**Effect of GA₃ and Silver Compounds on Staminate Flower Induction in Gynoecious Parthenocarpic Cucumber Under Polyhouse Conditions**

**ABSTRACT**

Cucumber (*Cucumis sativus* L.) is a predominantly cross-pollinated self-fertile species characterized by diverse floral morphologies, including staminate, pistillate, and hermaphroditic flowers, which generally develop singly at each node. The determination and differentiation of floral sex in cucumber are profoundly regulated by exogenous application of plant growth regulators, which can alter floral architecture and sex expression. Gynoecious parthenocarpic cucumber lines, which are highly advantageous for off-season production due to their exclusive female flowering habit and seedless fruit development, naturally lack staminate flowers. Therefore, the exogenous induction of male flowers through hormonal treatments becomes imperative for effective line maintenance and seed propagation in breeding programs. A study conducted under Naturally Ventilated Polyhouse Condition” during *Kharif* season of 2023 and *Summer* season of 2024 in the naturally ventilated polyhouse of Department of Horticulture, S.K.N. College of Agriculture, Jobner (Jaipur) with aimed to manipulate the sex expression in the gynoecious parthenocarpic cucumber variety ‘PPC-6’ using a Randomized Block Design (RBD) with three replications. Three different chemicals *viz*., Gibberellic acid (GA3) @ 500 and 1000 ppm, silver nitrate (Ag NO3) and silver thiosulphate (Ag2S2O3) @ 300 and 500 ppm were sprayed at 2-4 leaf stage at 7 days interval till the 10-12 leaf stage whereas, control was sprayed with distilled water only. Among the three chemicals, silver thiosulphate @ 300 ppm exhibited superior results for days taken to first staminate flowering (28.45 days), lowest node on which first staminate flower initiated (4.52), highest node number up to which staminate flower appeared (23.61), induced maximum staminate flowering nodes (19.09) and maximum number of staminate flowers per plant (134.28) was recorded under treatment MG5 (Ag2S2O3 @ 300 ppm) while, MG4 (AgNO3) was superior over other treatments in terms of diameter of staminate flower (5.30 cm). All the seven treatments were found to produce staminate flower, except control.

**Keywords:** Sex expression, silver thiosulphate, gynoecious, parthenocarpy, staminate flower.

1. **INTRODUCTION**

Vegetable kingdom comprise of a large number of plants, mostly annuals, of which different parts like stem, leaf, flower bud, flower, fruit, root *etc*. are consumed. Vegetables provide all the nutrient components, *viz*. carbohydrate, protein, fat, vitamins, minerals and roughages which are the essential constituents of a balance diet. Vegetables contain abundance of vitamins and minerals which are rightly called as protective foods. Vegetables can be grown in a wide range of agro- climate zones of India from snowcapped Himalayan Mountains in the north to coastal regions of south and humid tropics of east to the hot arid zones of west and vegetables are the major contributor with around 60% to the total horticultural production in India.

Cucumber (*Cucumis sativus* L., 2n=2x=14) is one of the most valuable herbaceous, annual, crawling vine plant of Cucurbitaceae family and is generally grown for its immature tender fruits, which are mainly consumed as a salad. It is one of the most potential greenhouse vegetable crops (*Cucumis sativus* L.), known as *Khira* in Hindi (Swamy,2023). This crop is of Asian origin (India) and the progenitor may be closely related to its wild relative *Cucumis sativus* *var*. *hardwickii*, first found in the Himalayan Mountains (foothills of Nepal) and used by native peoples of Northern India as a laxative (Deakin *et al*., 1971). In India, it was cultivated over an estimated area of 1.27 lakh hectares, producing approximately 20.14 lakh metric tonnes with an average productivity of 15.85 tonnes per hectare (Anonymous, 2024-2025). Among its diverse floral types, gynoecious lines—characterized by the exclusive presence of female flowers—are particularly valued in hybrid breeding programs due to their high yield potential and uniformity. In addition to genetic control, the development of floral organs in cucurbits is highly responsive to environmental conditions and endogenous hormonal balance. External application of plant growth regulators has been shown to significantly influence sex expression and flowering behavior, often promoting or inhibiting the development of female and male flower formation. Such hormonal interventions offer an eco-friendly and non-toxic alternative for modifying sex expression, without adverse effects on the environment or human health. Notably, applying these substances during the early vegetative phase, particularly at the 2–4 leaf stage, has proven to be a critical window for manipulating floral sex differentiation (Kumar *et al*., 2011).

