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PLANT GROWTH REGULATORS: THEIR IMPACT ON CUCURBITS

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ABSTRACT

Cucurbitaceous crops are referred to as "cucurbits" in general. Cucurbits cover the most land in India and other tropical nations. Cucurbits are high in calories, minerals, and vitamins. Cucurbit seeds are prized for their high oil and protein content. To boost productivity and food safety, by adopting inputs such as plant growth regulators, Indian agriculture has become more mechanized and science-based; plant growth regulators have a faster influence on crop vegetative as well as yield. PGR administration in cucurbits stimulates growth by assisting in vine elongation, increases fruit setting, changes morphological and growth characteristics, and helps the plants tolerate disease-related difficulties. The application of GA_3 at low concentrations influences plant growth and boosts growth metrics such as the number of male flowers and the appearance of the first male bloom. Auxin stimulates development by increasing the number of branches and leaves. The use of ethereal altered the sex ratio by increasing the number of female flowers and suppressing male blooms, which increased the yield parameters. Exogenous application of PGRs has an influence on plant endogenous hormones, altering the plant's physiological processes. Various plant growth regulators in suggested concentrations promote faster growth, earlier blooming, a lower sex ratio, higher fruit output, and improved fruit quality. Generally, the growth regulator aids in the production of marketable fruit in a short period of time. Different PGR applications had a substantial effect on stem length, branch number, total number of flowers, fruiting, yield, and other yield contributing features. PGRS regulates physiological processes in cucurbit crop plants such as rooting, flowering, growth, sprouting, and ripening, and the usage of PGRS in cucurbit production has been proven to be favourable for yield and yield contributing features.

***Keywords* :** Cucurbits, PGRs, Auxin, Ethrel, GA_3

Introduction

Cucurbits are crops from Cucurbitaceae family. It includes a wide variety of vegetables that are used for salad (cucumber) or cooking (all gourds), pickling (West Indian gherkins), dessert fruit (muskmelon, watermelon) or candies or preserved (ash gourd) (Ashok *et al*., 2019). Cucurbits account for around 5% of total vegetable production in India, including indigenous cucurbits. Cucurbits, being the largest vegetable group, offer greater potential for increasing total productivity and vegetable production to meet the difficulties (Nayak, 2022). The majority of the cucurbits are annuals that are grown from seed. Cucurbits are sensitive to growth regulators. PGRs serve an important role in increasing the growth, productivity, and quality of cultivated cucurbitaceous crops. Plant growth regulators are chemical compounds that, when given in small doses, cause fast changes in plant phenotypes and influence plant growth from seed germination through senescence by augmenting or stimulating the natural growth regulatory system. Plant hormones regulate all aspects of development, including embryogenesis, organ growth regulation, pathogen defence, stress tolerance, and reproductive development (Toungos, 2018). The primary goal of cucurbit research in India is to double productivity on a sustainable basis. Plant growth substances are known to improve the source-sink connection and boost photo assimilate transfer, resulting in more effective flower creation, fruit and seed development, and eventually increased agricultural output (Nayak, 2022). Most physiological activities and plant growth are governed by the activity and interaction of several chemical molecules in plants known as hormones and other naturally occurring inhibitors. Plant growth regulators boost plant vigour, promote root and shoot growth, and are also known to decrease stress.Plant growth regulators are naturally occurring or synthesized chemicals that influence developmental or metabolic processes in higher plants (Rademacher, 2016). Plant growth regulators have a significant impact on cucurbit fruit output. It can change sex expression, promote fruit set, and ultimately increase cucurbit yield. In these plants, there is most likely a link between growth factors and sex expression. Certain growth regulators, such as NAA, GA_3, and 2,4-D, have been demonstrated to influence sex expression in a variety of cucurbits, either inhibiting male blooming or enhancing female flowers. Male blooms on lateral branches are reduced by growth regulators. As a result, they promote female flower production on lateral branches, ultimately increasing output. Plant growth regulators have an immediate influence on crop development programmes and are less time intensive. Vascular tissues transport hormones from one area of the plant to another, such as sieve tubes or phloem, which transport sugars from the leaves to the roots and flowers, and xylem, which transports water and mineral solutes from the roots to the foliage (Nayak, 2022). Growth hormones can boost physiological efficiency, particularly photosynthetic ability. As a result, plant growth regulators have a significant impact on the growth and, ultimately, the production of various produced cucurbits.

