SEXUAL REPRODUCTION IN FLOWERING PLANTS

FLOWER

- ✓ Reproductive unit of the flowering plants.
- ✓ Atypical bisexual flower consists of 4 different whorls – calyx, corolla, androecium and gynoecium.
- ✓ Calyx – outermost whorl consists of sepals.
- ✓ Corolla - composed of petals that are usually brightly colored.
- ✓ Androecium – represents the male reproductive organ.
  - o Composed of stamens.
  - o Each stamen is made up of Anther and a stalk / filament.
- ✓ Gynoecium – represents the female reproductive organ
  - o Composed of carpels.
  - o Carpels have 3 parts- stigma, style and ovary.
  - o Ovary is the basal enlarged portion.
  - o Style is the tubular structure that connects the stigma to the ovary.
  - o Stigma is the tip of the style that typically acts as the receptive surface for the pollen grains.
  - o Monocarpellary: gynoecium consisting of a single pistil.
  - o Multicarpellary: gynoecium consisting of more than one pistil.
  - o Syncarpous: When carpels are fused.
  - o Apocarpous: When carpels are free

PRE-FERTILIZATION: STRUCTURE AND EVENTS

➢ STAMENS, MICROSPORANGIUM AND POLLEN GRAINS

- ✓ ***Structure of stamen*** - Consists of 2 parts:
  - o Filament- Long, slender stalk
  - o Anther- Terminal, bilobed structure
- ✓ Proximal end of filament is attached to the base of flower (thalamus).
- ✓ ***Structure of Anther*** – Bilobed (2 parts of anther) and dithecous (Each lobe has 2 theca)
  - o A longitudinal groove separates the two theca.
  - o Due to the bilobed & dithecous nature the anther is tetragonal (four sided) structure.
  - o Each of the corner consists of one microsporangia, i.e. 2 microsporangia are present in each of the theca.
  - o Microsporangia develops into pollen sacs that contains the pollen grains.

➢ Structure of Microsporangia:

- ✓ In young anther, each of the microsporangium is consisting of sporogenous tissue surrounded by a total of 4 layers.
- ✓ The outer 3 layers (epidermis, endothecium & middle layer) perform the function of protection.
- ✓ The innermost layer (Tapetum) helps in nourishing the developing pollen grains.
- ✓ **Nature of the cells of Tapetum**

- Dense cytoplasm
- Possess more than one nucleus.

➢ Microsporogenesis

- ✓ Each of the cell of the sporogenous tissue acts as the pollen mother cell (PMC) or microspore mother cell.
- ✓ The process of formation of microspore from PMC is called microsporogenesis.
- ✓ The PMC undergoes meiotic cell division to form microspore tetrads (haploid cells arranged in cluster of 4 cells).
- ✓ The microspores dissociate from each other and give rise to the pollen grain as the anther matures and dehydrates.

➢ Male Gametophyte (Pollen Grains)

- ✓ It represents the male gametophyte.
- ✓ They have 2 layered wall.
  - Exine – outer layer, made up of sporopollenin.
    - Sporopollenin is resistant to high temperatures and strong acids and alkali.
    - They are also resistant to degradation by enzymes.
    - Due to this the pollen grains are well preserved as fossils.
    - Germ pore: Prominent aperture in the exine where the sporopollenin is absent.
    - Germ pore is essential for the pollen germination.
  - Intine – inner thin layer, made up of cellulose and pectin.
- ✓ Cytoplasm of the pollen grain is surrounded by plasma membrane.
- ✓ Matured pollen grains have 2 cells
  - Vegetative cell –
    - Bigger cell
    - Abundant food reserve
    - Large irregular shaped nucleus
  - Generative cell
    - Smaller cell
    - Floats in the cytoplasm of the vegetative cell
    - Dense cytoplasm
- ✓ In 60% angiosperms the pollen grains are released in 2 celled stage, while in the remaining 40% it is released in a 3 celled condition (generative cell divides mitotically to give rise to the two male gametes).
- ✓ Pollen grains can cause allergies and bronchial afflictions (infections), leading to asthma, bronchitis, etc. E.g. *Parthenium* or carrot grass
- ✓ Pollen products: pollen grains are rich in nutrients
  - Available in the form of tablets & syrups.
  - It can increase the performance of athletes & race horses
- ✓ Pollen Viability:
  - 30 Minutes: Cereals like Rice & Wheat.
  - Months: Members of Solanaceae, Rosaceae, Leguminoseae.
  - Years: Artificial means- Liquid Nitrogen (-196^0C)

