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SEXUAL REPRODUCTION IN FLOWERING PLANTS

- Sexual reproduction is the process of development of new organisms through the formation and fusion of gametes.
- The flower is the main structure concerned with reproduction, The reproductive organs or the sporophylls are produced within the flowers. The sporophylls are of two types microsporophylls (stamen) and megasporophylls (carpel)
- Stamen is distinguished as filament, anther and connective.
- Carpel is distinguished as ovary bearing ovule, style and stigma
- The whole process of sexual reproduction in flowering plants can be divided into three steps

i) Pre-fertilization
ii) Double fertilization
iii) Post-fertilization

PRE-PERTILISATION : STRUCTURE AND EVENTS

The pre-fertilisation events can be studied under following points

i) Pollen grain formation
ii) Embryo sac formation
iii) Pollination
iv) Pollen pistil interaction

POLLEN GRAIN FORMATION

Male reproductive unit (Stamen)

- A stamen is the male reproductive unit of angiosperms. It consists of an anther and a filament. The anther is bilobed and the lobe encloses four pollen sacs or microsporangia. Each pollen sac contains number of pollen grains. The four pollen sacs in a dithecous anther appear to lie in the four corners of anther
- The wall of anther consists of four layers of cells
- An anther dehisces by slits to liberate pollen grains

Anther development

- The anther initiates its development in the form of a homogenous mass of a meristematic cells surrounded by epidermis. It becomes four lobed and four longitudinal rows of aechesporial cells are differentiated. Each of these cells divides to form a primary parietal cell and a primary sporogenous cell. The parietal cell divides several times to form the anther wall and the sporogenous cell divides a few times to form the microscopes or pollen mother cells (PMC). The innermost layer of cell wall in contact with the PMC's form the tapetum which plays a significant role in pollen development. The layer below the epidermis later becomes the endothecium.

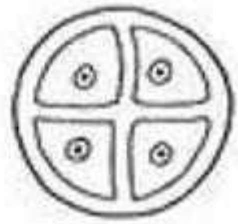
Wall layers of anther

- Epidermis – one cell thick and protective in function
- Endothecium – Second wall layer usually single layered. Cells have a cellulose thickening with a little pectin and lignin. It help in anther dehiscence
- Middle layers – The number of middle layer ranges from 1-6. The middle layer degenerate at the maturity of the anther
- Tapetum – This is the innermost layer of anther wall which surrounds the sporogenous tissue. Tapetal cells are nutritive. They are multinucleated and polyploidy. In these cells the ubisch bodies which is deposited in the exine of microscope wall. The tapetum is of two types
  - (i) Secretary / glandular – The tapetal cells remain in situ all through the development of microscope and finally they degenerate.
  - (ii) Amoeboid / periplasmodial – The radial wall of tapetum cell break up releasing the protoplast into the pollen chamber. All such protoplast now fuse to form the periplasmodium.

Microsporogenesis

- The formation and differentiation of microspore is called microsporogenesis. The PMCs divide meiotically each forming generally tetrahedral tetrads, Cytokinesis may be successive or simultaneous.
- Successive type is advanced type. Tetrad are of five types, tetrahedral, isobilateral, decussate, T shaped, linear tetrahedral is most common
- In successive type, the cell wall is formed after meiosis –I as well as meiosis –II thus an isobilateral pollen tetras is formed. It is a characteristic feature of monocot
- In simultaneous type, each nuclear division in microspore mother cell is most followed by cell wall formation

Tetrahedral



Isobilateral

Decussata

Linear

T-shaped

- The microspores separate from the tetrahedral configuration and get surrounded by a two layered wall, outer exine and inner intine. The pollen grains are the first cells of the male gametophyte.
- The tapetum get used up, the anther becomes dry structure and pollen are liberated by dehiscence of the anther.
- Mostly, all the four nuclei in a tetrad remain functional to form four microspores. However, in cyperaceae only one functions and therefore only one microspore instead of four is formed by one meiosis. In some cases, all the four pollens remain attached forming compound pollen grains e.g. Juncus jatropha. In family asclepiadaceae and orchidacae, all the microspores in a sporangium adhere together in a single mass called pollinium.

Pollen grain

- Pollen grains may be oval, ellipsoidal, triangular, lobed or even crescent shaped. It is generally round with size of 25 - 30μm
- Pollen grain is haploid, unicellular body with single nucleus. Therefore is an outer wall and 2-3 celled interior.
- Wall or sporoderm is made of two covering, outer thick exine of sporopollenin and inner thin intine of pecto-cellulose
- The outer layer exine is thick and sculptured or smooth. It is cuticularised and cutin is of special type called sporopollenin which is resistant to chemical and biological decomposition so pollen wall is preserved for long periods. It also possess proteins for enzymatic and compatibility reactions.
- Exine is differentiated into inner endexine and outer ektexine. Ektexine is further divided into inner continuous foot layer, middle discontinuous baculate layer and outermost discontinuous tectum.
- Tectum is helpful for identifying pollen grain and referring them to their family, genus or species.
- Exine is absent over certain areas called germ pores when circular or it is called germ furrow when elongated
- In insected pollinated pollen grain, exine is covered with yellowish, viscous and sticky substance called pollenkitt. Pollenkitt act as an insect attractant and protects the pollen from UV rays
- Intine is thin and elastic. It is made up of cellulose and pectin. It emerges out as the pollen tube from the germ pores during germination
- Internally pollen grains have cytoplasm which is rich in starch and unsaturated oils. Uninucleated protopeast becomes 2-3 celled at the later stages of development.
- In calotropis and orchids, the pollen of each anther lobe formed a characteristics mass called pollinium
- Pollen grains can be monoclopate (having one germ pores),bicolpate(two germ pores) and triclopate (3 germ pores).
- The branch of study of pollens is called palynology

Development of male gametophyte

- Size of nucleus in pollen grain increases and it divides mitotically to produce a bigger vegetative cell or tube cell and smaller generative cell
- Pollination can occur in two celled (tube + generative) or three-celled (tube + two male gametes)

- However, in plants such as cereals, the male gametes while the pollen is still within the anther. In those cases, where pollen is shed at two celled stage, the generative cell divides after pollen has landed on stigma.
- The cytoplasm contents of generative cell do not possess much of stored food material. Vegetative cell contains fat, starch and protein granules.

