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4. Reproduction Mechanism in Plants

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Abstract:

Reproduction is one of the most important and evolved processes of all living beings including plants. It can be defined as the process of production of offspring or one of its kinds from their parent generation. Reproduction is an essential process for progeny production and maintaining population ultimately helps in sustaining the ecosystem. Reproduction in plants helps in acquiring new variation and for better adaptation in a dynamic environment. Reproduction brings the most desirable characteristics in an individual that help in the continuation of the process of evolution in plant species. As plants are living in genesis, they are obliged to pass their genes to the future generations through offspring which can be possible through sexual and asexual reproduction. Plants usually reproduce by forming flowers which contain male and female reproductive systems. Act of pollination unites male and female parts which leads to the formation of seeds and germinating seeds give rise to new plants, completing the life cycle of plants. Choice of breeding procedure during varietal development program depends on the mode of pollination and reproduction of a crop species. Knowledge of fundamental aspects of plant reproduction is essential for a plant breeder for the genetic improvement of a crop species.

Keywords:

Reproduction, Asexual Reproduction, Sexual Reproduction, Progeny

4.1 Introduction:

The production of new individuals from their parents is known as reproduction. Plant reproduction is the process by which plants produce new individuals or offspring. It is an inherent characteristic of all living organisms to continue or maintain their races by the mechanism of reproduction. Mode of reproduction varies from species to species depending on the condition available. In crop plants, the mode of reproduction is basically of two types: viz. 1) sexual reproduction and 2) asexual reproduction. Multiplication of plants by forming embryos, which are developed by the fusion of male and female gametes is known as sexual reproduction. Most of the seed-producing plant species come under the category of sexual reproduction. Plants show alternation of generation in its life cycle by forming sporophyte and gametophyte with the help of sporogenesis (formation of spores viz. microspore and megaspore) and gametogenesis (formation of gametes viz. male and female gamete). Flower (a modified shoot) as a reproductive organ bearing pistil, stamen and usually sepals and petals aids in sexual reproduction. Haploid gametophyte produces male and female gamete by mitosis in distinct multicellular structure of plant and fusion of these male and female gametes forms the diploid zygote bringing the diploid phase of plant life cycle. After reaching maturity diploid sporophyte produces spores by meiosis which again divide to produce haploid gametophyte and the cycle continues. Life cycle of most of the higher plants are dominated by sporophytic stage. Multiplication of plants without the fusion of male and female gametes is known as asexual reproduction. Asexual reproduction can take place either by vegetative parts of plants or by vegetative embryos which develop without sexual fusion known as apomixis. Apomixis is defined as the process of formation of seed without fertilization. In apomixis, an embryo is developed without sexual fusion.

