Review Article

Effect of Plant Growth Regulators on Cucurbits: An Overview

Abstract

Cucurbits, a popular vegetable, can thrive in deserts and moist tropics. About 825 species are in the Cucurbitaceae family, which contains 118 genera. These crops are mostly grown in India during the summer and rainy seasons, with certain southern and western regions cultivating them in winter. These crops are annual and perennial. Plant Growth Regulators (PGRs) in cucurbits have shown promise in improving crop growth, productivity, and quality. Plant growth regulators ~~(PGRs)~~ affect several physiological and developmental processes in cucurbits. There are different effects of the various kind of the PGRs in cucurbits such as watermelon with 25-50 ppm of Gibberellic acid (GA3) yielded earlier and more fruits; the fruit were increased~~. Fruit count rose~~ with 250 and 500 ppm ethrel, and~~.~~ ~~The~~ 40 ppm of GA3 increased vegetative growth and production. Triiodobenzoic acid (TIBA) at ~~(~~20 ppm~~)~~ increased fruit weight and yield. In case of cucumber GA3 at 20 ppm and NAA at 100 ppm increased cucumber growth and production. Application of GA3 (20 ppm) at the 4-leaf stage enhances growth, flowering, and yield in bottle gourd. In bitter gourd fruit per plant, fruit weight, and yield increased significantly with GA3 at 60 ppm. Ethrel at 50 ppm improved fruit set and weight. Gibberex treatments increased fruit quantity, weight, and yield per plant. Further study and fieldwork are needed to understand plant growth regulators (PGRs) and determine the appropriate effects for cucurbits.

1. INTRODUCTION~~ntroduction~~

1.2. Cucurbitaceae generalities and information on plant grow regulators

Cucurbits, a prominent category of vegetables, have extensive adaptability across many climatic conditions, ranging from desert regions to the wet tropics. The ~~taxonomic classification known as~~ Cucurbitaceae has around 825 species distributed among approximately 118 genera (Karmakar *et al.*, 2018) [1]. In the continent of Asia, a diverse range of around 23 cultivars of cucurbits, both major and minor, are cultivated and utilized for their culinary properties. In India, these crops are predominantly cultivated throughout the summer and rainy seasons, with certain regions in the southern and western sections of the country also growing them during winter. These crops may be classified as both annual and perennial (Rai *et al.*, 2008) [2]. Significant genera within this family include *Lagenaria* Ser., *Momordica* L., *Luffa* Mill., *Cucurbita* L., *Cucumis* L., and *Citrullus* Schrad.. Cucurbits are commonly employed in traditional medicine for their therapeutic properties, including anti-inflammatory, anticancer, hepatoprotective, cardiovascular, and immunoregulatory effects (Rahman *et al*., 2008;) [3]. Given their minimal carbohydrate content and capacity to provide essential minerals and vitamins, these food items are strongly advised for those with diabetes (Khulakpam *et al*., 2015) [4]. The pollination and fruit setting of cucurbit species are mostly influenced by insect pollinators due to the prevalence of unisexual blooms, with male and female flowers being produced on distinct plants. The use of plant growth regulators by

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spraying has proven to be highly effective in altering sex expression and promoting the development of female characteristics. Cucurbits, being a vine crop, necessitate certain considerations in terms of crop management (Acharya *et al*., 2020; Mondal *et al*., 2020~~, Acharya *et al*., 2020~~)[5,6].

Plant growth regulators are employed to modify the growth of crops by manipulating the pace or pattern of their response to both intrinsic and extrinsic elements that regulate their development from seed germination through the production of new seeds. These regulators can have physiological effects on the plants during their growth as well as influence their postharvest characteristics (Acharya *et al*., 2020) [6].

