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Prospects of Cleistogamy in Plant Breeding

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Abstract

Cleistogamy is a mode of reproduction which promotes self-pollination as the flower remains closed even after anthesis. This system avoids contamination of foreign pollen to outcross the clesitogamous flower. In nature, under suboptimal environmental condition, few plant species produce cleistogamous flower which requires fewer resources to reproduction. Three different types of cleistogamy occur in plants namely dimorphic cleistogamy, induced cleistogamy, and complete cleistogamy. This kind of sexual reproduction maintains the locally adopted gene complex and homogeneity of the genes in the population. This system of reproduction helps in achieving the genetic purity of any species. This system can be transferred to other species to exploit the cleistogamous nature of reproduction.

1. Introduction

Cleistogamy is a form of reproductive mechanism which promotes self-pollination. It is a condition in which the flower remains closed even after anthesis, such a closed flower ensures there is no pollen outcrossing from outside. Cleistogamy, the term first used by Kuhn in 1867 to denote the bud-like flower in plants, cleistogamy literally means closed marriage, while chasmogamy is open marriage in which the flower part is open and which facilitates outcrossing. Darwin (1877) observed cleistogamy in Viola, Oxalis, and Impatiens species. This phenomenon was noticed in 59 families of 228 genera in 693 species of angiosperm. Recently Lord (1981) reported the occurrence of cleistogamy in 56 families of 287 species. Type of flowers and kind of pollination mechanism determines the nature of cleistogamous or chasmogamous flowers. In case of cleistogamous flowers, pollen grains from the anther column of the same flower fall into the stigma and allow the self-fertilization.

2. Types of Cleistogamy

Initial primordial bud is converted into flower bud based on the developmental pathway which is formed into cleistogamy (CL) and chasmogamy (CH). Cleistogamy is grouped into three types based on the reproductive nature of flowers, *viz*., (i) Dimorphic cleistogamy, (ii) Induced cleistogamy, and (iii) Complete cleistogamy.

2.1 Dimorphic Cleistogamy

Both cleistogamous and chasmogamous flower produced in the same plant is called dimorphic cleistogamy or facultative cleistogamy. Two kinds of strategy are widely involved in dimorphic cleistogamy. Cleistogamy and chasmogamy flowers occur in different parts of a single plant. Such spatial separation of different forms of flower formation is called a multiply strategy. In the case of conditional strategy, temporal separation of flower formation determines the chasmogamy and cleistogamy flower appearance. Different types of flowers appear during different season. Chasmogamy flowers mostly appear under a favorable period of a season, while cleistogamy flower appears under unfavorable condition. Example: Impatiens and Viola species, annual and perennial grasses (Campbell *et al.,* 1983; Culley, 2002; Lu, 2002). Two different floral morphs present in this dimorphic cleistogamy plants provides a unique opportunity of mixed mating system of reproduction which comprises of both selfing and crossing progenies.

2.2 Induced Cleistogamy

In this system, there is no fixed developmental pathway and each flower bud develops into a chasmogamous flower unless the environment prevents its mechanical opening. Such unopened chasmogamous flower mimics like cleistogamous flower. Such environmental condition changes the flower into cleistogamous nature is called induced cleistogamy or pseudocleistogamy or ecological cleistogamy (Uphof, 1938). Example: Festuca species produces cleistogamy flower under low temperature and less relative humidity (Connor, 1998).

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2.3 Complete Cleistogamy

The plant produces only cleistogamous flowers irrespective of environments; it is called as complete cleistogamy or obligatory cleistogamy. Example: *Schiedea trinervis always* produce cleistogamous flowers only (Wagner *et al.,* 2005). Floral biology of complete cleistogamous flowers fetches much attention as this mechanism has to be transferred to other plants to convert the normal lines into true clesitogamous lines.

2.4 Advantages of Cleistogamy

• Reproductive assurance is high when pollinators are less available or absence.

• It serves as a backup mechanism of reproduction in case of stochastic environmental conditions.

• Less partitioning of resource or energy needed to produce cleistogamy flowers compared to chasmogamous flower, which makes particular plants to survive for longer time with available resources and produces the progeny for next generation by producing cleistogamous flowers with assured self-pollination.

• The inherent nature of selfing assures the advantages of fixing maternal genes, so that purity of offspring gets ensured.

• Preserving locally adapted gene complexes without recombination through outcrossing.

• Complete selfing allows isolation of deleterious recessive alleles in offspring.

2.5 Disadvantages of Cleistogamy

• Decreased genetic variation because of forced self-pollination in cleistogamous flowers.

• Increased genetic drift because of nonrandom mating reproduction.

• High level of inbreeding depression through continuous self-pollination.

• Since locally adopted genes allows the sibling completion among the cleistogamous lines in the vicinity of the maternal environment.