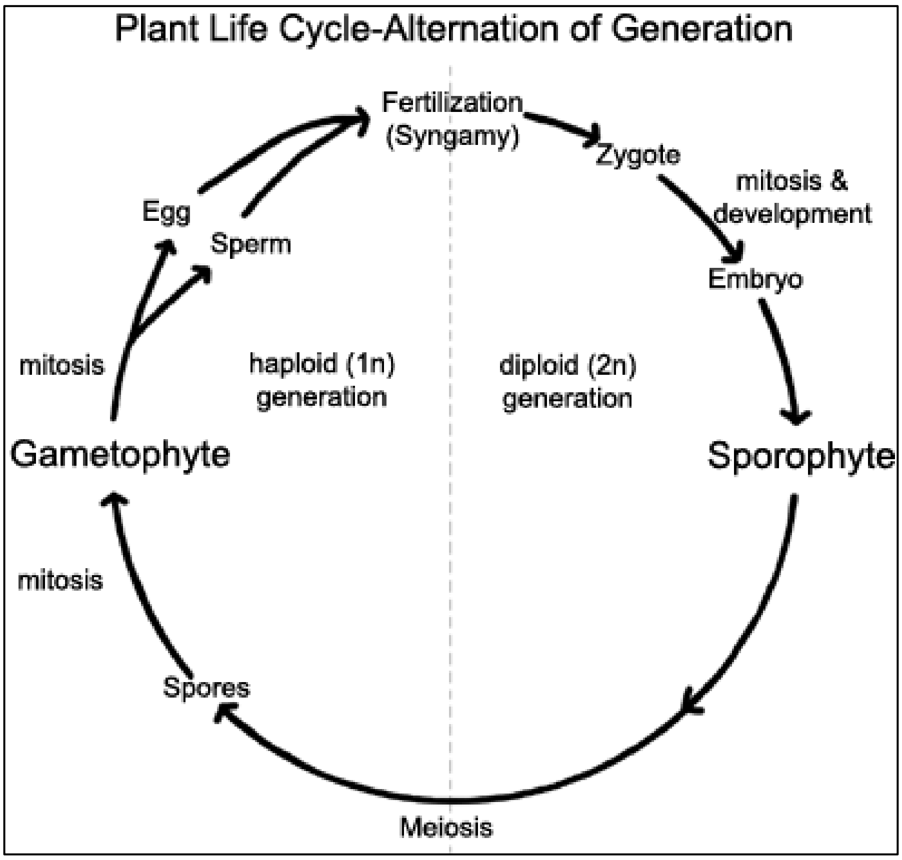


Figure 4.1: Alternation of Generation in Plants

4.2 Mode of Reproduction:

A mode of reproduction determines the genetic constitution of a plant and helps to understand its characteristics. Also, the mode of reproduction determines the method of breeding the species and how the product of breeding is maintained for product identity preservation.

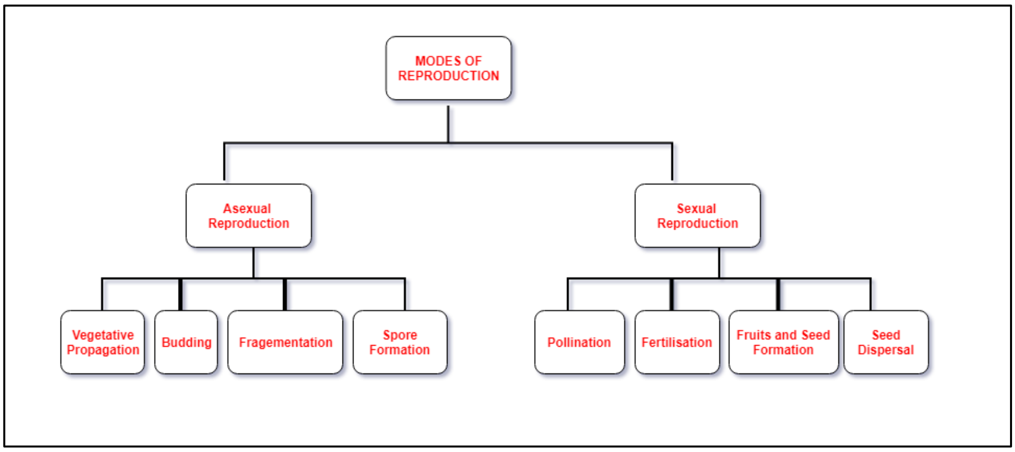
4.2.1 Importance of Mode of Reproduction to Plant Breeding:

Plant breeders need to understand the reproductive systems of plants for the following key reasons:

- The genetic structure of plants depends on their mode of reproduction. Methods of breeding are generally selected such that the natural genetic structure of the species is retained in the cultivar. Otherwise, special efforts will be needed to maintain the newly developed cultivar in cultivation.
- In flowering species, artificial hybridization is needed to conduct genetic studies to understand the inheritance of traits of interest and for transfer of genes of interest from one parent to another. To accomplish this, the breeder needs to understand thoroughly the floral biology and other factors associated with flowering in the species.
- Artificial hybridization requires an effective control of pollination so that only the desired pollen is allowed to be involved in the cross. To this end, the breeder needs to understand the reproductive behavior of the species. Pollination control is critical to the hybrid seed industry.
- The mode of reproduction also determines the procedures for multiplication and maintenance of cultivars developed by plant breeders.

The modes of plant reproduction can be majorly classified as:

- **Asexual mode of reproduction**
- **Sexual mode of reproduction**



4.2.2 Asexual Mode of Reproduction:

In this mode of reproduction, plants can give rise to new plants without the involvement or fusion of male and female reproductive parts (gamete). In this mode, plants do not produce fruits and seeds. Asexual reproduction in plants can occur in a variety of forms:

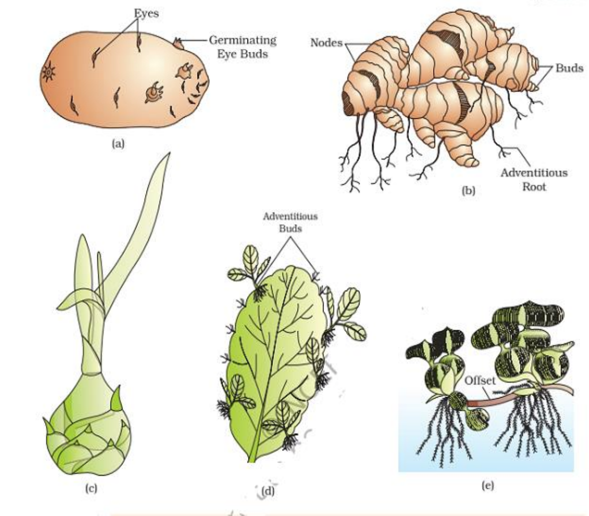
A. Vegetative Propagation:

New plant develops from the portion of the body of parent plant. This can occur through fragmentation and regeneration of specific vegetative parts of plants.

