability estimate breeder can differentiate the proportion of heritable/non heritable as well as fixable variation



- He can also understand about the kinds of correspondence between genotype and phenotype, which is useful for doing the further selection

### Genotype x Environment Interaction

#### What is Genotype x Environment Interaction?

- A phenotype is the result of interplay of a genotype and its environment. A specified genotype does not exhibit the same phenotypic characteristics under all environments and different genotypes respond differently to a specified environment.
- This variation arising from the lack of correspondence between the genetic and non-genetic effects is known as the **genotype – environment interaction**.
- In other words, the failure of a genotype to give the same phenotypic performance when tested under different environments is the reflection of the **genotype – environment interaction**.

#### **Environment and its kinds:**

- ❖ **Environment:** It is the sum total of physical, chemical and biological factors.
- ❖ **Micro-environment:** It is the environment of a single organism, as opposed to that of another growing at the same time and in almost the same place. It includes physical and chemical attributes of soil, climate variables (temperature and humidity), solar radiation, insect pest and diseases.
- ❖ **Macro-environments:** It is the environment which is associated with a general location and period of time and is a collection of micro-environments.
- ❖ **Predictable/Controlled environment:** It includes the permanent features of the environment, such as climate, soil type and day length. It also includes what are called controllable variables, e.g. the level of fertilizer application, sowing dates, sowing density and methods of harvesting.
- ❖ For the controllable variables, a high level of interaction will be desirable to produce the maximum increase in performance.
- ❖ **Unpredictable/Uncontrolled environment:** It includes weather fluctuations, such as differences between seasons in terms of the amount and distribution of rainfall and the prevailing temperatures.
- ❖ For the uncontrolled variables, a low level of interaction would be desirable so as to have the maximum uniformity of performance over a number of seasons.
- ❖ **Genotype:** The genetic constitution of an organism.
- ❖ **Stable genotype:** A genotype which gives consistence performance over a range of environments is called stable genotype.  
Stable genotype may or may not give high yield.
- ❖ **Well buffered genotype:** A genotype which can adjust its genotypic states in response to the changing environmental conditions.  
This is also called **genetic homeostasis**.
- ❖ **Adaptation:** It is the property of genotype permitting its survival under selection.

- ❖ **Adaptability:** It is the property of a genotype or population of genotypes permitting subsequent alteration of the norms of adaptation in response to changed selection pressure. **OR**
- ❖ It is the capacity for genetic response to selection and depends upon the provision of variability.
- ❖ **Adapted Genotype:** Adapted genotype of population is one which survives the selection pressure by exhibiting a better performance than that of the standard.
- ❖ **Measurement of Interaction:**

G X E interaction can be measured by using various approaches, as listed below:

**1. Stability Factor (SF)**

**2. Regression Approach:**

(i) **Model of Finlay and Wilkinson (1963)**

(ii) **Model of Eberhart and Russell (1966)**

(iii) **Model of Perkins and Jinks(1968)**

1) Lewis (1954) suggested a simple measure of phenotypic stability which he termed “**Stability Factor (SF)**” and is expressed as:

$$\text{S.F.} = \frac{\bar{X}_{HE}}{x_{LE}}$$

Where  $\bar{x}$  is the mean value, H.E. and L.E. are high and low yielding environments, respectively.

- SF=1 indicates the maximum phenotypic stability.
- The greater the SF deviates from unity, the less stable is the phenotype.

2) **Regression Approach:**

**A) Model of Finlay and Wilkinson (1963):**

- A dynamic approach to the interpretation of varietal adaptation to varying environments was developed by Finlay and Wilkinson (1963).
- It led to the discovery that the components of a genotype and environmental interactions were linearly related to environmental effects.
- The technique involves the growing of a large number of genotypes (inbreds, clones, varieties, populations, etc.) in a number of environments.
- The mean yield of all the genotypes for each site and season gave a quantitative grading of the environment.
- Then the linear regression of the mean values for each genotype on the mean values for environments is estimated.
- Finlay and Wilkinson (1963) used two stability parameters viz., **regression coefficient** and the **mean over all the environments**, in this type of analysis.
- Since the individual variety means are regressed against the mean of all the varieties, the population mean has a regression coefficient of 1.0
- Hence, when the regression coefficient  $\approx 1.0$ , it indicates average stability.
- When it is associated with high mean, varieties have general adaptability.
- When it is associated with low mean, varieties are poorly adapted to all environments.
- Regression value above 1.0 describes varieties with below average stability and increasing sensitivity to environmental changes, i.e. they have greater specificity of adaptation to favourable environments.

- Reverse is true when regression coefficient is below 1.0 which means greater resistance to environmental change or above average stability and hence these genotypes have specific adaptability to low yielding environments.

**B) Model of Eberhart and Russell (1966):**

- According to this model, the regression of variety mean on environmental index and a function of the squared deviations from these regressions would provide an estimate of the desired stability parameters.
- **Stable variety:** A variety that performs above average in all environments.
- Hence stable variety has high mean ( $\bar{X}_i$ ), unit regression ( $b_i \approx 1$ ) and the deviations from regression as small as possible. ( $s^2 d_i \approx 0$ ).

**C) Model of Perkins and Jinks(1968):**

- In this model genotypes X interactions is obtained on the environmental index.
- In this Genotype X environment sum of squares is further divided into two parts namely
  1. Sum of squares due to heterogeneity among regressions
  2. SS due to remainder.