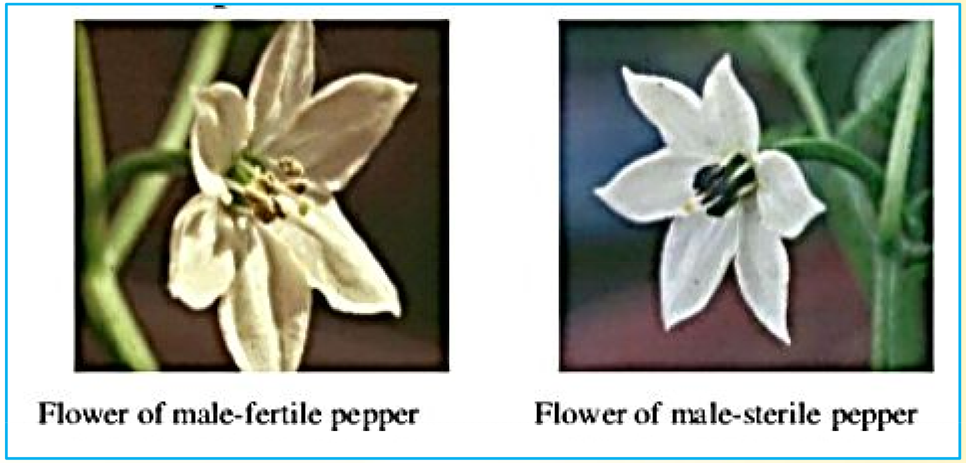

Male Sterility in Plants

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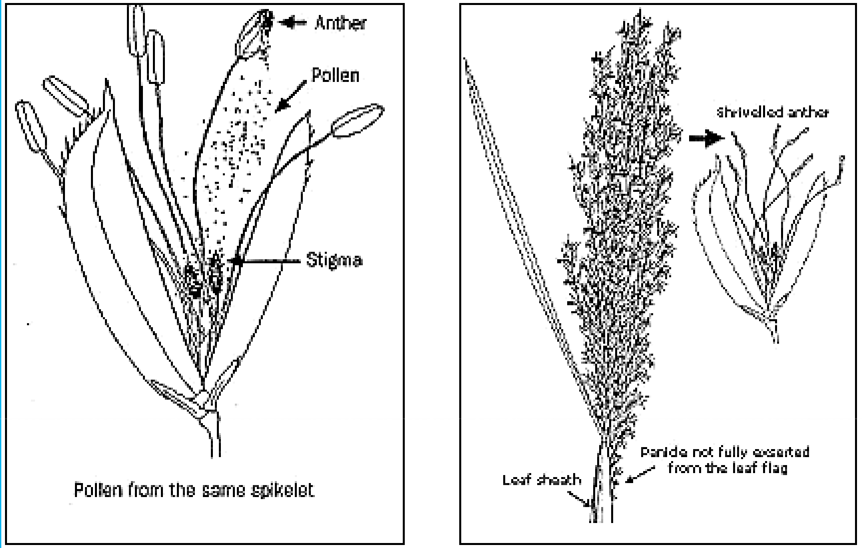
What is male sterility?

- Male sterility is defined as an absence or non-function of pollen grain in plant or incapability of plants to produce or release functional pollen grains.



Normal Rice Spikelet (self pollinated crop)

Sterile Rice Spikelet (Male Sterility)

Features of Male Sterility

- Prevents self pollination, permits cross pollination.
- Leads to heterozygosity
- Female gametes function normally
- Assayed through staining techniques
- In nature, occur due to spontaneous mutations
- Can be induced artificially

Types of Male Sterility

- Cytoplasmic male sterility (CMS) – governed by cytoplasmic genes
- Genetic male sterility (GMS) – governed by nuclear genes
- Cytoplasmic-Genetic male sterility (CGMS) – governed by both nuclear and cytoplasmic genes
- Transgenic male sterility – induced by the technique of genetic engineering
- Chemical induced male sterility – induced by the use of chemical

Limitations of Male Sterility system

- In some crops, sterile cytoplasm has adverse effect on yield.
- Unsatisfactory restoration of fertility
- Break down of male sterility because of some reasons like, certain environmental conditions which leads to some pollen production by the male sterile lines and cytoplasm contribution (though small) by the sperm in some cases,
- Difficult to identify line with GMS
- Unsatisfactory or poor pollination
- Modifiers or modifying genes may affect cytoplasmic male sterility

Cytoplasmic Male Sterility

- Cytoplasmic male sterility is governed by cytoplasmic or plasma genes.
- Progeny of male sterile plant is always male sterile, as its cytoplasm is derived entirely from female gamete
- Usually the cytoplasm of zygote comes primarily from the egg cell.