2.6 Advantages of Chasmogamy

• Higher chances of production of heterosis or hybrid vigor.

• Increased genetic variability resulting from out crossing favors survival in spatio and temporal heterogeneous environment.

• High vigor seeds of cleistogamous flower favor longer dispersal and survival in heterogeneous environments which eliminates sibling competition.

2.7 Disadvantages of Chasmogamy

• Higher energy and partition needed to produce chasmogamous flowers affects the plant survival under unfavorable environmental conditions.

• Genetic purity maintenance is difficult because of outcrossing through wind or pollinators in open flower.

3. Dimorphic Cleistogamy

In dimorphic condition, the plant produces cleistogamous flowers under unpredictable environmental conditions such as less light, drought, and rare pollinators available for fertilization. In favorable condition, plant starts producing chasmogamous flowers, even in case of pollinator's availability. Fewer resources needed for the production of cleistogamous flower eventually smaller in size and less vigor seeds. Inbreeding is the major constraint for cleistogamous production. Favorable environment conditions, resources are partitioned more towards the production of bigger size chasmogamous flowers which looks conspicuous to attract pollinators. In such flowers, out crossing promotes more vigorous seeds and higher dispersing capacity. However, geitonogamy is the major constraint in chasmogamous flower.

4. Mixed Mating Strategies

Cleistogamy prevailing in 693 species across 50 families also reported to have 77% of chasmogamous flowers, which provides an opportunity to have the phenomena of mixed mating (Culley and Klooster, 2007). These conditions of dimorphic cleistogamous plants have the advantage of selfing progeny from cleistogamy flowers and outcrossing progeny from chasmogamy flowers. In this selfed progeny preserve the locally adopted gene complexes for survival (Lord, 1981; Schoen and Lloyd, 1984; Culley and Klooster, 2007) and outcrossed progeny maintains the genetic diversity which allows nature to exercise its selection as an evolutionary adoptive mechanism (Waller, 1984; Schoen and Lloyd, 1984; Mitchell-Olds and Waller, 1985; Schmitt *et al.,* 1985; Winn and Moriuchi, 2009).

There are two strategy-based hypothesis been reported for mixed matting among dimorphic cleistogamous flowers. Reproductive assurance strategy which is based on the availability of pollinators and environmental conditions (Goodwillie *et al.,* 2005; Oakley *et al.,* 2007). If there is less pollinators available or stochastic environment niche prevails which promotes production of cleistogamous flowers. It is one of the reproductive back up strategy which allows mixed mating strategy (Le Corff, 1993; Masuda and Yahara, 1994; Culley, 2002; Lu, 2002). Allocation of resources is another strategy in which energy resources available in plants get shifted based on the priority of different floral morphs (Schemske, 1978). Less resources are needed for producing cleistogamous flowers which in turn produce small flowers with less number of seeds with smaller size (Waller, 1980; Steets and Ashman, 2004). However, chasmogamous flowers need higher resources to produce bigger flowers which are in quantum to attract pollinators for allowing outcrossing. These chasmogamous flowers produce more number of seed with bigger size (Schoen and Lloyd, 1984). In this mixed mating systems, cleistogamous flowers aid in selfing to purge the deleterious alleles in progenies (Lande and Schmske, 1985; Charlesworth and Charlesworth, 1987). However, chasmogamous flowers help in production of heterosis or hybrid vigor via outcrossing (Lu, 2002; Oakley *et al.,* 2007).

4.1 Relevance of Cleistogamy in Breeding

- Genetic purity and uniformity can be maintained through assuring complete self-pollination in cleistogamous flowers.
- Maintenance of pure line especially developing inbred lines possible by using cleistogamous reproduction mechanisms.
- Need not enforce isolation distance for seed production especially preventing foreign pollen contamination.
- Gene flow can be controlled using cleistogamy lines as they preserve the genetic integrity of the plant.
- Floral evolutionary system can be studied especially in spatial and temporal strategy.
- Adopted gene complex of a plant can be fixed and maintained throughout the progenies.
- Less energy resources need for the production of cleistogamous flowers as the reserve can be used for survival of the plants.
- In unfavorable condition, it serves as an assured reproduction strategy as a backup mechanism of survival.

5. Conclusion

Plant species employ different modes of reproduction strategy depends upon their environmental niche. Cleistogamy one such strategy where plants ensure assured self pollination. Under adverse environmental condition induces the cleistogamous nature of reproduction. Such a reproduction system can be transferred or induced in other species to exploit the cleistogamous sexual reproduction. Till now there is less molecular mechanism about cleistogamous study undertaken. Understanding reproductive patterns and limitations can provide needed insight to its reproductive ecology and better inform conservation effort.

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