Pollen products

(i) Pollen food supplements : Pollen grain contains abundant carbohydrates and unsaturated fat. They are used in form of tablets and syrups for enhancing vital body functions. Pollen consumption increases performance and used by athletes and given to race horses

(ii) Pollen creams : Pollen grain protect themsevles from UV rays. Thus they are used in creams, emulsions for providing smoothness and protection to skin.

Pollen viability

The period for which pollen grains remain viable or functional is called pollen viability. It depends upon temperature, humidity. Pollen grains remain viable in 30 minutes. Pollen grain can be cryopreserved in liquid nitrogen (temp – 196^{O}C) and used as pollen banks.

Pollen allergy

Pollen grain produce severe allergy. It causes have fever and common respiratory disorders are asthma, bronchitis. Carrot grass (Parthenium hysterophorus) that came in India along with imported wheat is major source of pollen allergy besides harming internal body organs.

FEMALE REPRODUCTIVE UNIT (Pistil)

- The pistil or gynoceium of a flower is the female reproductive unit
- A carpel or pistil has a stigma or receptive region for pollen grains, a stalk or style and basal swollen region or ovary. Ovary contains one to several ovules
- Ovule is integumented megasporangium which on fertilization ripens into a seed. It is oval and whitish.
- The ovule is attached to placenta by means of a stalk called funiculus or funicle. The point of attachment of funicle to the ovule is known as hilum. A raphe (ridge) is formed by the fusion of funiculus with the body of ovule.

— The actual megasporangium equivalent is a parenchymatous tissue called nucellus. It may be thin (tenuinucellate, e.g. compositae) or massive (crassinucellate e.g casuarinaceae)

— On the basis of number of integuments, ovules are of following types

(i) Unitegmic – With one integuments, higher dicots e.g. composital, gymnosperms

(ii) Bitegmic – Ovules with two integuments (monocots and primitive dicots like cruciferae and malvaceae)

(iii) Tritegmic – With three integuments (Asphodelus)

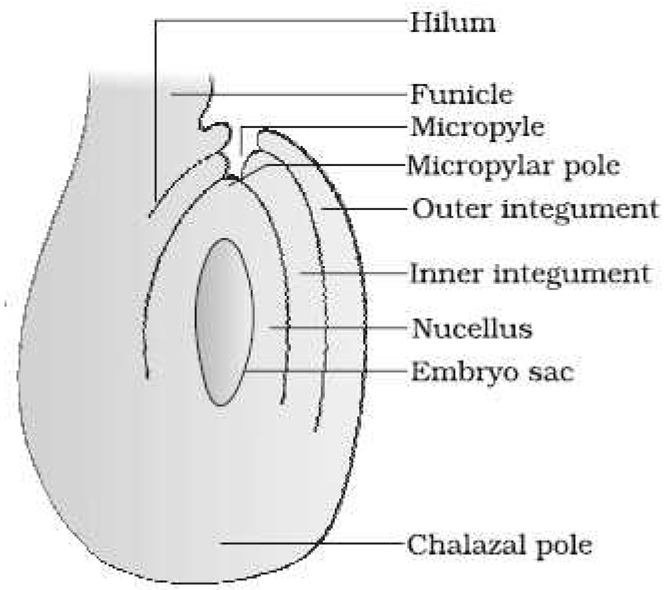
(iv) Ategmic – Without integument (Santalum, Loranthus, Ziriosoma and olax)

— Place of origin of integuments is called chalaza, A pore is present in the integuments at one end. It is known as micropyle. The inner region of integument may provide nourishment to developing embryo sac and it is called endothelium. Outer side of each integument as well as nucellus possesses cuticle.

— In castor bean (Ricinus) proliferation of the integumentary cells at micropylar region is called caruncle. It performs two functions

I. It acts as water absorbing pas and helps in seed germination

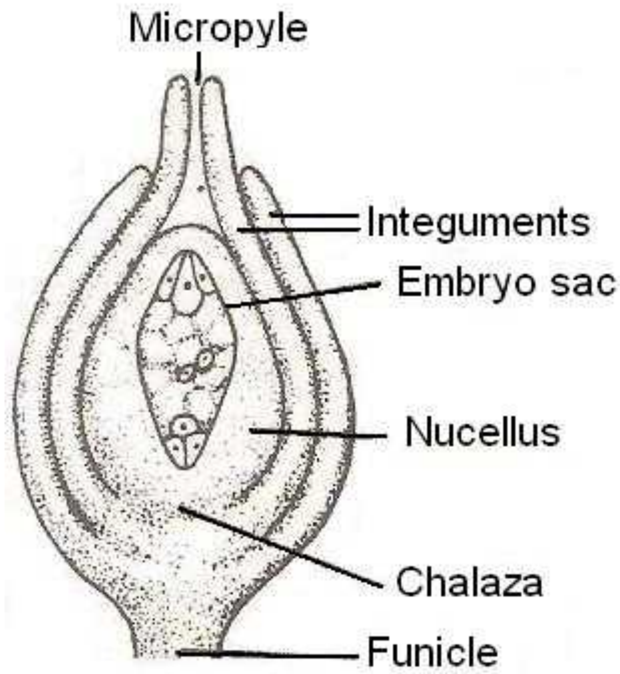
I. It is made up of sugary substance and thus seed dispersal occurs by ants.



Forms of ovule

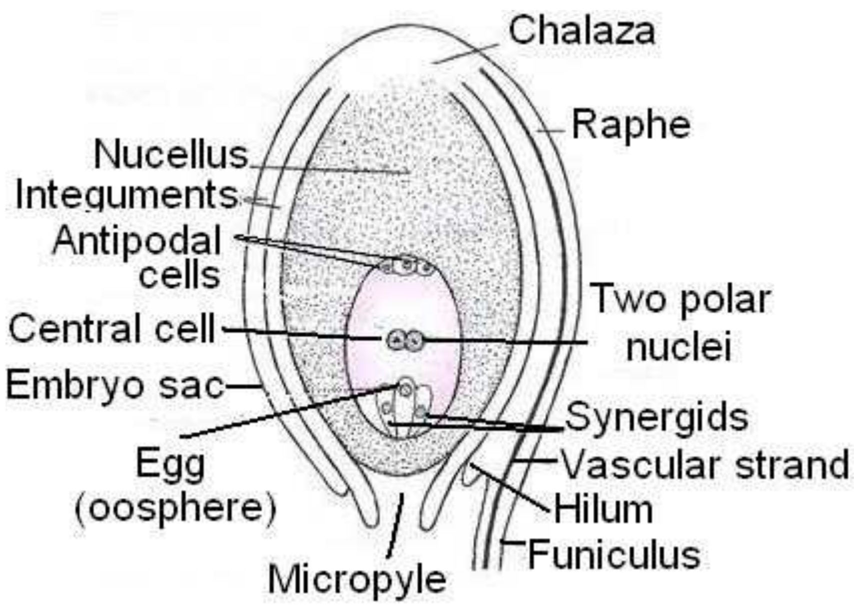
1. Orthotropous (Erect)

