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Chemical Hybridizing Agents and their Role in Modulating Flowering Time of Sponge Gourd (*Luffa cylindrica*)

Vibhootee Garg[1]*, Akhilesh Tiwari[1], S.K. Pandey[1], Simran Choudhary[1] and Vedant Gautam[2]

[1]Department of Horticulture,
Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (Madhya Pradesh), India.
[2]Department of Mycology and Plant Pathology,
Banaras Hindu University, Varanasi (Uttar Pradesh), India.

(Corresponding author: Vibhootee Garg)*

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ABSTRACT: This study investigates the influence of various CHAs (Chemical Hybridizing Agents) on the flowering time of sponge gourd (*Luffa cylindrica*) over two growing seasons (2022-2023 and 2023-2024). A total of 13 treatments, including Maleic Hydrazide, Gibberellic Acid (GA_3), 1-Naphthalene Acetic Acid (NAA), 2,3,5-Triiodo Benzoic acid, Ethrel and Sulphonyl Urea, were applied at different growth stages to assess their effects on the days to first male and female flower appearance. Results indicated that the control group consistently exhibited the earliest male flower emergence, averaging 50.43 days across both years. Among treatments, NAA and GA_3 effectively promoted earlier flowering, with averages of 56.23 days and 56.45 days, respectively. Conversely, Sulphonyl Urea resulted in delayed male flowering, averaging 63.60 days when applied at both cotyledon and true leaf stages. For female flowers, Sulphonyl Urea also yielded the earliest average emergence at 56.50 days, while the control group showed the latest at 77.43 days. The statistical analysis revealed significant differences among treatments, with a critical difference (C.D.) of 3.05 days for male flowers and 3.98 days for female flowers at a significance level of 5%. These findings underscore the potential of specific Chemical hybridizing agents in managing flowering times effectively, providing valuable insights for enhancing sponge gourd production in agricultural practices.

Keywords: Flowering phenology, foliar treatments, Sulphonyl Urea, NAA and GA_3.

INTRODUCTION

Sponge gourd (*Luffa cylindrica* (L.) Roem.), a member of the Cucurbitaceae family, represents a significant agricultural crop with diverse applications in food, medicine and industrial sectors. This versatile plant, widely cultivated across tropical and subtropical regions, offers substantial economic and nutritional potential that merits continued scientific investigation (Rakesh & Archana 2018). The complex interactions between chemical hybridizing agents and developmental processes, particularly flowering dynamics, present critical opportunities for agricultural enhancement and productivity optimization. Chemical hybridizing agents have emerged as pivotal tools in modern agricultural science, offering researchers and farmers unprecedented mechanisms to modulate crop development, improve yield and manage plant physiological processes (Taiz *et al.,* 2015). By strategically manipulating hormonal pathways, scientists can potentially overcome significant agricultural challenges, including delayed flowering, reduced fruit set and inconsistent crop performance (Davies, 2010). Recent studies have shown that specific hybridizing agents can enhance flowering times significantly; for instance, research by Sharma *et al*. (2023) indicated that the application of hybridizing agents led to a marked reduction in days to first flower appearance in various cucurbits. Similarly, Segura *et al.* (2023) demonstrated that these agents could effectively synchronize flowering in monoecious species like sponge gourd. Furthermore, Gupta *et al.* (2023) highlighted the role of chemical hybridizing agents in improving fruit set and overall yield through optimized flowering dynamics. The intricate process of flowering in cucurbits involves complex interactions between endogenous hormones and environmental stimuli. Previous research has demonstrated that exogenous applications of chemical regulators can substantially influence reproductive developmental stages, potentially accelerating or modifying flowering patterns (Weaver, 1972). However, the specific mechanisms and optimal strategies for such interventions remain incompletely understood, particularly for crops like sponge gourd. Hormonal regulation in plants encompasses multiple signaling pathways involving auxins, gibberellins, cytokinins and other growth-modifying compounds. These molecular interactions govern critical developmental transitions, including seed germination, vegetative growth and reproductive phase change (Santner & Estelle 2009). Understanding these mechanisms provides crucial insights into potential agricultural interventions that could enhance crop productivity and resilience. Researchers have long recognized the potential of chemical hybridizing agents in modulating flowering time. Gibberellic acid (GA_3), for instance, has been extensively studied for its role in promoting cell elongation and influencing reproductive development across various plant species (Sponsel & Hedden 2004). Similarly, auxins like 1-Naphthalene Acetic Acid (NAA) have demonstrated significant potential in regulating plant growth and developmental processes (Mok & Mok 2001). The unique physiological characteristics of sponge gourd, including its monoecious flowering pattern with distinct male and female flower development, present fascinating research opportunities. Understanding the precise mechanisms governing flower initiation and development could provide critical insights for breeding programs and agricultural management strategies (Wehner, 2008). Environmental factors such as photoperiod, temperature and nutrient availability also play crucial roles in determining flowering patterns. The interaction between these external stimuli and internal hormonal regulation represents a complex network that significantly influences crop performance (Bäurle & Dean 2006). By systematically exploring these interactions, researchers can develop more nuanced approaches to crop management and improvement. Previous studies have highlighted the potential of chemical treatments in modifying plant developmental trajectories. For example, research by Kumar *et al.* (2017) demonstrated significant variations in flowering patterns across different horticultural crops following exogenous hormone applications. However, crop-specific responses necessitate targeted investigations to develop precise context-specific strategies. The current research aims to comprehensively evaluate the effects of various chemical hybridizing agents on sponge gourd's flowering dynamics. By examining multiple chemical treatments at different developmental stages, this study seeks to provide empirical insights into potential agricultural interventions that could enhance sponge gourd productivity.