Cucurbits exhibit favorable responses to the utilization of plant growth regulators (PGRs). In order to optimize production and ensure food safety, the agricultural sector in India has increasingly adopted mechanization and science-based approaches. This includes the utilization of various inputs, such as plant growth regulators, which have demonstrated rapid effects on both vegetative development and crop output. There are several advantages associated with this approach, including its efficiency in terms of time management for plant treatment and its environmentally beneficial nature. The utilization of plant growth regulators (PGRs) in cucurbits has been seen to enhance growth by facilitating vine elongation, promoting fruit development, influencing morphological and growth characteristics, and increasing resistance to disease-related challenges (Meena *et al*., 2022) [7]. The utilization of GA3 at a reduced concentration has an impact on plant development and enhances growth metrics, such as the quantity of male flowers and the onset of the first male flower (Khan & Chau~~ow~~dh~~a~~ry 2006) [8]. Auxin typically exerts an influence on plant development by promoting branching and leaf proliferation. The utilization of ethereal substances has been seen to impact the sex ratio of plants, specifically by promoting the development of a greater number of female flowers while inhibiting the growth of male flowers. This phenomenon has been found to have a positive effect on many yield indices (Nayak,~~ D. A.,~~ 2022) [9]. The exogenous application of plant growth regulators (PGRs) has an impact on the endogenous hormones of plants, leading to alterations in their physiological processes. The use of several plant growth regulators at specified doses has been found to enhance plant growth, promote early blooming, minimize sex ratio variations, and ultimately result in the largest fruit output with improved fruit quality. Primarily, the growth regulator facilitates the efficient development of commercially viable fruit within a reduced timeframe. Various uses of plant growth regulators (PGRs) have demonstrated a notable impact on stem length, branch quantity, total flower count, fruiting, yield, and other factors that contribute to yield. It is evident that alterations in endogenous hormone levels resulting from biotic and abiotic stress have a significant impact on crop development (Prajapati *et al*., 2015) [10]. Consequently, the implementation of various interventions, such as the exogenous administration of growth chemicals, may contribute to enhancing crop output or, at the very least, maintaining it. Hormones often undergo translocation inside a plant, moving from their source of synthesis to their site of physiological activity. Phytohormones, also known as plant hormones, serve as crucial intercellular messengers that play a pivotal role in regulating the whole life cycle of plants, spanning from germination to the eventual demise of the organism. Furthermore, the

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secretion of plant hormones is triggered by several environmental circumstances, including nutrition availability, drought conditions, light intensity, temperature fluctuations, as well as chemical or physical stress(Sabagh *et al.*, 2021) [11]. Therefore, the concentrations of hormones undergo fluctuations throughout the life cycle of a plant, exhibiting a reliance on both seasonal variations and environmental factors. The utilization of growth regulators in the cultivation of cucurbits necessitates a targeted mode of action, as well as adherence to stringent standards of toxicological and environmental safety (Nayak, ~~D. A.,~~ 2022)[9].

~~2.~~ 1.3. Effect of Plant growth regulators on ~~different~~ cucurbits~~-~~

~~2.1~~1.1 1.3.1. Watermelon~~-~~ [*Citrullus lanatus* (Thunb.) Matsum. & Nakai]

The application of Gibberellic acid (GA3) in watermelon at concentrations of 25-50 parts per million (ppm) resulted in the development of female flowers at lower nodes and the initiation of early blooming, ultimately leading to an early yield. In addition, the application of GA3 at different concentrations resulted in an early yield, as well as a decrease in the sex ratio and an increase in the number of fruits per plant. Similarly, the use of the PGR ethrel at both 250 and 500 ppm concentrations also led to a higher number of fruits per plant. The efficacy of Maleic hydrazide (MH) and naphthalene acetic acid (NAA) treatments was shown to be comparatively lower in terms of early and high yield, as compared to the treatments including GA3 and ethrel (Dixit *et al*., 2001) [12]. Kumar *et al*.~~,~~ (2022) [13] concluded that the application of the GA3 in the concentration of the 40 ppm give best vegetative growth with characters like length of vine, number of sub branches, yield is also recorded highest that is 44 t/ha and the quality content like total soluble solid and total sugar is found to be highest. Application of the PGR Triiodobenzoic acid (TIBA) 20 ppm give best result as compared to GA3 20 ppm and recorded 10.07 kg fruit per plant or 50.3 t/ha and produced average fruit weight of the 3.06 kg/ fruit (Mehsram, *et al*., 2022) [14]. The cultivar Shine Beauty of the watermelon produced yield of 34.9 t/ha during the application of the MH 200 ppm also total sugar, reducing sugar and pulp weight were noted highest (Sinojiya *et al*., 2015) [15].