Cytoplasmic Male Sterility

- In the system, there are A and B line.
- The **male sterile line** is also known as **A line**. The line used to maintain male sterile line is **male fertile**, **B line**. The A line is maintained by crossing it with B line (pollinator strain used as **recurrent parent in the backcross program**), as its nuclear genotype is identical with that of the A line. The restorer line only can provide fertility in F1.
- It is **stable** i.e. not influenced by environmental factors.

Applications in Plant Breeding

- It is applicable in production of hybrids in ornamental crops and vegetatively propagated crops, overall, where grain or fruit is not the economic product.
- **Examples** – Observed in sugarcane, potato, and forage crops.

Drawbacks

- It cannot be used in asexually propagated crops to produce hybrids in crops where improvement in seed / fruit is considered.

Genetic Male Sterility

- It is governed by nuclear genes, in most of the cases by single gene.
- The gene causing male sterility are ordinarily recessive (ms) and rarely dominant (e.g. safflower).
- The male sterility alleles may rise spontaneously or it can be induced artificially and is found in several crops viz. Pigeon pea, castor, tomato, limabean, barley, cotton, etc.

Genetic Male Sterility

- In the system, there are A and B line.
- A line (mm) is genetic male sterile line. B line is heterozygous male fertile line (Mm). A line is maintained by crossing it with B line, the cross produces male sterile and male fertile lines in 1:1 ratio.
- Male fertile line is identified in seeding stage.

Applications in Plant Breeding

- It is applicable in production of hybrids in both, vegetatively propagated crops and crops important for fruit or seed yield.
- **Examples** – Wheat, maize, barley, sorghum, cotton, sunflower, tomato and cucurbits

Drawbacks

- In this rouguing of male fertile plant from the female is costly operation and due to this cost of hybrid seed is higher.
- Therefore, GMS has been exploited commercially only in few crops by few countries. E.g. In USA used in castor while in India used for hybrid seed production of Arhar (cajanus cajan).

Cytoplasmic-Genetic Male Sterility

- It is governed by both nuclear and cytoplasmic genes.
- Jones and Davis first discovered this type of male sterility in 1944 in onion.
- Here, nuclear genes for fertility restoration (Rf) is dominant and is found in certain strains of the species, or may be transferred from a related species e.g., in wheat. This gene restores male fertility in the male sterile line, hence it is known as restorer gene.

Cytoplasmic-Genetic Male Sterility

- The Rf genes do not have their own expression of any kind unless the sterile cytoplasm is present.
- Rf genes are required to restore fertility in sterile cytoplasm which contains genes causing sterility.

Cytoplasmic-Genetic Male Sterility

- This system includes A, B, and R lines. A line is a male sterile line, B is similar to 'A' in all features but it is a male fertile and R is restore line as it restore the fertility in the F1 hybrid.
- Since B line is used to maintain the fertility it is also referred as maintainer line.
- Thus plants with N cytoplasm are fertile and S cytoplasm with genotype *Rf-* leads to fertiles while S cytoplasm with *rfrf* produces only male steriles.

Applications

- Evades the need for emasculation in cross-pollinated species.
- It is used in commercial production of hybrid seeds in maize, sorghum and bajra.
- Examples – It is observed in maize, sorghum, bajara, sunflower, rice and wheat. The one with cytoplasmic male sterility would be included in the cytoplasmic genetic system as and when restorer genes for it discovered.

Transgenic Male Sterility

- When the male sterility is induced by the techniques of genetic engineering, it is called as transgenic male sterility.
- It is heritable and basically comes under genetic male sterility.

Transgenic Male Sterility

- In this system, the two kinds of genes are involved.
- One gene causes male sterility (integrated with genome of A line) while the other suppresses it (in R line).

Chemical Induced Male Sterility

- The chemical which induces male sterility artificially is called as male gametocide. It is rapid method but the sterility is non-heritable.
- In this system A, B and R lines are not maintained. Some of the male gametocides used are gibberellins (rice, maize), Sodium Methyl Arsenate (rice) and Maleic hydrazide (wheat, onion).