Effect of pgrs on cucurbits

Cucumber

Thappa *et al.* (2011) carried investigation on the effects of plant growth regulators on the morphological, floral, and yield traits of cucumber cv.green cucumber, long and found that the application of maleic hydrazide @ 100 ppm + Ethephon @ 100 ppm increased the number of nodes per main stem, number of nodes per unit length of vine, maximum number of fruits, maximum fruit weight (kg), and yield per hectare (t). Plant growth regulators influence crop physiology and improve cucumber plant production characteristics. This treatment also offered the highest economic outcomes for cucumber output. Trivedi (2011) conducted the trial on the effect of plant growth regulators on cucumber cv. Guj-Cucumber-1 growth, flowering, sex-expression, quality, and yield and concluded that application of ethrel 300 ppm increased the number of fruits per vine and produced the highest fruit yield. Similarly, in terms of economics, Ethrel 300 ppm provided the best net return and CBR. Hikosaka and Sugiyama (2015) examined the effects of exogenous plant growth regulators on cucumber production, fruit growth, and endogenous hormone concentration in gynoecious parthenocarpic cucumber, fruit abortion and reduced fruit yield have been documented in parthenocarpic cucumbers with many female flowers and a substantial fruit load. To ensure sustained fruit production, the process of fruit abortion in cucumbers via fruit load and endogenous plant hormones must be understood.The effects of exogenous plant growth regulators (PGRs) on yield and fruit growth in a gynoecious, parthenocarpic cucumber were studied. Finally, fruit load may have a higher influence on fruit abortion than PGRs. Pal *et al.*, (2016) exogenously applied potassium nitrate and gibberellic acid in combination on growth, development, and yield of the F1 hybrid cucumber cv. 'KUK-9' under protected cultivation and concluded the overallresult that foliar applications of GA@ 0.01g/l and Potassium nitrate @ 2.5 g/l had the greatest influence on plant growth, development, and production. Foliar potassium and gibberellic acid administration may be helpful in maximizing cucumber growth, physiological condition, and yield indices. In another study, the combination of GA_3 20 ppm + NAA 100 ppm improved vine length, number of primary branches, number of leaves, maximum number of fruits per plant, weight of fruit (g), fruit yield per plant, and total yield per hectare (q) in cucumber cv. Uday Pusa (Dalai *et al.*, 2015). Barholia *et al.* (2017) investigated the effect of plant growth regulators on cucumber under protected cultivation and discovered that the influence of plant growth regulators on cucumber morphological traits was variable, but floral and yield traits were significantly affected by a combined application of maleic hydrazide @ 200 ppm and ethephon 200 ppm. This treatment encouraged early development, maximized yield, and offered the greatest economic outcomes for cucumber production. Nayak *et al.* (2018) examined the effects of pinching and plant growth regulators on the morphological and physiological characteristics of cucumber cv. Gujarat cucumber-1 and found that pinching treatments and PGR application significantly influenced morphological characters such as vine length, number of primary branches, number of nodes, and internodal distance. All pinching treatments had a considerable affect on cucumber total leaf area and leaf area index, however PGRs had no striking effect on these physiological properties but considerably boosted the morphological characters. Baqi *et al.* (2018) conducted experiment on the effect of GA_3 and NAA with pruning levels on cucumber (*Cucumis sativus* L. Malini F1) growth, sex expression, and yield attributes under protected conditions. The study's findings revealed that combining GA_3 and NAA (50 ppm + 500 ppm) with double stem pruning had more significant effects on vegetative growth, increased flowering, suppressed staminate flowers, and enhanced pistillate flowers, resulting in higher fruit yield per plant and per hectare. Dhakal *et al.