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CONTENTS

Effect of chemical treatments on seed yield and quality in parthenocarpic cucumber (*Cucumis sativus* L.)

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ABSTRACT: Cucumber is a cross-pollinated crop exhibiting diverse flower morphology including male, female and hermaphrodite flowers. Parthenocarpic cucumber varieties produce female or gynoecious flower leading to formation of fruit without fertilization, which poses a challenge in seed production due to the absence of male flowers. Hence, the present study aimed to access the impact of chemical treatments on male flower induction, seed yield and quality in parthenocarpic cucumber (Pant Parthenocarpic Cucumber-3). The experiment was conducted at the V. R. C., Pantnagar, from 2021-22 to 2023-2024 in a RBD layout with three replications. Nine treatments, including different concentrations of silver nitrate, gibberellic acid (GA_3), and silver thiosulphate, were applied at the 2 and 4 true leaf stages. On the basis of 3-year pooled data it was observed that application of silver nitrate at 500 ppm induced the maximum number of male flowers (60) followed by 250 ppm (56.89) and 750 ppm (47) silver nitrate. Application of silver nitrate at 500 ppm also recorded the maximum number of seeds per fruit (82.62) and seed yield (462.48 Kg/ha) with no significant difference in seed quality parameters of different treatments. The benefit cost ratio was highest (3.46) in application of silver nitrate at 500 ppm followed by application of 750 ppm silver nitrate (3.22). Therefore, it can be concluded that foliar spray of silver nitrate at 500 ppm at 2 and 4 true leaf stages might be recommended for induction of male flowers in parthenocarpic cucumber under *Tarai* region of Uttarakhand.

Key words: Cucumber, GA_3, parthenocarpic, seed quality, seed yield, silver nitrate

Cucumber (*Cucumis sativus* L.) is a very important horticultural crop which is a crucial member of Cucurbitaceae family grown globally for its consumption as salad or pickle (Dhall *et al.,* 2024). It exhibits a wide range of floral morphology having male, female and hermaphrodite flowers which are generally borne solitary (Mandal *et al.,* 2022 and Acharya *et al.,* 2024). Although the monoecious sex form is found predominantly in cucumber but the gynoecious sex form has been exploited for production of F_1 hybrids and induction of parthenocarpy (Rao *et al.,* 2017 and Dhall *et al.,* 2022). Parthenocarpy in cucumber is a desirable trait for greenhouse cultivation, ensuring fruit set without pollination (Kim *et al.,*1992). However, in seed production, the absence of male flowers necessitates exogenous intervention to induce their formation (Zhang and Wang, 2017). Hence, there is a need to develop an approach for overcoming a significant challenge in the seed production of parthenocarpic cucumbers i. e.,the absence of male flowers. Various chemicals including silver nitrate, gibberellic acid (GA_3), and silver thiosulphate, have been tested for their ability to induce male flowers in gynoecious and parthenocarpic cucumber lines (Choudhary and Singh, 2020 and Basu and Sinha, 2021). The present study hence, evaluates the efficacy of several chemical treatments in initiating male flowers and enhancing the seed yield and quality in Pant Parthenocarpic Cucumber-3. By assessing the efficacy of various chemical treatments, including silver nitrate ($AgNO_3$), gibberellic acid (GA_3), and silver thiosulphate (STS), the research was attempted to identify the effective methods for inducing male flower formation and enhancing seed yield and quality in Pant Parthenocarpic Cucumber-3.

MATERIALS AND METHODS

The field trial was conducted at the Vegetable Research Centre, G. B. Pant University of Agriculture and Technology, Pantnagar, U. S. Nagar, Uttarakhand from 2021-22 to 2023-24. The experiment followed a Randomized Block Design (RBD) layout using Pant Parthenocarpic Cucumber-3 as the test variety. Geographically, Pantnagar lies in the *Tarai* foothills of the Shivalik range of the Himalayas. The region experiences a humid subtropical climate, with summer temperatures ranging from 32°C to 43°C (May-June) and winter temperatures from 0°C to 9°C (January). Summers are hot and dry, while winters are cold, with frost occurring from late December to late January. Nine treatments were applied as foliar sprays at the 2 and 4 true leaf stages of parthenocarpic cucumber (Table 1) with each treatment replicated thrice. Observations were recorded on the fruit yield per plot (kg), number of seeds per fruit, 100 seed weight (g), seed yield per plot (g), seedyield (Kg/ha), seed germination (%), seed vigour index-I, seed vigour index-II and B:C ratio. The data were collected from randomly selected and tagged plants and were analyzed using ANOVA statistical method devised by Panse and Sukhatme (1967).