Understanding the nuanced interactions between chemical hybridizing agents and developmental processes represents a critical frontier in agricultural science. By elucidating these complex mechanisms, researchers can develop more sophisticated strategies for crop management that potentially address global challenges related to food security and agricultural productivity.

MATERIAL AND METHODS

Experimental Site. The present study was conducted at the Vegetable Research Centre, Maharajpur, under the Department of Horticulture, Jawaharlal Nehru Krishi Vishwa Vidyalaya (JNKVV), Jabalpur, Madhya Pradesh, during the 2022-2024 growing season. The experimental site is geographically located at 23°22'34.93" N latitude and 79°96'35.26" E longitude, at an altitude of 300 meters above mean sea level. The soil utilized for the experiment is classified as laterite, characterized by high drainage capacity and a homogeneous texture. It exhibits moderate water retention and rich in iron and aluminium, typically forming in hot, humid subtropical climates.

Experimental Details. The experimental design employed in this study was a Randomized Block Design (RBD) with three replications, aimed at evaluating the effects of various treatments on sponge gourd (*Luffa cylindrica*). The specific variety used was Jawahar Gilki14 and the experiment was conducted over two growing seasons: 2022-2023 and 2023-2024. A total of 13 distinct treatments were applied across the experimental plots, which were organized into blocks to control for variability. Each block consisted of plots measuring 15.00 m², resulting in a total of 39 plots (13 treatments multiplied by 3 replications). To ensure optimal growth conditions, basal nutrients were applied in the form of 10 tons of Farm Yard Manure, along with 45 kg of phosphorus (P_2O_5) and 50 kg of potassium (K_2O) per hectare. This structured approach allows for a comprehensive analysis of treatment effects while minimizing the influence of environmental variability. A detailed list of treatments is provided in Table 1.

Table 1: Description of treatments involving different Chemical hybridizing agents and their concentrations applied at two growth stages (cotyledon stage: 10-12 DAS; true leaf stage: 24-28 DAS) in sponge gourd.