The induction of staminate flowers is a critical requirement for F1 hybrid seed production in gynoecious cucumber lines. The consistent expression of the gynoecious trait has played a pivotal role in harnessing heterosis, contributing significantly to the success and efficiency of hybrid breeding programs in cucumber (Golabadi *et al.,* 2015). The improvement of any crop plant which is ultimate objective of the plant breeder worldwide is not a simple task.

The primary objective of this investigation was to establish a viable method for the maintenance of gynoecious cucumber lines under local agro-climatic conditions, where such protocols have not yet been developed. Successful maintenance of these lines is essential for their effective utilization as female parents in hybrid breeding programs. This study was designed to lay the groundwork for future hybridization efforts aimed at enhancing and standardizing locally adapted cultivars. Accordingly, the present research focused on assessing the impact of various plant growth regulators or other chemical substances to determine the most effective treatment for inducing staminate flower development specifically targeting prolonged male flowering duration and increased male flower production in gynoecious cucumber lines.

1. **MATERIALS** **AND** **METHODS**

A study conducted under Naturally Ventilated Polyhouse Condition” during *Kharif* season 2023 and *Summer* season 2024 in the naturally ventilated polyhouse at Department of Horticulture, S.K.N. College of Agriculture, Jobner (Jaipur) with aimed to manipulate the sex expression in the gynoecious parthenocarpic cucumber variety ‘Pusa Seedless 6’ using a Randomized Block Design with three replications. Five plants were selected randomly and subjected to seven different treatments. Three different chemicals *viz*., Gibberellic acid (GA3) @ 500 & 1000 ppm, silver nitrate (AgNO3) and silver thiosulphate (Ag2S2O3) @ 300 & 500 ppm were sprayed. Control was sprayed with distilled water only. Application of these chemicals was performed as per the treatments (Table 1) at two to four true leaf stage of plant and subsequent application at seven-day interval. The solutions of chemical were prepared with distilled water and about 10 ml solution per plant was applied with hand sprayer. The observations *viz*., days taken to first staminate flowering, lowest node on which first staminate flower initiated, highest node number up to which staminate flower appeared, induced maximum staminate flowering nodes, maximum number of staminate flowers per plant and diameter of staminate flower in each treatment were recorded.

**2.1. CHEMICAL PREPARATION**

The gibberellic acid (GA) solutions of 500 and 1000 ppm were prepared by dissolving 500 and 1000 mg of GA salt, respectively, in distilled water and adjusting the final volume to one liter. Similarly, silver nitrate solutions of 300 and 500 ppm were prepared by dissolving the respective quantities of silver nitrate salt in distilled water, with the final volume made up to one liter. The stock solution of each of 4 mM silver nitrate and sodium thiosulphate (Na2S2O3.5H2O) was prepared by dissolving 680 mg silver nitrate in one litre and 1000 mg of sodium thiosulphate separately in one liter of distilled water. For safer use, each bottle was kept in dark and stored in refrigerator till final use. The solution of silver thiosulphate was prepared by slowly pouring the calculated volume of silver nitrate into sodium thiosulphate, stirring rapidly as the SOLUTIONS were mixed as needed on the day of experiment. To prepare 300 and 500 ppm solution of silver thiosulphate from 4mM stock solution of silver nitrate and sodium thiosulphate were mixed using normality equation as per requirement.

* 1. **STATISTICAL ANALYSES**

Analysis of variance for individual character was done on the basis of mean values as suggested by Panse and Sukhatme (1985). The critical difference (CD) was worked out to assess the significance of treatment means wherever the ‘F’ test was significant at a 5 per cent probability level. To elucidate the nature and magnitude of treatment effects, summary tables along with SEm± and CD at 5 per cent are given in the text of the chapter “Experimental Results”.