RESULTS AND DISCUSSION

Effect of chemical treatments on fruit yield per plot

The Table 2 and fig.2 presents the effects of different chemical treatments on fruit yield in Pant Parthenocarpic Cucumber-3. The maximum fruit yield (44.94 kg) was recorded in T_2 (500 ppm silver nitrate), followed by T_1 (250 ppm silver nitrate) with the yield of 35.54 kg and T_3 (750 ppm silver nitrate) with 32.89 kg. The lowest fruit yield was observed in T_8 (3mM silver thiosulphate)with the yield 28.91 kg. This superior yield aligns with the findings by Gao *et al.* (2019), who emphasized that silver nitrate promoted male flower formation, thereby facilitating better pollination and fruit set. In contrast, lower yields in GA_3 and silver thiosulphate treated plants suggest limited effectiveness in male flower induction when applied alone.

Effect of chemical treatments on seed yield parameters

Table 2 fig.1 and fig.2 present the impact of various foliar spray treatments on different parameters related to seed production in Pant Parthenocarpic Cucumber-3. The highest number of seeds per fruit (82.62) were produced by the treatment T_2 (500 ppm silver nitrate), indicating its effectiveness in promoting male flowers and pollination. The lowest seed count (54.44) was recorded in T_7 (1mM silver thiosulphate) also the GA_3 treated plants (T_4-T_6) had lower seed numbers, ranging between 58.55 and 72.24 seeds per fruit which suggests that these treatments were less effective in promoting seed formation likely due to their suboptimal influence on pollen availability. Basu and Sinha (2021) observed that GA_3at 50-100 ppm could promote male flowers, but the present findings show that $AgNo_3$ at 500 ppm had a more pronounced effect. This discrepancy might be attributed to the cultivar specific response or environmental conditions under which the present study was conducted. The highest 100-seed weight (3.76 g) was observed in T_2 (500 ppm silver nitrate), followed by T_8 (3.55 g) and T_1 (3.55 g). GA_3 treated

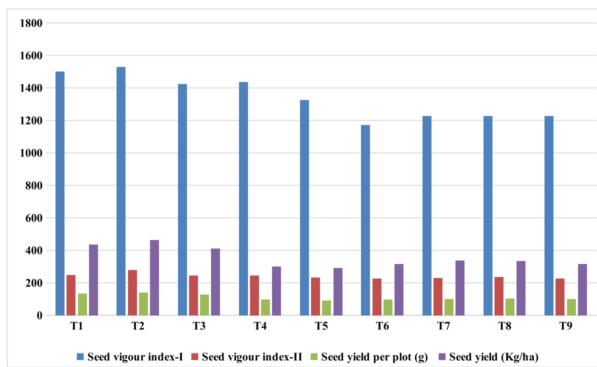

Fig.1: Effect of various foliar spray treatments on seed vigour index and seed yield of Pant Parthenocarpic Cucumber-3 based on 3 years pooled data

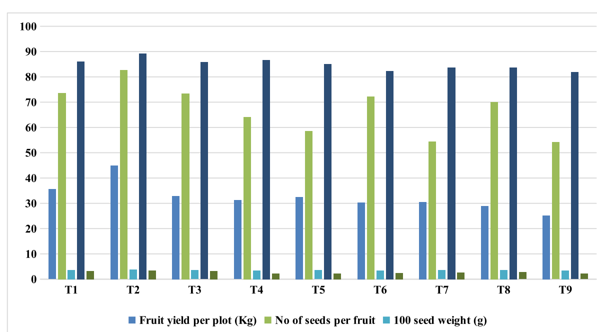

Fig.2: Effect of various foliar spray treatments on fruit yield, seed parameters and economics of Pant Parthenocarpic Cucumber-3 based on 3 years pooled data

