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Impact of Auxin and Gibberellin on Vegetable Crops: A Review

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Review Article

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ABSTRACT

Plant growth regulators, also known as phytohormones, are a class of organic chemicals, either naturally occurring or artificially synthesised, that exert control over specific physiological processes in plants. The application of these substances elicits a range of effects on vegetables, encompassing seed germination, the disruption of seed dormancy, the commencement of flowering, the induction of gametocidal effects, the promotion of fruit set, the stimulation of

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parthenocarpy, and the facilitation of fruit ripening, among others. Auxin plays crucial factor in the development of several vegetable crops, including cucurbits. Notably, the application of Naphthalene acetic acid at a concentration of 10 ppm has been observed to exert a significant influence on sex expression, fruit set, and overall production in cucumber plants. The application of 4-CPA resulted in the greatest quantity of commercially viable fruit in tomato plants. The application of Naphthalene acetic acid at a concentration of 40 ppm exhibited the most substantial enhancements in leaf area, percentage of fruit set, total fruit production, as well as the quantity and weight of seeds per fruit in chilli plants. The treatment involving the application of 80 ppm Naphthalene acetic acid in brinjal resulted in the observation of increased fruit length, average weight of fruit per plant, and greatest fruit diameter. Gibberellin is also of significant importance, since it participates in using the gibberellic acid route to produce tomato plants that exhibit enhanced performance in both irrigated and water-limited environments, hence increasing their drought tolerance. The application of GA3 at a concentration of 75 ppm has been found to be highly beneficial in improving vegetative growth and yield characteristics in brinjal, as well as in several other vegetable crops as detailed in the present study. Additionally, they serve a crucial function in augmenting the output and productivity of many vegetables breeding programmes, and ensuring food safety.

Keywords: Phytohormones; auxin; breeding programme; fruit set.

1. INTRODUCTION

Plant growth regulators are also called as plant hormones,. Sometimes they are called phyto hormones (a term coined by Thiman, 1948, [1]; the term phytohormones or plant hormones are used only in case they are produced organically or inside plant while the plant growth regulator is used when they are produced synthetically [2]. They are the chemical or organic compounds (phytohormones) which are produced in the plant or created outside it, which affect the various plant metabolism and physiological activities that govern the growth and development of the plant. They are produced at one location and transported to another for their influence; however, some of them have the same site of synthesis and effect [3]. Although both auxins and GAs can stimulate parthenocarpic fruit formation, there are still some differences in the development process of the parthenocarpic fruits [4].

Table 1. The various types of the plant hormones [5,6]

Hormones	Role	Site of production	General Use
Auxins	Shoot Growth	Meristem of apical buds, embryo of seed, young expanding leaves	Used to enhance rooting, also in flower formation
Gibberellins	Stimulate cell division and cell growth	Immature seeds	Enhance the size of the fruit and the flower also aids in stalk length
Cytokinins	Increase cell division	Root apex, endosperm of seeds, young fruits	Help in root growth and bud initiation also increase the storability of vegetables and flowers.
Ethylene	Senescence	Ripe fruits, flowers and leaves and nodes of stem.	Used in ripening of fruit and vegetables
Growth inhibitors	Growth seizure	-	decrease the intermodal length and increase the number of flowers
Growth retardants	Decrease growth rate	-	Slow the development of tobacco sucker and other parts of different crops

2. AUXIN

In 1880, Charles Darwin was the first to postulate the presence of auxins. It was revealed to be the first-class growth regulator. Auxins are chemicals that have a favourable influence on cell expansion, root initiation, and bud development. Auxin aids in the production of other growth hormones. IAA is a naturally occurring auxin, whereas NAA, IBA, 2-4D, and various other synthetic auxins [5].

Structure: Normally, native auxin molecules are generated from the amino acid tryptophan. This amino acid has a six-sided carbon ring linked to a five-sided carbon ring. This 5-sided ring is part of a set. What is linked to this ring is the only distinction between most auxin molecules and tryptophan. The common auxin IAA is shown below in figure-