➢ THE PISTIL, MEGASPORANGIUM (OVULE) AND EMBRYO SAC

- ✓ Each pistil consists of the stigma, style and ovary.
- ✓ The ovary contains the ovarian cavity (locule).
- ✓ The megasporangia (ovules) are located inside the ovarian cavity connected by placenta.
- ✓ The number of ovules depends on the plant species:
  - o One: wheat, paddy, mango
  - o Many: Papaya, water-melon, orchids

➢ Structure of Megasporangium (Ovule)

- ✓ Ovule connects with the placenta via a stalk called funicle.
- ✓ Hilum is the junction funicle and ovule.
- ✓ The protective layers of the ovule are called the Integuments (1 or 2 layers).
- ✓ Inner to the integuments are the nucellus.
- ✓ Integuments are present all around the nucellus except at a small opening called the micropyle.
- ✓ Chalaza end represents the basal part of the ovule, and is opposite to the micropylar end.
- ✓ The female gametophyte (embryo sac) is located inside the nucellus.
- ✓ Generally, the ovules have a single embryo sac.
- ✓ The embryo sac develops into the megaspore.
- ✓ Nucellar cells are rich in reserve food materials.
- ✓ The nucellus provides nutrition to the developing embryo sac.

➢ Megasporogenesis

- ✓ The process of formation of the megaspore from the megaspore mother cell is called megasporogenesis.
- ✓ A single megaspore mother cell (MMC) is formed in the micropylar region of the nucellus of the megasporangium (ovule).
- ✓ The MMC undergoes meiotic cell division resulting in 4 megaspores.

➢ Female Gametophyte (Embryo sac)

- ✓ The development of the embryo sac in majority of the flowering plants follows the monosporic development process.
- ✓ Out of the 4 megaspores only one remains functional while the remaining three degenerates.
- ✓ Only the functional megaspore develops into female gametophyte.
- ✓ The functional megaspore undergoes free nuclear cell division.
- ✓ Three mitotic nuclear division of the functional megaspore nucleus gives rise to a 8 nucleate stage of embryo sac.
- ✓ After this stage the six of the eight nuclei are surrounded by cell walls and are organized into six different cells.
  - o 3 of these cells move towards the chalazal end are called the antipodals.
  - o The remaining 3 cells move to the micropylar end and form the egg apparatus.
    - ▪ Egg apparatus consists of the egg cell and two synergids.
    - ▪ The synergids have special cellular thickenings called the filiform apparatus.
- ✓ The remaining two nuclei (polar nuclei) are placed in the large central cell.

- ✓ As a result of this organization, a typical angiospermic embryo sac, at maturity is 7-celled but 8-nucleate.

➢ POLLINATION

- ✓ In case of plants both gametes are non-motile.
- ✓ The transfer of pollen grains to the stigma of the pistil of the same flower or another flower is called pollination.
- ✓ This process occurs with the help of external agents – pollinating agents.

➢ Pollination Types: Based on the source of pollination.

- ✓ ***Autogamy*** : (Self-pollination)
  - Involvement of a single flower.
  - Pollen grains is transferred from the anther to the stigma of the same flower.
  - Complete autogamy is rare in a flower remains open with exposed anther and stigma.
  - Criteria for the autogamy.
    - Synchrony in pollen release and stigma receptivity.
    - Close proximity of the anther and stigma.
  - Plants with 2 types of flower – *Viola* (common pansy), *Oxalis*, and *Commelina*
    - Chasmogamous Flower: (Regular flower with exposed anther & stigma)
    - Cleistogamous Flower: (Flowers do not open at all)
      - Anther and stigma lie close to each other.
      - Pollen falls directly on the stigma upon pollen dispersal.
      - No need of the pollinating agents
      - No chance of cross pollination.
      - Advantage of Cleistogamous flower:
        - Production of assured seed-set even in the absence of pollinators.
      - Disadvantage of Cleistogamous flower:
        - Due to self-pollination variation may not be created.
        - Prevent the evolution of genetically superior variety.
- ✓ ***Geitonogamy*** : (Cross pollination involving one plant)
  - Pollen grains is transferred from the anther of one flower to the stigma of another flower but from the same plant.
  - It is functionally cross pollination.
  - Genetically it is similar to the autogamy as pollen grain is from one plant.
- ✓ ***Xenogamy*** : (Cross pollination involving different plant)
  - Pollen grain is transferred from anther of one flower to the stigma of another flower of a different flower.
  - Unites genetically different types of pollen grains.

