The Phenomenon of Parthenocarpy in Cucurbitaceous Vegetables: A Overview

Suvojit Bose[1], Sourav Roy[2]* and Chandan Karak[3]

1,2 & 3Department of Vegetable Science, BCKV, Mohanpur, Nadia

Corresponding Author: sourav1995roy@gmail.com

Introduction

The word parthenocarpy is originated from two Greek words "parthenos" meaning virgin and "karpos" which means fruit. The term "parthenokarpie" was introduced by Noll in 1902. Later parthenocarpy is defined by Winkler in 1908.

In botany and horticulture, parthenocarpy (literally meaning virgin fruit) is the natural or artificially induced production of fruit without fertilization of ovules. These fruits are either non-viable or seedless. In other words, the process which limits female fertility and allows growth of seedless fruits without fertilization is known as parthenocarpy (Schwabe and Mills, 1981) as reported in banana (*Musa paradisiaca*) (Joldersma, 2018), tomato (Lycopersicum esculentum L.) (Rotino *et al,* 1997), watermelon (*Citrullus lanatus*) (Kihara, 1951;), grapes (*Vitis vinifera*) (Gustafson, 1942;) and cucumber (*Cucumis sativus L.*) (Pike and Peterson, 1969; Li, J *et al*, 2017).

Another physiological phenomena similar to parthenocarpy known as, stenospermocarpy majorly observed in grape (Vitis vinifera) (Royo *et al* ,2018), is a process where fertilization of gametes happen yet the seed becomes rudimentary that is why it may also produce apparently seedless fruit, but the seeds are actually aborted while still small.

Classification

Parthenocarpy is classified primarily into 2 types as suggested by Varoquaux *et al.* (2002),

- Natural / Genetic parthenocarpy
- Induced or artificial parthenocarpy

Natural/ Genetic parthenocarpy

Natural parthenocarpy is when seedless fruits are produced without any special treatment. Seedless fruits are produced from the ovaries in the absence of pollination and fertilization without any special treatment. Since this is the natural process by which seedless fruits are produced so, that the process is called natural parthenocarpy.

Induced Parthenocarpy

Induced parthenocarpy is when seedless fruits are produced from the ovary by giving with special treatment to the flower. In this case, special treatments are given to flower to produce seedless fruits. The special treatment used to induce parthenocarpy is either water extract of pollen grains or growth-promoting hormones. As the name suggests induced (Artificial) + Parthenocarpy (Production of Seedless Fruit). So an Artificial Process to produce seedless fruits so this is called induced parthenocarpy.

- Irradiated pollen.
- Plant growth regulator (i.e. Auxin, Gibberellins) application.
- Polyploidy breeding.

Importance

- Seedless fruits like watermelon has better consumer acceptance. (Baker *et al.*, 1973).

- Parthenocarpy improves quality of fruits like in brinjal. We can get high-quality fruits with the help of parthenocarpy which is not possible by nature. (Dalal *et al*., 2006).
- Increases economical profit in postharvest industry. (Lukyanenko, 1991).
- Parthenocarpy improves stability in crop production as there is no need for pollinator insects and as well as pollinator plants thus yield of the crop also improves.(Rao *et. al*. , 2018)
- Parthenocarpy keeps the insects and pests away because there is no need for pollination. Insects are required for pollination. So parthenocarpy protects the plant from being attacked by pesticides.

Parthenocarpy in cucurbits

Cucurbitaceae family also known as cucurbits is one of the largest and economically important families, which consists of 95 genera and 965 species. Genus like *Cucurbita, Lagenaria, Citrullus* is included in this vast family. Which is equally important considering India's climatic and socio-economic factors this family is very important. So, producing seedless or parthenocarpic cucurbits also is favourable and profitabl for the following reasons: Seedlessness in fruits, more flesh content and more nutritious, parthenocarpic gynoecious varieties of cucumber are generally early in nature, yields more than other seeded varieties, due to the seedless nature parthenocarpic fruits don't need pollinators unlike other cucurbits, and for this reason parthenocarpic fruits are well suited for protected cultivation, year round propagation and production.

Parthenocarpy exploited in production of Cucurbits

Watermelon (*Citrullus lanatus*)

In watermelon parthenocarpy is not natural is induced by applying plant growth regulators, using soft X-ray irradiation, producing polyploidy fruits and sometimes by distant inter-specific hybridization.

But seedless fruit is more nutritious and economically profitable.

