# Apomixis and polyembryony

(Definition, types and practical applications)

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## Apomixis

**What is apomixis? Give its main features.**

**Ans.** The term apomixis was first used by Winkler in 1906. Apomixis refers to the development of seed without fertilization. In other words it does not involve sexual fusion for development of seed. It differs from amphimixis which involves union of male and female gametes for development of seed.

**Main features of apomixis are given below:**

i. It is an asexual means of plant reproduction.

ii. Apomixis is found in many plant species. It is more frequent in fruit crops than in field crops.

iii. In some plant species, reproduction occurs only by apomixis. This type of apomixis is referred to as obligate apomixis.

iv. In some plant species, sexual reproduction also occurs in addition to apomixis. This type of apomixis is known as facultative apomixis.

v. Apomixis does not permit segregation. It is useful in maintaining the genetic purity of mother plant.

vi. Apomixis does not involve union of male and female gametes hence it does not permit recombination. In other words, it does not lead to generation of variability in the population.

vii. It does not permit gene flow. In other words, it does not permit combination of genes from different sources.

viii. It helps in rapid development of pure lines. It can be achieved by haploid parthenogenesis.

ix. It is useful in conserving superior genotypes as well as hybrid vigour.

x. Apomixis is genetically controlled. In majority of cases it is governed by single dominant gene.

xi. Apomixis has been reported in more than 300 plant species of 35 families.

**What are the differences between apomixis and amphimixis?**

**Ans.** Apomixis and amphimixis differ from one another in several ways. The important differences between apomixis and amphimixis are presented in Table

**Table. 5.1 Differences between Apomixis and Amphimixis**

| Particulars | Apomixis | Amphimixis |
|---|---|---|
| 1. Term first used or coined by | Winkler 1906 | Weismann 1891. |
| 2. Sexual Fusion or union of male and female gametes | Does not involve | Involved |
| 3. Gene combination or gene flow | Not possible | Possible |
| 4. Segregation | Does not occur | Occurs |
| 5. Rapid development of inbred lines | Possible | Not possible |
| 6. Conservation of heterosis | Possible | Not possible |
| 7. Type of reproduction | Asexual | Sexual |
| 8. Types | Parthenogenesis Apogamy, Apospory Adventive embryony | Autogamy Allogamy |
| 9. Frequency in plants. | Low | High |

**Q.3. Give classification of apomixis.**

**Ans. The apomixes is generally classified on the basis of:**

(i) Cell involved,

(ii) Occurrence, and

(iii) Frequency.

**These are presented in Table 5.2. Brief description of each type is also given in the following paras:**

Table 5.2 Classification of Apomixis

| Basis of classification | Types of Apomixis | Brief description |
|---|---|---|
| *(i)* Cell involved | Parthenogenesis | Embryo develops from egg cell. |
| | Apogamy | Embryo develops from either synergids or antipodal cells. |
| | Apospory | Embryo develops from the embryosac which has developed from the cell of archisporeum/ nucellus or integument. |
| | Adventive Embryony | Embryo develops directly from the diploid cell of either nucellus or integument |
| *(ii)* Occurrence | Recurrent Apomixis | Embryosac has diploid cells and embryo develops from the diploid cells. |
| | Ncn-Recurrent Apomixis | Embryosac consists of haploid cells and embryo develops from haploid cell. |
| *(iii)* Frequency | Obligate Apomixis | The reproduction occurs by apomictic means only. |
| | Facultative Apomixis | The reproduction occurs by both sexual and apomictic means. |

**Classification Based on Site of Origin:**

**Based on the site of origin the apomixis is of four types, viz.:**

(i) Parthenogenesis,

(ii) Apogamy,

(iii) Apospory and

(iv) Adventive embryony.

**Q.4. What is Parthenogenesis?**

**Ans.** The term parthenogenesis was coined by Owen in 1849. It refers to development of embryo from the egg cell without fertilization. Parthenogenesis has been reported in several crop plants such as grain *Sorghum*, *Hordeum bulbosum*, and cotton. It has also been reported in Solanum nigram and grass like *Taraxacum*. Parthenogenesis is of two types, viz. haploid parthenogenesis and diploid parthenogenesis.

**Thus main points about parthenogenesis are as follows:**

(i) (ii) The embroyo develops from egg cell.