In summary, applying GA3 (25-50 ppm) to watermelon resulted in early yield and more fruits. Ethrel (250 and 500 ppm) also increased fruit count. GA3 (40 ppm) enhanced vegetative growth and yield. TIBA (20 ppm) improved fruit yield and weight. MH (200 ppm) in Shine Beauty cultivar enhanced yield and sugar content. GA3 and ethrel are promising for watermelon cultivation.

~~2.2~~1.2 1.3.2. Cucumber (*Cucumis sativus* L.)

The application of a combination of GA3 at a concentration of 20 ppm and NAA at a concentration of 100 ppm resulted in considerably improved growth metrics, including vine length per plant (cm), number of primary branches per plant, and number of leaves per plant, compared to both the control group and other treatment groups. Likewise, GA3 20 ppm with NAA 100 ppm was found to have a good impact on several aspects, including flowering, yield, and yield attributing characteristics. In the

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context of cucumber yield, it was observed that the application of a combination of GA3 at a concentration of 20 ppm and NAA at a concentration of 100 ppm resulted in the maximum production (Dalai *et al*., 2015) [16].The utilization of plant growth regulators resulted in a substantial enhancement in growth. Gibberellic acid (GA3) at a concentration of 100 parts per million (ppm) has been shown to have a significant role in enhancing yield-related traits. Similarly, the application of Naphthaleneacetic acid (NAA) at a concentration of 100 ppm has also been seen to contribute to this effect. Additionally, the use of ethrel at a concentration of 300 ppm has been shown to reduce the ratio of male to female flowers. The administration of GA3 at concentrations of 150ppm and 200ppm resulted in an improvement in both fruit set and fruit retention percentage (Pandey *et al.,* 2021) [17]. Iskandaria *et al.*, (2023) [18] concluded that the hormone gibberellins, at a concentration of 200 ppm, exhibited a more pronounced impact on the development of cucumber seeds as compared to treatments 0 ppm, 150 ppm, and 175 ppm.

In summary, the combined application of GA3 at 20 ppm and NAA at 100 ppm significantly improved various growth metrics and yield attributes in cucumber plants. This included enhanced vine length, primary branches, number of leaves per plant, flowering, and overall yield. Furthermore, GA3 at 100 ppm and NAA at 100 ppm were identified as key contributors to increased yield-related traits, while ethrel at 300 ppm reduced the male to female flower ratio. Higher concentrations of GA3 (150 ppm and 200 ppm) positively affected fruit set and retention, emphasizing the influence of plant growth regulators on cucumber seed development. Additionally, gibberellins at 200 ppm demonstrated a substantial impact on cucumber seed development compared to other concentrations. These findings highlight the potential of plant growth regulators in optimizing cucumber yield and seed development.

2.31.3 1.3.3. Bottle gourd [*Lagenaria siceraria* (Molina) Standl.]

The application of GA3 (20 ppm) at the 4-leaf stage, resulted in notable improvements in many plant characteristics such as growth, flowering, and yield. This was followed by the application of NAA (100 ppm) at the 4-leaf stage. The experiment has determined that the application of treatment GA3 (20 ppm) at the 4-leaf stage is suitable for promoting the development and production of bottle gourd (Rapha, S. E., 2022) [19]. The application of the NAA 250ppm gave maximum vine length of 6.7 m with maximum leaf area. The treatment with Chlorocholine chloride (CCC) at 300 ppm resulted in the highest number of primary branches (20.95) and secondary branches (9.36) per vine. However, this treatment exhibited the lowest vine length (4.33), number of nodes per vine (18.05), and leaf area (218.36 cm2). The highest net return (Rs.204440 per hectare) and benefit-cost ratio (2.76) were seen when ethrel was applied at a concentration of 400 ppm (Kumar *et al.,* 2019) [20]. The application of Ethrel at a concentration of 200 ppm resulted in the highest fruit production (361.1q/ha) for cultivar GH-22 (Rahman *et al.,* 202019) [21]. The yield for same cultivar GH-22 was recorded 349.2 q/ha with same spray of Ethrel at a concentration of 200 ppm by Duhan *et al.*, (2022) [22].The application of Ethrel at a concentration of 300 ppm at the 2-4 leaf stage was determined to be the most effective

