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Importance of PGRs in vegetable production: A review

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Abstract
Indian Agriculture become more mechanized and science based by using inputs and the PGRs are among of them; PGRs has quicker impact on vegetative as well as yield of the crops. As it has various advantages like less time consuming to treat the plant and environment friendly. Vegetables crops are rich sources of vitamins and minerals. Use of growth regulators in vegetable production must be specific their action and toxicologically and environmentally safe. The physiological activity of vegetable crops regulate and after the application of growth regulator finally enhance the vegetable production.

Keywords: vegetable crop, PGRs, production

Introduction
Plant hormones are chemicals in plants that regulate cellular processes. They are usually found in small amounts throughout the plant. These hormones are very important as they determine many different attributes of a plant. Plant hormones can be natural or synthetic. Plant hormones are also known as phytohormones. Thimann in 1948 was coined the term "Phytohormone" The five major plant hormones are auxins, gibberellins, cytokinins, abscisic acid, and ethylene. (P. Hazra and M.G. Som, 2006) [11]. These hormones will work independently or together to influence plant growth and health. Auxins and gibberellins help promote plant growth, particularly in stem elongation. Cytokinins promote cell division and are produced in growing areas of plants. Abscisic acid plays a role in cell dormancy and is involved in the opening and closing of the stomata on leaves. Finally, ethylene is a gas that is produced by ripening fruits. Ethylene is one particular hormone that is often synthetically produced so gardeners can purposefully ripen fruits of many plants at the same time. The classes are discussed in following table 1

Auxin
Charles Darwing was the first who proposed the existence of auxin in 1880. 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.

Gibberellin
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". GA stimulate germination of seed and maturation of flower and fruit.

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.

Abscisic acid
It is also called plant stress hormone. It act 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 inhibit mRNA and synthesis of protein.

Ethylene
This hormone is a gaseous plant hormone which is synthesized from methionine and it is synthesized in all organs of plant.

Contribute of PGRs in vegetable production
Chilli
The treatments 2,4-D @ 2ppm, triacontanol @ 5ppm, NAA 40ppm and GA_3@ 10ppm produced 28.75%, 25.70%, 13.61% and 2.30% maximum fruit yield over control. It was recorded that maximum net profit and B: C ratio was found in case of 2ppm 2,4-D. The use of GA_3 as foliar spray was not economical (Chaudhary *et al.*, 2006) [7]. Maximum seed yield per plant (8.30 g), seed yield per fruit (0.35 g), per plant average fresh weight of fruits (39 g) and per plant average dry weight of fruits (19.67 g) were obtained by spraying of NAA @ 40ppm as against control (Patel *et al.*, 2016) [18]. In capsicum, NAA @ 60ppm gave maximum plant height (120.59 cm), number of branches (16.05), days to first flowering (32.51), per plant number of flowers (11.83), weight of fruit (169.66g), per plant number of fruits (9.87), per fruit number of seeds (110.78), per plant yield (1.67 kg) and per plot yield of fruit (15.07kg), yield per hectare (69.76t) were recorded (Singh *et al.*, 2017) [27]. Different concentrations of growth regulators such as NAA (25, 50 and 75ppm), GA_3 (20, 40 and 60ppm), 2, 4-D (5, 7.5 and 10ppm) and ethrel (300, 400 and 500ppm) were used in chilli and applied after 30 and 60 days after transplanting. It was recorded that NAA @ 75ppm gave maximum yield per plant (182.31g) and yield per hectare (6.37t). On the other hand, GA_3 @ 20 and 60ppm treated plants gave maximum plant