(iii) It may be either haploid or diploid.

(iv) It is genetically controlled.

(v) It occurs in nature as well as can be induced artificially.

(vi) It is useful for conserving heterosis (diploid parthenogenesis).

(vii) It is useful in developing purelines (haploid parthenogenesis).

The term was coined by Owen in 1849.

**Q.5. What are types of parthenogenesis.**

**Ans. It is of two types:**

**(i) Haploid Parthenogenesis:**

The development of embryo from the haploid egg cell is referred to as haploid parthenogenesis. It has been reported in *Hordeum bulbosum*, *Solanum nigram* and some other plant species. Haploid parthenogenesis is very useful in developing inbred/pure lines. The pure lines can be obtained by chromosome doubling of haploid plants.

**(ii) Diploid Parthenogenesis:**

The development of embryo from the diploid egg cell is known as diploid parthenogenesis. Sometimes embryo-sac develops without reduction division. All cells viz. egg cell, antipodals and synergids in such embryo-sac are diploid. It gives rise to diploid embryos. Diploid parthenogenesis has been reported in grasses like *Taraxacum*. It is very useful in conserving heterosis.

In some plant species, pollen grains can be induced to develop into embryos. This development of embryos from pollen grains or anthers is called androgenesis. It has been reported in tobacco, rice and some other species.

**Q.6. What are Causes of Parthenogenesis.**

**Ans.** There are several causes of parthenogenesis in crop plants.

**The main causes are presented below:**

(i) Inability of the pollen tube to discharge the contents inside the embryo-sac

(ii) Insufficient attraction between male and female gametes

(iii) Early degeneration of the sperm

(iv) Very long style

(v) Schlerenchymatous style

(vi) Short pollen tube

(vii) Slow rate of pollen tube growth

(viii) Stimulation of pollination in the absence of pollen tube

(ix) Self incompatibility and cross incompatibility.

**Q.7. What is Apogamy?**

**Ans.** The term apogamy was coined by Winkler in 1908. It refers to origin of embryo either from synergids or antipodal cells of the embryo-sac.

**The main points about apogamy are presented below:**

(i) The term apogamy was coined by Winkler in 1908.

(ii) In apogamy the embryo originates either from synergids or antipodal cells.

(iii) It may be either haploid or diploid.

(iv) Embryo develops from the cells of normal embryo-sac.

(v) It has been reported in Allium, Iris and many other plant species.

(vi) It occurs in nature and can also be induced by artificial means.

**Q.8. What are types of apogamy?**

**Ans. It is of two types:**

**(i) Haploid Apogamay:**

The development of embryo from haploid synergids or antipodal cells is referred to as haploid apogamy. It is useful in development of pure lines.

**(ii) Diploid Apogamy:**

The development of embryo from diploid synergids or antipodal cells is called diploid apogamy. Sometimes, embryo-sac develops without reduction and thus all cells of such embryo-sac are diploid. This leads to development of diploid apogamy. Diploid apogamy is useful in conserving heterosis. It has been reported in Allium, Iris and many other plant species.

**Q.9. What is Apospory?**

**Ans.** In apospory, first diploid cells of ovule lying outside the embryo-sac develop into another embryo-sac without reduction. The embryo then develops directly from the diploid egg cell without fertilization.

**The main points about apospory are presented below:**

(i) The term apospory was coined independently in 1886 by De Very and Bower.

(ii) The embryo develops from the diploid egg cell of another embryo-sac which originates from the cell of ovule lying outside the normal embryo-sac.

(iii) It gives rise to diploid embryos.

(iv) The another embryo-sac may develop from the cell of archesporium, nucellus or integument.

(v) **It is of two types, viz.:**

(a) Generative apospory and

(b) Somatic apospory.

(vi) This is the most frequent type of apomixis.

**Q.10. What are types of apospory?**

**Ans. It is of two types:**

**(i) Generative Apospory:**

The development of embryo from the embryo-sac that has originated from the cell of archesporium is referred to as generative apospory. It has been reported in Parthenium.

