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PARTHENOCARPIC CUCURBITS: EXPLORING SEEDLESS FRUIT DEVELOPMENT AND ITS APPLICATIONS

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Introduction:

Cucumber (*Cucumis sativus* L.), muskmelon (*Cucumis melo* L.), watermelon (*Citrullus lanatus* L.), squash/pumpkin (*Cucurbita spp*.), bitter gourd (*Momordica charantia* L.) and bottle gourd (*Lagenaria siceraria* L.) are among the many commercially important crops in the Cucurbitaceae family. Cucurbits, like other monoecious plants, require favourable pollination conditions for fruiting to occur. Yield can be reduced in the absence of pollinators or in unfavourable environmental conditions such as a lack of light, high humidity or high temperature. Parthenocarpy has the potential to solve the problem of low fruit set caused by unfavourable pollination conditions.

Parthenocarpy comes from the Greek words "parthenos" (virgin) and "karpos" (fruit). Noll introduced the term "parthenokarpie" in 1902. Winkler defined parthenocarpy later in 1908. Parthenocarpy (literally, "virgin fruit") refers to the natural or artificial production of fruit without ovule fertilisation. The fruits are either non-viable or seedless. Parthenocarpy is a process that limits female fertility and allows for the growth of seedless fruits without fertilisation. This has been observed in banana (Joldersma, 2018), tomato (Rotino *et al.,* 1997), watermelon (Kihara, 1951), grapes (Gustafson, 1942) and cucumber (Pike and Peterson, 1969). The demand for seedless fruits is increasing because consumers prefer them due to their improved flavour, longer shelf life and do not require seed removal. Furthermore, it significantly lowers the labour requirement, which is generally associated with artificial pollination to boost yields of cross-pollinated Cucurbitaceae crops. As a result, parthenocarpy is a very beneficial agronomic characteristic for crops in the Cucurbitaceae family. In certain cucurbits, parthenocarpic fruits are produced due to an increased flow of phytohormones to the gynoecium from sources other than developing seeds. Parthenocarpic genes modify hormone production, transport, and metabolism in the ovary, leading to increased hormone levels that can stimulate fruit formation without fertilisation (Vivian-Smith *et al.,* 2001).

Classification of Parthenocarpy:

Varoquaux *et al.* (2002) identified two forms of parthenocarpy:

- Natural/Genetic Parthenocarpy
- Induced/Artificial Parthenocarpy

Natural parthenocarpy: Seedless fruits are produced by the ovaries in the absence of pollination and fertilisation, with no external treatment. Natural parthenocarpy is the term used to describe the natural process of producing seedless fruits.

It is of two types:

- **Obligatory parthenocarpy:** Genetic sterility has led to the production of fruit without seeds. Eg.: Ivy gourd (*Coccinia*) and certain cucumber genotypes produce seedless fruits by nature
- **Facultative parthenocarpy:** Poor pollination and fertilisation lead to the production of seedless fruits. Natural parthenocarpy in brinjal is seen only when the plants are exposed to chilling temperatures (7-10°C). This trait is only expressed in cold temperatures; however, when pollination temperature is favourable, normal fruit and seed set occur. Eg.: Tomatoes, Brinjal

Induced parthenocarpy: In this situation, specific treatments are applied to the bloom to yield seedless fruits. As the name implies, induced (artificial) + parthenocarpy (production of seedless fruit).Parthenocarpy can be induced by using water extracts of pollen grains,irradiated pollen, application of plant growth regulators (Auxin, Gibberellin) and polyploidy breeding.

Advantages of Parthenocarpy:

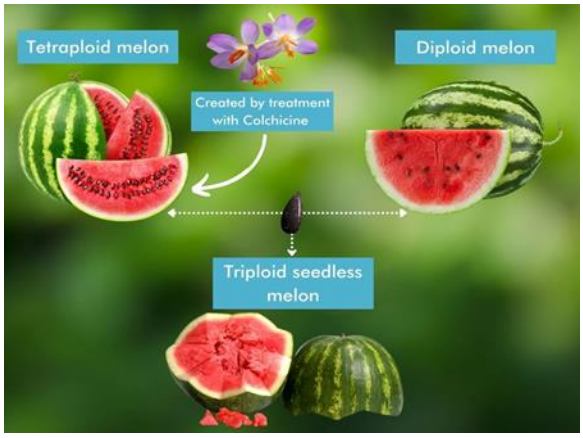
1. Parthenocarpic vegetables do not require pollination or fertilisation for fruit development. Pollination is hindered by unfavourable environmental conditions, which negatively impact fruit yield and productivity.
2. **Novelty:** Seedless watermelon and parthenocarpic cucumber, together with longer shelf lives for improved preservation.
3. **Better quality:** Seedless brinjal prevents browning and deterioration of the pulp texture (Maestrelli *et al.,* 2003). Additionally, seeds of watermelon and brinjal release compounds that speed up the deterioration (Dalal *et al.,* 2006).
4. The hard, leathery texture, bitter flavour, and toxin concentration of seeds make them unsuitable for use in a variety of crops. Therefore, replacing seeds with edible tissue is a desirable option for customers.
5. Parthenocarpic cucumbers produce an early crop and seedless tomatoes taste better and have a higher TSS than seeded tomatoes.
6. Producing fruits and vegetables without seeds improved processing firms' profitability.
7. **Vertical fruit harvest**: Because parthenocarpic cucumbers continue to set fruit on their vines, cultivating them in greenhouses will give more profits.
8. "Crown set inhibition" has no effect on parthenocarpic cucumbers, fruit growth is constant.
9. Parthenocarpy improves stability in crop production as there is no need for pollinator insects or polliniser plants, thus the yield of the crop also improves.