The body of the ovule lies straight and upright over the funicle. Hilum, chalaza and micropyle occurs on the same line. E.g. Polygonum

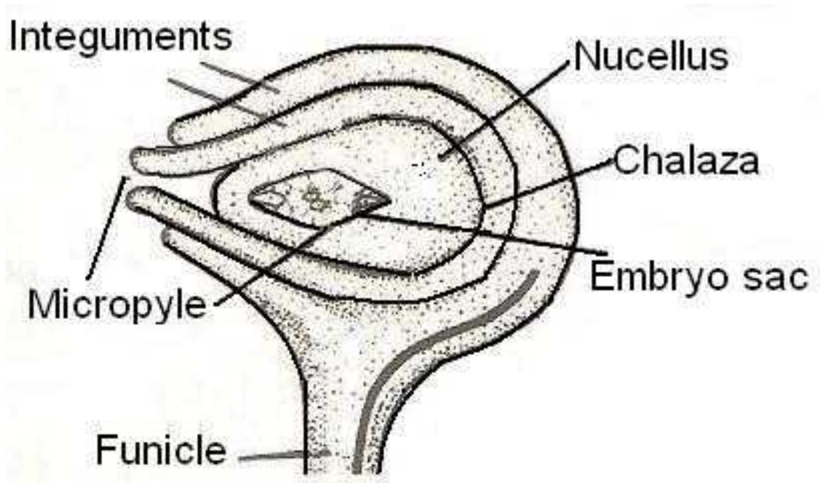


Orthotropous ovule

2. Anatropous (Inverted)
   The body of ovule is inverted and gets fused with funicle forms ridge called raphe. Hilum and micropyle are nearby with chalaza on opposite sides. It is the most common type of ovule. E.g. Ranunculus

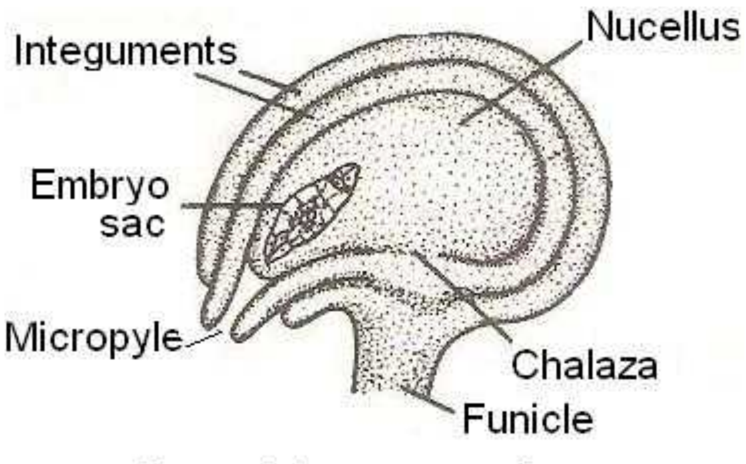


3. Hemianatroppous
   The body of ovule is placed at right angle (90^o) to the funicle e.g. Malpighiaceae.



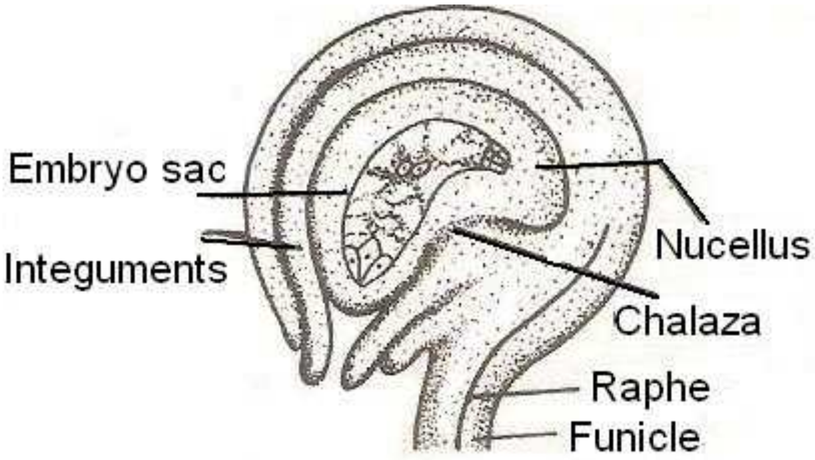
Hemianatropous ovule

4. Campylotropous
   The body is curved but embryo sac is straight. Hilum, chalaza and micropyle come nearby e.g. Caspells, Capparis, Chenopodiaceac



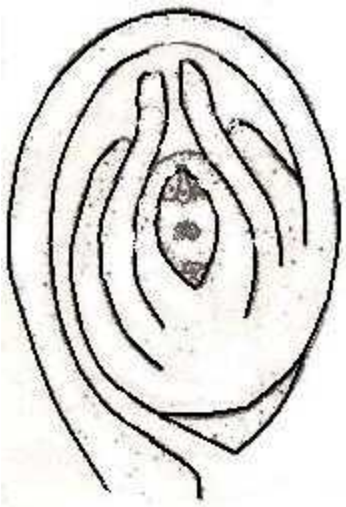
Campylotropous ovule

5. Amphitropous
   Both body of ovule and embryo sac are curved e.g. crucifers



Amphitropous ovule

6. Circinotropous
   The ovule turns at morethan 360^O angle so funicle becomes coiled around the ovule. Example opuntia.