Table 1: Treatments for standardization of initiation of male flowers

S. No.	Treatment	Treatment Details
T_1	250 ppm silver nitrate	Foliar spray at 2 and 4 true leaf stages
T_2	500 ppm silver nitrate	Foliar spray at 2 and 4 true leaf stages
T_3	750 ppm silver nitrate	Foliar spray at 2 and 4 true leaf stages
T_4	50 ppm GA3	Foliar spray at 2 and 4 true leaf stages
T_5	100 ppm GA3	Foliar spray at 2 and 4 true leaf stages
T_6	150 ppm GA3	Foliar spray at 2 and 4 true leaf stages
T_7	1 mM silver thiosulphate	Foliar spray at 2 and 4 true leaf stages
T_8	3 mM silver thiosulphate	Foliar spray at 2 and 4 true leaf stages
T_9	Control	Foliar spray of water at 2 and 4 true leaf stages

Note: True leaf stages of the cucumber plant are the mature, lobed, and serrated leaves.

Table 2: Impact of various foliar spray treatments on fruit and seed yield parameters in Pant Parthenocarpic Cucumber-3 based on 3 years pooled data

Entry	Treatment details	Fruit yield per plot (Kg) 3x1 m^2	No of Seed per fruit	100 seed weight (g)	Seed yield per plot (g) 3 x 1 m^2	Seed yield (Kg/ha)
T_1	Foliar spray of 250 ppm silver nitrate at 2 and 4 true leaf stage	35.54	73.65	3.55	132.88	435.20
T_2	Foliar spray of 500 ppm silver nitrate at 2 and 4 true leaf stage	44.94	82.62	3.76	139.78	462.48
T_3	Foliar spray of 750 ppm silver nitrate at 2 and 4 true leaf stage	32.89	73.47	3.54	127.06	411.14
T_4	Foliar spray of 50 ppm GA_3 at 2 and 4 true leaf stage	31.22	64.12	3.48	96.71	299.26
T_5	Foliar spray of 100 ppm GA_3 at 2 and 4 true leaf stage	32.43	58.55	3.50	89.72	289.68
T_6	Foliar spray of 150 ppm GA_3 at 2 and 4 true leaf stage	30.39	72.24	3.45	95.52	316.75
T_7	Foliar spray of 1mM sliver thiosulphate at 2 and 4 true leaf stage	30.49	54.44	3.53	100.76	337.00
T_8	Foliar spray of 3mM sliver thiosulphate at 2 and 4 true leaf stage	28.91	70.02	3.55	101.89	335.34
T_9	Foliar spray of water at 2 and 4 true leaf stages	25.24	54.14	3.41	100.00	315.41
	CD at 5%	3.12	2.04	9.54	6.83	3.65
	CV (%)	6.41	3.94	15.29	12.97	8.9

Table 3: Impact of various foliar spray treatments on fruit and seed quality and economic parameters in Pant Parthenocarpic Cucumber-3 based on 3 years pooled data

Entry	Treatment details	Seed germination (%)	Seed vigour index-I	Seed vigour index-II	B:C ratio
T_1	Foliar spray of 250 ppm silver nitrate at 2 and 4 true leaf stage	86.11	1499.33	246.35	3.19
T_2	Foliar spray of 500 ppm silver nitrate at 2 and 4 true leaf stage	89.22	1527.86	278.47	3.46
T_3	Foliar spray of 750 ppm silver nitrate at 2 and 4 true leaf stage	85.78	1424.67	245.12	3.22
T_4	Foliar spray of 50 ppm GA_3 at 2 and 4 true leaf stage	86.67	1437.02	244.85	2.22
T_5	Foliar spray of 100 ppm GA_3 at 2 and 4 true leaf stage	85.11	1326.11	230.89	2.30
T_6	Foliar spray of 150 ppm GA_3 at 2 and 4 true leaf stage	82.33	1171.49	225.01	2.38
T_7	Foliar spray of 1mM sliver thiosulphate at 2 and 4 true leaf stage	83.78	1226.35	228.25	2.58
T_8	Foliar spray of 3mM sliver thiosulphate at 2 and 4 true leaf stage	83.67	1227.53	236.20	2.72
T_9	Foliar spray of water at 2 and 4 true leaf stages	81.85	1225.85	224.85	2.12
	CD at 5%	3.05	2.21	9.32	3.12
	CV (%)	8.72	8.72	3.28	6.41