Treatment	Chemical	Concentration	Application Timing
T_1	Maleic Hydrazide	200 ppm	Cotyledon stage (10-12 DAS)
T_2	Gibberellic acid	200 ppm	Cotyledon stage (10-12 DAS)
T_3	2,3,5-Triiodo Benzoic acid	25 ppm	Cotyledon stage (10-12 DAS)
T_4	1-Naphthalene acetic acid	100 ppm	Cotyledon stage (10-12 DAS)
T_5	Ethrel	1250 ppm	Cotyledon stage (10-12 DAS)
T_6	Sulphonyl urea	0.4 ml/L	Cotyledon stage (10-12 DAS)
T_7	Maleic Hydrazide	200 ppm	True leaf stage (24-28 DAS)
T_8	Gibberellic acid	200 ppm	True leaf stage (24-28 DAS)
T_9	2,3,5-Triiodo Benzoic acid	25 ppm	True leaf stage (24-28 DAS)
T_{10}	1-Naphthalene acetic acid	100 ppm	True leaf stage (24-28 DAS)
T_{11}	Ethrel	1250 ppm	True leaf stage (24-28 DAS)
T_{12}	Sulphonyl urea	0.4 ml/L	True leaf stage (24-28 DAS)
T_{13}	Control	-	-

Phenological Parameters.

The following phenological parameters were recorded:

—Days to First Female Flower Appearance: The number of days from sowing to the appearance of the first female flower was recorded for each vine.

— Days to First Male Flower Appearance: Similarly, the time taken for each vine to produce its first male flower was noted.

Statistical Analysis. Data collected on various parameters were subjected to statistical analysis using the methodology outlined by Clarke & Green (1988). The analysis of variance (ANOVA) for Randomized Block Design was conducted to determine treatment effects.

A significant value of F test indicates that the entire differ significantly among themselves, which requires computing

$$SEM\pm = \sqrt{EMS/R}$$

RESULT

Days to first male flower appearance. In 2023, the study investigated the effects of various treatments on the days to first male flower appearance in plants (Table 2). The results indicated that the control group exhibited the earliest male flower emergence, with an average of 52.53 days. Among the treatments, 1-Naphthalene Acetic Acid (NAA) at 100 ppm, applied at the cotyledon stage, resulted in an average of 56.13 days to first male flower appearance. In contrast, Sulphonyl Urea at 0.4 ml/L, also applied at the cotyledon stage, showed the latest emergence, averaging 61.33 days.

Notably, 2,3,5-Triiodo Benzoic Acid at 25 ppm yielded an average of 56.40 days, while GA_3 at 200 ppm resulted in slightly faster emergence at 58.73 days. Treatments involving multiple applications, such as Maleic Hydrazide and GA_3, showed varied results; Maleic Hydrazide applied at both cotyledon and leaf stages averaged 57.00 days, while GA_3 under similar conditions had a mean of 57.40 days.

In 2024, the investigation into the effects of various treatments on the days to first male flower appearance yielded significant results (Table 2). The control group again demonstrated the earliest emergence of male flowers, averaging 48.33 days. Among the treatments, 1-Naphthalene Acetic Acid (NAA) at 100 ppm, applied at the cotyledon stage, resulted in an average of 56.33 days to first male flower appearance. Notably, 2,3,5-Triiodo Benzoic Acid at 25 ppm showed a marked increase in days to flowering, averaging 62.17 days, indicating a delayed response compared to other treatments.

The application of GA_3 at 200 ppm resulted in an average of 54.17 days, demonstrating its efficacy in promoting earlier flowering relative to some other treatments. When treatments were administered at both cotyledon and leaf stages, Maleic Hydrazide and Ethrel yielded averages of 56.00 and 54.00 days, respectively. In contrast, Sulphonyl Urea at 0.4 ml/L, applied at both stages, resulted in the latest average flowering time of 69.67 days.

The pooled data from both 2023 and 2024 provided a comprehensive overview of the effects of various treatments on the days to first male flower appearance (Table 2). Across the pooled analysis, the control group consistently exhibited the earliest emergence of male flowers, with an average of 50.43 days. Among the treatments, 1-Naphthalene Acetic Acid (NAA) at 100 ppm, applied at the cotyledon stage, resulted in an average of 56.23 days, demonstrating its potential effectiveness in promoting flowering.

The treatment with GA_3 at 200 ppm yielded a pooled average of 56.45 days, indicating its beneficial role in accelerating male flower development. Conversely, 2,3,5-Triiodo Benzoic Acid at 25 ppm showed a delayed response with an average of 59.28 days to first male flower appearance. Notably, Sulphonyl Urea at 0.4 ml/L, when applied at both cotyledon and leaf stages, resulted in the latest flowering time, averaging 63.60 days.

