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An Overview: Role of plant growth regulator in vegetable production

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ABSTRACT

Plant growth regulators may be defined as any organic compounds, which are active at low concentrations in promoting, inhibiting or modifying growth and development. The naturally occurring (endogenous) growth substances are commonly known as plant hormones, while the synthetic ones are called growth regulator. Plant growth regulators (PGRs) are chemicals used to modify plant growth such as increasing branching, suppressing shoot growth, increasing return bloom, removing excess fruit, or altering fruit maturity. To maximize productivity and food safety plant growth regulators are one of the inputs that have enabled Indian agriculture become more mechanized and scientifically oriented. Plant growth regulators have a quicker effect on the vegetative development and production of the crops. As it have many benefits, like being environmentally friendly and taking less time to treat the plant. Crops grown for vegetables are abundant in vitamins and minerals. When used in vegetable production, growth regulators must have a precise activity and be both toxicologically and environmentally safe. Vegetable crops' physiological activity is regulated, and once growth regulators are applied, the yield of vegetables is ultimately increased.

Keywords: Plant growth regulators, Vegetable crops

INTRODUCTION

Plant hormones are also referred to as phytohormones. These hormones, which are tiny chemicals derived from various vital metabolic pathways, help to regulate plant growth. Thimann in 1948, coined the term “Phytohormone” as organic substance that are produce naturally in plants. These phytohormones have also been termed as growth hormones, growth promoting substances, growth substances, growth factors, growth regulators etc., by various workers and are defined accordingly. The auxins were the first hormones to be discovered in plants and at one time considered to be the only naturally occurring plant growth hormones. Since then besides other less important hormones, two important groups of chemical substances having profound influence on the regulation of growth and development in plants have been discovered which are also considered as natural plant growth hormones. They are gibberellins and cytokinins. Beside these, ethylene and absicisic acid (ABA) and more recently brassinosteroids have also acquired status of natural plant growth hormones. According to Pincus and Thaiman (1948) a plant hormone is defined as organic substance produced naturally in higher plants, controlling growth or other physiological functions at a site remote from its place of production and active in minute amounts. Till date five major classes of plant hormones have been discovered namely, Auxins, Gibberellins, Cytokinins, Abscisic acid and ethylene. It is possible that many other growth regulators, present in plants may be classified as plant hormone in future. Not all plant hormones fit the definition of hormones which is a chemical synthesized in one part of an organism that stimulates or inhibits a specific response in a target tissue elsewhere in the organism. The five group of natural hormones- auxin, gebberellins, cytokinins, ethylene and abscisic acid fit the classical definition of hormones. Synthetic chemicals used as hormones are referred to as plant growth regulators. Plant growth regulators are widely using in the agricultural sector for different purposes from seed germination to final yield. PGRs improved the germination of vegetable seeds, increased total yield, protected the plant from pests and sometimes also used to avoid the loss of yield due to unfavorable condition. In addition to these PGRs were extensively used for the quick plant growing purpose through seed soaking. PGRs have an excellent effect on the sex expression and flowering in different vegetables.

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Class of Plant Growth Regulators

Auxin	IAA, NAA, IBA, 2,4-D, 4-CPA
Gibberellins	GA3
Cytokinins	Kinetin, Zeatin
Ethylene	Ethereal
Abscissic acid	Dormins, Phaseic acid
Growth inhibitors	AMO-1618, Phosphon-D, Cycocel, B-999
Phenolic substances	Coumarin
Flowering hormones	Florigin, Anthesin, Vernalin

Auxin

Charles Darwin was the first who proposed the existence of auxin in 1880. Went (1926) was successful in isolating this growth substance from avena coleoptile tips which still retained the growth promoting activity. He cut off the tips of the avena coleoptiles and placed them on small agarblocks for certain period of time and then placed the agar-blocks asymmetrically on cut coleoptile stumps. All the coleoptiles showed typical curvature even in dark. It was the first class growth regulator that was discovered. Auxins are those compounds that give positive effect on formation of bud, enlargement of cell and root initiation and they are also helpful for the formation of other growth hormones. IAA is natural occurring hormone while NAA, IBA, 2-4D etc. are synthetic in nature. The auxin may increase the rate of respiration indirectly through increased supply of ADP (Adenosine diphosphate) by rapidly utilizing the ATP in the expanding cells. Auxin is widely distributed in plant but relative concentrations differ in different parts of the plant. Since auxin is synthesized in growing tips or meristematic regions of the plant from where it is transported to other plant parts, the highest concentrations of the auxin are found in these parts such as growing shoot and root tips, young leaves and developing axillary shoots.