Parthenocarpy in Cucurbits:

Growing seedless or parthenocarpic cucurbits is advantageous and lucrative for the following reasons: parthenocarpic varieties are typically early in nature, yield more than other seeded varieties and have a higher flesh content and higher nutritional value. Because they are seedless, they don't require pollinators like other cucurbits, which makes them ideal for protected cultivation, year-round propagation and production.

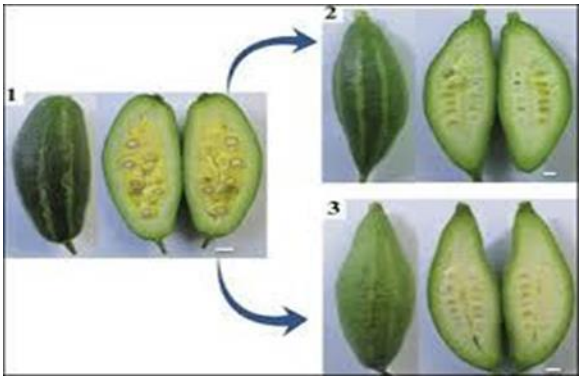
(a) **Watermelon:** In watermelon, parthenocarpy does not occur naturally; it can be produced by employing plant growth regulators, using soft X-ray irradiation, doubling the chromosome by colchicine treatment which

produces the polyploid fruits, and occasionally by distant inter-specific hybridisation.



Seedless fruit is more profitable and nutrient-dense. Parthenocarpy is induced in non-pollinated watermelon ovaries by using the plant growth regulator CCPU @ 200 ppm (up to 89.5%). Parthenocarpy is also strongly induced when CPPU @ 200 ppm and NAA @ 150 ppm are applied. The quantity of papery or empty seeds is reduced by application of 2,4-D at 25 ppm. Using colchicine treatment Kihara (1951) created a seedless polyploid (4n) watermelon through polyploidy breeding. By pollination with soft X-irradiated pollen at 800 and 1000 Gy in 'Fujihikari TR', diploid seedless watermelon was produced with small empty seeds, while the best results were obtained with 400, 800, and 1000 Gy doses and partially gamma ray irradiated partially functional pollen at 600 and 800 Gy in 'Benikodama'. The findings showed that watermelon cultivars without seeds had much higher levels of carotenoid and total sugar, making them a valuable dietary source of phytonutrients.

Bottle gourd pollen is used to pollinate watermelon to get parthenocarpic fruit. Bottle gourd pollen was used to fertilize the female watermelon flowers, resulting in a seedless fruit set of 57.1%. Other than a few tiny, white and empty seeds, there were no conventional seeds in those parthenocarpic watermelons. The oblong or triangular shape of seedless fruits obtained after pollination with bottle gourd pollen is thought to be a typical trait of seedless watermelon. Arka Madhura from IIHR, Bengaluru, Happy Family from Syngenta, Pusa Bedana, Yellow Seedless, Red Seedless, Yamato, etc., are some parthenocarpic varieties of watermelon.



(b) **Cucumber:**

The cucumber is a cucurbit crop that naturally bears parthenocarpic fruit. In addition to being gynoecious, parthenocarpic cucumbers yield early crops. However, under certain situations, transgene induction and the use of plant growth stimulants might cause parthenocarpy. According to Pike & Peterson (1969), parthenocarpy was controlled by a single partially dominant gene (P). PP (the homozygous dominant) develops parthenocarpic fruits early, typically, the first fruit appears by the fifth node. Whereas, the heterozygous Pp plants are less common and yield parthenocarpic fruits later than the homozygous plants. No parthenocarpic fruits are produced by the homozygous recessive pp. Cantliffe (1972) discovered that at a concentration of 50 ppm, TIBA and Morphactin IT 3456 caused development of parthenocarpy, additionally; the node for the formation of the first fruit was significantly reduced. Zhimin Y *et al.*

(2006) used an *Agrobacterium tumefaciens* mediated technique to introduce the DefH9-iaaM chimeric transgene into the cucumber genome, causing parthenocarpy. Deunff and Sauton (1994) used a 400 Gy dose of gamma rays to pollinate female flowers with irradiated pollen in the non-parthenocarpic cucumber "Bellafem" in the spring and fall, which resulted in abortive embryogenesis. A parthenocarpic line can only be maintained via inbreeding or selfing, but as the majority of parthenocarpic variations are gynoecious by nature, the only method to keep parthenocarpic plants alive is to induce male flowers.