**(ii) Somatic Apospory:**

When the embryo develops from the embryo-sac that has originated from the cell of either nucellus or integument is known as somatic apospory. It has been reported in *Malus, Rubus, Allium, Crepis, Poa* and *Opuntia.*

**Q.11. What is Adventive Embryony?**

**Ans.** The development of embryo directly from the diploid cells of ovule lying outside the embryo-sac belonging either to nucellus or integument is referred to as adventive embryony.

**Main points about adventive embryony are given below:**

(i) The term adventive embryony was first used by Strasburger in 1878.

(ii) The embryo develops directly from the diploid cells of either nucellus or integument.

(iii) It always gives rise to diploid embryos.

(iv) In this case another embryo-sac is not formed.

(v) It is a type of sporophytic budding.

(vi) It has been reported in *Citrus* species.

**Q.12. What is recurrent apomixis?**

**Ans.** Where apomictic lines are obtained from one generation to another, it is known as recurrent apomixis.

**Main features of recurrent apomixis are given below:**

(i) The embryo-sac develops from diploid cells without reduction in chromosome number.

(ii) The plants produced by this method have diploid (2n) chromosome number.

(iii) Such plants are always fertile.

(iv) **It is of three types, viz.:**

(a) Diploid parthenogenesis,

(b) Diploid apogamy and

(c) Apospory.

(v) In this case even the heterozygous plants will breed true.

**Q.13. What is non-recurrent apomixis?**

**Ans.** When apomictic plants are not obtained from one generation to another, it is called non-recurrent apomixis.

**Main features of non-recurrent apomixis are given below:**

(i) The embryo-sac has usual haploid cells (n).

(ii) Plants produced by this process are haploid and sterile.

(iii) It includes haploid parthenogenesis and haploid apogamy.

(iv) It is useful for development of inbred lines.

**Q.14. What is obligate apomixis?**

**Ans.** In some species, reproduction occurs only by apomixis. Such apomixis is known as obligate apomixis. Such species produce uniform progeny identical to the mother plant.

**Main features of obligate apomixis are given below:**

(i) Reproduction occurs by apomictic means only.

(ii) The progeny is uniform.

(iii) The progeny is identical to mother plant.

**Q. 15. What is facultative apomixis?**

**Ans.** In some species sexual reproduction also occurs in addition to apomixis. Such apomixis is termed as facultative apomixis.

**Main features of facultative apomixis are as follows:**

(i) Reproduction also occurs by sexual process in addition to apomixis.

(ii) The progeny is heterogeneous in such case.

(iii) It has been reported in Sorghum and some other plant species.

**Q.16. How can you Induce apomixis?**

**Ans. Apomixis particularly the parthenogenesis can be artificially induced by various ways as given below:**

(i) By the stimulation of widely related pollen or foreign pollen.

(ii) By low temperature treatment to ovule.

(iii) By pollinating by X-ray irradiated pollen.

(iv) By treatment with certain chemicals like belviton.

**Q.17. What are advantages of apomixis?**

**Ans.** Apomixis has several useful applications in plant breeding.

**Some important applications/advantages of apomixis are presented below:**

**i. Development of Purelines:**

Apomixis is an effective means of rapid production of pure lines. Haploid parthenogenesis and haploid apogamy give rise to haploid plants which after colchicine treatment will produce diploid purelines. Such purelines can be used in breeding programmes for developing high yielding cultivars and hybrids.

**ii. Maintenance of Purity:**

The obligate apomixis breeds true for the characteristics of mother plant. Thus it is useful in maintaining the genetic purity from generation to generation. It can maintain a genotype for unlimited number of generations. In other words, apomictic lines always breed true irrespective of homozygosity and heterozygosity.

**iii. Conservation of Heterosis:**

The obligate recurrent apomixis is useful in conserving heterosis or hybrid vigour for unlimited generations. Apomixis does not permit segregation. Hence heterosis can be easily conserved.

**iv. Easy Hybrid Seed Production:**

Apomixis provides an easy way of hybrid seed production. The hybrid seed is automatically produced by apomictic means. There is no need of crossing. In other words, in apomictic genotypes crossing is not required for hybrid seed production. Once the hybrid is developed using apomictic line as one of the parents, the hybrid seed production will occur automatically. Thus it permits commercial seed production of hybrids.

**v. Cheaper Hybrid Seed:**

Use of apomixis is the cheaper way of hybrid seed production. It does not require crossing. Hence it helps in saving lot of money which is required for engaging labourers for crossing purpose in conventional hybrids for production of hybrid seed.