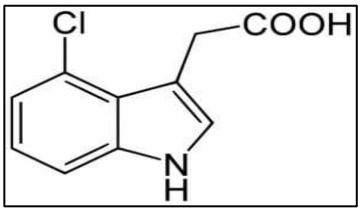

Fig. 1. Structure of the common auxin IAA

2.1 Effect of the Auxins on Different Vegetable Crops

Cucurbits: Auxin is a crucial factor in the growth and stress response of cucumbers (*Cucumis sativus* L.), and its utilisation in cucumber production is widely favoured in agricultural practices. An important aspect of enhancing productivity and minimising labour in cucumber cultivation is the regulation of branch numbers and the induction of parthenocarpy through auxin control [7] Dahal & Dahal, [8] revealed that NAA @ 10 ppm had a higher effect on sex expression, fruit set and yield in the Bhaktpur local variety of the cucumber. Mandal et al*.,* [9], reported that application of indole acetic acetic will cause the underdeveloped fruit and having the fruit bearing percentage of 67.77% in cucumber genotype IMPU-1 while the maximum fruit set of 89.30% is reported during the application of idole acetic acid and BAP together and fruit is well developed. Acharya et al., [10] reported that the application of GA_3 at concentrations of 50-100 ppm has been found to enhance plant growth, raise the abundance of male flowers, and augment the weight of fruits. The application of three at concentrations of 400-500 ppm resulted in an increase in the number of female flowers, an acceleration of the maturity cycle, and an improvement in the sex ratio through the suppression of male flowers. The application of auxin at concentrations ranging from 50 to 100 parts per million (ppm) has been found to have a significant impact on the growth of plants. Similarly, the use of three has been observed to enhance the yield-related characteristics of cucurbit crops.

Tomato: Vendrell, [11] reported that when mature tomato fruit is treated with the 2,4-D with different concentrations, the result shows in all treatments is increase in respiration and ethylene production as compared to control, Rahim, [12], reported that tomato plants (*Lycopersicon esculentum* Mill.) subjected to 4-CPA treatment exhibited the most substantial output of commercially viable fruit. The treatment with 4-CPA resulted in the most significant augmentation in both overall yield and the production of parthenocarpic fruit. Alam et al*.,* [13] revealed that The application of indole-3-acetic acid (IAA) to tomato plants experiencing salt stress through foliar means resulted in the successful rescue of the plants. Additionally, this application had a notable and positive impact on the growth and yield of the tomato plants.

Chilli: In the case of the chilli (*Capsicum annuum* L.) Auxins were used as a foliar spray at two-time points, specifically 40 and 60 days following the planting of the seedlings. Pant C-1 had the highest measurements in terms of plant height, root and shoot diameter, number of fruits per plant, and total yield of red-ripened fruits per hectare. The application of auxins resulted in enhancements in various plant attributes, with the exception of shoot diameter. The application of 2,4-D at a concentration of 1 ppm and NAA at a concentration of 40 ppm led to the most significant enhancements in plant height, shoot and root growth. Moreover, the use of NAA at 40 ppm demonstrated the highest augmentation in leaf area, percentage of fruit set, overall fruit production, as well as the number and weight of seeds per fruit [14]. Topno., [15] concluded that the use of foliar NAA at a concentration of 50 ppm has demonstrated superior results in terms of growth and yield indices while also proving to be economically feasible for the cultivation of chilli plants. Singh and Mukherjee [16] have documented that the utilisation of naphthalene acetic acid at a concentration of 75 ppm has been found to enhance the harvest of chilli crops.

Radish: The study conducted by Frankenberger et al*.* [17] shown that the treatment of L-tryptophan at rates of 20.4 and 204 mg m^{-2} resulted in a considerable increase in radish production in plots that received fertilization. The shoot dry weight exhibited a 1.29 fold increase, while the root dry weight showed a 1.15-fold increase compared to the control, in response to an application of 20.4 mg L-TRP m^{-2}. The results of this study suggest that the application of L-tryptophan, when administered at optimal timings and concentrations, has the potential to enhance the yield of radishes.

Beetroot: Saftner and Wyse [18] reported that indole acetic acid (IAA) and other auxins strongly inhibited active sucrose uptake in beetroots. Abts et al*.,* [19] showed that the use of exogenous auxin, namely indole-3-acetic acid (IAA), has been observed to induce root elongation and enhance the production of ethylene, hence resulting in increased root length. Additionally, it was discovered that the application of auxin induces the synthesis of ethylene by altering the distribution of 1-aminocyclopropane-1-carboxylic acid (ACC), favouring its conversion to ethylene rather than malonyl-ACC (MACC). This shift leads to an extended duration of elevated ethylene production, ultimately resulting in the elongation of the root in beetroot root.