height (60.67 cm), maximum dry weight of 20 fruit (9.39g). The plant spread in (N-S) (36.97 cm) and maximum number of seeds per fruit (60.47) were recorded in 2,4-D @ 7.5ppm treated plants (Raj *et al.,* 2016) [25]. There were three plant growth regulators were use with different combinations and were applied by foliar application at 30 DAT, 60 DAT, 90 DAT to assess the effect on growth and quality of green chilli. The investigation revealed that, the vegetative growth observations in terms of plant height of plant was produced in the treated with NAA at 50 ppm and number of branches per plant were produced significantly the maximum due to application of CCC at 500 ppm. The plant spread was found significantly the maximum when the treated with an NAA at 50 ppm. As regards to the yield parameters which were recorded viz. fruits per plant of green chilli were produced significantly the maximum due to an application of NAA at 50 ppm concentration. As far as the fruit quality concern in terms of fruit length was observed significantly the maximum obtained an application of GA3 at 50 ppm, significantly the maximum fruit breadth was obtained with an application of CCC at 500 ppm concentration and the other quality parameter like in respect to the chlorophyll content i.e. chlorophyll A, chlorophyll B and total chlorophyll were observed maximum when the treated with CCC at 500 ppm concentration, (Mahindre, PB *et al.* 2018) [15].

Brinjal

Moniruzzaman *et al.,* (2014) [16] used different growth regulators such as GA_3 (30, 40 and 50ppm) and NAA (20, 40 and 60ppm) and two varieties such as BARI Begun-5 and BARI Begun -10. It was reported that highest percentage of long and medium styled flower, leaf photosynthesis, number of fruits per plant and fruit yield (45.50 t/ha) was reported by application of NAA @ 40ppm. The variety BARI Begun-5 took 40 days for flowering after transplanting which was earlier to 100% flowering of BARI Begun-10. Application of NAA @ 40ppm coupled with BARI Begun-5 gave the maximum long-styled flower percent, number of fruits/plant, and the highest fruit yield (49.73 t/ha). Netam and Sharma (2014) studied that GA_3 @ 10ppm and NAA @ 20ppm gave maximum number of branches, number of fruits, fresh fruit weight, total soluble solid. Observes that GA_3@ 150ppm gave heighest plant height, per plant number of leaves, length of leaf, per plant number of branches and stem diameter as compared to GA_3 @ 100ppm and 200 ppm and minimum recorded in control. Dhakar and Singh (2015) [8].

Tomato

Role of PGRs are beneficial for growth parameters and yield of tomato. The different concentrations of NAA at 25, 50, 75 and 100ppm and GA_3 20, 40, 60 and 80ppm were sprayed on the plants of tomato and it was reported that maximum plant height i.e. 85.3 cm and 82.3 cm was observed by using NAA at 100ppm and GA_3 at 80ppm and yield was also increased 483.6 q/ha and 472.2 q/ha with the use of NAA at 100 ppm and GA_3 at 80ppm (Prasad *et al.,* 2013).GA_3 @ 125ppm gave maximum plant height, number of leaves, number of branches per plant, number of fruits, number of flowers, fruit clusters, diameter of fruit, yield per plant (kg) and per plot (kg) and yield per hectare (tonnes) were found to be maximum (Akand *et al.,* 2015) [3]. In BARI Hybrid Tomato-8, 4-CPA (4- Chlorophenoxy acetic acid) + GA_3 applied together after 75 days of transplanting and observed that the tallest plant (79.35 cm), number of flowers (38.11) and fruits and (19.04) per plant, height (87.90 cm), number of flowers (49.04) and fruits (21.9) per plant, individual fruit weight (61.16 g), and fruit yield (27.28 tha-1) individual weight (58.44 g) and fruit yield (22.75 t ha-1) were found to be maximum (Rahman *et al.,* 2015). The application of CCC (Cycocel) @ 500ppm gave increased in height of plant, number of fruits per plant, fruit diameter and per plant seed yield after 45 days of transplanting of tomato seedlings as compared to NAA @ 50ppm and GA_3@ 50ppm (Chauhan *et al.,* 2017) [6]. The different treatment concentration tested were NAA (15, 20, 25 and 30 ppm), GA3 (20, 30, 40 and 50 ppm) and control (distilled water spray). All variables parameters related to yield and quality parameters were significantly influenced by different concentrations of the plant bio-regulators. Results revealed that among all the treatments, the foliar application of GA3 (50 ppm) registered significantly higher reproductive aspects viz., number of cluster per plant (7.07), number of fruit per cluster (6.73), number of fruit per plant (20.60), fruit set (65.09 %), fruit length (4.75 cm), fruit diameter (5.05 cm), fruit weight (61.95 g) and yield (531.74 q/ha). Themaximum TSS (4.93˚B) was recorded with the foliar application of GA3 (50 ppm), while minimum acidity per cent (0.463) in fruits was recorded under the foliar spray of NAA @ 25 ppm. (Ujjwal, Vivak.*et al,* 2018) [32].