Biosynthesis: The auxin precursor in plants is tryptophan or substances derived from its degradation. It is formed by following three steps involving three enzymes: transaminase, which catalyzes the conversion of tryptophan into tryptamine, decarboxylase-from tryptamine to indole pyruvic acid, which transforms into β-indole acetaldehyde and aldehyde dehydrogenase, which catalyzes the formation of β-indole acetic acid. All the parts of the plant body produce auxin. However, the major sites of auxin production are the shoot tips, developing seeds and buds.

Synthetic Auxins: There are a number of synthetic chemicals which are similar to IAA in their biological activity. However, they do not occur in any plant. The important synthetic auxins are IBA (Indole Buteric Acid), NAA (α and β-Naphthalene Acetic Acid), 2, 4-D (2, 4-dichlorophenoxyacetic acid), 2, 4, 5-T (2, 4, 5-trichlorophenoxyacetic acid), IPA (Indole Propionic Acid), naphthoxyacetic acid etc.

Physiological Effects Of Auxin: Auxins have been used variously and some of the aspects are as follows: (i) it causes cell elongation by loosening of the cell wall, (ii) promotes secondary growth of stem through cambium activity, (iii) promotes callus and root formation in cutting, (iv) restores apical dominance, (v) induction of flowering, (vi) increases fruit setting and size, (vii) delays leaf abscission, (viii) prevention of premature drop of fruits, (ix) develops parthenocarpic fruits, (xi) acts as herbicide at higher concentration, (xii) inhibition of prolonged dormancy, and (xiii) inhibiting aging processes in tissues.

Gibberellic acid

Kurosava was the Japanese scientist who discovered gibberellins in 1926. It is the second growth regulator. It was extracted from the fungus *Gibberella fujikuroi* which is the causal organism of “foolish seedling of rice”. In 1935, Yabuta isolated the active substance which was quite heat stable and gave it the name gibberellin. Gibberellins are found in all parts of higher including shoots, roots, leaves, flower, petals, anthers and seeds. Gibberellins activity has also been shown in plastids. In general, reproductive parts contain much higher concentrations of gibberellins than the vegetative parts. In growing embryos after fertilization, cell division takes place vigorously, aided by auxin followed by cell expansion. Gibberellins are responsible for cell wall loosening and cell enlargement. These enlarged cells import assimilates from the source for storage in the reproductive organs. Hence, gibberellins play major role in increasing yields of seeds and fruits. Immature seeds are especially rich in gibberellins (10-100 mg per g fresh weight) and are most favorite plant parts for isolation of gibberellins.

Biosynthesis: Gibberellin predecessor is kaurene. In the chemical structure of both of them there is a common backbone-gibban, to which certain side groups are attached that determines their specificity. Thus each plant species has its own set of gibberellins. Gibberellins are synthesized in the young leaves (major site), shoot tip, root tip and immature seeds (embryo).

Physiological Effects of Gibberellins: GA finds application in a variety of ways, some of them are discussed here: (i) it induces maleness, (ii) promotes growth of dwarf plants, (iii) possesses pollenicide effect, (iv) replaces chilling and light requirements of plants, (v) promotes seed germination, (vi) used for breaking of dormancy, (vii) delays senescence of fruits, (viii) enhances seedless fruits, (ix) for stem elongation, (x) accelerates flowering in long day plants, and (xi) intensifies transpiration, photosynthesis and respiration.

Cytokinins

Skoog in 1995 experimented that when pith tissues of *Nicotiana tabaccum* were separated from the vascular tissues they grew without division of cell. There are so many different synthetic cytokinins such as 6-benzylamino purine (BAP), kinetin, 6-(benzyl-amino)-9-(2-tetrahydropyranyl)-9H-purine (PBA), 1,3-diphenylurea, thidiazuron (TDZ), etc. Zeatin is the most abundant and widely distributed natural cytokinin in higher plants and in some bacteria.