* (2019) investigated the influence of ethephon dosages on cucumber (*Cucumis sativus* cv. Bhaktapur Local) vegetative characteristics, sex expression, and yield. With 300 ppm ethephon, the number of nodes, branches per plant, total number of female flowers, and total yield were determined to be maximum. Ethephon was discovered to transfer male and female flowers to upper and lower nodes, respectively. Ethephon at 300 ppm was proven to be superior at lowering the (male: female) sex ratio. Farmers benefit from the judicious application of ethephon. Kadi *et al.* (2019) concluded that the GA_3 100 ppm treatment resulted in the highest growth characteristics such as vine length, number of leaves, number of branches, leaf area such as length of fruits, diameter of fruits, number of fruits per plant, and fruit yield (q/ha). In the treatment of NAA, the internodal distance was the greatest (50 ppm).Phenological factors such as average days to first flowering, days to 50% blooming, and days to first picking, maximum fruit set percentage, and maximum fruit retention percentage are also important when plant growth regulators are applied in polyhouse conditions. Pandey *et al.* (2019) investigate the effect of ethephon on the vegetative character, blooming behaviour, and sex expression of the cucumber cultivar Bhaktapur Local. It was discovered that ethephon @ 400 ppm resulted in a much higher number of nodes per plant, the maximum number of primary branches, earlier female blossoming, more total female flowers per plant, and a higher sex ratio. Ethephon at 600 ppm generated more nodes, female flowers at the lowest node and male flowers at the highest node, and delayed the development of the first male flower by 3 days. Dinesh *et al.* (2019) examined the effects of plant growth regulators (GA_3, ethereal, and salicylic acid) on cucumber cv. Malini on development and flowering and observed that GA_3 at 75 ppm recorded maximum vine length, number of leaves, number of nodes on main stem, length of primary branches, and leaf area, whereas ethrel 300 ppm recorded maximum number of primary branches. Furthermore, the maximum internodal distance was measured using GA_3 at 250 ppm. In terms of phenological metrics, ethrel at 300 ppm produced the best results in terms of the number of days required for the first female flower appearance, the number of nodes required for the first female flower appearance, and the male to female sex ratio. Finally, the highest yield was observed in GA3 75ppm. To evaluate the potential of seed pre-soaking in different concentrations of gibberellins on cucumber growth, flowering, and yield. Sanoussi (2019) studied the effect of seed pre-soaking in gibberellic acid on cucumber on plant growth, flowering, and yield and reported that application of GA_3 concentration inducing flowering decreased staminate flower number and increased pistillate flower number. In terms of growth and yield qualities, the results clearly revealed that foliar application of 10g/ml GA was the optimum choice for growing cucumber. Mir *et al.* (2019) investigated Plant growth regulators: One of the strategies for improving growth and yield of the Bangladeshi native cucumber variety (*Cucumis sativus*) 'Baromashi' and discovered that ethephon 200 ppm produced the best results. Gosai *et al.*, (2020) studied the effects of plant growth regulators on cucumber growth, flowering, fruiting, and fruit yield and discovered that the usage of auxins and gibberellins together results in higher secondary growth. At 100 ppm, maleic hydrazide (MH) and Ethephon both increase the number of nodes and principal branches. At 300-400 ppm, ethrel slows secondary growth and increases femaleness, whereas at 200-300 ppm, it smoothes the fruit surface. The use of Ethephon at 300 ppm shortens the harvesting time of the fruit. Dalai *et al.*, (2020) investigated the effect of foliar GA_3 and NAA application on cucumber [*Cucumis sativus* L.] growth, flowering yield, and yield attributes and found that a dose of GA_3 @20 ppm + NAA@100 ppm was significantly superior in terms of growth parameters such as Vine length plant-1 (cm), number of primary branches plant^{-1}, number of leaves plant^{-1}, and yield attributes.