Cauliflower

The performance of GA_3 and NAA at different levels as dipping of roots and by foliar spray on "SNOWBALL- 16" variety of Cauliflower. It was reported that foliar spray of GA_3 at 50 mg/l in cauliflower gave better results for diameter of curd (17.78 cm), length of stalk (5.22 cm), net weight of curd (3.53 kg/plant), curd yield (12.5 kg/plot) and required minimum days to 50 % marketable curd (88.80 days) was reported by Sitapara *et al.,* (2011) [31]. Highest plant height (63.10 cm), number of leaves per plant (23.66), leaf length (59.05 cm), leaf breadth (18.98 cm) at the time of harvest, diameter of curd (22.39 cm), marketable yield per hectare (29.88 t/ha) were recorded by using IAA 10ppm + GA_3 70ppm than control. Also studied that the highest plant height (65.96 cm), number of leaves per plant (26.42), leaf length (63.64 cm), leaf breadth (20.92 cm) at the time of harvest, curd diameter (25.75 cm), marketable yield per hectare (31.03 t ha-1) were recorded from planting on 15 November and IAA 10ppm with GA_3 70ppm (Rahman *et al.,* 2016) [23]. Jadon *et al.,* 2009 [14] used different doss of NAA@ 100, 120 and 140ppm. They revealed that higher dose of NAA @ 140ppm gave higher plant height (33.83 cm), diameter of the stem (1.65 cm), spread of the plant (45 cm) and number of leaves per plants (22.10). Yield attributing characters viz., diameter of curd (15.10 cm), weight of curd per plant (0.61 kg), weight of the head per plant (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 also increased than control.

Cabbage

Islam *et al.,* 2017 [13] used different concentrations of GA_3 on cabbage. They took four different levels of GA_3 such as 0, 90, 120 and 150ppm.They reported that GA_3 at 120ppm gave highest marketable yield (65.5 t/ha) while minimum yield was recorded in GA_3 0ppm (41.2 t/ha). Heighest plant height, maximum number of loose leaves per plant and diameter of head was recorded by using GA_3 at 120ppm while minimum

in GA_3 0ppm. On the other hand, minimum days were recorded for formation of head in GA_3 120ppm and maximum days was recorded in GA_3 0ppm. So, they found that GA_3 at 120ppm was more effective. Chaurasiy *et al.*, (2014) [19] used different concentrations of NAA (40, 80 and 120ppm) and GA_3 (30, 60 and 90ppm) and applied as foliar spray on plants of cabbage at 30 and 45 days after transplanting. They reported that NAA 80ppm and GA_3 60ppm gave heighest plant height, number of leaves per plant, plant spreading, diameter of stem, weight of plant, weight of head, and head yield as compared to all the other treatments and control.

Pea

Singh *et al.*, 2016 [30] reported that GA_3 at 200ppm gave significantly increased in height of plant, number of leaves, total number of branches, number of pods, length of pod and 100 seed weight. From this review it has been concluded that PGRS regulate physiological process to the crop plants like rooting, flowering, growth, sprouting, ripening and use of PGRS in vegetable production found to be beneficial for yield and yield contributing characters of various vegetable crops.

Garlic and Onion

Patel *et al.*, 2010 [20] recorded that root dipping treatment of NAA @ 100ppm significantly reduced physiological loss of weight, reduced loss in spoilage. Anbukkarasi *et al.*, 2013 [1] recorded that CCC, ethylene and and fungicides play an important role in delay in sprouting and extant shelf life in onion. Bannu Priya *et al.*, 2014 [4] reviewed the work done on pre and post-harvest treatments in onion to extend shelf life.