➢ Agents of Pollination

- ✓ Biotic pollinating agents - living organisms: [used by majority of plants]
- ✓ Abiotic pollinating agents – Wind and Water

- ✓ *Why do plants produce a large amount pollen grains compared to the numbers of ovules available for pollination??*
    - *Ans- As the event of pollen grain coming in contact with the stigma is a chance factor, to compensate this uncertainty and the probable loss of pollen large amount of pollen grain is released.*

Pollination by wind - Anemophily

- ✓ Common in grasses.
- ✓ Nature of Flower:
    - Pollen grains are light weight.
    - The pollens are non-sticky.
    - Well exposed stamen.
    - Large feathery stigma.
    - Inflorescence consists of numerous flowers.
        - Example- corn cob

Pollination by Water – Hydrophily

- ✓ Rare – limited only to 30 plant genera (mostly monocotyledons)
- ✓ Example- *Vallisneria* and *Hydrilla* (Fresh water), *Zostera* (marine sea-grass)
- ✓ Pollination in *Vallisneria* :
    - Female flower reaches the top of the water surface
    - Male flower/pollen grains released on the water surface
    - The pollen grains reach the stigma via passive water current.
- ✓ Pollination in Seagrasses :
    - The female flower remains submerged in the water.
    - Pollen grains (long & ribbon shaped) are released inside the water.
    - Pollen grains reach the stigma via passive water current and achieve pollination.
- ✓ Property of pollen grain in water pollinated plant species
    - Presence of protective mucilaginous covering that prevents them from wetting.
- ✓ Aquatic plants like water hyacinth and water lily – follow pollination by insects or wind, as the flower reach the water surface.

Pollination by Biotic organisms

- ✓ Pollinating agents includes- Bees, butterflies, flies, beetles, wasps, ants, moths, birds (sunbirds and humming birds) and bats.
- ✓ Among the animals, insects, particularly bees are the dominant biotic pollinating agents.
- ✓ Other organisms - primates (lemurs), arboreal (tree-dwelling) rodents, or even reptiles (gecko lizard and garden lizard).
- ✓ Nature of flower :
    - Large flowers
    - Colorful
    - Fragrant and rich in nectar
    - Pollen grains are sticky
    - In case of small flower- many are clustered into an inflorescence.
- ✓ Animals are attracted towards flower due to the foul odours.
- ✓ Floral rewards are provided to sustain the animal visit.

- Pollen and nectar are floral rewards

✓ When the pollinator visits the flower to harvest the floral reward the bod of the pollinator gets a coating of the pollen.
✓ When these animals come in contact with stigma it brings about the pollination.
✓ Floral rewards as a safe place to lay egg
- E.g.-Amorphophallus – tallest flower
- E.g.- Yucca plant and a moth species.
  - They can't complete their life cycle without each other
  - Moth deposits the egg in the locule of ovary
  - The flower in turn gets pollinated by the moth
  - The moth larva comes out of the eggs as the seeds stat developing.

➢ Outbreeding Devices:

✓ Continued self-pollination result in inbreeding depression.
✓ As majority of the flowers are bisexual, there is a need for the plants to develop methods by which it can prevents self-pollination and promote cross pollination.
✓ The outbreeding devices enables them to achieve it.
- Pollen release and stigma receptivity are not synchronized,
- Different position of the stigma and the anther so that the pollen grains do not come in contact with the stigma
- Self-incompatibility: genetic mechanism that prevents the self-pollen from pollen germination or pollen tube growth.
- Production of unisexual flowers.