Natural Vegetative Propagation:

This occurs when plants grow and develop naturally without any human interference. Natural vegetative propagation can be enabled by the development of adventitious roots. Thus, new plants may emerge from the roots, stem and leaves of the parent plant. Examples:

- **a. Underground stem:** tuber (potato), bulb (onion, garlic), rhizome (ginger, turmeric) and corm (bunda, arwi).
- **b. Sub-aerial stem:** runner (cynodon dactylon, mentha), stolon (strawberry, iris), sucker (banana, chrysanthemum) and offshoot (date palm, water hyacinth).
- **c. Bulbils:** they are modified flowers develop into plant without seed formation. Cardamom, agave americana are examples
- **d. Leaves:** Leaves of a few plants get detached from the parent plant and develop into new plants. Bryophyllum is the example
- **e. Underground root:** New plants emerge out of swollen, modified roots known as tubers. Buds are formed at the base of the stem. Sweet potato is the example



Vegetative propagules in angiosperms: (a) Eyes of potato; (b) Rhizome of ginger; (c) Bulbil of *Agave*; (d) Leaf buds of *Bryophyllum*; (e) Offset of water hyacinth

Figure 4.2: Vegetative Propagation methods in angiosperms

Artificial Vegetative Propagation:

This is the type of vegetative reproduction carried out by humans in the fields and laboratories. Stem cuttings are commercially used for the propagation of sugarcane, grapes, roses etc.

Root cutting, budding, grafting, layering, and Gootee are the other methods used for the propagation of fruits and mainly for ornamental species.

a. **Cutting:** Cutting is a simple method of vegetative propagation in which a part of stem or root having node is cut and planted into the soil with some nutrients. **Examples** Root cutting- Lemon, tamarind etc. Stem cutting- rose, sugarcane etc. Leaf cutting- Sansevieria.
b. **Layering:** Layering is a very common method of artificial vegetative reproduction in which a twig or a branch is bent down below the soil and a small incision is made in this portion after that this portion is covered with soil and moistened regularly, soon the portion develops new roots and separated from the main plant body to give rise to new plant. **Examples:** Jasmine, Strawberry, Grapevine and Cherry. Different forms of layering are Tip layering, trench layering, mound layering and serpentine layering.
c. **Grafting:** grafting is a technique of joining two plant parts to continue their growth together, after the joined area is tied up tightly and covered with wax to avoid infection. One part is known as scion (upper part) which has desired and superior characteristics and another one is stock (base part) which has strong root system. **Examples:** Mango, Guava, Apple, Rubber plant, Citrus and Pear etc. different types of grafting are tongue, wedge, crown and side grafting.
d. **Gootee:** better known as air layering. A healthy, leaf-bearing branch from any suitable main plant is selected, and a ring of bark of 2-5cm is removed from the basal part of the branch. After that, this portion is covered with moist clay which is enriched in root-promoting chemicals. This clay portion is wrapped with polythene paper to prevent desiccation, which ultimately develops roots within 1-3 month. At last, the root containing portion of the branch is separated from the main plant and placed into a new location. **Examples:** litchi, guava, lemon, orange etc.
e. **Micropropagation:** The production of large number of individual plantlets from a small piece of plant tissue cultured in a nutrient medium. Various steps of micropropagation are explant isolation, surface sterilization, washing of plant tissue, establishment of explant into nutrient medium, and hardening. The major advantage of micropropagation is disease free plants can be obtained by culturing meristem of infected plants.

Advantages of Vegetative Propagation Are:

a. Vegetative propagation is one of the most basic, easy and quick method to produce offspring.
b. The plants cultivated are genetically identical to their parents.
c. Plants can be cultivated faster as compared to growing them from seeds.
d. mutant buds, branches or seedlings, if found desirable can be multiplied and directly used as a variety.

e. Grafting method helps to develop such economically important plants, which have useful character combined from two different individuals.
f. Vegetative propagation helps in cloning of perennial plants and develop a unique population from them.