1. **RESULTS AND DISCUSSION**

A study conducted under Naturally Ventilated Polyhouse condition during *Kharif* season 2023 and *Summer* season 2024 with the objective of modifying sex expression in a gynoecious parthenocarpic cucumber cultivar through the induction of staminate (male) flowers. This intervention was crucial for the effective maintenance and propagation of gynoecious lines, which inherently do not produce male flowers. By stimulating male flower development, the study aimed to support successful hybridization and seed production, thereby contributing to the sustainability of off-season cultivation and enabling more efficient implementation of controlled breeding strategies in cucumber improvement programs. The results of study are presented below. Three different chemicals *viz*., Gibberellic acid (GA3) @ 500 & 1000 ppm, silver nitrate (AgNO3) and silver thiosulphate (Ag2S2O3) @ 300 & 500 ppm were sprayed at 2-4 leaf stage at 7 days interval till the 10-12 leaf stage to induce male flowers in gynoecious lines and their subsequent effect on sex expression was studied (Table 1). The result of present investigation deciphered that foliar application of different chemical substances (gibberellic acid,silver nitrate and silver thiosulphate) had favourable effect on induction of staminate flowers in PPC-6 gynoecious line of cucumber over control. Foliar spray of Ag2S2O3 @ 300 ppm (MG5) on PPC-6 cultivar significantly influenced the days taken for appearance of first staminate flower, node on which first staminate flower induced, node number up to which staminate flower appeared, total number of nodes induced staminate flower per plant and total number of staminate flowers induced per plant, except the diameter of staminate flowers where AgNO3 performed better over Ag2S2O3.The minimum number of days taken to first staminate flowering (28.45 days), lowest node on which first staminate flower initiated (4.52), highest node number up to which staminate flower appeared (23.61), induced maximum staminate flowering nodes (19.09) and maximum number of staminate flowers per plant (134.28) was recorded under treatment MG5 (Ag2S2O3 @ 300 ppm) while, MG4 (AgNO3) was superior over other treatments in terms of diameter of staminate flower (5.30 cm) in gynoecious cucumber. Whereas, the maximum number of days taken to first staminate flowering (32.51 days), highest node on which first staminate flower initiated (6.54), lowest node number up to which staminate flower appeared (17.56), induced minimum staminate flowering nodes (11.02), minimum number of staminate flowers per plant (134.28) and minimum diameter of staminate flower (3.58 cm) was recorded under treatment MG1 (GA3 @ 500 ppm). These results is conformation with the results obtain by Beyer (1976), Golabadi *et al*. (2015), Verma *et al*. (2018) and Dhall *et al*. (2022) in cucumber.

These findings clearly indicated that foliar spray of Ag2S2O3 @ 300 ppm (MG5) played a significant role in induction of staminate flowers in gynoecious line of cucumber. The better response of silver thiosulphate (Ag2S2O3) on these characters may be due silver ions (Ag+) of silver thiosulphate (Ag2S2O3) that binds to ethylene receptors in plant tissues. This binding prevents ethylene to activate its receptors, effectively blocking its feminizing effects and favoring the formation of male flowers (Beyer, 1976), thereby promoting male flower formation and reducing the production of female flowers in plant of gynoecious cucumber (Hatwal *et al*., 2015). These results are in proximity with the results obtained the studies of by Nagar *et* *al*. (2014) in gynoecious cucumber cutivars. These findings also support Behera *et* *al*. (2010) in bitter gourd, Dhall *et* *al*. (2022) in cucumber except the study conducted by Choudhary *et al*. (2020), where it was reported that silver nitrate was effective staminate flower induction for the maintenance of gynoecious cucumber lines. Staminate flower production also depends on the environment and genotype. In other study, Susaj and Susaj (2010), Sanwal (2011) and Zhang *et al*. (2007) also revealed the formation of staminate flower at the highest number of nodes, induction of male flower at lowest node and minimum mortality with application AgNO3 in gynoecious seedlings of cucumber. However, Mishra *et* *al*. (2022) suggested that the higher doses of silver nitrate exhibited toxicity effect on leaves which recovered within seven to ten days while gibberellic acid treatments were not very effective in flower induction as they induced some flowering only in few genotypes.