Circinotropous Ovule

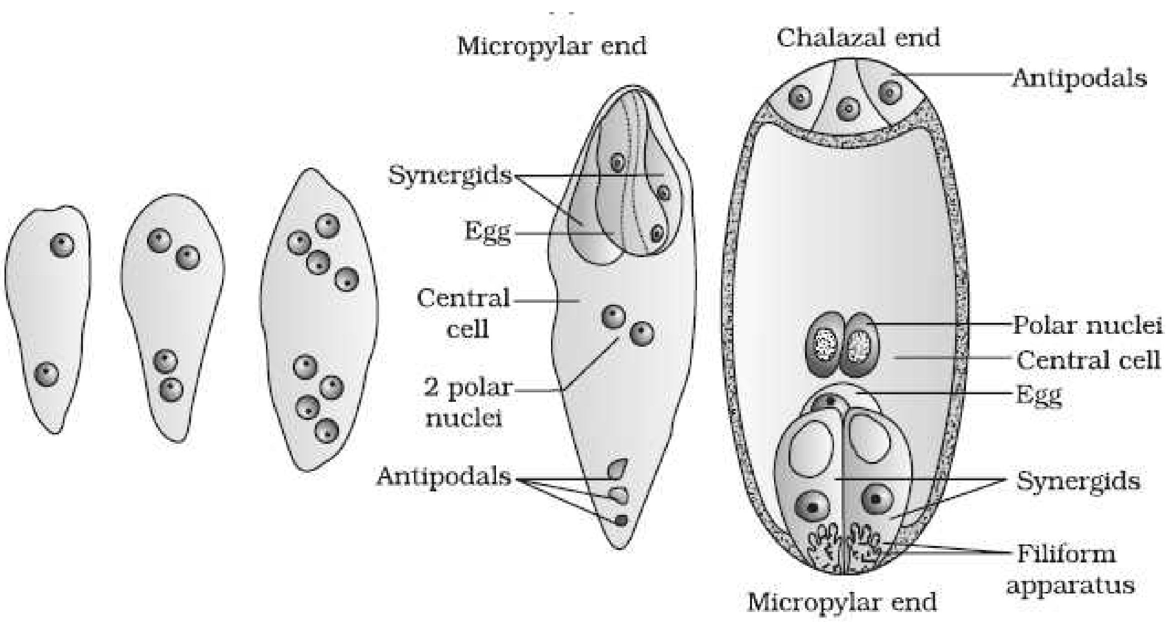
Megasporogenesis

— The process of formation of megaspores from megaspore mother cell is called megasporogenesis. Ovules generally differentiate a single megaspore mother cell (MMC) in micropylar region of the nucellus. It is a large cell containing dense cytoplasm and prominent nucleus. The MMC undergoes meiotic division. Meiosis results in the production of four megaspores

- In a majority of flowering plants, one of the megaspores is functional while the other three degerate Only the functional megaspore develops into the female gametophyte. This method of embryo sac formation from single megaspore is termed monosporic development

Formation of embryo sac

- The nucleus of the functional megaspore divides mitotically to form two nuclei which move to the opposite poles, forming the two nucleate embryo sac. Two more sequential mitotic nuclear division results in formation of four nucleate and later eight nucleate stages of embryo sac.
- These mitotic division are strictly free. i.e. nuclear divisions are not followed immediately by cell wall formation. After the eight nucleate stage, cell walls are laid down leading to the organization of the typical female gametophyte or embryo sac.
- Six of eight nuclei are surrounded by cell walls and organized into cells, the remaining two nuclei, called polar nuclei are situated below the egg apparatus in the large central cell
- Three cells are grouped together at the micropylar end and constitute the egg apparatus. The egg apparatus consists of two synergids and one egg cell. The synergids have special cellular thickenings at the micropylar tip called filiform apparatus, which play an important role in guiding the pollen tubes into the synergid. Three cells are at chalazal end and are called the antipodals. Thus a typical angiosperm embryo sac, at maturity, though eight nucleate is seven celled.



Pollination

- Pollination refers to the process of transfer of pollen grains from anther and their deposition on stigmatic surface of the flower
- Pollination is of two types self pollination and cross pollination

  Self pollination

  Self pollination is the transfer of pollen grains from anthers to the stigma of same or genetically similar flower

  Self pollination is of two types : autogamy and geitonogamy

1. Autogamy

   It is a self pollination which occurs between anther and stigma of the same flower.

   a) Chasmogamous devices

      When the flower expose their mature anther and stigma to the pollinating agents.

      In Lilac the stigma lies exactly below the anthers

   b) Cleistogamy

      The flowers remain close so there is no alternative self pollination.

      Examples: Pisum, Lathyrus, commelina, benghalensis

   c) Bud pollination

      Anthers and stigma of bisexual flowers mature before opening of bud and thus self pollination takes place at the time of bud stage e.g. pea, wheat etc.

2. Geitonogamy
   It is transfer of pollen grain from anther of one flower to stigma of another flower of same plant or genetically similar plants

   Advantages of self pollination

— It maintains purity of the race
— The plant does not need to produce large number of pollen grains
— It ensures seed production
— Self pollination eliminates bad recessive characters.

   Disadvantages of self pollination

— Variable and hence adaptability to changed environment reduced.
— Vitality decreases and ultimatey leads to degeneration.

Cross pollination

— It is defined as the deposition of pollen grains from anther of a flower to the stigma of a different flower of another plant of same or different species. It is also known as allogamy
— In Xenogamy, pollination takes between two flowers of different plants (genetically & ecologically)

Devices for cross pollination

1. Dicliny: There are two types of flowers, male and female. The plants may be monoecious or dioecious
2. Dichogamy: Anther and stigmas mature at different times
   (i) Protandry: Anthers mature earlier. E.g, Salvia, clerodendron, sunflower, rose
   (ii) Protogny : Stigmas mature earlier. E.g. plantago, magnolia, mirabilis
3. Self sterility : Pollen grains are incapable of growing over the stigma of the same flower e.g. Tobacco, some crucifers. Quicker growth of pollen on another plant than pollen of same plant is called prepotency (e.g. apple)
4. Heterostyly: Flower have two or three heights of styles and stamens. Primula and Jasminum have two types of flower (dimorphic heterostyly) , pin-eye (long style and short stamen) and thrum-eye (short style and long stamens) Some plants have trimorphic (3) hetrostyly e.g. Lythrum, oxalis.

5. Herkogamy : It is the presence of natural or physical barrier between androecium and gynoecium which help in avoiding self pollination. In calotropis stignui, gynoecium is fused with pollinium and form gynostegium

Advantages of cross pollination

— Cross pollination introduces genetic recombinations and hence variation in offspring.
— Cross pollination increases the adptability of the offspring towards changes in environment.
— The defective character of race is eliminated and replaced by better character.