Onion: Benkeblia, N., [20] stated that in dormant bulbs, the strongest induction of sprouting was observed with auxin treatment (0.1 mg NAA per bulb, sprouting after 12 weeks). Hye et al., [21] observed that the use of indole acetic acid in conjunction with gibberellic acid has been found to enhance the proliferation of roots, elongation of roots, rise in root weight, enlargement of bulb diameter, and augmentation of bulb weight. The bulb weight and diameter exhibit their maximum values when subjected to an application of 200 parts per million (ppm) for both variables.

Brinjal: Singh et al., [22] reported that the application of NAA at a concentration of 40 ppm resulted in the highest recorded values for various growth and yield parameters in brinjal plants. These parameters include plant height, number of branches, number of leaves, days to 50% flowering, fruit length, fruit girth, average weight of fruit, number of fruits per plant, fruit yield per plant, and yield per hectare. Based on these findings, it can be concluded that the application of 40 ppm of NAA is recommended for promoting optimal growth and yield in brinjal plants. Basnet et al., [23] conducted an experiment and the results revealed that the experimental treatment involving the application of 80 ppm of NAA resulted in the highest fruit output and exhibited superior plant height, fruit length, number of fruit per plant, and time taken for first flowering. The treatment with 80 ppm NAA exhibited the highest recorded values for maximum plant height, plant spreading, number of leaves, and highest number of primary branches per plant. The treatment that involved the application of 80 ppm NAA exhibited the highest fruit length, average fruit weight per plant, and maximum fruit diameter. Therefore, it is recommended that an optimal concentration of 80 ppm of NAA be used for the cultivation of brinjal.

3. GIBBERELLINS

Gibberellins were found in Japan in the early twentieth century as the causal factor for overgrowth symptoms in rice plants suffering from 'balance' (foolish seedling) disease. The illness was found to be caused by the phytopathogenic fungus Gibberella fujikuroi (now known as Fusarium fujikuroi), from which an active principle was isolated that replicated the balance symptoms when applied to rice plants. Teijiro Yabuta coined the word 'gibberellin' for this active compound in 1935, from which two crystalline solids, gibberellin A and gibberellin B, were subsequently evolved [24,25]. Gibberellic acids (GAs) have influence on various physiological processes in plants, including stem elongation, germination, dormancy release, flowering, sexual differentiation, reactions to floods, activation of enzymes, as well as leaf and fruit senescence. The use of GA3 through foliar treatment has been observed to induce changes in physiological and developmental processes in many vegetable crops. These changes encompass alterations in plant vegetative growth, sex expression, yield, and yield components. The primary objective of this research is to investigate the impact of growth regulators, known as GAs, on several dimensions of agricultural production, specifically emphasising vegetable crops [26].

Structure: Gibberellin molecules of various sorts are synthesized in several regions of the plant. There are currently approximately 100 distinct gibberellin molecules. These chemicals are produced in numerous plant cells but are most concentrated in the roots. This contrasts with auxin, which tends to concentrate at the apex.

Gibberellin is a diterpenoid, which is a well-known and widely used chemical in biochemistry. It is the building block for compounds such as vitamin A and vitamin E. Gibberellin A1, the first identified gibberellin, is shown below.

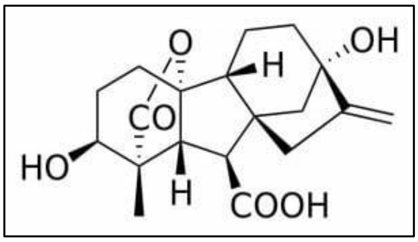

Fig. 2. Structure of gibberellin GA_1

Other gibberellins share the same fundamental structure but have different side groups. These groups influence where and how gibberellin operates, which explains why gibberellin may perform so many diverse and distinct activities in various tissues (Biologydictionary.net, 2018).

