



International Journal of Research in Agronomy

E-ISSN: 2618-0618
P-ISSN: 2618-060X
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NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(5): 887-890
Received: 17-02-2026
Accepted: 21-03-2026

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Sex expression and breeding of gynoecious lines in cucurbitaceous vegetable crops

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DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i5l.5635>

Abstract

Cucurbits, crops of the Cucurbitaceae family, are the world's biggest group of fruit vegetables, extensively spread and cultivated in tropical and subtropical regions of the world. Most of the economically important cucurbits find it uses in various ways. They can be eaten or used as a dessert (Muskmelon, Watermelon), vegetables (gourds), pickles (West Indian gherkin), and confectionery (Ash gourd). Cucurbitaceae is a predominant family characterized by different sex expression, which is viewed as a significant determinant in influencing economic yield and quality. The combination of genetic, environmental and hormonal factors helps determine the sex expression in cucurbits. Detection of sex expression is anyway considered as crucial. Aside from sex expression, development of gynoecious lines is another aspect that contributes to increased output and early harvest. The following article briefly enumerates about the sex expression and the exploitation of gynoecious lines in cucurbitaceous vegetable crops in enhancement of their yield.

Keywords: Sex expression, cucurbits, Gynoecey, hybrid breeding

Introduction

Cucurbitaceae considered as a largest family of vegetable and fruit crops comprises of approximately 134 genera and 965 species. Sex expression plays a significant role in hybrid breeding of cucurbitaceous crops. Wide range of sex types has been reported in Cucurbitaceae family. They generally produce staminate, pistillate, and hermaphrodite blooms. The pistillate form has the most primitive sex expression, while the hermaphrodite is considered the most advanced sex form.

Most of developing countries production system rely heavily on hybrid kinds of cucurbits. The number of hybrid cultivars is day by day gradually rising, hence gynoecious lines are considered critical for hybrid seed production. At present, several hybrid breeding programmes are focusing on stabilizing gynoecious character and development of stable gynoecious lines.

Different sex types in cucurbitaceous crops

Based on the ratio of different types of flowers produced, sex forms are broadly classified into the following types;

1. **Monoecious:** Bears staminate and pistillate flowers on the same plant.
2. **Dioecious:** Bears staminate and pistillate flowers on the separate plant.
3. **Gynoecious:** Bears only female flowers
4. **Andromonoecious:** Bears staminate and hermaphrodite flowers in the same plant
5. **Gynomonoecious:** Bears female and hermaphrodite flowers in the same plant
6. **Androecious:** Bears staminate flowers only
7. **Gynodioecious:** Bears staminate and pistillate flowers in the separate plant
8. **Trimonoecious:** Bears staminate, pistillate and hermaphrodite flowers altogether in the same plant.

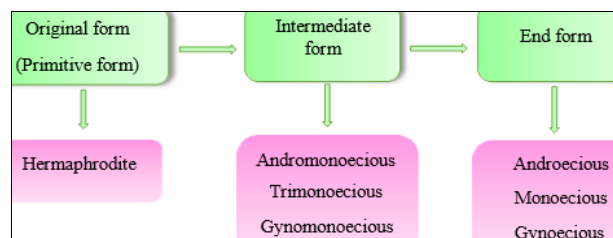


Fig 1: Evolution of Sex Expression In Cucurbits (Whitaker and Davis, 2008) ^[13]