Disadvantages of cross pollination

— Plants have to produce a large number of pollen grains
— The very good character are likely to be spoiled
— As external agency is involved chance factor is always there

Agents of pollination

Anemophily (wind pollination) characteristics

(i) Pollens are very light. They may have air sac or wings
(ii) Flowers are small and are colourless, odouless
(iii) Pollen grains are dry
(iv) Anthers have long filament and are abundant
(v) Stigmas are sticky and feathery.
Examples : Date palm, coconut, grass, willow, maize, jowar, cannabis, mulberry.

Hay fever is allergic reaction due to presence of pollen in air

Hydrophily (water pollination) characteristics

(i) Flowers are small and colourless, odourless, nectarless
(ii) Stigma is long, sticky and unwettable

Water pollination is of two types

(a) Epihydrophily (on surface of water e.g. Vallisneria)
(b) Hypohydrophily (inside water) e.g. zostera, ceratophyllum. Pollen grains are without exine and often elongated. Vallisneria is dioecious. Male plants

produces a large number of male flowers, which after breaking, rise upwards in closed state and open on surface of water. The female plant produces flowers that brings it on surface of water with the help of long pedicels. After pollination, the female flower is brought down into water

Entomophily (Insect pollination) characteristics

(i) Flowers are coloured. Bluish-purplish – violet – yellow flowers attracts bees while reddish flowers attract butterflies and wasps.
(ii) Flowers commonly posses an aroma or scent
(iii) Visiting insects are fed by either nectar and pollen
(iv) Pollen grains are sticky due to pollenkitt
(v) Stigmas are sticky

Ornithophily (Bird pollination)

- Pollination by birds is common is coral tree, bottle brush and silk cotton tree
- Two types of long –beasked small birds take place pollination – sun birds and hummingbird
- Other birds are Bulbul, parrot, crow etc
- Ornithophilous flower are large and strong with abundant nectar and edible part. Example Bombax, agave, Butea, Bignonia

Chiropterophily (Pollination by bats)

- The flowers they pollinate are large dull coloured and produce strong aroma
- Chiropterophilous flower produce abundant pollen grains and secrete more nectar than the orinthophilous flower.
- Bats carry out the pollination in Adansonia and kigelia

Malacophily (pollination by snails)

Snails perform pollination Arisaema (snake orcobra plants)and some arum lilies

Myrmecophily (pollination by ants)

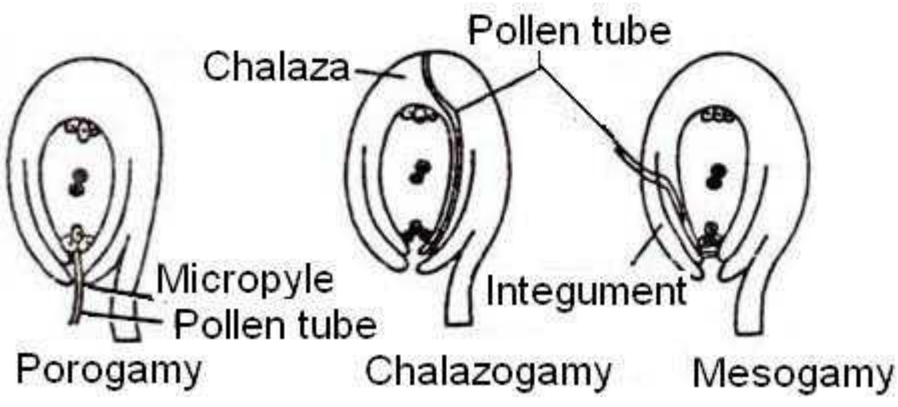
- Plants pollination by ants are called myrmecophytes examples some members of family rubiaceae.

Significance of pollination

- Pollination leads to fertilization and production of seeds and fruits, which ensure continuity of plant life
- It stimulates growth of ovary.
- It results in production of hybrid seeds
- The seeds and fruits are also a source of nutrition

Post pollination events

- The nucleus of the pollen grain divides to produce vegetative and generative cells. A short outgrowth called germ tube, emerges from the pollen and secrete enzymes which digests the tissues of stigma and continues to grow as pollen tube
- The generative nucleus divides to form two male nuclei, which become surrounded by cytoplasmic masses and appear as distinct male gametes
- The pollen tube grows through the stigma and passes into the tissues of style.
- Depending upon the region of entry into ovule. These are:-
    i) Porogamy : The entry of pollen tube into the ovule through micropyle e.g. ottelia
    ii) Chalazogamy: The entry of pollen tube into the ovule through chalaza e.g. Casuarina
    iii) Mesogamy: The entry of pollen tube through funicle or integuments e.g. cucurbita.
- Generally pollen tube enters the ovule through micropyle and enters synergids through filiform apparatus. Filiform apparatus guides the entry of pollen tube.



Pollen – pistil interaction

- Only the compatible pollen of the same species are able to germinate. Germination is connected with compatibility incompatibility reaction between proteins present over the pollen grains and stigma.
- Plant breeders are able to obtain hybrid between different species.
- If the female parent bears bisexual flowers, removal of anthers from the flower bud before the anther dehisces using a pair of forceps. This step is referred to an emasculation.
- Emasculated flowers have to be covered with a bag of suitable size, generally made up of butter paper, to prevent contamination of its stigma with unwanted pollen. This process is called bagging.