3.1 Effect of the Gibberellins on Different Vegetable Crops

Tomato: Chen et al*.,* [27] found that gibberellic acid has the ability to prolong the ripening process by modulating the expression levels of genes associated with ethylene production. In contrast, the administration of PAC resulted in a drop in fruit form index and a reduction in fruit ripening time. The findings of this study indicate that the modulation of gibberellic acid concentrations can have a dual impact on both the morphology and maturation process of tomato fruits. Shohat et al*.,* [28] present the potential of using the GA pathway to generate drought-tolerant tomato plants with improved performance under both irrigation and water-limited conditions. Jayasinghe et al., [29] reported that the application of a 20 µM GA3 solution through the foliar method was conducted at regular intervals of 6 days. The growth of plants was observed to be diminished when exposed to NaCl-induced stress. The administration of GA3 via foliar spraying on plants subjected to salt stress resulted in enhanced vegetative development. When comparing plants treated with NaCl and water spray to plants treated with NaCl and GA3 spray, the latter exhibited a 24.0% rise in the number of branches, a 19.7% increase in internode number, an 18.8% increase in internode lengths, as well as an increase in fresh and dry weights of both shoot and root. In comparison to plants treated alone with NaCl, tomato plants treated with GA3, in addition to NaCl, exhibited a 4.4% rise in leaf relative water content, a 19.2% increase in stomatal density, and a 38.6% increase in total chlorophyll content. Li et al., [30] found that the administration of exogenous bioactive gibberellic acid (GA1 and GA4) and paclobutrazol (PAC) was found to have distinct effects on the locule number. Specifically, GA1 and GA4 were observed to increase the locule number, but PAC resulted in a decrease in locule number. The findings indicate that a decrease in overnight temperature resulted in a decrease in the expression of SlGA2ox genes. This decrease in gene expression led to an increase in the accumulation of GA1 and GA4 hormones in tomato plants. Consequently, the increased hormone levels contributed to an increase in the number of locules in the tomato fruit.

Brinjal: In their study, Sahu and Chaudhary [31] observed that the highest fruit production per plant (3.09 kg) was achieved in the treatment including the administration of GA3 at a concentration of 75 ppm. Furthermore, they found that the application of GA3 at 75 ppm was highly beneficial in promoting both vegetative growth and yield characteristics in brinjal. According to a study conducted by Kumar and Bhatnagar in [32], it was found that the Arka Keshav variety of brinjal exhibited the highest germination percentage (88.90%) when subjected to treatment with a concentration of 800 mg/l of gibberellic acid.

Okra: In a study conducted by Aminu et al*.* [33], it was found that the application of gibberellic acid to grafted okra plants resulted in a notable disparity in survival rates. Additionally, this treatment exhibited a positive and statistically significant impact on the quantity of fruits produced, as well as the weight of these fruits. As a result, the researchers concluded that the utilisation of gibberellins in conjunction with grafting techniques enhances key qualitative characteristics of the okra plant.

Coriander: Yugandhar et al*.,* [34] reported that the spraying of GA3 75 ppm resulted in highest plant height might be due to effect on increased cell elongation and rapid cell division in the growing portion leading to increased length of internodes also germination percentage and took least number of days to 50 per cent flowering and maturity. Chudamani et al*.,* [35] revealed that the application of GA3 100 ppm along with Trichoderma viride 2 ml per liter of water was found best for cultivation of coriander with higher green foliage yield and economic return.

Chilli: Singh and Singh et al., [36] observed in the application of GA_3 @ 150 PPM found significantly superior over other treatments in terms of plant height at 30 DAT, 60 DAT and at harvest, No of branches/plant at 30 day after transplanting and at harvest, fruit length, fresh weight of 10 fruits of chilli, number of fruits/plant, fruit yield/plant, fruit yield/ha and vitamin C content in the chilli. Naga et al., [37] show that the use of GA3 at a concentration of 10 ppm resulted in improved outcomes in terms of vegetative development, including plant height, number of branches per plant, and leaf area. This study aims to investigate the yield parameters, including the minimum days required for 50 per cent blooming, the minimum days to first harvest, the length and girth of the fruit, the weight of the fruit, the number of chilli fruits per plant, the average fruit yield per plant, and the fruit yield per hectare. Additionally, the quality parameter of total soluble solids in chilli will also be examined.

Cucurbits: The study conducted by Khan and Chaudhry in [38]. It was reported that the utilisation of GA3 at a concentration of 400 ppm resulted in early flowering, leading to an increase in the quantity of pistillate and staminate flowers in *Cucumis sativus* L. and *Momordica charantia* L. Rahman et al*.* [39] demonstrated that the application of GA3 through foliar spraying exhibited significant superiority compared to the control group in terms of various growth, flowering, and fruiting characteristics of cucumber. The administration of GA3 through foliar method resulted in the highest fruit yield of 24.58 t ha^{-1} in the Sufala-1 variety, while the lowest fruit yield of 19.73 t ha^{-1} was seen in the Sarothi variety. The remaining two varieties, Shila and Shohag, had a moderate fruit output, with recorded values of 23.95 and 20.50 t ha^{-1}, respectively. Mandal et al*.,* [9], reported that application of GA3 will cause the underdeveloped fruit and having the fruit bearing percentage of 34.33% in cucumber genotype IMPU-1.