Biosynthesis: Zeatin is synthesized from mevalonic acid and adenine. Usually Zeatin is the most abundant naturally occurring free cytokinin. It was found that cytokinins are the result of degradation of nucleic acids and therefore, could serve as an indicator of the rate of DNA replication. In plants cytokinins exist in free and bound form. Bound cytokinins are synthesized in the cytoplasm and chloroplasts. It is assumed that they may be synthesized also in mitochondria based on their own DNA. This confirms the endosymbiotic theory organelle genesis. Root tip is an important site of cytokinin synthesis. However, developing seeds and cambial tissues are also the site of its biosynthesis.

Synthetic Cytokinins: Several substances have been found showing cytokinins like activities. The common examples are 6-aminopurine (adenine), benzimadazole, 6-benzyladenine, 1-benzyladenine etc.

Physiological Effects of Cytokinins: Some important roles of cytokinins are as follows: (i) it promotes seed germination and radical growth by breaking dormancy, (ii) it helps in cotyledon expansion in immature seedling of dicots, (iii) it stimulates chlorophyll synthesis, (iv) it induces cell division and shoots development, (v) it delayed senescence of leaves, (vi) nucleic acid metabolism, (vii) protein synthesis, and (viii) it incorporation in RNA.

Ethylene

This hormone is a gaseous plant hormone which is synthesized from methionine and it is synthesized in all organs of plant. Neljubow in 1901 identified ethylene in laboratory air from illuminating coal gas which caused typical symptoms in etiolated pea seedlings grown in dark in the lab, viz., (i) inhibition of stem elongation, (ii) stimulation of radial swelling of stems and (iii) horizontal growth of stems with respect to gravity. These symptoms were later termed as ‘triple response’ and were not observed in etiolated pea seedlings grown in normal air free from coal gas. One of the most pronounced effects of ethylene is in ripening of fruits and therefore, ethylene is also known as fruit ripening hormone.

Biosynthesis: In higher plants, all most the parts of the plant body produce ethylene. In general, meristematic region and nodal regions are most active in ethylene biosynthesis. However, ethylene production also increases during leaf abscission and flower senescence, as well as during fruit ripening. This is otherwise called as phytogerontological hormone. Very little is known about its synthesis inside the plants but it appears that methionine (an amino acid) may be an immediate precursor of ethylene. ACC (aminocyclopropane carboxylic acid) is the penultimate precursor of ethylene.

Synthetic Ethylene: Ethepon, ethrel, cepha etc.

Physiological Effects of Ethylene: Following are some important roles: (i) ethylene acts as fungistasis, (ii) it hastens abscission of plants, (iii) it encourages root formation, (iv) it acts as fruit ripening hormone, (v) it enhances seed germination, (vi) it induces production of female flowers, (vii) it induces male sterility, and (viii) it inhibits vegetative growth and triggers reproductive growth.

Abscisic Acid

In 1963, a substance strongly antagonistic to growth was isolated by Addicott from young cotton fruits and named Abscisin II. Later on, this name was changed to Abscisic acid (ABA). It is also called plant stress hormone. It acts as inhibitory chemical compound that gives direct effect on growth of bud, seed and dormancy of bud. It has inhibitory effect and occurs naturally in plants. It inhibits mRNA and synthesis of protein. ABA is known to produce abscission layers at the base of the leaf petiole where dead cells are formed. ABA production increases in senescing leaves once the photosynthetic activity of the leaves decreases below the compensation point.

Biosynthesis: Is synthesized in mature leaves and fruits. ABA biosynthesis occurs via two pathways.
• from mevalonic acid → isopentenyl pyrophosphate → heranylpirophosphate;
• by carotenoid and violaxanthine decomposition → xanthoxin → abscisic acid.
It was found that induction of ABA synthesis occurs during genome reprogramming and synthesis of increased amounts of ABA-inducing polypeptides, of which lectins are more significant.

Physiological Effects of ABA: Some important roles of ABA are as follows: (i) it cause stomatal closure in response to water stress, (ii) it inhibits cell wall loosening, (iii) it inhibits viviparous germination of the developing embryo, (iv) it enhances tuberization, (v) it accelerated senescence of leaves and fruits, (vi) accumulates sucrose in seeds, sweet fruits, reserve tissues of the roots, and (vii) has anti-gibberellin, anti-auxin, anti-quinine action.

Growth Inhibitors

These are substances which suppress the growth of plants.