The Disadvantages of Vegetative Propagation Are:

a. Vegetative propagated plants are short-lived, small compared to seed propagated plants.
b. No new varieties can be produced as this method does not allow the transfer of gene/cytoplasm from one variety to another.
c. Skilled persons are required and often expensive compared to seed propagation.
d. More susceptible to diseases as the entire plant may get affected as there is no genetic variation.
e. The plants may show degeneration in important characters due to the absence of sexually exploited variation.
f. Due to the absence of genetic variability, adaptation of plants to changing environment decreases.

B. Budding:

In this mode of asexual reproduction, new plants grow from an outgrowth or bud in the plant body.

In other words, budding also known as bud grafting, is a form of asexual plant propagation by which an exact replica of the parent plant is produced with the help of an outgrowth separated from the main plant.

C. Fragmentation:

New plants are developed from fragments of the parent plant.

D. Apomixis:

It is the type of asexual reproduction in which seeds are formed, and the embryo is developed without the fusion of male and female gametes.

Hence, the offspring produced from such apomictic seeds are identical in genotype with each other and with the parent plant. Citrus trees commonly use this method of asexual reproduction by using their seeds.

It is one of the most important methods of asexual reproduction. Some species reproduce only by the mechanism of apomixis known as obligate apomicts.

Examples are bahia grass (*Paspalum notatum*) and buffel grass while most of them reproduce through sexual reproduction along with apomixis known as facultative apomicts. Examples are blue grass, sea buckthorn etc.

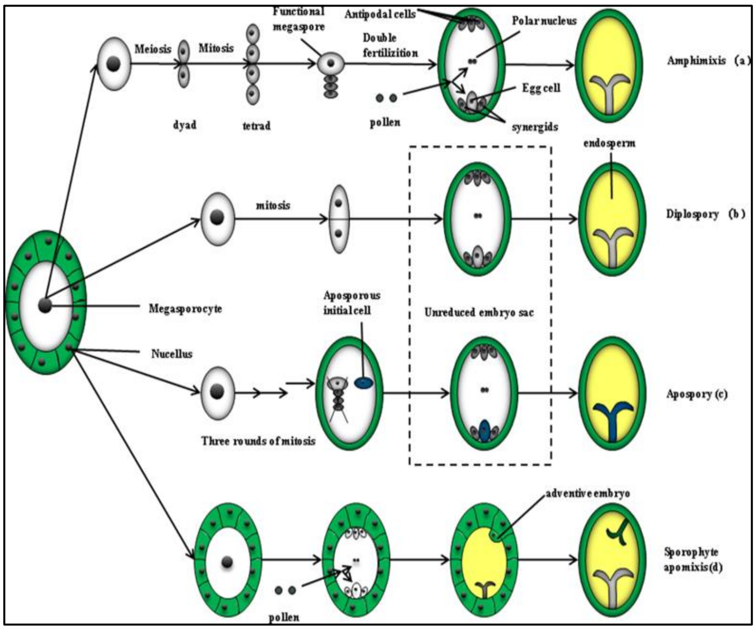


Figure 4.3: Different Types of Apomixis

Types of Apomixis:

There are mainly five categories of apomixis present

a. **Parthenogenesis:** parthenogenesis occurs when embryo develop from the embryo sac without pollination. It is mainly of two types viz., gonial and somatic parthenogenesis. When embryo develop from egg cell of embryo sac it is gonial parthenogenesis and when embryo develop from other cells of embryo sac except egg cell, this is termed as somatic parthenogenesis.
b. **Apogamy:** when the origin of embryo takes place from either synergids or antipodal cells of the embryo sac is known as apogamy
c. **Apospory:** vegetative cells of ovule lying outside the embryo sac develop into unreduced type of embryo sac through the series of mitotic division and without the involvement of meiosis. Examples: malus, orchids, hieraceum etc.
d. **Diplospory:** In diplospory, embryo sac is produced from the megaspore which may be haploid or diploid in nature, which further results in development of embryo.
e. **Adventive embryony:** when embryo develop directly from the vegetative cells of ovule such as nucellus, integuments and chalaza, without the production of embryo sac. This phenomenon is termed as adventive embryony.

In another terms, when embryo originated from haploid cells it is termed as recurrent apomixis and when embryo produced from diploid cells it is known as non-recurrent apomixis. In species such as nicotiana and datura sometimes pollen grains produce haploid embryos *in vitro,* this is called as androgenesis. Development of apomictic lines can be made possible from gene transfer from wild species, through induced mutations and also by interspecific recombination.