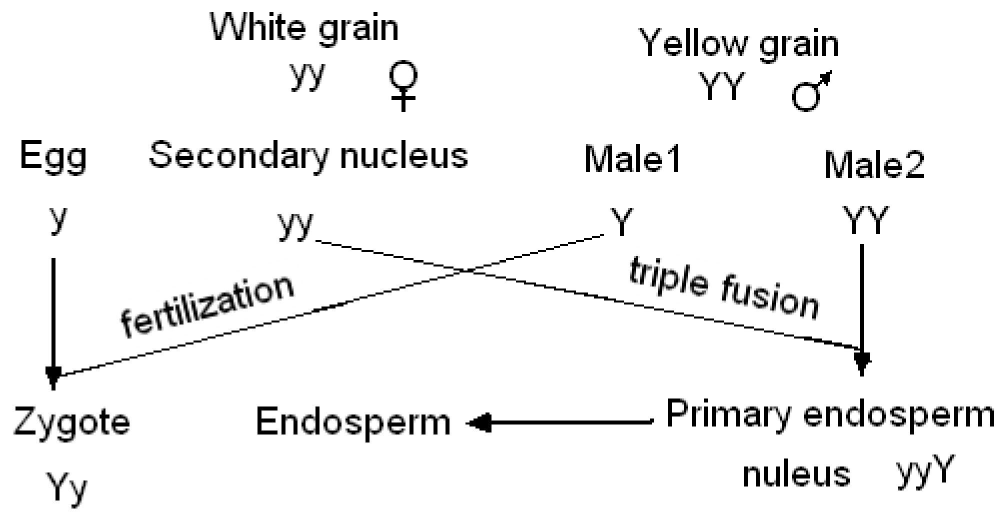
DOUBLE FERTILIZATION

- Fertilization is defined as the fusion of male and female gametes to form the zygote which eventually develops into an embryo.
- Two male gametes are discharged into embryo sac through pollen tube. One of the male gametes fuse with the egg, resulting in the production of diploid zygote. This is called syngamy or also called generative fertilization
- The second male gametes fuses with two polar nuclei, producing a triploid primary endosperm nucleus. This is called triple fusion and is also known as vegetative fertilization.
- In an embryo sac there occur two sexual fusion – one in syngamy and other in triple fusion. This phenomenon is called double fertilization.

POST FERTILIZATION : STRUCTRE AND EVENTS

Endosperms

- Endosperm is a nutritive tissue formed from vegetative fertilization. Endosperm is meant for nourishing the embryo. It is generally triploid
- Since endosperm develops fully in the fertilized ovule, it may show the effect of genes present in the male gamete. The phenomenon is called xenia.
- The direct or indirect effect of pollen on structure inside embryo sac except embryo has been termed by Focke 1881 and limited to endosperm part. It is seen in Zea mays (maize) alone.



- The metaxenia may be defined as the effect of pollen on the seed coat or pericarp lying outside the embryo sac
- Depending upon its mode of development endosperm is of three types

1. Nuclear endosperm

- Primary endosperm nucleus divides to form a large number of free nuclei
- A central vacuole appears and massive peripheral multinucleate cytoplasm is formed. Wall formation occurs and central vacuole disappears. Example maize, wheat, rice.
- In coconut there is an outer multicellular solid endosperm and inner free nuclear liquid endosperm in the centre.

2. Cellular endosperm

- Wall formation occurs after every division of primary endosperm nucleus, so that endosperm is cellular from the beginning e.g. Datura, balsam, Petunia

3. Helobial endosperm
   First division produces two cells within each of which free nuclear division occur but ultimately they may also become cellular. E.g. Eremurus, Asphodelus.

Functions of endosperms are

(i) In plants with albuminous seeds the endosperm reserves support early seedling growth.

(ii) Endosperm provides nutrition to developing embryo

(iii) Liquid endosperm of coconut contains auxins, cytokinins and GA and induces cytokinesis. When added to basic nutrient medium. Coconut milk also induces the differentiation of embryo and plantlets from various plant tissues

(iv) Zeatin, a very potent cytokinin is extracted from the young endosperm of maize.

Embyrogeny (embryo formation)

— It is the development of mature embryo from zygote or oospore
— Early development produces a pro embryo which has an axial symmetry. Embryo passes through globular stage.
— Development of embryo is endoscopic or on inner side because of presence of suspensor.
— Dicot embryogeny (crucifer / onagrad type)
— Zygote divides into two unequal cells, larger suspensor cell towards micropyle and a smaller embryo cell towards antipodal region.
— The suspensor undergoes transverse division forming 6-10 celled suspensor. The first cell of suspensor is called haustorium and last cell (towards embryo cell) is called hypophysis. It forms radical.
— Embryo cell divides twice. Vertically and once transversely to produce a two tired eight called embryo. The epibasal (terminal) tier forms two cotyledons and a plumule while the hybobasal (near the suspensor) tier produces only hypocotyls. It is initially globular than becomes heart shaped and further assumes typical shape.
— A typical dicotyledonous embryo consists of an embryonal axis and two cotyledons. The part of embryonal axis above the level of cotyledons is called epicotyle. It terminates with the stem tip, called plumule (future shoot)
— The part below the level of cotyledons is called hypocotyls which terminates in the root tip called radical (future root) The root tip is covered with root cap.
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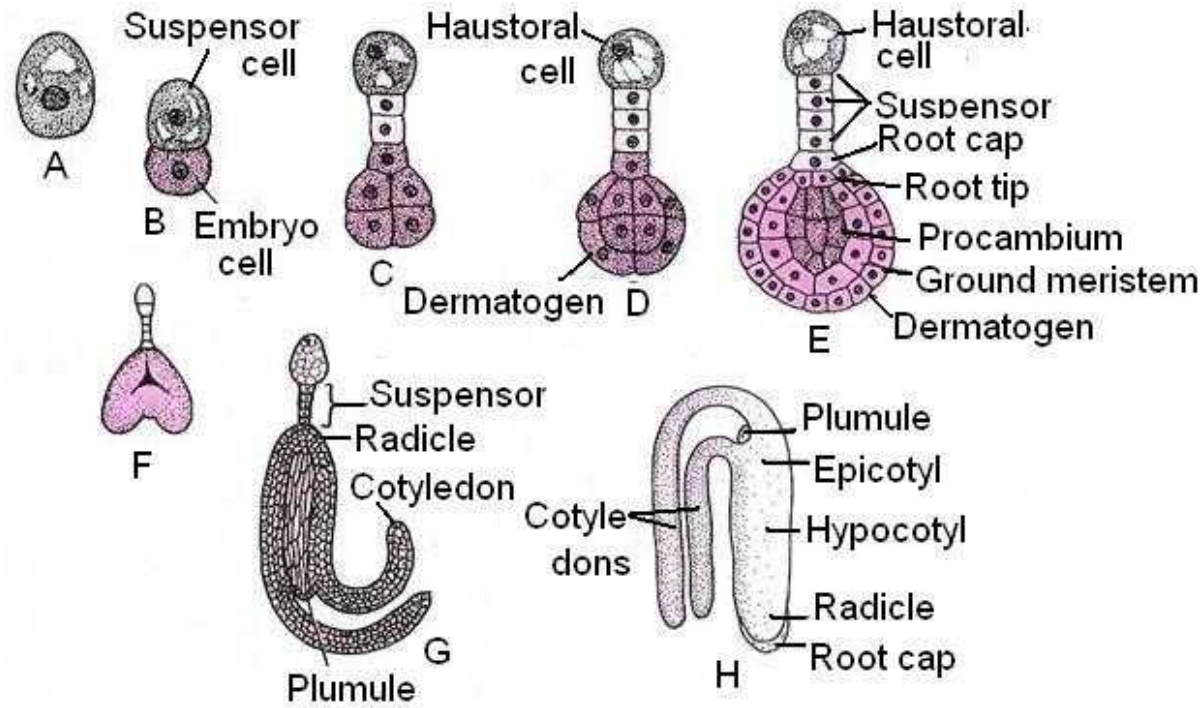