• **Phenolic Inhibitors:** Benzoic acid, salicylic acid, cinnamic acid, caffeic acid, ferulic acid, coumarin, juglone, scopoletin, naringenin, cholugenic acid.
• **Synthetic Inhibitors:** Maleic hydrazide, TIBA.

Functions: Following are some important roles: (i) it accelerates degreening, (ii) it induces abscission, (iii) it suppresses the vegetative growth and induce flowering, (iv) it induces sterility, and (v) it increases diseases resistance, salt tolerance and resistance to low temperature.

Growth Retardants

These are diverse groups of chemical having common physiological effect of reducing stem growth by inhibiting cell division of the sub-apical meristem. The formation of leaves, flowers and fruits remain unaffected. Growth retardation is primarily induced by inhibition of gibberellin biosynthesis between ent-kaurene and ent-kaurenoic acid. The important growth retardants are uniconazole, paclobutrazole (P333, Cultar), triapenthenol, flurpirimidol, inabefide, AMO-1618, CCC, Phosphon-D, C-111, B9, B2, 4-DNC.

Functions: Following are some important roles: (i) it retards stem elongation, (ii) it prevents cell division, (iii) it accelerates flower initiation, (iv) it inhibits root development, (v) it increases IAA oxidase activity, (vi) it inhibits staminate flower production, (vii) it block the synthesis of gibberellins, and (viii) it increases resistance to salt tolerance, drought resistance and pest resistance.

Other Plant Growth Regulators

Brassinolides (Syn. Brassinosteroids or Terpenoids)

Brassinolides are a plant steroid discovered in pollen of member of the mustard family. The have been studied in Arabadopsis. Brassinolides represent a new sixth class of plant hormones with wide occurrences in the plant kingdom in addition to auxins, gibberellins, cytokinins, abscisic acid and ethylene. The substances from various pollen sources named 'brassins' a steroidal lactone, termed brssinolide, was first time isolated from pollen of *Brassica napus* by Grove and his associates in 1979. The first brassinosteroids-biosynthesis inhibitor named brassinazole, was first time reported by

List of plant growth regulator sand their important uses in vegetable crops

Growth Regulators	Conc. (mg/l)	Method of application	Crops	Attributes affected
Indole-3-Aceticacid(IAA)	10-15	Foliar spray	Okra, tomato, brinjal	Seed germination, fruit set and yield
Naphthalene acetic acid (NAA)	0.2 10-20 25-30	Seedling roots Foliar sprays Seed/ foliar	Tomato, brinjal, onion Chillies and tomato okra, Tomato, brinjal, onion, cucurbits	Growth and yield Flower drop, fruit set and yield Seed germination, growth and yield
Naphthoxy-Acetic acid (NOA)	25-100	Seed/ foliar	Tomato, okra	Germination, growth and yield
Para – Chloro Phenoxy Acetic acid (PCPA)	50	Foliar spray	Tomato	Fruit set and Yield
Gibberellic acid (GA)	10	Foliar spray	Water melon, tomato	Sex expression, fruiting, yield
Ethephon (CEPA)	100-500	Foliar spray	Cucurbits, okra and tomato	Flowering, fruiting, sex expression and yield
	2000	Post- harvest	Tomato, chillies	Fruit ripening
Silver nitrate	500	Foliar spray	Cucumber	Induction of male flower in gyn.Lines
Silver thiosulphate	400	-	Musk melon	Induction of male flower in gynoecious lines
Cycocel (CCC)	250-500	Foliar spray	Cucurbits, tomato, okra	Flowering, sex expression, fruit yield
2,3-5, tri-iodobenzoic acid (TIBA)	25-50	Foliar spray	Cucurbits	Flowering, sex expression and yield
Tricontanol	2	Foliar spray	Chilli and peas	Fruit set and yield

Asami and Yoshida (1999). Generally, pollen and immature seeds are rich source of brassinolide (with ranges of 1-100 ng g-1 fresh weight), while the concentrations in vegetative tissues are very low compared to those of other plant hormones. The functions of brassinosteroids analogous to that caused nyauxins and gibberellins such as stem elongation and plant morphogenesis. Therefore, it is difficult to study the brassinolides because their effects overlap those of auxins and gibberellins. Brassinosteroids activate signal transduction pathway that promote cell elongation and cell division. Brassinosteroids control a broad range of responses in plant, including seed germination, stem and root elongation, vascular differentiation, leaf expansion and apical dominance. Interestingly, each of these responses is also controlled by auxins, suggesting there might be considerable interplay between these two hormones in the control of development. In addition to their role in plant development, brassinosteroids have the ability to protect plants from various environmental stresses, including drought, extreme temperatures, heavy metals, herbicidal injury and salinity.