Bittergourd

GA_3 at 50 ppm improves the quantity of fruits per plant and the yield per plant (kg) in cv. Pusa Hybrid 1 (Nagamani *et al.*, 2015). Biradar *et al.* (2012) examined the effect of plant growth regulators on the yield, biochemical, and physiological characteristics of bitter gourd (*Momordica charantia* L.), and discovered that growth regulators had a significant effect on flower sex ratio conversion, which aids in crop yield enhancement. Plant growth regulators boosted the biochemical and physiological characteristics of bitter gourd, and foliar application of GA_3 @ 20 ppm was most efficient in raising fruit yield and yield components such as the number of female flowers and fruits per plant. Auxin increases plant growth, increasing the number of male and female flowers and influencing the sex ratio in cucurbits. When GA_3 was treated at 75 ppm to bitter gourd, it resulted in a decrease in the male female ratio and an increase in the number of fruits per vine and total fruit yield per vine (kg) in cv. Faisalabad Long (Ghani *et al*., 2013). Mia *et al*., (2014) discovered that plant growth regulators and NPK fertilization improved flower synchrony, growth, and yield of small type bitter gourd (*Momordica charantia* L.) and revealed that application of different doses of NPK fertilizer and plant growth regulators (GA_3, NAA, and Ethephon) significantly influenced flower initiation and fruit setting. The use of N90-P45-K60 fertilizer in conjunction with Ethephon resulted in a higher yield of little bitter gourd.The use of NAA at 50 ppm in bitter gourd resulted in increased leaf area and index (Kumar *et al*., 2014). Hirpara *et al*. (2015) investigated the effect of exogenous application of Gibberellic Acid ([GA3-25 and 50 ppm), ethrel (250 and 500 ppm), Naphthalic Acetic Acid (NAA; 50 and 100 ppm), and Cycocel (CCC; 100 and 200 ppm) on flowering fruiting and fruit yield in bitter gourd. The response of GA_3 and ethrel was determined to be the best of all foliar agents. Khatoon *et al*. (2019) reviewed the influence of foliar GA_3 and NAA spray on bitter gourd var. BARI Karola-1 sex expression, yield, and yield component. Spraying NAA at 150 ppm resulted in the highest fruit output, gross return, and net return with the highest BCR of 3.17, but greater concentrations of NAA at 150 ppm also resulted in a drop in the sex ratio. In several cucurbits, ethrel is used to increase female flowers. In bitter gourd cv. VK 1 Priya, ethrel @ 200 ppm led in earlier initial pistillate flower appearance, later male flower appearance, more female flowers, fewer male flowers, and a narrow sex ratio (Aishwarya *et al*., 2019). The use of GA_3 increased the number of staminate blooms, the number of fruits per hill, and the fruit production. GA_3 at 10 ppm increased the quantity of staminate blooms. Using 50 ppm produced more fruits per hill and yield per hectare than no application. The use of PGR dramatically boosted fruit yield. According to Raymond *et al*. (2018), GA_3 application was more profitable than no application.