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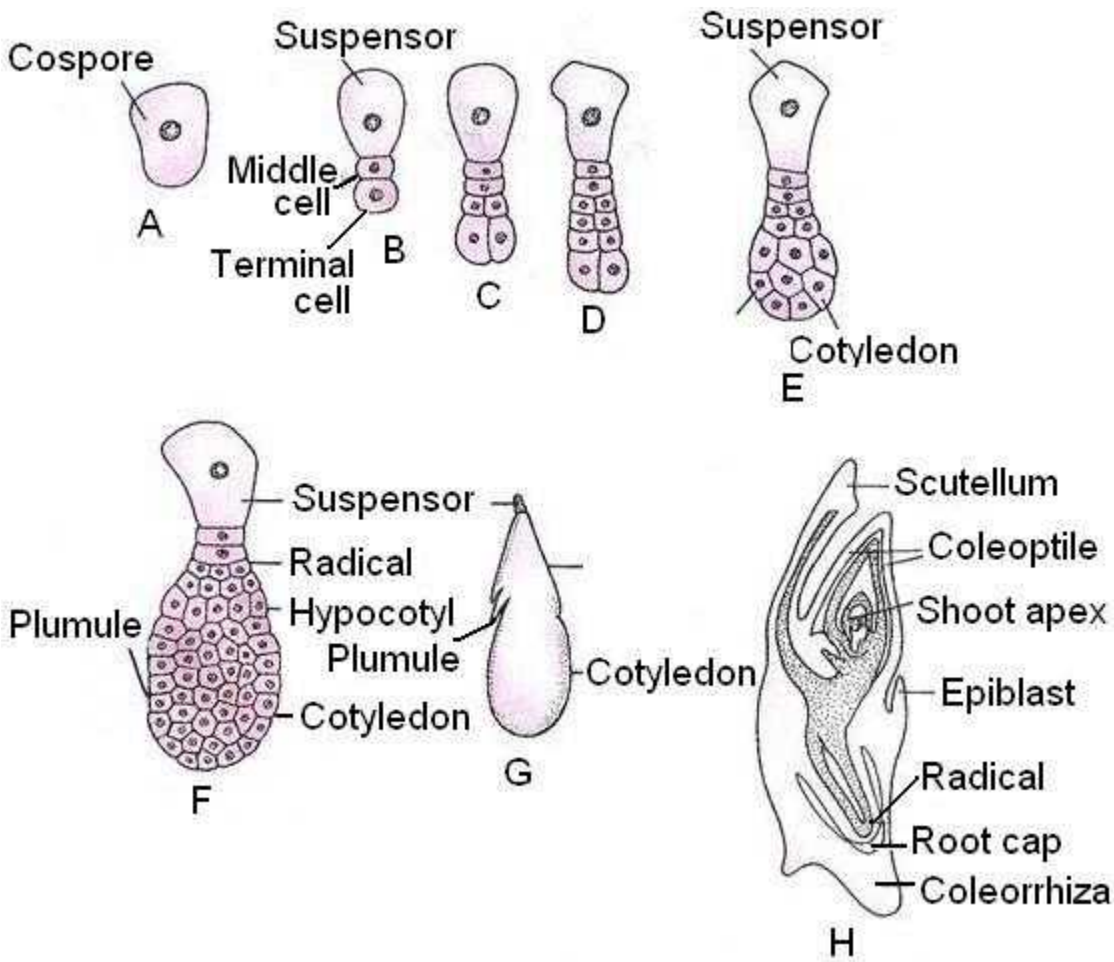
In caspella bursa pastoris, the elongating cotyledons curve due to curving of the ovule itself. In orchids, orboanche and utricularis, the embryo does not show differentiation of plumule, cotyledon and radical.

— Monocot embryogeny (sagittaria type)

— The zygote divides transversely producing a vesicular suspensor cell towards micropylar end and embryo cell towards the chalazal end. The embryo cell divides transversely again into a terminal and middle cell. The terminal cell divides vertically and transversely into globular embryo. It forms a massive cotyledon and a plumule. Growth of cotyledon pushes the plumule to one side. Remains of second cotyledons occurs in some grasses. It is called epiblast. The single cotyledon of monocots is called scutellum. It is shield shaped and appears terminal.

— The middle cell gives rise to hypocotyls and radical. It may add a few dells to the suspensor. Both radical and plumule develop covering sheats called coleorhizae and coleoptiles respectively. They appear to be extensions of scutellum.



Transformation of parts of flower

	BEFORE FERTILIZATION	AFTER FERTILIZATION
1	Calyx, corolla, androccium, style, stigma	Wither off
2	Ovary	Fruit
3	Ovary wall	Pericarp
4	Ovule	Seed
5	Integuments	Seed coats
	Outer integuments	Testa
	Inner integuments	Tegmen
6	Micropyle	Micropyle
7	Funicle	Stalk of seed
8	Nucellus	Perisperm
9	Egg cell	Zygote
10	Synergids	Disintegrate and disapper

Formation of seed and fruit

Fruit

Ripened ovary or fertilized ovary is called fruit. Wall of the ovary forms fleshy or dry fruit wall called pericarp. Fleshy fruit or pericarp is having three layers – epicarp, mesocarp and endocarp

Pericarp

— It is the covering of fruit that develops from ovary wall
— It is a part of fruit and is dry or fleshy
— It is protective covering and nutrition