Plant growth regulator

CCPU @ 200 ppm induces parthenocarpy in non pollinated ovaries of watermelon (up to 89.5 %) as reported by Hayata *et al* in 1995, again when CPPU @ 200 ppm and NAA @ 150 ppm is applied parthenocarpy also induced significantly.2,4-D @ 25ppm minimizes number of empty seeds or papery seeds.

Polyploidy breeding

Kihara (1951) produced seedless polyploid (4n) watermelon using colchicine.

Irradiation

Diploid seedless watermelon was produced when pollination is done with soft X-irradiated pollen @ 800 and 1000 Gy in 'Fujihikari TR' resulted small empty seeds whereas for 'Benikodama' 400, 800 and 1000 Gy doses gave the best result (Sugiyama and Morishita, 2000) and gamma ray irradiated partially functional pollen @ 600 and 800 Gy. Results indicated that seedless watermelon cultivars had a significant increase in total sugar and carotenoid contents thus, providing an important source of phyto-nutrients in the diet. (Moussa and Salem 2009)

Interspecific hybridization

Parthenocarpic watermelon fruit obtained by pollinating with bottle gourd pollen. Female flowers of watermelon were pollinated with bottle gourd pollen (*Lagenaria siceraria* Standl.) produced seedless watermelon with

fruit set of 57.1 % (Sugiyama *et al*., 2014). There were no normal seeds except for some small, white empty seeds. Seedless fruits from bottle gourd pollen tended to be oblong or triangular and is considered to be a common tendency of seedless watermelon (Wong, 1938; Gustafson, 1941). The triangular shape was presumed to result from the inability of pollen tubes to reach the lower part of the ovary. That is, it was hypothesized that the secretion of hormones was insufficient in the lower part of ovary since deformation of fruit was related to hormone secretion (Yamane *et al.*, 2010).

Parthenocarpic Varities:

Arka Madhura from IIHR, Bangaluru, Happy family from Syngenta, Pusa Bedana [Developed from IARI by crossing Tetra-2(4n) x Pusa Rasal(2n)], Yellow Seedless (KAU-CL-TETRA 1 x CL-1), Red Seedless (KAU-CL-TETRA 1 x CL-4), Farrukhabadi, Asahi Yamato

Cucumber (*Cucumis sativus L.*)

Cucumber (Cucumis sativus L.), the fourth most cultivated vegetable around the world (Plader *et al*. 2007, Innark *et al*. 2013), is one of the most economically important cucurbit vegetable plants (Robinson & Walters 1997). Cucumber is a cucurbit crop which naturally produces parthenocarpic fruit, along with gynoecy parthenocarpic cucumbers produce early fruits with very high yield. But in some cases parthenocarpy can be induced by applying plant growth regulators and inducing transgene.

Natural / Genetic parthenocarpy

Pike (Pike, L. M., & Peterson, C. E., 1969) report that a single incompletely dominant gene (P) controlled parthenocarpy. The inheritance of parthenocarpy in cucumber is conditioned by an incomplete dominant gene *P*. In the homozygous condition *PP* produces parthenocarpic fruits early, with the first developing generally by the fifth node. Heterozygous *Pp* plants produce parthenocarpic fruits later than homozygous plants and fewer in number. The homozygous recessive *pp* produces no parthenocarpic fruits.

Artificialy induced parthenocarpy

Using plant growth regulators: Cantliffe (1972) found that Morphactin IT 3456 (methyl-2chloro-9-hydroxyfluorene-(9)-carboxylate), and TIBA (2,3,5-tiiodobenzoic acid) induced parthenocarpic fruit to develop at a concentration of 50 ppm; also the node for the formation of the first fruit was significantly lowered. Again at 100 ppm Morphactin IT 3456, CCDP (3-carboxy-1-(p-chlorophenyl)-4,6-dimethyl-2-pridone) and TIBA produced both morphactin and TIBA again lowered the node number at which the first fruit developed.

Transgenic induction

Zhimin Y *et al.*, (2006) induced parthenocarpy in cucumber by introducing DefH9-iaaM chimeric transgene into cucumber genome with *Agrobacterium tumefaciens* mediated method.

Irradication

Deunff and Sauton (1994) induced abortive embryogenesis by pollinating female flowers with irradiated pollen by at 400 Gy dose of gamma rays in the non-parthenocarpic cucumber 'Bellafem' was during spring and autumn.

Maintenance of genetic parthenocarpy in cucumber

The only way to maintain a parthenocarpic line is to inbred or selfing, but most of the parthenocarpic varieties are gynoecious in nature that's why induction of male flower is the only way to maintain parthenocarpic plants.