Bottlegourd

Kore *et al*. (2003) viewed the effect of growth regulators on growth, flowering, and yield of bottle gourd *Lagenaria siceraria* variety Samrat under Konkan conditions and discovered that triacontanol, NAA, gibberellic acid, and paclobutrazol had a significant effect on growth, flowering, and yield. Kakroo *et al*. (2005) examined the effect of growth regulators on flowering, fruiting, and yield characteristics of the bottle gourd cv SH-BG-1 under Kashmir conditions and discovered that ethrel at 150 ppm produced the most female flowers and the fewest male flowers per plant, with the lowest sex ratio. Kumar *et al*. (2006) studied the influence of plant growth regulators on yield and yield contributing characteristics of bottle gourd cv. Pusa Naveen and discovered that Ethephon at 300 ppm produced the most fruits and fruit production per plant. Exogenous GA_3 administration may have increased cell division and elongation as a result, the plant's growth and development rate will accelerate. GA_3 30 mol/L enhanced the number of pistillate flowers, the lowest sex ratio, the most fruits per plant, and the average fruit weight (kg) in cv. Faisalabad Round Hidaytullah *et al*. (2012). Kumari (2013) experimented the effects of plant growth regulators and thiourea on bottle gourd on growth, yield, and quality. Summer Prolific Cv. Pusa Long and the findings revealed that ethrel 450 ppm was the most effective treatment for enhancing the fruit growth and yield of bottle gourd. In bottle gourd, ethrel at 100 ppm resulted in the highest yield per vine (kg) and yield per hectare (q) (Mahala *et al*., 2014). In cv. ABG 1, ethrel @ 600 ppm treatment resulted in the greatest number of female flowers and the lowest sex ratio (Patel *et al*., 2017). Ansari and Chowdhary (2018) discovered the effects of boron and three plant growth regulators (PGRs) on the vegetative, physiological, and fruit characteristics of bottle gourd, namely gibberellic acid (GA), maleic hydrazide (MH), and ethrel (E) and proposed that spraying ethrel @100 ppm at 2 and 4 true leaf stages, together with seed soaking in boron (0.05%) for 12 hours, will result in a considerable increase in growth, sex expression, and fruit characteristics. Kumari *et al*. (2019) studied the effect of plant growth regulators on the growth and yield of bottle gourd and concluded that spraying ethrel 200 ppm at 2 and 4 true leaves would result in a significant increase in growth and fruit characters. In the case of bottle gourd, Kumar *et al*. (2020) concluded that foliar application of ethrel @ 300 ppm sprayed at distinct phases of growth, namely at two true leaf stage, four true leaf stage, and flower initiation stage, was helpful for higher seed yield and plant growth. Soni *et al*., reported that 200 ppm ethrel significantly reduced the number of days to first flower and first harvesting, improved the female flower, narrowed the sex ratio, increased fruit weight, length, and diameter, and increased fruit yield, followed by 200 ppm NAA and 5 ppm GA_3. Moniruzzaman *et al*., 2020 found that growth regulator treatments had a significant effect on the number of primary branches/plants, the node number of the first male and female flower appearance, the number of days to the first male and female flower appearance, the number of male and female flowers, the sex ratio (male: female flower), the number of fruits/plants, the individual fruit weight, and the fruit yield. Spraying with MH at 150 ppm resulted in the most primary branches per plant, the most female flowers at lower nodes, the earliest appearance of female flowers on the nearest node (from the bottom), the lowest sex ratio, the most fruits/plant, the most fruit weight/plant, the highest fruit yield per hectare, the highest mean yield, and the highest gross and net returns.

Watermelon

GA_3 concentrations of 15 ppm enhanced the number of branches and the length of the main axis in CV. Glow with beauty. GA_3 150 ppm enhanced the number of primary branches, the length of the main axis, and the number of days until the appearance of the first male flower in watermelon cv. Sugar Baby (Dadwadiya, 2012). The use of GA_3 at 30 ppm increased the main axis and the quantity of male flowers in cv. Lal of Durgapura (Chaudhary *et al*., 2014). Sinojiya*et al*., 2015 examined the effect of plant growth regulators on the growth, flowering, yield, and quality of watermelon (*Citrullus lanatus* Thunb.) cv. Shine Beauty and discovered that growth characters such as main axis length, number of branches and nodes, and average fruit weight were highest with GA_3 15 ppm. In terms of flowering, MH 200 ppm had the shortest days to first male, female, and hermaphrodite flower appearance, the highest female: male sex ratio, the most fruits per plant, and the highest fruit production.The maximum length of main creepers at 60 and 90 DAS, number of sub-creepers at 60 and 90 DAS, number of leaves/plants at 60 and 90 DAS, maximum chlorophyll content at 45 and 60 days, and maximum number of male flowers were recorded with treatment GA_3 @ 30 ppm, according to Chaudhary *et al*., (2016). TIBA @ 20 ppm revealed to be the most effective for producing the lowest node number at which the first female flower appears, the greatest number of female flowers, the lowest sex ratio, and the greatest number of fruits, fruit yield/plant, fruit yield/ha, and fruit length. The maximum average weight of the fruit and fruit diameter in TIBA 15ppm. Meshram *et al*. (2022) discovered the influence of plant growth regulators on watermelon output and quality. The results of the experiment revealed that at TIBA 20 ppm, the yield contributing characters, chlorophyll index, highest sex ratio (Female: Male), minimum days to first female flower appearance, minimum node at which first female flower appeared, maximum number of fruits, average weight of fruit, fruit yield kg per plant, fruit yield kg per plot, and yield per hectare were all maximum.