**vi. Easy for Handling:**

The handling of apomictic genotypes is easy. When the hybrid is developed using apomixes, we have to handle one genotype only. When the hybrid is developed using cytoplasmic genie male sterility, the breeder has to handle three type of material i.e. A, B and R lines. The purity of apomictic lines/genotypes is maintained automatically, whereas A, B and R lines require lot of labour and care for maintenance of their genetic purity. In other words, when obligate apomixis is available, there is no need for using male sterility for hybrid development.

**vii. No Need of Isolation:**

In case of apomixis, there is no need of isolation distance, where as in case of hybrid seed production by conventional method by using male sterility system, the proper isolation distance is required for maintaining the genetic purity of parental lines.

**viii. No Outcrossing:**

The apomixis is genetically controlled. It is governed by one or few dominant or recessive genes. Hence no seed setting occurs with cross pollination. Thus it does not permit outcrossing. In other words, contamination of apomictic genotypes through outcrossing is not possible.

**ix. No Segregation:**

Apomictic lines always breed true (as stated above) to the characteristics of mother plant. The hybrid seed is produced automatically. There is no need of making crosses every year to produce hybrid seed. This is the cheaper method of hybrid seed production. The apomictically propagated hybrid can be used as a variety, because it does not permit segregation.

**x. Useful to Farmers:**

Apomictically propagated cultivars and hybrids are useful to the farmers, because farmers can produce their own seed. Thus farmers need not to purchase fresh seed every year from seed companies.

**Q.18. What are limitations of apomixis?**

**Ans.** Apomixis has several advantages as stated above. However, there are some disadvantages or limitations of apomixes.

**Some limitations of apomixis are briefly presented below:**

**i. Genetic Diversity:**

Obligate apomictic lines have low genetic diversity. In other words apomictic lines are highly uniform. As a result such lines have narrow adaptation and narrow genetic base. Such lines are adaptable to a specific environment. The diversity arises through mutation.

**ii. Lack of Gene Flow:**

Apomixis particularly obligate type does not permit natural gene flow in the population. As a result re-combinations do not occur in such population.

**iii. Selection in Ineffective:**

In apomictic (obligate) lines, selection is ineffective due to lack of heritable variation. All the plants of apomictic line have exactly the same genotype. It may be homozygous or heterozygous.

**iv. Low Frequency:**

Apomictic lines have very low frequency. Such lines are available in limited crop plants. However, such lines are more frequent in fruit crops and some grasses.

**v. Problems with Facultative Apomixis:**

It is easy to use obligate apomixis in plant breeding. However, use of facultative apomixis (which reproduces both by apomictic and sexual means) is difficult. It becomes difficult to identify apomictic and sexually reproduced plants. Facultative apomixis is more useful in forage crops.

**vi. Adverse Effect on Seed Industry:**

The seed production is very easy in apomictic lines than seed production lines than seed production by sexual means. Farmers can easily produce their own seed and they need not to purchase fresh seed every year from seed companies. This will lead to reduced seed sale resulting in adverse effect on seed Industry.

**vii. Sexual Reproduction:**

Sometimes, apomictic lines are influenced by environmental conditions and they reproduce by sexual means. It poses problem in the use of apomictic lines in plant breeding.

**Q. 19. What are sources of apomixis?**

**Ans.** It has been reported that apomixis is genetically controlled. It is governed by oligogenes. In some cases it is governed by dominant gene while in others it is controlled by recessive genes. In few cases, it is governed by epistatic gene.

Thus it is governed by one or few genes that can be dominant, recessive or epistatic in expression. Apomictic genes are generally found in wild species. As a result apomictic lines are obtained from interspecific derivatives. Sometimes, apomictic lines are also obtained from the germplasm of cultivated species.

## Polyembryony

The phenomenon of the development of more than one embryo in one ovule, seed or fertilized ovum is called polyembryony. It occurs in both animals as well as plants. Most striking cases of polyembryony are seen in certain animals {e.g. parasitic Hymenoptera), where up to 2,000 embryos may spring from one zygote.