**Table 1. Effect of GA3, AgNO3 and Ag2S2O3 on various parameters in gynoecious cucumber**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| S. No.  Treatment details | Notation | Days taken for appearance of first staminate flower | Node number at which first staminate flower induced | Node number up to which staminate flower appeared | Total number of nodes induced staminate flowers/ plant | Number of staminate flowers induced per plant | Diameter of staminate flower |
| Control | MG0 (Control) | \*0.10 | \*0.10 | \*0.10 | \*0.10 | \*0.10 | \*0.10 |
| GA3 @ 500 ppm | MG1 | 32.51 | 6.54 | 17.56 | 11.02 | 78.19 | 3.58 |
| GA3 @ 1000 ppm | MG2 | 31.64 | 6.10 | 18.62 | 12.52 | 91.49 | 3.95 |
| AgNO3 @ 300 ppm | MG3 | 30.94 | 5.73 | 19.50 | 13.77 | 104.10 | 5.06 |
| AgNO3 @ 500 ppm | MG4 | 28.99 | 5.10 | 21.80 | 16.70 | 126.40 | 5.30 |
| Ag2S2O3 @ 300 ppm | MG5 | 28.45 | 4.52 | 23.61 | 19.09 | 134.28 | 4.52 |
| Ag2S2O3 @ 500 ppm | MG6 | 29.69 | 5.40 | 20.48 | 15.07 | 116.82 | 5.16 |
| S.Em.± | | 0.57 | 0.11 | 3.58 | 0.10 | 3.58 | 0.10 |
| C.D. at 5 % | | 1.65 | 0.32 | 10.45 | 0.28 | 10.45 | 0.28 |
| C.V. % | | 5.31 | 5.62 | 9.43 | 5.92 | 9.43 | 5.92 |

\*The actual value of control was 0.0 but for statistical analysis, it was kept 0.10.

**Table 2. Pooled analysis of variance (MSS) for days taken for appearance of first staminate flower and node on which first staminate flower induced**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source of Variance | *d.f.* | Mean Sum of Squares | | | |
| Days taken for appearance of first staminate flower | | Node on which first staminate flower induced | |
|  |  | Season-I | Season-II | Season-I | Season-II |
| Replication | 2 | 0.83 | 0.20 | 0.04 | 0.05 |
| Treatment | 6 | 405.38 | 392.63 | 14.03 | 14.19 |
| Error | 12 | 1.97 | 1.86 | 0.05 | 0.09 |

**Table 3. Pooled analysis of variance (MSS) for node number up to which staminate flower appeared and total number of nodes induced staminate flowers**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Source of Variance | *d.f.* | Mean Sum of Squares | | | |
| Node number up to which staminate flower appeared | | Total number of nodes induced staminate flower | | |
|  |  | Season-I | Season-II | Season-I | Season-II | |
| Replication | 2 | 0.18 | 243.58 | 0.29 | 0.61 | |
| Treatment | 6 | 182.50 | 6404.29 | 108.57 | 116.67 | |
| Error | 12 | 0.31 | 116.45 | 0.39 | 0.78 | |

**Table 4. Pooled analysis of variance (MSS) for number of staminate flowers induced per plant and diameter of staminate flower**

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Source of Variance | | *d.f.* | | Mean Sum of Squares | | | | | | | | |
| Number of staminate flowers induced per plant | | | | Diameter of staminate flower | | | | |
|  | |  | | Season-I | | Season-II | | Season-I | | Season-II | | |
|  | |  | |  | |  | |  | |  | | |
|  | |  | |  | |  | |  | |  |
| Replication | | 2 | | 18.93 | | 0.20 | | 0.04 | | 0.05 | | |
| Treatment | | 6 | | 5972.70 | | 392.63 | | 14.03 | | 14.19 | | |
| Error | | 12 | | 37.38 | | 1.86 | | 0.05 | | 0.09 | | |

1. **CONCLUSION**

On the basis of the preceding discussion it can be concluded that the production of sufficient quantity of staminate flower on gynoecious lines can be induced through foliar application of silver thiosulphate @ 300 ppm concentration during both the season under NVP condition for maintaining the inbred lines of gynoecious cucumber. However, there is need to test the efficacy of silver thiosulphate, silver nitrate and gibberellic acid along with other chemicals on lateral branches of cucumber.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author (s) hereby declare that NO generative AI technologies such as Large Language Models (Chat GPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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