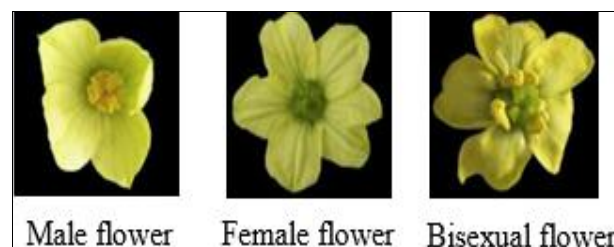


Fig 2: Sex identification of cucurbits

Table 1: Sex forms of various types in cucurbits

S. No.	Sex forms	Crops
1	Monoecious	Cucumber, Muskmelon, Water melon, Pumpkin, Summer squash, Winter squash, Sponge gourd, Round melon, Bitter gourd, Bottle gourd
2	Hermaphrodite	Ridge gourd cultivar (Satputia) and Kashi kushi, Cucumber
3	Gynoecious	Cucumber, Bitter gourd, Watermelon, Muskmelon, Ridge gourd
4	Androecious	Cucumber, Muskmelon
5	Dioecious	Pointed gourd, Ivy gourd (Coccinia), Spine gourd, Luffa sp- Luffa echinata, Citrullus sp- Citrullus naudianus, Cucumber sp- Cucumis esper.
6	Andromonoecious	Cucumber, Musk melon
7	Gynomonoecious	Cucumber, Musk melon, Ridge gourd
8	Trimonoecious	Cucumber, Musk melon, Ridge gourd and sometimes Bitter gourd

Sex Modification

Most of the cucurbitaceous crops exhibits monoecious sex form in common and their sex ratio normally ranges from 25-30:1 to 15:1. Sex expression is modified by various factors such as;

1. Environment factors
2. Cultural factors
3. Growth regulators/hormones

Environmental Factors

Influence of sex expression by environmental factors mainly depends upon the factors such as temperature, photoperiod, nutrients and moisture content. Short day condition, low temperature and high moisture content promotes the female sex expression in cucurbits while high nitrogen content in soil, long day condition accompanied with high temperature encourages male flower production. High temperature coupled with low light conditions significantly decreased the ratio of female flowering node. Controlled environmental conditions with temperature of 30° C and 16 hours photoperiod produced up to 160 nodes without a female flower. While decrease in temperature at night attributed the formation of female flowers at 20 to 30 nodes. Due to anticipation of ethylene synthesis involved in the environment dependent sex expression of cucurbits, shoot apices of monoecious plants is known to be more active under short day than the long day conditions.

Cultural factors

Cultural practices like irrigation, nutrient supply and the planting season tend to alter the sex ratio or expression in cucurbitaceous crops. Inadequate supplement of water can lead to gradual decrease in flowering. Nutrients like nitrogen, phosphorus and potassium given in sub-optimal application results in male flowers whereas high level of nitrogen promoted more vegetative growth and leads to delay in flowering process thus suppressing the production of female flowers. Planting during the season of heavy rainfall encounters less flower production and as like that hot season planting favours more male flowers and reduces the female flower development (Kraup *et al.*, 2002) ^[5].

Growth regulators

Altering the flowering sequence is the major component in sex modification of cucurbits. Flowering behaviour changes with the

cultivars and the sex expression in cucurbits can be modified by hormonal factors like plant growth regulators. Plant growth regulators which include plant growth promoters or retardants works primarily by regulating sex expression to enhance the crop growth, early flowering, maximum fruit set and yield especially when applied at 2 or 4 leaf stage and flower initiation stage (Sarkar *et al.*, 2019) ^[10]. Exogeneous application of growth regulators such as NAA, Ethrel, Maleic Hydrazide helps to increase the femaleness in cucurbits by producing more number of female flowers and fruits as well as stimulates the yield thus suppressing the male flowers. Effect of ethrel on female flower production is considered profound. It helps in the early development of female flowers at the lowest node of the main stem. GA3, Silver nitrate (Ag NO₃) and silver thiosulphate, Ag (S₂O₃) as growth hormones inhibits the synthesis of ethylene action and helps to promote more male flowers.