Jasmonates (Jasmonic Acid)

Jasmonates are a group of fatty acid derivatives. They appear to have a role in seed germination, root growth and the storage of protein (especially in seeds). In 1990, airborne jasmonic acid methyl ester (JAME) was shown to induce proteinase inhibitors in tomato, thereby attributing to an ‘immunization’ against herbivore attack. Jasmonic acid and JAME are lipid-derived signals. Jasmonic acid and its related compounds are short-chain alkylcyclopentanone or alkylcyclopentane carboxylic acids and their derivatives. It is recognized as a new type of plant growth regulator. It widely occurs in the plant kingdom together with abscisic acid like physiological activities at low concentrations.

Application of Plant Growth Regulators in Different Vegetable Crops

Tomato

The function of plant growth regulators is advantageous for tomato growth parameters. The tomato plants were exposed to various soil concentrations of NAA at 25, 50, 75, and 100 ppm and GA_3 at 20, 40, 60, and 80 ppm. It was reported that the use of NAA at 100 ppm and GA_3 at 80 ppm resulted in maximum plant heights of 85.3 cm and 82.3 cm, respectively, and increased yields of 483.6 q/ha and 472.2 q/ha (Prasad *et al.*, 2013). The highest plant height, number of leaves, number of branches per plant, number of fruits, number of flowers, number of clusters of fruit, diameter of fruit, yield per plant (kg), yield per plot (kg), and yield per hectare (tonnes) were all obtained with GA_3 at 125 ppm (Akand *et al.*, 2015). In BARI Hybrid Tomato-8, 4-CPA (4- Chlorophenoxy acetic acid) + GA_3 was applied together after 75 days of transplanting, and it was observed that the tallest plant (79.35 cm), the number of flowers (38.11) and fruits (19.04) per plant, height (87.90 cm), the number of flowers (49.04) and fruits (21.9) per plant, the individual fruit weight (61.16 g), and the fruit yield (27.28 tone/ha) (Rahman *et al.,* 2015). After 45 days of transplanting tomato seedlings, CCC (Cycocel) @ 500 ppm application increased plant height, number of fruits per plant, fruit diameter, and per plant seed yield compared to NAA @ 50 ppm and GA_3 @ 50 ppm (Chauhan *et al.,* 2017). plant height (63.0 cm), branches/plant (7.1) were highest with spraying of 75 mg/l GA. Boron spraying (0.3%) also improved these parameters over no boron spraying. The biochemical parameters, i.e. chlorophyll 'a' and 'b', total phinol, carotene and reducing and non-reducing sugars were also improved with sprayings of GA over control. The contents of N, P and K in tomato plants were higher under 75 mg/l solution of GA (Yadav *et al.*, 2019).

Chilli

The higher dose 60 ppm NAA resulted in increasing maximum plant height (67.82 cm), number of leaves (185.10), number of branches (25.42) and it also increased the, yield attributing characters such as fruit length (12.44 cm), fruit girth (1.15 cm), number of fruits per plant (140.77), number of seeds per plant (49.24), seed weight per fruits (0.81 g), chlorophyll content (2.56 mg/ 100g), capsicum content (0.18%), ascorbic acid content (121.54 mg/ 100g) and fruit yield per hectare (13.34 t) followed by 40 ppm NAA. There was an increase of 35 per cent in fruit yield with application of NAA 60 ppm respectively as compared to control. The minimum values of these characters were recorded under control (Anbarasi *et al.*, 2022).