(c) Pointed Gourd:

The green fruits of the pointed gourd, a dioecious cucurbit vegetable, are edible. Fruit with fewer or no seeds is desired since the' hard coverings of seeds make it unappealing. In pointed gourd parthenocarpic fruits can also be produced.When compatible diploid (paternal parent) and tetraploid (maternal parent) were crossed, the (4x) X (2x) progeny had significantly fewer seeds than their diploid parent, but the fruit set rate and shape were comparable to the diploid's. Vines can be pruned to readily maintain this tetraploid female.In contrast to equivalent hand-pollinated fruits, which produce several well-developed, normal-sized, hard seeds, the application of plant growth regulators to unpollinated pointed gourd blossoms successfully produces parthenocarpic fruits. Nevertheless, a few parthenocarpic fruits were produced by the application of NAA and GA_3 @ 200 ppm, which contained fewer than five seeds, which appeared typical in appearance and were smaller than typical seeds. The parthenocarpic fruits treated with TIBA, CPPU, 2,4-D and other plant growth regulators have a seed-like hollow structure that was empty and coated in a thin coating of edible soft material.

Methods to induce parthenocarpy:

(1)Environmental factors: The various stages of the reproductive process are negatively impacted by high or low temperatures, humidity, low light intensity, heavy rain, and strong winds. The most common of these is temperature stress, which makes many vegetable crops produce parthenocarpic fruit.

(2)Plant growth regulators: Parthenocarpic fruits may develop in vegetable crops when exogenous plant growth hormones like auxins, cytokinins, and gibberellins are applied. The use of exogenous auxin to induce parthenocarpy in a flower was originally revealed by Gustafson (1936).

(3)Mutation: Parthenocarpic mutants have been successfully produced by gamma irradiation in *Citrullus lanatus* and soft X-rays in watermelon.

(4)Polyploidy: Scientists employed an imbalanced embryo and endosperm development on a triploid background to create parthenocarpic fruit. Watermelon fruits with only residual integuments are produced by F_1 hybrid plants, which are developed by crossing tetraploid and diploid parents (Kihara, 1951), as a result of which a triploid plant is produced. By crossing diploid and tetraploid, triploidy in cucumbers has been seen, leading to increased capacity to withstand high temperatures (45°C) in cucumbers.

(5)Conventional Breeding: In traditional breeding, there are two essential steps:

- Establishing a breeding population that separates according to one parental genotype's parthenocarpic character
- Choosing offspring with parthenocarpy and advantageous non-parthenocarpic parent traits from a separated population

(6) Biotechnological Approaches: Biotechnological techniques have been used to leverage the increased hormone levels in the ovary or ovules, which take the place of pollination for fruit growth. When it came to parthenocarpy induction, the different methods of raising auxin levels in the ovary produced positive outcomes. The auxin-synthesising gene iaaM from *Pseudomonas syringae* pv. *Savastanoi* can be expressed to produce seedless fruits and this process is regulated by the ovule/placenta-specific promoter from the *Antirrhinum majus* DefH9 gene. Transgenic methods and gene silencing are efficient ways to disrupt the expression of genes that synthesise phytohormones and are involved in the development of parthenocarpic fruits.

Bottle necks of parthenocarpic fruits:

- Seed production of parthenocarpic plants is a challenging task that requires specialised knowledge and is occasionally not financially viable.
- When compared to seeded versions, seeds are rather pricey.
- Sometimes fruits are distorted and unfit for sale.
- Fruits can also have disagreeable tastes or textures. For instance, parthenocarpic cucumbers have a mushy, watery feel that Indian consumers dislike.

Future scope:

Parthenocarpy is a very lucrative characteristic of many horticultural crops, particularly cucurbits. Parthenocarpic fruits can be developed in unfavourable environmental circumstances. It is possible to make excellent use of the parthenocarpic fruits under protected circumstances. Steps like combining several genes with the parthenocarpic gene, adding parthenocarpy to high-value crops to increase yield and earliness and combining the parthenocarpy and male sterility genes to encourage crossover and increase production, the benefits of parthenocarpy can be raised manyfolds.

Conclusion:

For cucurbitaceous crops, parthenocarpy is a crucial trait for enhancing production, quality and processing characteristics. This characteristic proved to be very helpful in greenhouse farming, especially for highly cross-pollinated vegetable crops like cucurbits. It is well known that phytohormones are crucial for fruit setting, yet manipulating them genetically can result in seedlessness. For the good of humanity, biotechnology tools can also be used to improve the efficiency and identification of parthenocarpic genes in various crops.

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