Gynoecious cucumber lines and its maintenance

Gynoecy or gynoecious lines refers to the condition, which predominantly produces only female flowers ensuring 100% pure hybrid seed production. Development of stable gynoecious lines is of major importance in developing high yielding F₁ hybrids in cucurbits. This sex form has been exploited commercially all over world for cucurbits breeding. Gynoecious F₁ hybrid seeds are produced by crossing two different unisexual breeding lines. Different cross combination of sexual breeding lines are used to develop the hybrids which may be of Gynoecious and Monoecious, Gynoecious and Hermaphrodite and Gynoecious and Gynoecious. Selection of gynoecious cucumber lines is somewhat critical process. However, they are selected on the basis of sex expression of flowers in those breeding lines. Use of gynoecious line as one parent mostly as maternal parent in hybrid breeding showed positive impact in terms of yield, earliness and more of female flowers (Gangadhar Rao *et al.*, 2018) ^[4].

Maintenance of Gynoecious lines

GA₃, silver nitrate and silver thiosulphate were used in induction of male flowers to maintain the gynoecious lines in cucurbits for the development of F₁ hybrids. Among those different chemicals, silver nitrate was reported to be less phytotoxic and more effective in maintenance of gynoecious lines.

GA₃ causes excessive stem elongation with malformed and

erratic male flower induction, while silver nitrate exhibits burning effect on plant.

The following are the required recommendations of chemicals inducing male flowers in cucurbits for regulation of gynoecious lines.

- Two concentrations of chemical GA3 at 500 and 1000 ppm is applied thrice at two- or four-leaf stage at fortnightly intervals.
- Two or three applications of silver nitrate at 200 and 400 ppm concentration and silver thiosulphate at 6 and 9 pm before the emergence of first flower.

Three applications of GA4 or GA7 is applied at 50 ppm concentration from second leaf stage.

The first application of these chemicals is to be given at 23 days after sowing and further application at 7 days interval.

Genes involved in Gynoecious cucurbits

Several genes are involved in inducing gynoecy in various cucurbits. There are two kinds of gene loci conferring either dominance or recessiveness in controlling gynoecy in cucurbits. In cucumber crop, inheritance of gynoecy is controlled by a single dominant gene (Acr/acr) (Pati *et al.*, 2015) ^[7], while single recessive gene called gy-1 governs the gynoecy in bitter gourd and in ridge gourd gynoecism is found to be governed by a major recessive gene (Singh *et al.*, 2012) ^[11].

Development and utilization of gynoecious lines in different cucurbitaceous crops

The first gynoecious breeding line in cucumber, MSU 713-52 was developed by Peterson and Anhder in (1960) ^[8] by crossing Shogoin with Wisconsin SMR 18. This gynoecious line is reported with a strong tendency to bear more pistillate flowers even under different environment conditions. The potentiality of gynoecious lines in cucumber improvement of breeding programme led to the development of three tropical gynoecious lines at Indian Agricultural Research Institute, New Delhi, which includes Gyc 1 (87-304), Gyc 2 (87319), Gyc 3 (87-338) and they were developed by More and Seshadri (1988) ^[6]. Tropical gynoecious lines in cucumber, GY 14, SR551F, GY 3, GY 57 and Table green 68 pioneered by Munger in (1979) enriched to produce slicing and pickling F1 hybrids. Due to the unstability of these lines for expression of gynoecy sex form under high temperature and photoperiodic conditions in tropical climatic areas, it led to need for developing suitable tropical gynoecious lines for that area. As a result, crosses were made between temperate gynoecious lines involving (GY 14, SR551F, GY 3, Tablegreen 68 x Gy 3, Wisconsin 2757) along with tropical monoecious lines, (Poona khira, RKS296, RKS300) and segregation of generation has been made for selection of recombinant with true breeding gynoecious sex. Four cucumber inbred lines namely, IIHR- 434, IIHR-435, IIHR-436 and IIHR-