Significance of Apomixis:

- Apomixis helps in attaining major breeding objective such as fixation of heterosis, production of homozygous lines, and production of Vybrids (progeny of a cross between two facultative apomicts) too.
- Farmers are able to reshow their seeds generation after generation due to fixation of heterosis.
- With the help of apomictic seeds, minimum isolation distance is required to avoid mechanical admixture.
- Apomictic seed make maintenance of nucleus seeds very feasible of the hybrid varieties.

4.2.3 Sexual Mode of Reproduction:

Sexual reproduction is the process by which plants multiply by developing embryos formed by the union of male and female gametes. All species that propagate seeds are included in this group. In crops, specialized structures known as flowers are used to produce both male and female gametes.

A. Flower:

A flower is made up of sepals, petals, stamens, and/or pistils. A flower that is perfect or hermaphrodite has both pistils and stamens. A flower is referred to as staminate, if it has stamen but no pistil and pistillate if it has pistil but no stamens. In monoecious species like maize, coconut, Colocasia, castor (Ricinus communis), etc., staminate and pistillate blooms are produced on the same plant. But in dioecious species, staminate and pistillate flowers occur on different plants, e.g., papaya, date palm (Phoenix dactylifera), pistachio nut (Pistacia vera), etc. In crop plants, meiotic division of specific cells in stamen and pistil yields microspores and megaspores respectively.

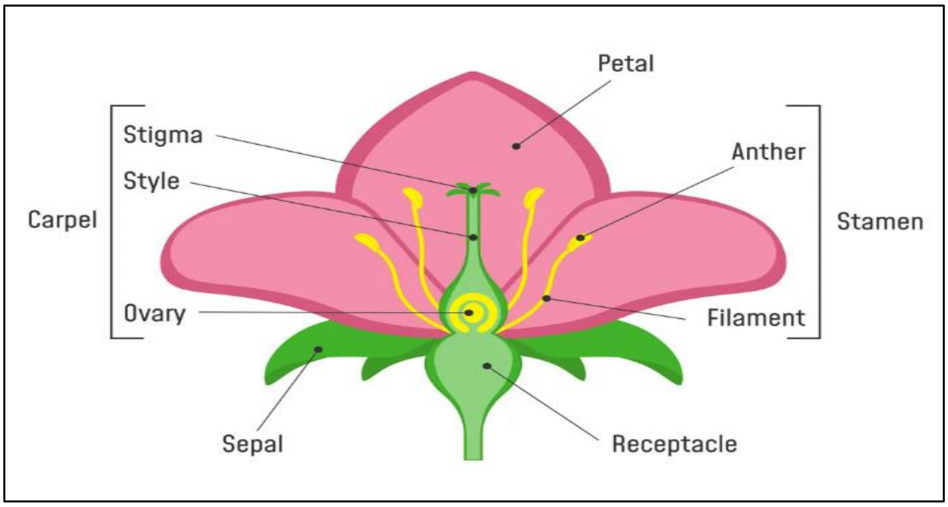


Figure 4.4: Complete Structure of a Flower

a. A Flower Comprises the Following Parts:

Calyx: It is an outermost whorl of flower. It is made up sepals. The calyx encloses the remaining part of the flower when it is in the bud stage. They are typically green in color, yet occasionally they might have a color similar to petals.

Corolla:

It is the second whorl of the flower and has a large number of petals. petals smell good they are soft, thin, and colored, they will attract insects and animals, which will aid in the pollination process.

b. Reproductive Structure of a Flower:

i. Androecium: It is the third whorl of a flower and contains the male reproductive organs, or stamens. Anther and filament are the two components that make up each stamen.

- **Anther:** This structure resembles a four-lobed bag and it is in charge of producing pollen.
- **Filaments:** These thread-like structures are attached to the anther, and they keep the anther in place.

ii. Gynoecium:

It is the last whorl of the flower and the reproductive organ for females. It is made up of pistil and present in the middle of the thalamus. The parts of the pistil are the ovary, stigma, and style. Ovules are internally produced by the ovary. Ovules generate megaspores during meiosis, which later mature into female gametophytes. Consequently, egg cells produced.

Gynoecium can be:

Monocarpellary: The gynoecium consists of a single pistil. For eg. peas and beans.

Multicarpellary: Here, gynoecium comprises more than one pistil.

Syncarpous: It is the gynoecium with combined pistil. For eg., Tomato, cucumber.

Apocarpous: It is the gynoecium with free pistil. For eg., Lotus Vinca.

Pistil- Each pistil has three parts:

- **Ovary**: The ovary is a chamber where ovules (eggs) are stored, waiting for fertilization.
- **Stigma:** It is attached to the top of the carpel, where the pollen from other flowers lands.
- **Style**: It is a tubular structure that connects the ovary and the stigma. It is responsible for the transportation of pollen from the stigma to the ovary and holding the stigma in place.