In plants, this phenomenon was first reported by Antoni van Leeuwenhoek (1719) in orange seeds. In several gymnosperms, the polyembryony is so common that it might be regarded as an important character of this group. In majority of the gymnosperms showing polyembryony, usually two or more archegonia develop in a female gametophyte. And as each archegonium contains an egg, two or more eggs may be fertilized and thus two or more potential embryos may be created. Only one embryo, however, survives usually, and all the others perish during the course of the development.

**Types of Polyembryony:**

Polyembryony may be of following two types:

**1.** Induced Polyembryony : It includes cases of experimentally induced polyembryony.

**2.** Spontaneous Polyembryony: It includes all cases of naturally occurring polyembryony.

**Webber (1940) classified polyembryony into following three types :**

**1.** Cleavage Polyembryony: In this type a single fertilized egg gives rise to number of embryos.

**2.** Simple Polyembryony: In this type number of embryos develop as a result of the fertilization of several archegonia.

**3. Rosette Polyembryony:**

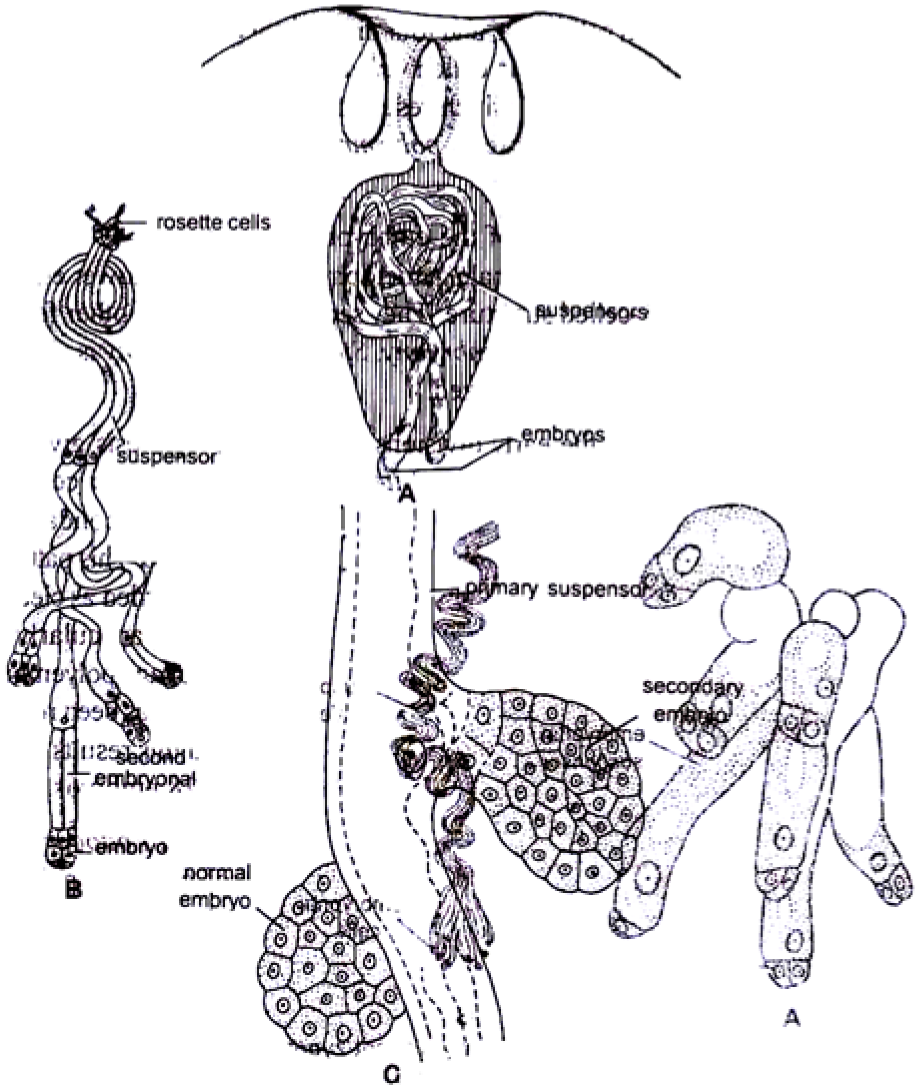
In some gymnosperms (e.g. a few species of Pinus), additional embryos develop from the rosette cells, and this type of polyembryony has been termed as rosette polyembryony.