Cauliflower

Sitapara *et al.*, (2011) studied the effectiveness of GA_3 and NAA on the "SNOWBALL- 16" type of cauliflower at various stages, including root dipping and foliar spraying. The diameter of the curd (17.78 cm), the length of the stalk (5.22 cm), the net weight of the curd (3.53 kg/plant), the curd yield (12.5 kg/plot), and the necessary minimum days to 50% marketable curd were all observed to be improved by the foliar application of GA_3 at 50 mg/l in cauliflower (88.80 days). By applying IAA 10ppm + GA_3 70ppm instead of control, the highest plant height (63.10 cm), number of leaves per plant (23.66), leaf length (59.05 cm), leaf breadth (18.98 cm), diameter of curd (22.39 cm), and marketable yield per hectare (29.88 t/ha) were observed. Additionally, it was discovered that planting on November 15 produced the highest plant height (65.96 cm), number of leaves per plant (26.42), leaf length (63.64 cm), leaf breadth (20.92 cm), curd diameter (25.75 cm), and marketable yield per hectare (31.03 t/ha) measurements, as well as IAA 10 ppm and GA_3 70 ppm (Rahman *et al.,* 2016). Different doses of NAA@ 100, 120, and 140 ppm were tested by Jadon *et al.*, (2009). They discovered that greater doses of NAA at 140 ppm resulted in higher plant height (33.83 cm), stem diameter (1.65 cm), spread (45 cm), and leaf count per plant (22.10). Characters that contribute to yield, such as curd diameter (15.10 cm), curd weight (0.61 kg), head weight (0.60 kg), length of head per plant (21.58 cm), yield (155 q/ha), and dry weight of curd per 100 g of fresh weight (10.40), were all higher than they were in the control group.

Okra

IAA @ 100 ppm gave maximum plant height (107.74 cm). However, the use of GA_3 @ 150 ppm needed a minimum number of days for first blooming (39.67 days) and a minimum number of days for first harvesting (44.67 days). The best seed quality attributes were provided by GA_3 @ 50 ppm, such as average pod weight (g) and 100 seed weight (g). While thiourea @ 500 ppm gave the largest number of pods per plant, length of pod (cm), number of seeds per pod, per plant seed yield (g), and seed production per hectare, GA_3 gave the maximum plant height, number of leaves, and number of nodes per plant (q) (Ravat *et al.*, 2015).

Onion and Garlic

According to Patel *et al.*, (2010), root dipping treatment with NAA @ 100 ppm dramatically decreased physiological weight loss and decreased loss in spoiling. According to Anbukkarasi *et al.* (2013), fungicides, ethylene, and CCC all have a significant impact on the shelf life and delay of sprouting in onions. To increase the shelf life of onions, pre- and post-harvest treatments have been studied, according to Bannu Priya *et al.*, (2014).

Cucurbits

According to Hidayatullah *et al.*, (2012), bottle gourds grown with GA_3 @ 30 ppm produced more pistillate flowers, the greatest number of fruits, and heavier fruits than controls. According to Dalai *et al.* (2015), GA_3At 20 ppm + NAA @ 100 ppm produced the most wine length/plant (cm) and amount of leaves/plant. However, for cucumber, GA_3 @ 20 ppm + NAA @ 100 ppm had the highest yield. According to Sandra *et al.*, 2015, NAA at 200 ppm, GA_3 at 50 ppm, and ethereal at 50 ppm were all highly efficient for enhancing vegetative growth, fruit and seed yield, and modifying sex expressions. GA_3 at 50 ppm was also successful in producing hybrid seed in bitter gourd.

Potato

Ethrel at 250 ppm applied topically changed the phenotypic of the plant and increased plant height, shoot diameter, number of tubers produced per plant, and overall tuber output as compared to the control (Awati *et al.,* 2016). The plant's height increased after GA_3 was applied 60 days after transplanting, but the quantity of tubers, weight, and dry matter content were unaffected. Inducing a large percentage of sprouted tubers before harvest and increasing the physiological age of the tubers are both results of late application of GA_3 (Alexios *et al.*, 2006).

Pea

According to Singh *et al.* (2016), GA_3 at 200 ppm greatly enhanced plant height, the number of leaves, the total number of branches, the number of pods, the length of the pods, and the weight of 100 seeds. This review's findings suggest that PGRS regulate physiological processes in crop plants, such as roots, flowering, growth, sprouting, and ripening, and that its application in the production of diverse vegetable crops has been proven to be advantageous for yield and yieldcontributing traits

CONCLUSION

Thus, it can be concluded from this review, use of plant growth regulator in vegetables has been found beneficial for improve yield, quality, synchronization in flowering, earliness, cold and high temperature fruit setting, sex modification, increases post-harvest life, and develop resistance to biotic and abiotic stresses. Those are also very effective for induction of male sterility in vegetable crops.

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