❖ **Sporogenesis:** Productions of microspores and megaspores is known as sporogenesis. Microspores are produced in anthers (microsporogenesis), while megaspores are produced in ovules (megasporogenesis).

Microsporogenesis:

- The process of formation of microspores from pollen mother cell through meiosis is called microsporogenesis.
- The sporogenous tissue of microsporangium differentiated into microspore mother cell or pollen mother cell.
- Each microspore mother cell undergoes meiosis and gives rise to haploid microspore tetrad.
- On dehydration microspore tetrad dissociated to form four microspores.
- Each microspore developed into a pollen grain.

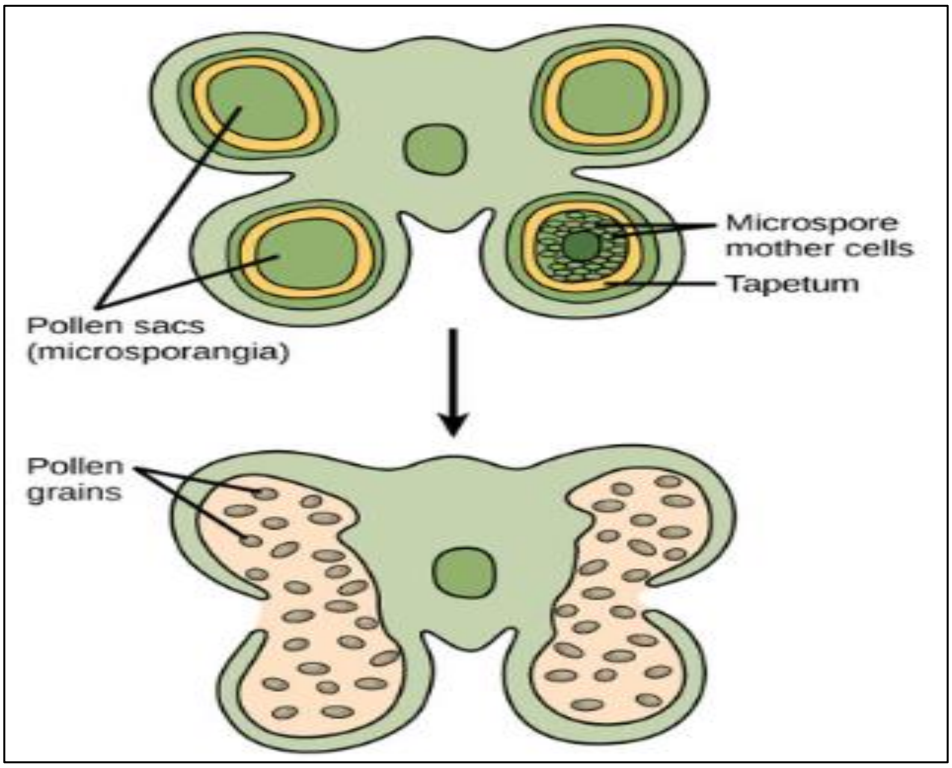


Figure 4.5: Transverse Section of a Young Anther

Megasporogenesis:

A single cell within each ovule divides into a megaspore mother cell, which goes through meiosis to create four haploid megaspores; three of the megaspores' degenerates, leaving one functional megaspore per ovule intact. Megasporogenesis takes place in ovules, which are found inside the ovary.

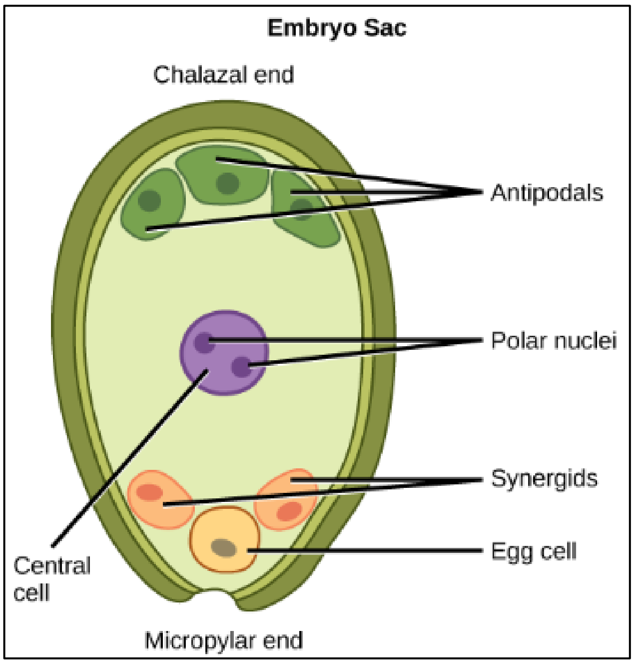


Figure 4.6: Structure of a Typical Embryo sac

❖ **Gametogenesis:** The production of male and female gametes in the microspores and the megaspores, respectively. known as gametogenesis.