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method for achieving increased production, improved quality, and maximum net return in bottle gourd cultivation Barot~~, D. C.~~ (2022) [23].The foliar application of NAA at a concentration of 200 ppm resulted with improvements in the moisture content, crude protein content, and total soluble solids content of bottle gourd Rehan *et al.*~~,~~ (2022) [24].

In conclusion application of GA3 (20 ppm) at the 4-leaf stage enhances growth, flowering, and yield in bottle gourd. Naphthalene acetic acid ~~NAA~~ (100 ppm) at the same stage also impacts growth positively. Ethrel at 400 ppm shows the highest net return and benefit-cost ratio (BCR). Ethrel at 200 ppm boosts fruit production, while 300 ppm at the 2-4 leaf stage is most effective for increased production and quality. The NAA at 200 ppm improves moisture, protein, and soluble solids content in bottle gourd.

~~2.4~~1.4 1.3.4. Muskmelon (*Cucumis melo* L.)

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Devi & Madhanakumari (2015) [25] documented the minimum count of male flowers (63.23), the maximum count of female flowers (17.43), the average number of fruits per vine (10.63), and the average weight of the fruits (0.679). The treatment including the application of NAA at a concentration of 150 ppm combined with Ethrel at a concentration of 250 ppm exhibited the highest recorded values for yield-related characteristics, namely fruit diameter (12.97) and yield per plant (7.01). The therapy that yielded the most favorable results was the administration of NAA at a concentration of 150 ppm in combination with ethrel at a concentration of 250 ppm, when compared to the other treatments. The data indicates that the percentage increase in yield achieved with the use of a high-yielding plant growth regulator (Ethrel), compared to a local check, ranged from 24.55% to 24.10% (Kumar *et al.,* ~~(~~2017) [26]. The GA3 at a concentration of 60 (ppm), and ethrel at a concentration of 150 ppm, exhibited superior performance across various parameters. These parameters include the number of days required for the emergence of the first true leaf (21.53), the emergence of the second true leaf (25.33), and the emergence of the first male flower (34.8). Additionally, demonstrated favorable outcomes in terms of average fruit weight (0.61), average fruit length (10.93), average fruit diameter (11.64), average fruit yield per plant (2.60), average fruit yield per hectare (27.61 t~~ons per~~ h~~ect~~a~~re~~), internode length (10.72), average vine length (1.44), the number of nodes at the first male flower emergence (2.26), the number of leaves (82.20), and the benefit-cost ratio (2.51:1). Hence, it can be concluded that treatment of GA3 at a concentration of 60 ppm~~PPM~~ combined with Ethrel at a concentration of 150 ppm~~PPM~~, exhibits superior performance in comparison to the remaining treatments and the control group (Prasad *et al.,* 2022) [27].

As per the above literature it is concluded that c~~C~~ombined application of specific plant growth regulators, such as NAA and Ethrel, or GA3 and Ethrel at specified concentrations, demonstrated significant improvements in fruit yield and quality parameters in plants, showcasing their potential for enhancing agricultural productivity.