✓ In case of monecious plants (maize, castor) where both the male and female flowers are present on the same plant - it prevents autogamy but not geitonogamy.
✓ In case of dioecious plants (papaya) where both the male and female flowers are on different plants – it prevents both autogamy and geitonogamy.

➢ Pollen-pistil interaction

✓ All the events–from pollen deposition on the stigma until pollen tubes enter the ovule–are together referred to as pollen-pistil interaction.
✓ Pollination might lead to the deposition of pollen grains of various plant species.
✓ The process of pollination does not guarantee fertilization.
✓ Only if the right type of pollen (compatible pollen grain of the same species) is landing on the stigma, it might lead to fertilization.
✓ If the pollen grain is the right type (compatible) then the post-pollination events continues leading to fertilization.
✓ If the pollen grain is wrong type (incompatible) the pistil rejects it.
✓ An incompatible pollen is rejected by:
- Prevention of pollen germination
- Prevention of pollen tube growth

✓ The decision of compatible and non-compatible pollen is due to the continuous chemical talk between the pollen grain and the pistil.
✓ Pollen germination:
- Compatible pollen grain germinates to form pollen tube through germ pore.

- The content of the pollen grain moves into the pollen tube.

✓ Pollen tube travels through the style and reaches the ovary.
✓ It enters the ovule through the micropyle and then enters one of the synergids through the filiform apparatus.
✓ The filiform apparatus guides the entry of the pollen tube.

Artificial Hybridization:

✓ These refer to the crossing experiments in plants where only the desired pollen grains are used for pollination and the stigma is protected from contamination of unwanted pollen grains.
✓ It is one of the major approaches in the crop improvement program.
✓ Steps:
  - Emasculation: Removal of anthers (in case of bisexual flower) before the dehiscence of anther.
    - In case of unisexual flower this step is not necessary.
  - Bagging: Covering of the emasculated flower with a bag (butter paper) of suitable size to prevent contamination of stigma by unwanted pollens.
  - Controlled pollination: When the stigma matures, the matured pollens from a desired male parent is dusted on it and the flower is rebagged and further development is allowed.

DOUBLE FERTILIZATION

✓ The pollen tube releases two male gametes to the cytoplasm of the synergids.
✓ One male gamete fuse with the nucleus of the egg forming a diploid cell called zygote.
  - This fertilization event is called syngamy.
✓ The remaining male gamete fuse with the two polar nuclei of the central cell and produces primary endosperm nucleus (PEN) that is triploid in nature.
  - This fertilization event is called triple fusion as it involves the fusion of 3 haploid nuclei.
✓ As there are two fertilization events taking place at the same time in the embryo sac, this phenomenon is called double fertilization.
  - This event is unique to the angiospermic plants.
✓ Fate of double fertilization:
  - The central cell after triple fusion becomes Primary endosperm cell and develops into Endosperm.
  - The zygote divides and develops into the embryo.

POST FERTILIZATION: STRUCTURE AND EVENTS

✓ This phase involves the following:
  - Endosperm development
  - Embryo development
  - Maturation of ovules into seeds
  - Maturation of ovary into fruits

➢ ENDOSPERM

- ✓ Development of the endosperm starts prior to the embryo development.
  - The PEN divides and forms the endosperm tissue.
  - The cells are filled with reserve food materials.
  - They provide nutrition to the developing embryo.
- ✓ Endosperm development:
  - PEN undergoes repeated division to give rise to the free nuclei (free nuclear endosperm)
  - The free nuclear endosperm forms the cellular endosperm when they undergo cellularization.
- ✓ Example – Coconut
  - Free nuclear endosperm: tender coconut water
  - Cellular endosperm: white kernel (edible part)

➢ EMBRYO

- ✓ The embryo develops from the zygote in the micropylar region of the embryo sac.
- ✓ Stages of embryogeny (embryo development):
  - Proembryo
  - Globular stage
  - Heart-shaped stage
  - Mature embryo
- ✓ Component of dicot embryo:
  - an embryonal axis and two cotyledons
  - Epicotyl: portion of embryonal axis above the level of cotyledons.
    - Terminates with Plumule (future shoot)
  - Hypocotyl: Cylindrical portion below the level of cotyledons.
    - Terminates with radicle (future root)
    - The root tip (radicle) is covered with root cap.
- ✓ Monocot Embryo:
  - Consists of only one cotyledon
  - Scutellum: Cotyledons of grass family
  - Coleorrhiza: Sheath of the radical and root cap
  - Coleoptile: Hollow foliar structure that encloses the shoot apex and few leaf primordia.