Polygenic inheritance

- Refers to the inheritance of quantitative traits, traits which are influenced by multiple genes (multiple factor inheritance).
- Polygenic inheritance also looks at the role of environment in someone's development.
- Early Mendelian genetics focused on very simple genetic traits which could be explained by a single gene.
- However, by the early twentieth century, people were well aware that most traits are far too complex to be determined by a single gene

Polygenic inheritance - features

- The term polygene was introduced by Mather in 1941
- Each polygenic character is controlled by several independent genes and each gene has cumulative effect.
- Polygenic characters exhibit continuous variation rather than a discontinuous variation. Hence, they cannot be classified into clear-cut groups.
- Effect of individual gene is not easily detectable in case of polygenic characters and, therefore, such traits are also known as minor gene characters.

Polygenic inheritance - features

- The statistical analysis of polygenic variation is based on means, variances and co-variances. Thus, polygenic characters are studied in quantitative genetics
- Polygenic traits are highly sensitive to environmental changes
- Generally the expression of polygenic characters is governed by additive gene action, but now cases are known where polygenic characters are governed by dominance and epistatic gene action

Polygenic inheritance - features

- In case of polygenic characters, metric measurements like size, weight, duration, strength, etc. are possible
- The transmission of polygenic characters is generally low because of high amount of environmental variation

Polygenic inheritance - analysis

- It requires various measurements of characters like weight, length, width, height, duration, etc., rather than classification of individuals into groups based on colour or shape.
- Observations are recorded on several individuals and the mean values are used for genetical studies. Segregation in F_2 generation exhibit continuous range of variation from one extreme (low) to other (high) for such traits.
- Fisher (1918) was the pioneer worker to interpret the quantitative characters in terms of Mendelian genetics

Polygenic inheritance - assumptions

- Each of the contributing genes involved in the expression of a character produces an equal effect.
- Each contributing allele has either cumulative or additive effect in the expression of a character.
- The genes involved in the expression of characters have lack of dominance. They show intermediate expression between two parents
- There is no epistasis among genes at different loci.

Polygenic inheritance - Examples

- Grain Color in Wheat
- Skin Color in Human Beings
- Height of Man
- Ear Length in Maize
- Ray Size in Flower Heads of Compositae

Height in humans

- One easily understood example of polygenic inheritance is height.
- People are not just short or tall; they have a variety of heights which run along a spectrum.
- Furthermore, height is also influenced by environment; someone born with tall genes could become short due to malnutrition or illness, while someone born with short genes could become tall through genetic therapy.
- Polygenic inheritance shows how multiple genes in combination with a person's environment can influence someone's phenotype, or physical appearance.

Kernel Colour in Wheat

- Nilsson Ehle (1908) studied the inheritance of kernel colour in wheat.
- He found that seed or kernel colour in wheat is governed by one, two and three gene pairs
- In the crosses between red and white kernel varieties, he observed that the F1 was intermediate between the parental values and in F2 he observed 3:1,15:1 and 63 : 1 ratios of red and white seeds in different crosses.

Kernel Colour in Wheat

- The two ratios (15:1 and 63:1) indicated that there was duplicate gene interaction
- The red seeds of 15 : 1 ratio could be easily divided into four classes on the basis of shade of colour, viz., dark red, medium dark red, medium red and light red.
- These colours were observed in the ratio of 1 : 4 : 6 : 4 : 1.
- This suggested that the seed colour in wheat is controlled by genes which show lack of dominance and have small cumulative effects.

Kernel Colour in Wheat

	Dark red		White
Parents	Dark red		White
Genotypes	$R_1R_1R_2R_2$	× ↓	$r_1r_1r_2r_2$
F_1		$R_1r_1R_1r_1$	Medium Red

F_2	R_1R_2	R_1r_2	r_1R_2	r_1r_2
R_1R_2	$R_1R_1R_2R_2$ [DR]	$R_1R_1R_2r_2$ [MDR]	$R_1r_1R_2R_2$ [MDR]	$R_1r_1R_2r_2$ [MR]
R_1r_2	$R_1R_1R_2r_2$ [MDR]	$R_1R_1r_2r_2$ [MR]	$R_1r_1R_2r_2$ [MR]	$R_1r_1r_2r_2$ [LR]
r_1R_2	$R_1r_1R_2R_2$ [MDR]	$R_1r_1R_2r_2$ [MR]	$r_1r_1R_2R_2$ [MR]	$r_1r_1R_2r_2$ [LR]
r_1r_2	$R_1r_1R_2r_2$ [MR]	$R_1r_1r_2r_2$ [LR]	$r_1r_1R_2r_2$ [LR]	$r_1r_1r_2r_2$ [W]

DR = Dark Red, MDR = Medium Dark Red,
MR = Medium Red, LR = Light Red and W = White

Kernel Colour in Wheat

Effective alleles for red colour	No. of individuals	Phenotype
4	1	Dark red
3	4	Medium dark red
2	6	Medium red
1	4	Light red
0	1	White

Where 4 effective alleles were present, the seed colour was dark red, where 3 such alleles were present, the seed colour was medium dark red, with 2 effective alleles, colour was medium red and with 1 effective allele, seed colour was light red. White seed colour was produced when all the non-effective alleles were present.