Cucurbits

Hidayatullah *et al.*, 2012 [12] revealed that GA_3 @ 30ppm increased in production of pistillate flowers, maximum no. of fruits and fruit weight as compared to control in bottle gourd. Dalai *et al.*, 2015 [9] reported that GA_3 @ 20ppm + NAA @ 100ppm gave heighest wine length/plant (cm), no. of leaves/ plant. On the other hand, GA_3 @ 20ppm + NAA @ 100ppm gave maximum yield in cucumber. Sandra *et al.*, 2015 [28] resulted that NAA @ 200ppm, GA_3@ 50ppm and etheral @ 50ppm were very effective for enhancement in vegetative growth, fruit and seed yield and modification in sex expressions and GA_3 @ 50ppm was effective in production of hybrid seed in bitter gourd.

Okra

Dhage *et al.*, 2011 [10] revealed that IAA @ 100ppm gave maximum plant height (107.74 cm), intermodal length (3.1 cm). However, by the application of GA_3 @ 150ppm, minimum days are required for first flowering (39.67 days) and minimum days were required for first harvesting (44.67 days). Ravat *et al* 2015 [21] recorded thatGA_3@ 50ppm gave best seed quality characters like average pod weight (g), 100 seed weight (g). While GA_3 gave maximum plant height, number of leaves, per plant number of nodes and thiourea @500pm gave maximum no. of pods per plant, length of pod (cm), number of seed per pod, per plant seed yield (g) and seed yield per hectare(q). The experiment comprised three level of Gibberellic acid such as 0ppm, 10ppm, and 20ppm and three spacing's viz., 60 x 30cm, 60 x 45cm and 60 x 60cm. Experiment was laid out in RBD (with factorial concept) with three replications. The results of the experiment showed that application of Gibberellic acid (20ppm) had significant influence on most of the parameters such as; Plant height (cm), number of leaves per plant, number of branches per plant and phenological traits i.e. days taken to first flower initiation and yield parameters such as; fruit length (cm), fruit yield per plant (g), fruit yield per plot (kg). The spacing 60 x 45cm had significant influence on most of the parameters such as Plant height (cm), number of leaves per plant, number of branches per plant and phenological parameter i.e. days taken to first flower initiation, and yield parameters such fruit yield per plant (g) and fruit yield per plot (kg). (Rajput, Jitendra Singh *et al.* 2018) [26].

Potato

Foliar application of ethrel at 250ppm was effective in changing phenotype of plant, increased in plant height, diameter of shoot, per plant number of tubers and total yield of tuber as compared to control (Awati *et al.*, 2016). Application of GA_3 at 60 days after transplanting had increased in height of plant but number of tubers, weight and content of dry matter were not affected. Late application of GA_3 leads for induction of high percentage of sprouted tubers prior to harvest and also lead to increase physiological age of tubers (Alexios *et al.*, 2006).

Table 1: PGRs and their classes

Plant growth regulators	Classes
Auxins	Indole-3-acetic acid (IAA), 1-Naphthaleneacetic acid (NAA), Indole-3-butyric acid (IBA), 2,4-Dichlorophenoxyacetic acid (2-4D), 4-Chlorophenoxyacetic acid (4-CPA).
Gibberellins	Gibberellic acid (GA3)
Cytokinin	Kinetin, Zeatin
Ethylene	Ethereal
Abscisic acid	Dormins, Phaseic Acid

Table 2: Different PGRs and their functions

Name of the plant growth regulators	Functions
Auxin	(1) Apical dominance (2) Cell division and enlargement (3) Shoot and root growth (4) Plant growth movement (5) Parthenocarpy (6) Abscission
Gibberellin	(a) Prevent genetical dwarfism (b) Regulation in bolting and flowering (c) Production of parthenocarpic fruit (d) Germination.
Cytokinins	(a) Cell and organ enlargement (b) Seed germination (c) Development of bud and shoot growth
Ethylene	(a) Ripening of fruit (b) Seedling growth and emergence (c) Abscission of leaf.
Abscisic acid	(a) Abscission (b) Dormancy (c) Inhibit seed development and germination of seed (d) Stomatal closing (e) Helps during water stress

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