Pointed Gourd (*Trichosanthes dioica Roxb.*)

Pointed gourd (*Trichosanthes dioica Roxb.*) is a dioecious cucurbit vegetable and

green fruits are only edible after cooking. Seedless or less-seeded fruit is preferred because; seeds are unpalatable due to their hard coats. Parthenocarpy is also induced in pointed gourd;

Polyploidy breeding

Hassan *et al.* (2020) conducted a study by immersing diploid seeds in 0.05%, 0.1%, and 0.5% colchicine for 24, 48 and 72 h to induce tetraploid. These tetraploides are used in inter- ploidy and intra-ploidy crossings as parents. Crossing between compatible tetraploid (maternal parent) and diploid (paternal parent) (4x × 2x) resulted in a similar fruit set rate and shape as those of the diploid; but the number of seeds in 4x × 2x offspring is drastically less than it's diploid parent. This tetraploid female can be easily maintained by vine cutting.

Plant growth regulators

Jahidul Hassan and Ikuo Miyajima,(2019) reported that application of plant growth regulators to unpollinated flowers of pointed gourd successfully induced parthenocarpic fruits compared to corresponding hand pollinated fruits which produced several numbers of well-developed normal-sized and hard seeds. However, some parthenocarpic fruits induced by NAA and GA3 at 200ppm contained less than 5 seeds which were morphologically seemed abnormal and shorter in size compared to normal seed. The other plant growth regulators i.e. TIBA, CPPU, 2,4-D etc., treated parthenocarpic fruits have seed like cavity structure that were empty and covered by thin edible soft layer.

Problems with parthenocarpic fruits

- Seed production is a tough job in parthenocarpic plants hence it needs expert knowledge and sometimes not economically profitable.
- Seeds are quite expensive comparing to seeded varieties.
- Fruits are sometimes malformed and not ideal for market.
- Taste or texture of fruit is also undesirable sometimes as example parthenocarpic cucumber has soft watery texture which is not preferred by Indian customers.

Future scope of parthenocarpy

- Combine several genes with parthenocarpic gene
- Improve character and quality of fruit.
- Developing parthenocarpy in high value crops to get more and early yield.
- Combine male sterility gene with parthenocarpy gene to improve yield and promote crossing.
- Maintain and produce crops with stable level of parthenocarpy.

Conclusion

- As these parthenocarpy plants don't need pollination this factor may play a major role to develop many diverse cucurbits as most of them are cross pollinated
- In spite of some serious problems mentioned there's lot to exploit in cucurbits through parthenocarpy fruits.

Reference

- Baker, L. R., Scott, J. W., & Wilson, J. E. (1973). Seedless pickles--a new concept. Res Rep *Mich State Univ Agric Exp Stn*.
- Chopra VL, Swaminathan MS., (1960); Induction of polyploidy in watermelon. Proceedings-Indian Academy of Sciences. 51(2):57-65.
- Dalal, M., Dani, R. G., & Kumar, P. A. (2006). Current trends in the genetic engineering of vegetable crops. *Scientia Horticulturae*, 107(3), 215-225.