Seed

— Ripened ovules are known as seeds
— Integuments of ovule forms seed coat. Outer integuments form testa and tegmen develops from inner integuments
— In some case like litchi, ingadulce (Pithecolobium, Asphodelus, Trianthema) a sort of third integuments or aril is present, which covers an additional covering of seed
— Some seeds like castor (ricinus communis) have a spongy outgrowth near the micropyle, which is known as caruncle and it absorbs water during seed germination.
— Funiculus (stalks of ovule) forms stalk of seed. Ultimately, stalk withers and leaves a minute scar called hilum.
— Smallest are found in orchids which are lightest in plant kingdom and are called dust seeds. Fresh weight of each orchid seed is 20.33μg
— Largest seeds are double coconut (Zodoicea maldivica) which are bilobed and each seed is having a weight of 6kg
— Depending upon the persistence of endosperm the seeds are classified as

i) Non-endospermic or ex-albuminous: Food stored in endosperm is completely exhausted by developing embryo. Example : Seed of gram, pea, bean, orchid.

ii) Endospermic or albuminous: Endosperm grows vigorously and is not exhausted by the developing embryo cotyledons are thin here Examples: Seed of wheat, barley, castor, poppy etc

Importance of seeds

- Evolutionary achievement: Seed is an evolutionary achievement. It provides protection to embryo
- Seeds colonise in new areas and spread its species because of dispersal
- Seeds has sufficient food reserve that nourishes the germinating embryo
- Being products of sexual reproduction, seeds have number of variation and variation helps in adaptation to varied environment.
- Germination and sowing of seeds by human gave rise to agriculture and it helped in development of civilization, science and technology.

Seed viability

- It is the period of time for which the seeds retain the ability to germinate. Seed viability is determined genetically as well as environmentally.
- Environmental conditions which can alter viability are humidity and temperature.
- Genetically seed viability ranges from a few days (e.g. oxalis) one season (e.g. Birch), 2-5 years (most crop plants) to 100 years (e.g. Trifolium). Seed viability has been found out to be more than 1000 years in Lotus. 2000 years old seeds of Phoenix dactylifera excavated from king Herod's palace near Dead sea have been found viable. Similarly 10,000 year old seeds of Lupins arcticus (Lupine) excavated from Arctic Tundra not only germinated but also produced plants that flowered
- Viability of the seed is tested by its (a) respiration (b) germination
- Respiring seed turns colourless triphenyl tetrazolium chloride into pink tripheyl formazan

i) Apomixis

[Gk . apo – without ,mixis – moarriage; Winklwr 1908]

- It is the formation of new individuals by asexual methods which mimic sexual reproduction including seed formation but do not involve fusion of gametes or sex cells.
- Normal type of sexual reproduction having two regular features, i.e. meiosis and fertilization, is called amphimixis.

- The organism reproducing through apomixes is called apomicts. Apomixis is controlled by gene and individual; are genetically similar to the parent producing i.e. are clone and members of a clone are called ramets.

  It occurs by following methods:

  a) It is mode of apomixis in which seeds are formed but are asexual in nature as the embryo develops directly without gametic fusion.

  b) The term sporophytic budding is used if embryo develops adventitiously from diploid cells of nucellus or integument, e.g. mango, orange, opuntia, onion.

ii) Parthogenogenesis

[Gk. Parthenos – virgin; genesis – descent, Owen 1848]

- It is the development of a new individual from a single gamete without fusion with another gamete.
- Depending upon the ploidy of the gametes, there are two types of gametes, there are two types of parthenogenesis – haploid and diploid
- In haploid parthenogenesis, the embryo sac and its egg are haploid
- In diploid parthenogenesis, the embryo sac as its contained egg is diploid. It undergoes parthenogenesis and forms diploid embryo. Diploid parthenogenesis is generally accompanied by failure of meiosis during megasporogenesis as well as direct formation of embryo sac from a nucellar cell, e.g. Poa, apple, rubus

iii) Apogamy (Gk. Apo – without, gamos – arriage)

- It is formation of sporophyte or embryo directly from cells of gametophyte.
- In higher plants, only diploid apogamy is successful, that is, the gametophytic cell forming the sporophyte is diploid. In lower plants, haploid apogamy is equally successful.

Polyembryony

- The phenomenon of having more than one embryo is called polyembryony.
- Occurrence of polyembryony due to fertilization of more than one egg cell is called simple polyembryony.
- Formation of additional embryos from different parts of ovule like synergids, antipodal, nucellus, integuments etc.

Example – Citrus, groundnut, onion, opuntia, mangifera

- Polyembryony was first discovered by Leeuwenhoek (1719) and was confirmed by Schnarf (1929). Polyembryony is more common in gymnosperm than in angiosperm
- There are two types of polyembryony false and true embryony
- In false embryony, more than one embryos arise in different embryo sac in the ovule; whereas in true, more than one embryos are formed in the same embryo sac
- The cause of polyembryony may be:
  - Cleavage of proembryo e.g. family orchidaceae.
  - Development of many embryos from other cells of embryo sac except egg. E.g. Argemone
  - Formation of many embryos due to presence of more than one embryo sac in same ovule e.g. citrus
  - Formation of many embryos from the structure outside the embryo sac e.g. mango, opuntia
- Polyembryony is practically important because genetically uniform parental type seedlings are obtained from nucellar embryos
- Nucellar embryos are superior to those obtained by vegetative propagation because nucellar embryo seedlings are disease free and maintain their superiority for long time.

Parthenocarpy : (Gk. Parthenos – virgin, karpos – fruit; Noll 1902)

- It is formation of fruit without fertilization. Parthenocarpic fruits are seedless e.g. apple, pear, banana, pineapple etc
- Technically, fruit having seeds (pseudoseeds) with an asexual embryo are also parthenocarpic fruit
- Parthenocarpy is of three types: genetic, environmental and chemically induced

— Genetic parthenocarpy:
Parthenocarpy is due to genetic alteration caused by mutation or hybridization. It is also called natural parthenocarpy. E.g. banana, apple, pineapple, varieties of grapes, pear

— Environmental parthenocarpy:
Low temperature, frost and fog have been known to induce parthenocarpy in a number of plants examples: pear, olive, capsicum, tomato

— Chemically induced parthenocarpy :

Spray or paste of auxins and gibberellins in low concentration of 10^{-6} – 10^{-7} M has been found to induce parthenocarpy in several plants. Example: tomato, citrus, strawberry, blackberry, fig etc.

Importance of parthenocarpic fruits

- They do not contain seeds which have to be removed before eating fruits.
- Fruits can be developed inside the green houses where pollinators are not available.
- Quicker food processing.