plants had the lowest seed weight (3.45 g in T_6), indicating a possible negative effect on seed development. This reinforces the idea that $AgNo_3$ not only increases the number of seeds but also enhances their development and maturation. Supporting this, Kim and Lee (2018) reported that silver nitrate plays a critical role in improving seed development when used in conjunction with GA_3 although the present findings suggest that silver nitrate alone at higher concentrations may be sufficient. Similar trends were seen in seed yield per plot and per hectare with T_2 (500 ppm silver nitrate) yielding 139.78 g per plot and 462.48 Kg/ha, respectively. These values further substantiate the role of silver nitrate in maximizing seed output, in agreement with Patel and Verma (2022), who observed increased seed productivity in cucumber plants with ethylene inhibitors like silver thiosulphate and silver nitrate. However, the present study suggests that silver nitrate at 500 ppm alone can outperform these combinations.

Effect of chemical treatments on seed quality parameters

The data regarding germination percentage and seed vigour indicesis showcased in Table 3 and depicted in fig.2 respectively. Thehighest germination (89.22%) was observed in T_2 (500 ppm silver nitrate), confirming its beneficial effect on seed viability. The lowest germination (82.33%) was recorded in T_6 (150 ppm GA_3). Treatments with silver nitrate showed higher germination percentages compared to $GA_3$and silver thiosulphate. Seed vigour index-I (based on seedling length) and seed vigour index-II (based on seedling dry weight) indicated seedling strength and quality. The highest SVI-I was observed under T_2 (1527.86), followed by T_1 (1499.33). Whereas, the lowest SVI-I was observed under T_6 (1171.49), showing that 150 ppm GA_3 negatively affected seedling vigour. The highest SVI-II was also recorded under T_2 (278.47), followed by T_8 (236.20), Whereas, lowest SVI-II was recorded under T_6 (225.01). These results demonstrate the dual benefits of silver nitrate in improving both seed quantity and quality. Susaj and Susaj (2010) and Ranjan and Sharma (2023) highlighted the importance of precisely timed growth regulator applications to improve male flower production and seed yield, which may explain the outstanding results in application of 500 ppm silver nitrate due to optimized application timing.

Effect of chemical treatments on overall economics of parthenocarpic cucumber seed production

Economically, the highest benefit-cost (B:C) ratio (3.46) was achieved with T_2 making it the most commercially viable treatment followed by T_1 (3.19) and T_3 (3.22). The lowest B:C ratio (2.22) was recorded in T_4 (50 ppm GA_3). The significantly lower B:C ratio in GA_3 treated plots emphasizes the inefficiency of GA_3 alone for profitable seed production (Table 3 and Fig.2). Singh and Mehta (2021) emphasized the role of ethylene inhibition in modulating sex expression and the present findings support that silver nitrate, as an effective ethylene inhibitor, contributes not only to enhanced agronomic traits but also economic returns.

In contrast to earlier studies that suggested combined use of GA_3 and silver nitrate or silver thiosulphate for optimal results (Zhang and Wang, 2017), the current study provides strong evidence that a single application of silver nitrate at 500 ppm is sufficient to induce high male flower counts (around 60 flowers), improves seed yield and quality and ensure economic sustainability in seed production of parthenocarpic cucumber. This highlights the need to revisit standard protocols and explore simpler, cost-effective strategies for hybrid seed production.

CONCLUSION

Parthenocarpic cucumber varieties, being naturally female-flowered and seedless, require external interventions for male flower induction to enable hybrid seed production. The application of growth regulators like silver nitrate plays a crucial role in modifying sex expression and ensuring pollination. The results obtained from the present study concluded that the foliar spray of silver nitrate at 2 and 4 true leaf stages at 500 ppm was the most effective treatment for enhancing seed yield, seed quality and economic returns in parthenocarpic cucumber. It significantly improved male flower induction, fruit yield, seed yield and economics compared to GA_3 and silver thiosulphate treatments. Therefore, silver nitrate at 500 ppm might be recommended under *Tarai* regions of Uttarakhand after field testing in specific environments as a reliable and efficient strategy for commercial hybrid seed production in parthenocarpic cucumber, offering both agronomic and economic advantages. Future studies may explore the synergistic effects of silver nitrate with other growth regulators to further optimize seed production techniques.

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