~~2.5~~1.5 **1.3.5. Pumpkin (*Cucurbita pepo* L.)**

The investigation analyzing the impact of plant growth regulators on callus, shoot, and root production in fluted pumpkin demonstrates that the use of a concentration of 1.5 mg/l benzylaminopurine (BAP) resulted in the maximum quantities of shoots, nodes, and leaves per stem ~~explant~~explants (Balogun *et al.,* 200~~1~~7) [28].The leaves and fruits of "giant pumpkin" were treated with a solution containing α-naphthalene acetic acid (NAA) and 24-epibrassinolide (EBR) at a concentration of 20 mg per liter NAA and 1.0 mg per liter EBR. This treatment was found to enhance the unloading of assimilates, thereby supplying carbon skeletons and energy for fruit growth. Additionally, it resulted in a significant increase in fruit weight, exceeding 44.1%. Hence, the application of exogenous NAA and EBR resulted in an augmentation in source capacity, transportation efficiency, and sink strength. Consequently, this facilitated the synthesis and dispersion of photo assimilate, eventually leading to an enhancement in fruit size (Chen *et al.,* 2022) [29].

~~2.6~~ **1.3.6. Bitter gourd (*Momordica charantia* L.)**

The application of gibberellic acid (GA3) at a concentration of 60 ppm resulted in increase in the number of fruits per plant (14.1), individual fruit weight (84.8 g), and overall yield (145.4 quintals per hectare). The observed increase in fruit output in treated plants can be due to the fact that these plants maintain a greater level of physiological activity, allowing them to accumulate an adequate amount of assimilates necessary for the development of flowers and fruits. This eventually results in a higher overall yield as was~~per~~ reported by Anayat *et al.*~~,~~ (2020) [30]. Sandra *et al.*~~,~~ (2015) [31] revealed that the use of GA3 at a concentration of 50 ppm resulted in a greater fruit set, with fruit ranging from 12.0 to 12.4. Additionally, the fruit weight was also seen to be larger, ranging from 90.4 g to 109.9 g. Following closely behind, the application of ethrel at 50 ppm demonstrated a fruit set of 11-11.3 fruits per plant and a fruit weight of 93.1 - 94.9 g. The application of GA3 at a concentration of 50 ppm resulted in a significantly greater fruit set, ranging from 12.0 to 12.4 fruits per plant, as well as increased fruit weight, ranging from 90.4 to 109.9 grams. The treatment of ethrel at the same concentration of 50 ppm also exhibited notable effects, with fruit set ranging from 11 to 11.3 fruits per plant and fruit weight ranging from 93.1 to 94.9 grams (Sandra *et al.,* 2015) [32]. The plants treated with indole acetic acid (IAA) 200 mg/L and GA3 50 with IAA 100 mg/L exhibited a greater abundance of male flowers (72.66) and female flowers (24.66). The plants treated with GA3 at a concentration of 100 mg/L exhibited the highest recorded fruit length of 18.33 cm. Similarly, these plants also had the highest recorded seed yield per plant, weighing 0.273 kg (Ahmada *et al.,* 2019~~5~~) [3~~2~~3]. Priyadarshi *et al.,* (2023) [3~~3~~4] concluded that the spray of ethephon at a concentration of 250 ppm during the ~~two-leaf stage, four~~ 2-4-leaf stages, and bud initiation stage resulted in the highest average fruit weight (140.08 g) and number of fruits per vine (10.41), highest gross return (Rs. 683400 /ha), net return (Rs. 565362 /ha), and benefit-cost ratio (4.79). Based on the findings, it can be inferred that the application of Ethephon at a concentration of 250 ppm by foliar spraying, performed three times