Additionally, treatments that involved multiple applications, such as Maleic Hydrazide and Ethrel, displayed varied results; Maleic Hydrazide averaged 56.50 days while Ethrel averaged 55.30 days across both years. The critical difference (C.D.) at a significance level of 5% was determined to be 3.05 days, highlighting significant differences in flowering times among the treatments.

The critical difference (C.D.) at a significance level of 5% was determined to be 3.05 days, indicating significant variations among treatments in their influence on flowering time. The standard error of the mean (SE(m) ±) was 1.04 days and the coefficient of variation (C.V.) was calculated to be 3.17%, reflecting a relatively low level of variability among the treatments. These findings underscore the importance of specific Chemical hybridizing agents in influencing flowering times, providing valuable insights for enhancing agricultural practices.

Overall, the pooled data underscores the influence of specific Chemical hybridizing agents on flowering time and provides a solid foundation for further research into optimizing flowering in agricultural practices. These findings emphasize the importance of treatment selection in managing flowering and enhancing crop productivity.

Table 2: Effect of foliar sprays with Chemical hybridizing agents on days to first male flower appearance in sponge gourd during 2022-2023, 2023-2024 and pooled data. Treatments at 10 DAS (cotyledon stage) and 10 & 24 DAS (2-4 leaf stage).

Treatment	2023	2024	Pooled
Maleic Hydrazide 200 ppm - Spray at 10 DAS (Cotyledon Stage)	59.00	60.50	59.75
GA_3 200 ppm - Spray at 10 DAS (Cotyledon Stage)	58.73	54.17	56.45
2,3,5-Triiodo Benzoic Acid 25 ppm - Spray at 10 DAS (Cotyledon Stage)	56.40	62.17	59.28
1- Naphthalene Acetic Acid 100 ppm - Spray at 10 DAS (Cotyledon Stage)	56.13	56.33	56.23
Ethrel 1250 ppm - Spray at 10 DAS (Cotyledon Stage)	57.53	55.67	56.6
Sulphonyl Urea 0.4 ml/L - Spray at 10 DAS (Cotyledon Stage)	57.20	55.50	56.35
Maleic Hydrazide 200 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	57.00	56.00	56.5
GA_3 200 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	57.40	54.00	55.7
2,3,5-Triiodo Benzoic Acid 25 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	58.73	58.83	58.78
1- Naphthalene Acetic Acid 100 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	56.73	50.67	53.7
Ethrel 1250 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	56.60	54.00	55.3
Sulphonyl Urea 0.4 ml/L - Spray at 10 and 24 DAS (2-4 Leaf Stage)	61.33	69.67	63.6
Control	52.53	48.33	50.43
C.D. at 5%	**3.36**	**6.79**	**3.05**
SE(m) ±	**1.14**	**2.32**	**1.04**
C.V.	**3.45**	**7.12**	**3.17**

(±) is standard error of data.

Days to first female flower appearance. In 2023, the study on the impact of various treatments on the days to first female flower appearance revealed significant results (Table 3). The control group exhibited the latest emergence, averaging 75.53 days. Among the treatments, Sulphonyl Urea at 0.4 ml/L, applied at the cotyledon stage, resulted in the earliest average of 59.73 days to first female flower appearance.

Other treatments also showed promising results; for instance, Ethrel at 1250 ppm led to an average of 63.80 days, while GA_3 at 200 ppm resulted in an average of 65.13 days. Interestingly, 2,3,5-Triiodo Benzoic Acid at 25 ppm had an average of 64.86 days, indicating a moderate effect on flowering time.

The application of Maleic Hydrazide at 200 ppm, both at the cotyledon stage and in subsequent applications, resulted in an average of 65.40 days when sprayed at the cotyledon stage and 63.60 days when applied at both cotyledon and leaf stages. In contrast, 1-Naphthalene Acetic Acid (NAA) at 100 ppm showed a longer average of 67.67 days under the same initial treatment conditions.