4. CONCLUSION

The aforementioned analysis provides evidence that plant growth regulators (PGRs), specifically auxins and gibberellins, possess the ability to significantly augment multiple facets of plant productivity. These objectives encompass enhancing crop productivity, optimizing product attributes, manipulating reproductive traits, facilitating fruit development, and augmenting resistance against both living organism-related and environmental challenges. The aforementioned improvements play a critical role in addressing the increasing requirements of food production and diverse breeding initiatives.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Pallabi N, Dhanalakshmi TN, Rudramuni T, Priyadarshini SK. Glimpses about role hormones in plants. Innov. Farm. 2016; 1(2):59-61.
2. Kaur P, Mal D, Sheokand A, Singh L, Datta D. Role of plant growth regulators in vegetable production: A review. Int. J. Curr. Microbiol. Appl. Sci. 2018;7(6):2177-2183.
3. Prajapati S, Jamkar T, Singh OP, Raypuriya N, Mandloi R, Jain PK. Plant growth regulators in vegetable production: An overview. Plant Arch. 2015;15(2):619-626.
4. Zhang X, Zhao B, Sun Y, Feng Y. Effects of gibberellins on important agronomic traits of horticultural plants. Front. Plant Sci. 2022;13:978223.
5. Thakur O. Recent advances of plant growth regulators in vegetable production: A review. Pharma Innov. J. 2022;11(3): 1726-1731.
6. Toungos MD. Plant growth substances in crop production: A Review. IJIABR. 2018; 6:1-8.
7. Sharif R, Su L, Chen X, Qi X. Involvement of auxin in growth and stress response of cucumber. Veg. Res. 2022;2(1):1-9.
8. Dahal K, Dahal KC. Response of cucumber (*Cucumis sativus* L. Cv. Bhaktapur local) to the application of plant growth regulators in a plastic tunnel. J. Agric. For. Univ. 2022;81-88.
9. Mandal NK, Kumari K, Kundu A, Arora A, Bhowmick PK, Iquebal MA, Dey SS. Cross-talk between the cytokinin, auxin, and gibberellin regulatory networks in determining parthenocarpy in cucumber. Front. Genet. 2022;13:957360.
10. Acharya SK, Thakar C, Brahmbhatt JH, Joshi N. Effect of plant growth regulators

on cucurbits: A review. J. Pharmacogn. Phytochem. 2020;9(4):540-544.