- Golabadi, M., Golkar, P., & Eghtedari, A. R. (2018). Use of chemical and hormonal agents for changing sex expression of cucumber for breeding programs. *Biharean Biologist*, 12(1), 27-32.
- Hassan J, Miyajima I, Ozaki Y, Mizunoe Y, Sakai K, Zaland W.(2020) Tetraploid Induction by Colchicine Treatment and Crossing with a Diploid Reveals Less-Seeded Fruit Production in Pointed Gourd *(Trichosanthes dioica Roxb.). Plants*.; 9(3):370.
- Hayata Y, Niimi Y, Inone K, Kondo S., (2000), CPPU and BA, with and without pollination, affect set, growth and quality of muskmelon fruit. Hortscience.; 35(5):868-870.
- Hayata Y, Niimi Y, Iwasaki N. (1995); Synthetic cytokinin-1(2=chloro=4=pyridyl)-3-phenylurea (CPPU)-promotes fruit set and induces parthenocarpy in watermelon. Journal of American Society of Horticultural Science.; 120(6):997-1000.
- Hossain ABMS., (2015), Seedless pumpkin vegetable production using gibberellic acid (GA3) as plant hormone and genetically modified technique. Global Journal of Biology, Agriculture& Health Sciences.; 4(3):6-8.
- Innark, P., Khanobdee, C., Samipak, S., & Jantasuriyarat, C. (2013). Evaluation of genetic diversity in cucumber (Cucumis sativus L.) germplasm using agro-economic traits and microsatellite markers. S*cientia Horticulturae*, 162, 278-284.
- Joldersma, D., & Liu, Z. (2018). The making of virgin fruit: the molecular and genetic basis of parthenocarpy. *Journal of Experimental Botany,* 69(5), 955-962.
- Juldasheva L., (1973), Inheritance of the tendency towards parthenocarpy in cucumbers. Byull Vsesoyuznogo Ordena Lenina Inst Rastenievodstva Imeni NI Vavilova.;32:58–59.
- Kihara, H. (1951). Triploid watermelons. In Proc. *Amer. Soc. Hort. Sci.* (Vol. 58, pp. 217-230).
- Kim IS, Okubo H, Fujieda K, (1992),. Genetic and hormonal control of parthenocarpy in cucumber (*Cucumis sativus L.)*. J Fat Agr.;36:173–81.
- Kvasnikov BV, Rogova NT, Tarakanova SI, Ignatov SI., (1970), Methods of breeding vegetable crops under the covered ground. Trudy Prikl Bot Genet Selek;. 42:45–57.
- Li, J., Xu, J., Guo, Q.W., Wu, Z., Zhang, T., Zhang, K.J., Cheng, C.Y., Zhu, P.Y., Lou, Q.F. and Chen, J.F., (2017). Proteomic insight into fruit set of cucumber (Cucumis sativus L.) suggests the cues of hormone-independent parthenocarpy. *BMC genomics*, 18(1), pp.1-18.
- Lukyanenko, A. N. (1991). Breeding tomato for mechanized harvesting. In *Genetic Improvement of Tomato* (pp. 213-230). Springer, Berlin, Heidelberg.
- Lukyanenko, A. N. (1991). Parthenocarpy in tomato. In *Genetic improvement of tomato* (pp. 167-177). Springer, Berlin, Heidelberg.
- Meshcherov, E., & Juldasheva, L. (1974). Parthenocarpy in cucumber. *Trudy Prikl Bot Genet Selek*, 51, 204-213.
- Moussa, H., & Salem, A. (2009). Induction of parthenocarpy in watermelon (Citrullus lanatus) cultivars by gamma irradiation. *Acta Agronomica Hungarica*, 57(2), 137-148.
- Quan JU., (1999), Parthenocarpy induced by N-(2-chloro-4-pyridyl)-N'phenylurea (CPPU) prevents flower abortion in Chinese white flowered gourd (Lagenaria leucantha). Environmental and Experimental botany.; 42:121-128.
- Rao, P. G., Prasad, B. V. G., Kumar, T. K.,

& Lakshmi, T. (2018). Breeding for Climate Resilient Parthenocarpic Vegetables. *Int. J. Curr. Microbiol. App. Sci,* 7(11), 2473-2492.

- Robinson, R. W., & Decker-Walters, D. S. (1997). *Cucurbits*. Cab international.
- Royo, C., Torres-Pérez, R., Mauri, N., Diestro, N., Cabezas, J. A., Marchal, C., ... & Carbonell-Bejerano, P. (2018). The major origin of seedless grapes is associated with a missense mutation in the MADS-box gene VviAGL11. *Plant physiology*, 177(3), 1234-1253.
- Schwabe, W. W., WW, S., & JJ, M. (1981). Hormones and parthenocarpic fruit set.
- Susila, T., Reddy, S. A., Rajkumar, M., Padmaja, G., & Rao, P. V. (2013). Studies on Exogenous Application of Cppu and Ga on Yield. *World Journal of Agricultural Sciences*, 9(2), 132-136.
- Tolentino, M. F., & Cadiz, N. M. (2005). Effects of Naphthaleneacetic Acid (NAA) and Gibberellic Acid (GA~ 3) On Fruit Morphology, Parthenocarpy, Alkaloid Content and Chlorophyll Content in Bittergourd (Momordica charantia L.Makiling'). *Philippine Agricultural Scientis*t, 88(1), 35.
- Varoquaux, P., Gouble, B., Ducamp, M. N., & Self, G. (2002). Procedure to optimize modified atmosphere packaging for fruit. *Fruits*, 57(5-6), 313-322.
- Wu, Z., Zhang, T., Li, L., Xu, J., Qin, X., Zhang, T., & Chen, J. (2016). Identification of a stable major-effect QTL (Parth 2.1) controlling parthenocarpy in cucumber and associated candidate gene analysis via whole genome re-sequencing. *BMC plant biology,* 16(1), 1-14.
- Yin, Z., Malinowski, R., Ziólkowska, A., Sommer, H., Plcader, W., & Malepszy, S. (2006). The DefH9-iaaM-containing construct efficiently induces parthenocarpy in cucumber. *Cellular and Molecular Biology Letters*, 11(2), 279-290.

❖❖