In 2024, the results of the study on the effects of various treatments on the days to first female flower appearance revealed significant findings (Table 3). The control group exhibited the latest average emergence of female flowers, with an average of 79.33 days. In contrast, Sulphonyl Urea at 0.4 ml/L, applied at the cotyledon stage, resulted in the earliest average of 56.83 days to first female flower appearance.

Other treatments also demonstrated notable effects; for instance, Ethrel at 1250 ppm led to an average of 62.50 days, while GA_3 at 200 ppm resulted in an average of 65.67 days. Interestingly, 2,3,5-Triiodo Benzoic Acid at 25 ppm showed a delayed response with an average of 72.50 days to first female flower appearance.

When treatments were applied at both cotyledon and leaf stages, Maleic Hydrazide at 200 ppm yielded an average of 67.67 days when sprayed at the cotyledon stage and 62.83 days when applied later. The application of 1-Naphthalene Acetic Acid (NAA) at 100 ppm resulted in an average of 64.00 days under the same conditions.

The pooled data from both 2023 and 2024 provided insightful results regarding the effects of various treatments on the days to first female flower appearance (Table 3). Across the pooled analysis, the control group consistently exhibited the latest emergence of female flowers, with an average of 77.43 days. In contrast, Sulphonyl Urea at 0.4 ml/L, applied at both cotyledon and leaf stages, resulted in the earliest average of 56.50 days to first female flower appearance. Among the treatments, Ethrel at 1250 ppm produced an average of 63.15 days, while GA_3 at 200 ppm yielded a pooled average of 65.40 days, indicating its effectiveness in promoting earlier flowering compared to several other treatments. The application of 2,3,5-Triiodo Benzoic Acid at 25 ppm resulted in a pooled average of 68.68 days, suggesting a delayed response in flowering time.

Notably, when applying Maleic Hydrazide at 200 ppm, the average days to first female flower appearance was 66.53 days when sprayed at the cotyledon stage and slightly lower at 63.22 days when applied at both cotyledon and leaf stages. Additionally, 1-Naphthalene Acetic Acid (NAA) at 100 ppm showed a pooled average of 65.83 days.

The critical difference (C.D.) at a significance level of 5% was determined to be 3.98 days, indicating significant variations among treatments in their influence on flowering time. Overall, these findings underscore the importance of specific Chemical hybridizing agents in managing flowering times effectively in agricultural practices.

Table 3: Effect of foliar sprays with Chemical hybridizing agents on days to first female flower appearance in sponge gourd during 2022-2023, 2023-2024 and pooled data. Treatments at 10 DAS (cotyledon stage) and 10 & 24 DAS (2-4 leaf stage).

Treatment	2023	2024	Pooled
Maleic Hydrazide 200 ppm - Spray at 10 DAS (Cotyledon Stage)	65.40	67.67	66.53
GA_3 200 ppm - Spray at 10 DAS (Cotyledon Stage)	65.13	65.67	65.4
2,3,5-Triiodo Benzoic Acid 25 ppm - Spray at 10 DAS (Cotyledon Stage)	64.86	72.50	68.68
1- Naphthalene Acetic Acid 100 ppm - Spray at 10 DAS (Cotyledon Stage)	67.67	64.00	65.83
Ethrel 1250 ppm - Spray at 10 DAS (Cotyledon Stage)	63.80	62.50	63.15
Sulphonyl Urea 0.4 ml/L - Spray at 10 DAS (Cotyledon Stage)	59.73	56.83	58.28
Maleic Hydrazide 200 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	63.60	62.83	63.22
GA_3 200 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	67.73	59.83	63.78
2,3,5-Triiodo Benzoic Acid 25 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	67.87	65.50	66.68
1- Naphthalene Acetic Acid 100 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	66.26	62.83	64.55
Ethrel 1250 ppm - Spray at 10 and 24 DAS (2-4 Leaf Stage)	65.86	61.33	63.6
Sulphonyl Urea 0.4 ml/L - Spray at 10 and 24 DAS (2-4 Leaf Stage)	57.33	55.67	56.5
Control	75.53	79.33	77.43
C.D. at 5%	**4.67**	**7.21**	**3.98**
SE(m) ±	**1.59**	**2.47**	**1.37**
C.V.	**4.21**	**6.65**	**3.64**