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during the two-leaf stage, four-leaf stage, and bud initiation stage, would give favorable results in terms of increased crop production, improved financial returns, and a greater benefit-to-cost ratio. Arvindkumar *et al.,* (2014) [345] reveals that application of boron at a concentration of 4mg/l resulted in the lowest seed moisture content (9.16 %) and the highest seed germination percentage (85.5 %). This was followed by treatment with NAA at a concentration of 50 mg/Ll, which recorded a seed moisture content of 9.21% and a seed germination percentage of 85.25%. In contrast, the control group exhibited the highest seed moisture content (9.84%) and the lowest seed germination percentage (74.5%) at the end of the storage period. Maximum increases of 17.8% and 31.4% in fruit number and 26.4 and 36.1% in fruit weight were seen with 1.2 gL−1 gibberex in Golu hybrid and Faisalabad Long. Maximum yield increases of 41% and 88% per plant were seen with 1.0 and 1.2 gL−1 gibberex treatments in Golu hybrid and Faisalabad Long, respectively (Abbas *et al.,* 2020) [356]. In foliar CCC (200 ppm), total sugars (18.03% above Control), phenol (10.93%), and nitrate reductase (16.12%) were highest. The GA3 (20 ppm) had the highest chlorophyll concentration (18.03% above Control). The GA3 (20 ppm) (39.88%) increased mean fruit output over Control, in cultivar MHBI-15 and Chaman Plus according Geeta *et al.,* (2014) [367]. The seedling vigor index in bitter gourd exhibited a substantial maximum value of 1835, which was seen at a concentration of 0.3 NAA (300 mg/1000 mLl). This was followed by a value of 1292 at a concentration of 1.5 NAA (1500 mg/1000 mLl) Muttaleb *et al.,* (202214) [378]. The flowering characteristics, including the number of days required for male flower initiation (35.08) and female flower initiation (24.87), exhibited the highest values when treated with NAA at concentrations of 100 ppm and 150 ppm. The yield parameters fruit weight (105.89 g), fruit length (16.30 cm), fruit diameter (7.60 cm), number of fruits per plant (38.67), and fruit yield per hectare (35.25 t/ha) were seen to be highest in the treatment GA3 at a concentration of 60 ppm in cultivar of Kashi Mayuri (Kokkirala *et al.,* 202214) [389]. The utilization of ethrel at a concentration of 200 ppm led to the advancement of the initial appearance of pistillate flowers (34.30), the postponement of male flower appearance (32.78), the largest count of female flowers per vine (41.40), and the lowest count of male flowers (253.46). A reduced sex ratio and a higher occurrence of female flowers at lower nodes were seen when ethrel was applied at a concentration of 200 ppm, resulting in sex ratios of 6.12 and 11.99, and female flower occurrences of 8.75 and 15.30, respectively. The use of growth regulators during the 2-4 leaf stage led to the quickest development of the first pistillate flower, with the fewest number of days required (35.42). This was followed by the application of growth regulators during the four-leaf and flower initiation stage (Sivashankary *et al.,* 2013) [3940].

Gibberellic acid (GA3), ethrel, IAA, ethephon, and NAA have been shown to affect bitter gourd fruit output, set, weight, blooming, and seedling vigor. Fruit per plant, fruit weight, and yield increased significantly with GA3 at 60 ppm. Ethrel at 50 ppm improved fruit set and weight. Ethephon at 250 ppm throughout key development phases optimized fruit weight and vine fruit number. Boron at 4 mg/Ll and NAA at 50 mg/Ll improved seed hydration and germination. Gibberex treatments increased

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fruit quantity, weight, and yield per plant. In bitter_gourd cultivation, growth regulators impact sugar, phenol, nitrate reductase, chlorophyll, and blooming.

3. 2. CONCLUSIONOnclusion

In summary, Tthe application of Plant Growth Regulators (PGRs) in cucurbits has exhibited encouraging prospects in augmenting the growth, productivity, and overall quality of agricultural produce. Plant growth regulators (PGRs) have been observed to exert significant influence on a range of physiological and developmental processes in cucurbits. These processes include seed germination, root and shoot growth, flowering, fruit setting, and overall plant vigor. Through the strategic utilization of plant growth regulators (PGRs) in accordance with specific crops, development stages, and prevailing environmental circumstances, cultivators have the potential to optimize productivity and effectively alleviate the adverse effects of stressors on cucurbit production. Nevertheless, it is important to persist with research endeavors and conduct field trials in order to get a deeper comprehension of the precise impacts of diverse plant growth regulators (PGRs) and determine the most suitable rates of application for distinct cucurbit species. This pursuit will finally culminate in the development of agricultural techniques that are both sustainable and efficient.

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