Micro Gametogenesis:

This is the process by which male gametes are produced. The microspore nucleus divides mitotically to create a generative and a vegetative or tube nucleus during pollen maturation. In most cases, pollen is discharged in the binucleate stage. Pollination occurs when pollen adheres to a flower's stigma. Pollen germinates soon after pollination, growing through the style and entering the stigma. Two male gametes, or sperm, are now produced by a mitotic division of the generative nucleus. Microgametophyte is the term used to describe the pollen and the pollen tube together. Finally, through a tiny opening called a micropyle, the pollen tube enters the ovule and releases the two sperm into the embryo sac.

Pollen Grain:

- Pollen grain represents the male gametophytes. It is spherical in shape and measuring about 25-50 micrometer in diameter. It is covered by two layers.
- One of the recognized most resistant organic compounds is sporopollenin, which makes up the hard outer coat known as the exine. It is resistant to strong acids, alkalis, and high temperatures. As of yet, no known enzyme is able to break down sporopollenin.
- The exine has prominent apertures called germ pore where sporopollenin is absent. The inner wall of pollen grain is called intine. It is thin and continuous layer made of cellulose and pectin.

- On maturity the pollen grain contains two cells, the vegetative cell and, generative cell. The vegetative cell is bigger, has abundant food reserve and, a large irregularly shaped nucleus. The generative cell is small and floats in the cytoplasm of vegetative cell.
- In 60% of angiosperms, pollen grains are shed at this 2-celled stage. In others the generative cell divides mitotically to form two male gametes before pollen grain are shed (3-celled stage).

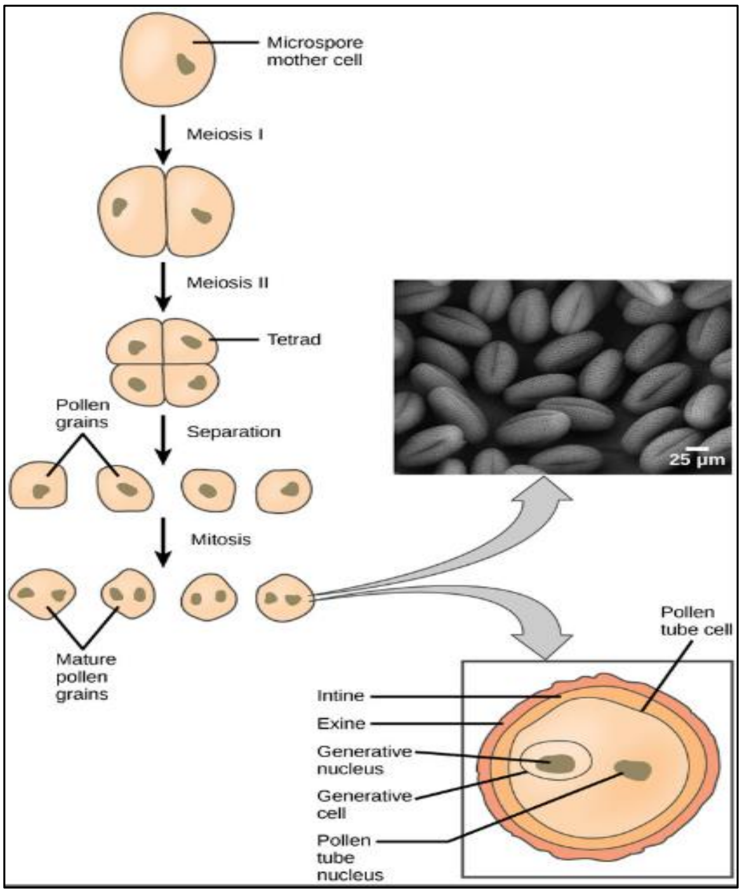


Figure 4.7: Process of Micro Sporogenesis and gametogenesis

Mega Gametogenesis:

A viable megaspore's nucleus divides mitotically to create four or more nuclei. The megaspore nucleus divides three times during mitosis in majority of the crop plants, yielding eight nuclei. A central egg cell and two synergid cells, which are located on either side of the egg cell, and three antipodal cells. A second nucleus is created when the two nuclei that are still in the center, known as the polar nuclei, unite. As a result, the megaspore matures into an embryo sac or megagametophyte. The process of a megaspore developing into an embryo sac is called mega gametogenesis. An embryo sac generally contains one egg cell, two synergids, three antipodal cells (all haploid), and one diploid secondary nucleus.