DISCUSSION

The results of this study on the days to first male flower appearance highlight the varying effectiveness of different chemical hybridizing agents (CHAs) in influencing flowering time. Among the treatments, Maleic Hydrazide (MH) at 200 ppm emerged as one of the better-performing treatments, leading to an average of 59.75 days across both years. This aligns with previous findings that MH can effectively regulate flowering by inhibiting ethylene production, which is known to delay senescence and promote flowering in various species (Sekhar & Saravanan 2021). Conversely, Sulphonyl Urea at 0.4 ml/L, which resulted in an average of 63.60 days in the pooled data, was identified as the poorest-performing treatment. Its prolonged flowering time suggests that it may act more as a growth inhibitor rather than a promoter, potentially due to its interference with hormonal signalling pathways essential for flowering (Hirohata *et al.*, 2022). The effectiveness of GA_3 (Gibberellic Acid), which averaged 56.45 days across both years, further supports its role as a potent flowering promoter. GA_3 is widely recognized for its ability to stimulate flowering and enhance growth by promoting cell elongation and division (Pradeepkumar *et al.*, 2020). However, it is important to note that excessive GA_3 application can lead to physiological disorders, such as extreme pedicel elongation and bent neck problems, as noted by Budiarto & Wuryaningsih (2007), where concentrations above 500 ppm resulted in undesirable stalk characteristics. King *et al.* (1987) highlighted that while low doses of GA_3 promote flowering, higher doses can inhibit it, indicating a delicate balance in application. This highlights the need for careful management of PGR applications to optimize their benefits while minimizing adverse effects.

In contrast to the positive effects observed with MH and GA_3, the effectiveness of 2,3,5-triiodobenzoic acid (TIBA) as a growth regulator varies depending on environmental conditions and application timing. In cucumbers, TIBA promotes staminate flower production when applied at the first true leaf stage (Freytag *et al.*, 1970). TIBA's effects on alfalfa growth and reproductive development have also been studied at various concentrations (Phillips & Chilcote 1981). Other growth regulators like indole acetic acid and 2-chloroethyl trimethyl ammonium chloride were found to be more effective in enhancing early flowering and improving quality parameters, respectively (Ahmed *et al.*, 2013). These studies highlight the variability in TIBA's effectiveness across different plant species and environmental conditions. The critical difference (C.D.)

of 3.05 days at a significance level of 5% underscores the significant variations among treatments and their influence on flowering time.

The results from the study on the days to first female flower appearance across various treatments in 2023 and 2024 provide significant insights into the effects of different chemical hybridizing agents (CHAs) on flowering time. The control group consistently exhibited the latest emergence of female flowers, with averages of 75.53 days in 2023 and 79.33 days in 2024, indicating a robust baseline for comparison. This finding suggests that untreated plants may have a natural flowering schedule that can be influenced by external factors, including PGR applications.

Among the treatments, Sulphonyl Urea at 0.4 ml/L emerged as the most effective treatment for promoting early female flowering, with an average of 58.28 days across both years. This aligns with previous studies indicating that Sulphonyl Urea can enhance flowering by modulating hormonal pathways (Kumar *et al.,* 2017). However, it is noteworthy that when applied at both cotyledon and leaf stages, Sulphonyl Urea resulted in an average of 56.50 days, suggesting that timing of application may significantly influence its effectiveness.

Maleic Hydrazide (MH) at 200 ppm also showed promising results, with averages of 65.40 days pooled across both years. MH is known to inhibit ethylene production, which can delay senescence and influence flowering patterns (Snyder *et al.,* 2018). This effect is particularly relevant in crops where delayed flowering can enhance yield potential by extending the growing season.

In contrast, Gibberellic Acid (GA_3) displayed variable performance, with pooled averages of 65.40 days. While GA_3 is widely recognized for its role in promoting flowering and enhancing growth through cell elongation and division (Hedden & Sponsel 2015), its effectiveness can be influenced by environmental conditions and application timing. Excessive use of GA_3 has been associated with physiological disorders such as excessive elongation and reduced flower quality (Davis *et al.,* 2022).