437 developed from gynoecious parthenocarpic cucumber hybrid. Further through individual plant selection from F2 to F4 generation and subsequent validation at phenotypic and molecular level through SSR markers confirmed stable gynoecious expression, supporting their use as female parents in hybrid breeding (Bommesh *et al.*, 2020) ^[2]. In muskmelon gynoecious breeding line GY-4 was developed from segregating population of stable gynoecious line, Wisconsin 998, which was evolved by Peterson *et al.* (1983) ^[8] carried a pair of recessive genes for gynoecy sex form (Yiggal 1993). For true breeding of gynoecious sex in muskmelon, three gynoecious lines namely, 86-104, 86-105 and 86-118 have been developed. The lines, 86-104 and 86-105 were derived from cross between gynomonoecious line and hermaphrodite-2 (Ac. No. 433) and while the line 86-118 was derived from crossing monoecious-1 and hermaphrodite-1 (Ac No. 354). Inheritance of gynoecism in bittergourd has been reported in gynoecious line, GY263B. This line was earlier found in a germplasm population of IC68263B and then been maintained through sibmating with monoecious plants of same group (Ram *et al.*, 2006) ^[9]. Apart from this gynoecious line in bitter gourd, two other gynoecious lines namely DBGY-201 and DBGY- 202 were found to be immense potential in breeding of hybrid bitter gourd (Behara *et al.*, 2006).

Inheritance of effect of gynoecium in different cucurbitaceous crops

Gynoecium in cucumber by utilization of GBS-1 as a gynoecious line and Pusa Uday and Punjab Naveen as two monoecious lines has resulted in the segregation of sex form in plants which indicated monogenic dominance of gynoecious sex form (Pati *et al.*, 2015) ^[7] as well as resulted as top performing hybrids with respect to productivity. In bitter gourd, a gynoecious line, KAU-MCGY-101 developed by Kerala agricultural university, crossed with three monoecious lines namely Preethi, Priyanka and MC133 has been proven superior in development of early and high yielding hybrids (Sunny *et al.*, 2022) ^[12]. GY-4, the gynoecious line of muskmelon when crossed with monoecious line, PI124111F or andromonoecious line '36', the resulting plants of F1 progeny that has been derived from both the crosses were found to be monoecious, while plants of F2 progeny of same cross showed segregation of monoecious, gynomonoecious and gynoecious in the ratio of 12:3:1 indicating the presence of two recessive genes that differ between monoecy and gynoecy. The hybrid cross, W 321 x N 233 developed in muskmelon by utilising W 321 as a gynoecious female parent, has been reported to be exploited for commercial cultivation as the cross was known for its commercial viability and economic yield (Dhaliwal *et al.*, 1996) ^[3].

Development of gynoecious hybrid varieties

Crop	Varieties	Description
Cucumber	Pusa hybrid cucumber-9 Pusa hybrid cucumber-18	Gynoecious hybrid Gynoecious cucumber hybrid suitable for cultivation in spring, summer and kharif season.
	Pusa sanyog Phule Prachi Phule champa KTCH-11 DCH-1, DCH-2, DGC- 102	The first cucumber hybrid derived from crossing (Japanese gynoecious line with Green Long of Naples). Tropical gynoecious lines utilized in hybrid development
Muskmelon	Gylan MH-10	An improved gynoecious variety that was developed from cross with line, 124111F. Hybrid derived from cross between Gynoecious line and Indian cultivar (Gynoecious x Indian cv).
Bitter gourd	Pusa Hybrid- 4	The first gynoecious early maturing and high yielding hybrid developed by using gynoecious line as female parent and monoecious line as male parent.

Conclusion

Sex expression in cucurbits is a genetically controlled and environmentally influenced trait that directly determines reproductive efficiency and yield. The exploitation of gynoecious lines has revolutionized cucurbit breeding by enabling higher female flower production, improved earliness and enhanced yield potential. These lines serve as efficient female parents in hybrid development, simplifying seed production while ensuring uniformity and cost effectiveness. Although maintenance of gynoecious lines requires induction of male flowers, their advantages in hybrid breeding outweigh this limitation. Overall, the integration of gynoecy into breeding programmes provides a reliable and practical approach for developing high-performing hybrids and improving productivity in cucurbit vegetable crops.

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