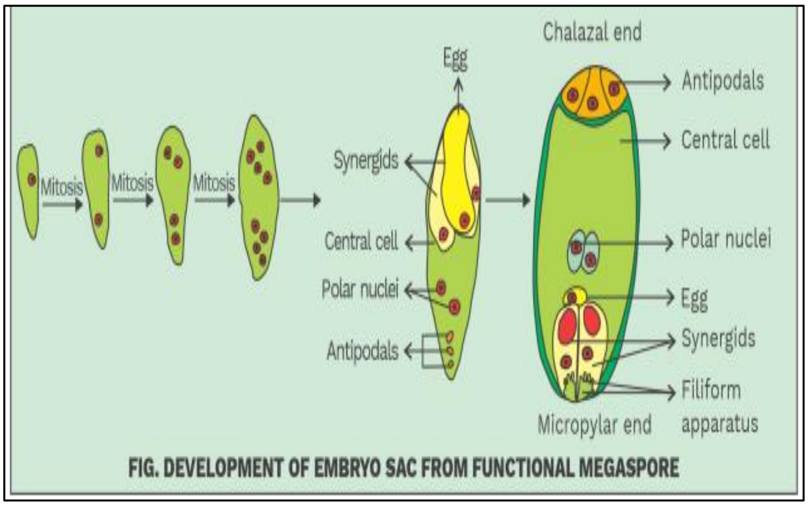


Figure 4.8: Development of Embryo Sac

4.3 Process of Fertilization:

Fertilization is defined as the fusing of one of the two sperm with the egg cell to produce a diploid zygote. Triple fusion is the production of a triploid primary endosperm nucleus through the fusion of the remaining sperm with the secondary nucleus. A diploid embryo is created during mitotic division of the zygote. Endosperm is produced by the primary endosperm nucleus through successive mitotic divisions. Endosperm supplies nourishment to the growing embryo during seed formation. In some monocots (like maize, wheat, etc.) and some dicots (like castor, Brassica spp., etc.), the endosperm may be fully absorbed, as in the case of legumes, or it may make up the majority of the seed.

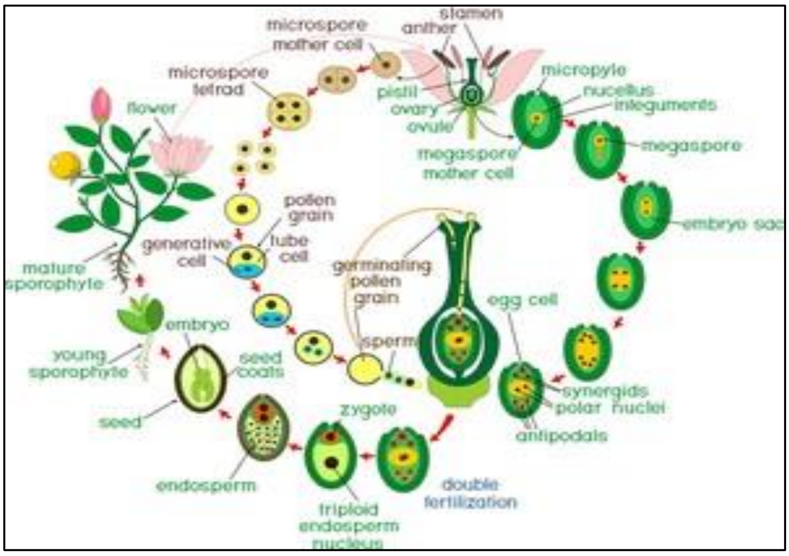


Figure. 4.9 Summarized View of Sexual Reproduction in Plants

4.4 Significance of Sexual Reproduction:

- Genetics from two or more parents can be combined during sexual reproduction to create a single hybrid. Many distinct genotypes are produced by recombination among these genes. This is a crucial stage in the hybridization process that produces genetic diversity.
- Sexual reproduction is the foundation of almost all plant breeding programmes. Inter-varietal hybridization takes place in the form of sexual reproduction.
- Sexual reproduction is employed to produce novel valuable genotypes even in asexually reproducing organisms, such as sugarcane, potatoes, sweet potatoes, etc.
- Sexual reproduction happens everywhere, to keep up the genetic diversity among almost all the species of the planet.
- Furthermore, sexual reproduction makes genetic analysis possible and makes the application of cutting-edge breeding technologies—such as gene and genome editing—possible.

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