### Polyembryony in Various Groups of Gymnosperms:

#### (i) Polyembryony in Cycadales:

Polyembryony in Cycadales is not a common occurrence Rao (1964), however, reported simple polyembryony in Cycas Circinalis (Fig. 20.1 A). Two adjacent archegoia of the same ovule in this species sometimes develop independently into two embryos and also rarely into two seedlings.

Polyembryony has also been reported in *Cycas rumphii* by De Silva and Tambiah (1952). Only one out of the several embryos, however remains potential and persists in this species.




***(ii) Polyembryony in Coniferales:***

Simple polyembryony occurs in majority of the members of Coniferales and number of embryo varies from 2 to many. Cleavage polyembryony has also been reported in several genera of Pinaceae {e.g. *Pinus, Cedrus* and *Tsuga*), Taxodiaceae (e.g. *Sciadopitys* and *Sequoia*), Cupressaceae (e.g. *Thuja*, *Juniperus*) and Podocarpaceae (e.g. *Podocarpus*). Both simple and cleavage polyembryony are common in *Cvpressus* In *Pinus*, the zygote divides two times to form four nuclei. In the chalazal end of the archegonium these four nuclei divide again to form two tiers of four cells each. Both tiers divide once to form four tiers. From below upwards these four tiers are called embryonal tier, suspensor tier, rosette tier and upper tier.

The cells of the embryonal tier divide further into proximal secondary suspensors, which split apart, and four distal embryos are formed. Because of the splitting process this type of polyembryony is called “cleavage polyembryony”. Some species of Pinus also exhibit “simple polyembryony” which results from the fertilization of several archegonia. A few species of Pinus also show “rosette polyembryony”. In this type, extra embryos develop from the cells of the rosette tier In Cedrus, the upper four cells of the embryonal suspensor or E-tier elongate to push the embryonal cells quite deep into the female gametophyte. Each of the lower embryonal cells divides repeatedly to form a 4 to 5-celled structure. They separate from each other forming four embryos, showing an example of cleavage polyembryony. Simple polyembryony is also common in Cedrus as more than one archegonia get fertilized.

In Sequoia (Fig. 20.2 A) the early divisions during embryogenesis give rise to three tiers of four cells each, i.e. an upper ‘u’ tier, an ‘s’ tier and an ‘e’ tier. Each cell of the ‘e’ tier gives rise to secondary suspensors and an embryo. This pattern of embryogenesis is regarded as cleavage polyembryony of a particularly precocious kind. Cleavage polyembryony of a very high order has been reported in Sciadopitys, and this results in the formation of 12 to 28 embryos.

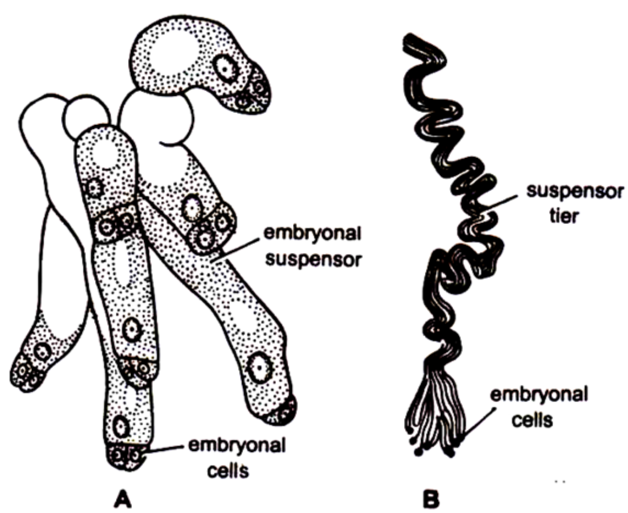



**Fig. 20.2.** A, Young embryo of *Sequoia* from adjacent zygotes showing elongating embryonal suspensors and embryonal cells that have divided; B, Showing highly coiled suspensor system and cleavage polyembryony in *Podocarpus*.

In Podocarpus, an advance type of cleavage polyembryony has been observed, and it “has an important bearing on the assessment of the evolutionary status of polyembryony in the conifers as a whole” (Sporne, 1965). Each embryonal tetrad behaves as an independent embryo in Podocarpus (Fig. 20.2B).