11. Vendrell M. Dual effect of 2, 4-D on ethylene production and ripening of tomato fruit tissue. Physiol. Plant. 1985;64(4):559-563.
12. Ramin AA. Effects of auxin application on fruit formation in tomato growing under stress temperatures in the field. J. Hort. Sci. Biotechnol. 2003;78(5):706-710.
13. Alam M, Khan MA, Imtiaz M, Khan MA, Naeem M, Shah SA, Khan L. Indole-3-acetic acid rescues plant growth and yield of salinity-stressed tomato (*Lycopersicon esculentum* L.). Gesunde Pflanzen. 2020;72(1):87-95.
14. Singh DK, Gulshan L, Singh RP. Effect of synthetic auxins on the performance of chilli (*Capsicum annuum* L.) cultivars under Tarai conditions of UP during winter season. Prog. Hortic. 1990;22(1-4):191-197.
15. Topno RKSSE. Effect of different plant growth regulators on growth and yield of chilli (*Capsicum annum*); 2022.
16. Singh L, Mukherjee S. Effect of foliar application of urea and NAA on yield and yield attributes of chilli (*Capsicum annuum* var: longum). Agric. Sci. Dig. 2000;20(2): 116-17.
17. Frankenberger WT, Chang AC, Arshad M. Response of Raphanus sativus to the auxin precursor, L-tryptophan, applied to soil. Plant Soil. 1990;129:235-241.
18. Saftner RA, Wyse RE. Effect of plant hormones on sucrose uptake by sugar beet root tissue discs. Plant Physiol. 1984;74(4):951-955.
19. Abts W, Vandenbussche B, De Proft MP, Van de Poel B. The role of auxin-ethylene crosstalk in orchestrating primary root elongation in sugar beet. Front. Plant Sci. 2017;8:444.
20. Benkeblia N. Effect of exogenous ethylene (ethephon), auxin, cytokinin and gibberellin on the sprouting of dormant and non-dormant onion bulbs (*Allium cepa* L.). Sultan Qaboos Univ. Res. J. Agric. Mar. Sci. 2006;11(1):1-61.
21. Hye MA, Haque MS, Karim A. Influence of growth regulators and their time of application on yield of onion. Pak. J. Biol. Sci. 2002;5(10):1021-1023.
22. Singh S, Saxena AK, Chand V. Influence of plant growth regulators (GA3) and (NAA) on growth and yield attributes of brinjal (*Solanum melongena* L.). Int. Res. J. Modern. Eng. Technol. Sci. 2021;03(5): 2582-5208.
23. Basnet S, Yadav A, Singh GK, Shekhar C. Effect of 1-naphthalene acetic acid (NAA) on growth and yield of brinjal (*Solanum melongena* L.) Cv Pusa purple cluster Kanpur, India; 2021.
24. Colebrook EH, Thomas SG, Phillips AL, Hedden P. The role of gibberellin signalling in plant responses to abiotic stress. J. Exp. Biol. 2014;217(1):67-75.
25. White CN, Proebsting WM, Hedden P, Rivin CJ. Gibberellins and seed development in maize. I. Evidence that GA/ABA balance governs germination versus maturation pathways. Plant Physiol. 2000;122(4):1081-1088.
26. Bagale P, Pandey S, Regmi P, Bhusal S. Role of plant growth regulator Gibberellins in vegetable production: An overview. Int. J. Hortic. Sci. Technol. 2022;9(3):291-299.
27. Chen S, Wang XJ, Tan GF, Zhou WQ, Wang GL. Gibberellin and the plant growth retardant Paclobutrazol altered fruit shape and ripening in tomato. Protoplasma. 2020; 257:853-861.
28. Shohat H, Eliaz NI, Weiss D. Gibberellin in tomato: Metabolism, signalling and role in drought responses. Mol. Hort. 2021;1(1):1-12.
29. Jayasinghe T, Perera P, Wimalasekera R. Effect of Foliar application of Gibberellin in mitigating salt stress in tomato (*Solanum lycopersicum*, Thilina Variety). In Proceedings of the 6th Int. Conf. Multidisciplinary Approaches (CMA); 2019.
30. Li Y, Sun M, Xiang H, Liu Y, Li H, Qi M, Li T. Low overnight temperature-induced gibberellin accumulation increases locule number in tomato. Int. J. Mol. Sci. 2019; 20(12):3042.
31. Sahu NK, Choudhary AS. Effect of plant growth regulators on growth and yield attributes of brinjal (*Solanum melongena* L.). Pharma Innov. J. 2022;11(12):347-349.
32. Kumar A, Bhatnagar V. The Effect of Plant growth regulators (PGRs) on the germination percentage in Brinjal (*Solanum melongena* L.). J. Rural Agric. Res. 2019;19(2):26-27.
33. Aminu Y, Maryam MG, Kabiru SA. Hormonal response of gibberellin (GA3), grafting and seasonal variations on growth and yield parameters on okra

(*Abelmoschus esculentus*). Am. Int. J. Biol. Life Sci. 2019;1(2):33-39.
34. Yugandhar V, Reddy PSS, Sivaram GT, Ramesh E. Impact of pre-soaking and foliar application of plant growth regulators on growth and seed yield of coriander (*Coriandrum sativum* L.). J. Crop Weed. 2017;13(1):100-102.
35. Chudamani JS, Kumari V, Singh R, Patel M. Effect of seed treatment with organic and inorganic substances on economics of coriander (*Coriandrum sativum* L.). Pharm. Innov. J. 2023;12(5):589-592
36. Singh S, Singh T. Effect of gibberellic acid on growth, yield and quality parameters of chilli (*Capsicum annum* L.). J. Pharmacognosy Phytochem. 2019;8(2): 2021-2023.
37. Naga BL, Deepanshu DS, Bahadur V. Effect of plant growth regulators on growth, yield and quality of chilli (*Capsicum annum* L.); 2022.
38. Khan AS, Chaudhry NY. GA3 improves flower yield in some cucurbits treated with lead and mercury. Afr. J. Biotechnol. 2006;5(2):149-153.
39. Rahman MA, Sikder S, Bahadur MM, Pramanik SK. Influence of gibberellic acid (GA3) on growth, flowering, and fruit yield of cucumber. J. Sci. Technol. 2020;33:42.

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