Cytoplasmic inheritance

- DNA and RNA is the genetic material that carries information from one generation to another.
- Apart from this genetic material in the nucleus, the cytoplasm also contributes to the inheritance of some characters. Such characters are cytoplasmic inherited characters and this phenomenon is called as cytoplasmic inheritance.
- It is also called extra nuclear inheritance, because in this type of inheritance factors lies outside the nucleus of the cell.

Cytoplasmic inheritance

- During sexual reproduction, the zygote is formed by the fusion of male gamete and female gamete. The male gamete which is the sperm, carries very little or no cytoplasm at all while female gamete carries large amount of cytoplasm. Hence in cytoplasmic inheritance, the male parent doesn't contribute while female parent alone contribute s cytoplasmic characters.
- The cytoplasm contains various cell organelles including mitochondria, chloroplast are regarded as semi-autonomous as they contain their own genetic material-DNA. Hence cytoplasmic inheritance involves inheritance of mitochondrial DNA and/or chloroplast DNA.

Plastid inheritance – *Mirabilis jalaba*

- One of the earliest and best known examples of cytoplasmic inheritance is that discovered by Correns in a variegated variety of the four-o'clock plant *Mirabilis jalapa*.
- In this plant, three types of branches are seen on the same plant; green, white and variegated (patches of green and white).
- This green colour is due to chloroplasts and white colour is due to **leucoplasts**.

Plastid inheritance – *Mirabilis jalaba*

- Correns discovered that seed produced by flowers carried on the green branches gave progeny which were all normal green. It made no difference whether the phenotype of the branch which carried the flower used for pollen was green, white or variegated.
- Seed taken from white branches likewise gave all white progeny, regardless of the pollen donor phenotype. These of course died in the seedling stage.
- Seeds from flowers on variegated branches gave three kinds of progeny, green, white and variegated, in varying proportions; again regardless of the pollen donor phenotype.

Plastid inheritance – *Mirabilis jalaba*

- The phenotype of the progeny always resembled the female parent and the male made no contribution at all to the character.
- Therefore in cytoplasmic inheritance, the male parent doesn't contribute and the inheritance factors totally come from female cytoplasm
- The explanation for this unusual pattern of inheritance is that the genes concerned are located in the chloroplasts within the cytoplasm, not in the nucleus, and are therefore transmitted only through the female parent.

Plastid inheritance – *Mirabilis jalaba*

- In eukaryote organisms the zygote normally receives the bulk of its cytoplasm from the egg cell and the male gamete contributes little more than a nucleus.
- Any genes contained in the cell organelles of the cytoplasm will therefore show **maternal inheritance**.
- The leaf variegation is due to two kinds of chloroplasts: normal green ones and defective ones lacking in chlorophyll pigment.

Plastid inheritance – *Mirabilis jalaba*

- Chloroplasts are genetically autonomous (i.e. self-determining) and have their own system of heredity in the form of chloroplast 'chromosomes'.
- These are small circular naked DNA molecules which carry genes controlling *some* aspects of chloroplast structure and function.
- A mutation in one of these genes, which affects the synthesis of chlorophyll as in *Mirabilis*, will therefore follow the chloroplast in its transmission and will not be inherited in the same way as a nuclear gene

Plastid inheritance – *Mirabilis jalaba*

- The other important point to note about the inheritance of chloroplasts is that they have no regular means of distribution, such as chromosomes do at mitosis, where they can be equally shared out to the daughter cells following division.
- A plant that begins life as a zygote containing a mixture of normal and mutant chloroplasts cannot therefore maintain the same mixture in all of its somatic cells.

Plastid inheritance – *Mirabilis jalaba*

- The two kinds of plastids are shared out randomly during cell division, according to the way they happen to be placed in the cytoplasm when it is partitioned.
- Some branches of variegated plants may therefore remain mosaic while others, by chance, may turn out to contain all white or all green chloroplasts in all of their cells.
- In a similar way the flowers on variegated branch may be of three kinds. Some will have egg cells with all green chloroplasts, some egg cells with all white and others will retain a mixture.

Plastid inheritance – *Mirabilis jalaba*