Muskmelon

Foliar spraying cv. Rasmadhuri with MH 300 ppm improved the number of fruits per vine, fruit weight, and fruit yield per hectare (Hadvani, 2010). According to Devi *et al*. (2015), a combination of NAA 150 ppm + ethrel 250 ppm increased the quantity of male and female flowers in PusaSharbati. The number of fruits per vine and the weight of the fruits. Fruit diameter and yield per plant were observed to be highest in the treatment NAA 150 ppm + ethrel 250 ppm. The application of NAA 150 ppm plus ethrel 250 ppm was found to be the most effective treatment. Chaurasiya *et al*. (2016) investigated the effects of plant growth regulators on the growth, sex expression, yield, and quality of Muskmelon (*Cucumis melo* L.), and discovered that GA_3 and NAA increased melon growth whereas Ethrel inhibited it significantly. The treatment GA_3 60 ppm measured maximum stem length, number of leaves per plant, number of nodes in main stem, and average fruit weight. Whereas ethrel 150 ppm revealed to be one of the best treatments in terms of primary branch number per plant, days to first pistillate bloom, number of pistillate flowers per plant, lowest sex ratio, number of fruits per plant, and yield per ha. Ethrel 200 ppm considerably delayed the anthesis of the first staminate flower from the anthesis of the first pistillate flower, as well as the earliest fruit maturity or the shortest number of days required to harvest the first fruit. Meshram *et al*., 2020 concluded that growth characters such as main stem length, number of leaves per plant, number of branches per plant, and inter nodal distance were maximum with GA_3 20 ppm. In terms of yield contributing characters, the treatment with TIBA 20 ppm had the highest chlorophyll index, highest sex ratio (Female: Male), minimum days to first female flower appearance, minimum node at which first female flower appeared, maximum number of fruits, average weight of fruit, fruit yield kg per plant, fruit yield kg per plot, and yield per hectare by spraying plant growth regulators on watermelon. Roopa *et al*., (2020) revealed that under stress conditions, exogenous application of gibberellic acid at 50 ppm and salicylic acid at 0.5 mM was effective in mitigating the deleterious effect of drought stress in muskmelon.

Ridge gourd

Sha and Seerangan (2019) during their study onthe effect of plant growth regulators and micronutrients on the growth and yield of ridge gourd (*Luffa acutangula*L) cv. PKM-1 and concluded that the plant growth regulators and micronutrients brassinosteroid 2 ppm + ethrel 250 ppm + micronutrient 2% were the best to increase yield. Hilli *et al*. (2010) investigated the influence of growth regulators and spray stages on ridgegourd growth, fruit set, and seed output and found that spraying GA_3 @ 50 ppm at the four leaf, flower, and fruit initiation phases greatly boosted vine length. The highest number of branches per vine was reported with ethrel 500 ppm spraying at the four leaf, flower, and fruit initiation stages, followed by spraying at the four leaf and flower initiation stages in both seasons. Maximum vine length and number of branches were measured using GA_3 50 ppm during the four leaf, flower, and fruit initiation stages.

Ivy gourd

Prabhu *et al*. (2006) investigated the effect of growth regulators on fruit characteristics and seediness in *Coccinia grandis* L. The results revealed that GA_3 100 ppm and 2, 4, D 100 ppm were more beneficial on fruit girth and weight.Among the treatments, GA_3 100 ppm and NAA 400 ppm resulted in fewer seeds and improved individual fruit weight.

Conclusion

Plant growth regulators are used to modify a crop by altering the rate or pattern, or both of its response to the innate and exposed elements that govern development from seed germination to new seed development via various physiological and postharvest effects. Cucurbits are the most common type of vegetable grown worldwide, and they are sensitive to growth regulators. PGRs serve an important function in increasing growth, yield and quality. Some growth regulators enhance plant growth, while others function as inhibitors, reducing plant growth and yield. Exogenous application of PGRs has an influence on plant endogenous hormones, altering plant physiological processes. In this way, review article achieves its goal of evaluating the role of different concentrations of plant growth regulators on cucurbit growth, flowering, fruiting and yield.

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