The treatment with 2,3,5-Triiodo Benzoic Acid showed a marked increase in days to first female flower appearance, averaging 68.68 days pooled across both years. This variability suggests that while it may have potential as a growth regulator, its effectiveness can be influenced by external conditions or timing of application (Zhang *et al.,* 2020). The critical difference (C.D.) at a significance level of 5% was determined to be 3.98 days, indicating significant variations among treatments regarding their effects on flowering time. In the future, researchers can work on metabolomics approaches to have insights into understanding interactions that provide valuable opportunities for promoting sustainable agriculture by enhancing crop resilience. Moreover, the identification of key metabolic pathways and biomarkers offers a foundation for developing novel plant growth regulators (CHAs) to strengthen defense mechanisms against pathogens (Gautam *et al.,* 2024).

Interestingly, treatments involving multiple applications, such as GA_3 and Maleic Hydrazide, demonstrated varied results; GA_3 applied at both cotyledon and leaf stages averaged 63.78 days, while Maleic Hydrazide resulted in an average of 63.22 days. This suggests that the timing and frequency of applications are crucial factors influencing flowering outcomes.

Kalpana *et al.* (2023) reported significant variances in GCA and SCA effects for fruit yield and related traits in sponge gourd, highlighting the preponderance of non-additive gene action for most traits except a few, such as the number of primary branches per vine and days to first fruit harvest. Bhagyashree *et al*. (2024) demonstrated that number of fruits per vine exhibited significant positive correlation and direct effects with yield-contributing traits, such as vine length, number of primary branches at 90 DAT and average fruit weight, emphasizing their importance in direct selection for crop improvement.

CONCLUSIONS

The results of this study provide significant insights into the effects of various treatments on the phenological parameters of sponge gourd, particularly regarding the days to first male and female flower appearance. The control group consistently exhibited the earliest emergence of male flowers across both years, averaging 50.43 days, while treatments such as 1-Naphthalene Acetic Acid (NAA) and Gibberellic Acid (GA_3) demonstrated their potential to promote flowering, with averages of 56.23 days and 56.45 days, respectively. Conversely, Sulphonyl Urea consistently resulted in delayed male flowering times, highlighting its less favorable impact on flowering initiation.

For female flower appearance, Sulphonyl Urea again emerged as the most effective treatment when applied at the cotyledon stage, achieving an average of 56.50 days in the pooled analysis. This contrasts sharply with the control group, which had an average of 77.43 days, underscoring the role of specific Chemical hybridizing agents in managing flowering times effectively. The critical differences observed in flowering times among treatments were statistically significant, indicating that careful selection of growth regulators can enhance crop productivity.

Overall, these findings emphasize the importance of utilizing specific Chemical hybridizing agents to optimize flowering times in sponge gourd cultivation. This research lays a solid foundation for further studies aimed at refining agricultural practices to improve yield and efficiency in sponge gourd production, ultimately contributing to better management strategies in horticultural practices.

FUTURE SCOPE

The use of chemical hybridizing agents as alternatives to traditional Chemical hybridizing agents (CHAs) offers a promising avenue for enhancing flowering times and overall plant development. Chemical hybridizing agents, which can modify hormonal pathways and influence plant physiology, may provide distinct advantages in managing flowering schedules. Future research should focus on the comparative effectiveness of these agents against established CHAs like Gibberellic Acid (GA_3) and Maleic Hydrazide. For instance, studies could investigate how chemical hybridizing agents impact the days to first male and female flower appearance, potentially leading to earlier flowering compared to conventional treatments. Additionally, exploring the mechanisms by which these agents operate could yield insights into their efficacy in promoting flowering while minimizing adverse effects associated with excessive PGR applications. Moreover, the interaction of chemical hybridizing agents with environmental factors such as temperature and soil conditions warrants investigation. Understanding these dynamics could optimize application strategies for maximizing flowering benefits.

Finally, conducting economic analyses to assess the cost-effectiveness of using chemical hybridizing agents in commercial agriculture will be crucial for practical adoption. This research could significantly contribute to sustainable agricultural practices by providing farmers with effective tools for enhancing crop productivity while reducing reliance on traditional CHAs.

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Conflict of Interest. None.

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