➢ SEED

- ✓ Developed from the fertilised ovule.
- ✓ Components of seed:
  - seed coat(s)
  - cotyledon(s)
  - an embryo axis.
- ✓ Non-albuminous seeds:
  - Matured seeds with no residual endosperm
  - E.g.- Pea, Groundnut

- ✓ Albuminous seeds:
  - Matured seeds with residual endosperm
  - E.g.- wheat, maize, barley, castor
- ✓ Perisperm: The residual, persistent nucellus in seeds.
  - E.g.- black pepper, beet
- ✓ Seed Development:
  - Seed coat develops as the integuments hardens.
  - Micropyle remains as a small pore in the seed coat.
    - Essential to facilitates the entry of oxygen and water for seed germination.
  - When the seed matures, it becomes dry & the metabolic rate of the embryo slows down.
  - At this stage the embryo enters the dormancy stage.

➢ Fruit

- ✓ It is developed from the ovary.
- ✓ The ovarian walls develop into the fruit wall.
- ✓ Types of fruit
  - Fleshy fruit : guava, orange, mango, etc.,
  - Dry fruit : groundnut, and mustard, etc.
  - True fruit: when fruit is developed from ovary
    - E.g.- Mango, Pea, etc.,
  - False fruit: fruit developed from parts other than ovary like thalamus
    - E.g.- apple, strawberry, cashew, etc.,

➢ Parthenocarpy

- ✓ Development of fruit without fertilization.
- ✓ The fruit developed by this process is called parthenocarpic fruit.
- ✓ They are generally seedless.
- ✓ E.g.- pineapple, banana, cucumber, grape, orange, etc.
- ✓ Can be induced with the help of hormones.

➢ Advantage of seeds:

- ✓ Pollination and fertilization are independent of water, seed formation is more dependable.
- ✓ seeds have better adaptive strategies for dispersal to new habitats.
- ✓ They can nourish the young seedlings as they are rich in reserve food materials.
- ✓ The Hard seed coat provides protection to the embryo.
- ✓ Produce new genetic combinations leading to variations, as they are the product of sexual mode of reproduction.

➢ Seed Viability:

- ✓ Ability of seed to remain alive after their dispersal.
- ✓ It can be few months to several years.
- ✓ Oldest recorded Viable Seed: Lupine(*Lupinus arcticus*) excavated from Arctic Tundra.
  - 10000 years of dormancy.
- ✓ Date Palm (*Phoenix dactylifer*) : 2000 years old viable seed

APOMIXIS & POLYEMBRYONY

Apomixis

- ✓ It is a form of asexual reproduction that mimics sexual reproduction.
- ✓ Process of production of seeds without fertilization.
- ✓ Example- Some species of Asteraceae and grasses.
- ✓ Method-1:
  - Diploid egg cell is produced without reduction division and it develops onto embryo without fertilization.
- ✓ Method-2:
  - Nucellar cells surrounding the embryo sac starts dividing, protrudes into the embryo sac and develops into embryo. (Citrus, Mango)
  - Such cases each ovule have more than one embryo – **POLYEMBRYONY**

Hybrid Seeds and Apomixis

- ✓ Cultivation of hybrids has tremendously increased productivity
- ✓ Problems with Hybrid Seeds:
  - Hybrids seeds has to be produced every year.
  - Seeds obtained from hybrid plants when grown, tend to segregate and loose the hybrid traits.
  - Cost factor
- ✓ Solution to this problem
  - Apomictic Hybrid Seeds
  - As there is no fertilization, there will be no segregation in the hybrid progeny.
  - The farmer can use the apomictic hybrid seeds for many years to raise the crop and need not buy the seed every year.
- ✓ Because of its importance there is active research going on to understand the genetics of apomixis and to transfer apomictic genes into hybrid varieties.

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