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# PLANT HORMONES: PHYSIOLOGICAL ROLE AND HEALTH EFFECTS

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**ABSTRACT**

Hormones are signal molecules that are naturally occurring plant growth substances, as well as synthetic compounds and chemical substances. Plant hormones are major growth regulating hormones such as auxin, gibberellin, and cytokinins. However, few plant hormones also work as growth inhibitor such as ethylene and abscisic acid. PGRs play important role in the whole life cycle of plants include plant growth, development, flowering, fruiting , ageing, senescence, color enhancement of fruits, prevention or promotion of stem elongation, leafing, leaf fall. Auxin and gibberellin are used for increasing crop grain productivity, increasing higher yield in leafy vegetables, to increase the size of fruits and vegetables and to make them look attractive for consumer and to improve the agricultural production. The residues of PGRs (auxin, gibberellin) in agricultural products are seriously detrimental to human health because they have been found with hepatotoxicity, nephrotoxicity, genotoxicity. Furthermore, PGRs are suspected to disrupt the function of human and animal reproductive systems. Therefore, there is a need to check the overdoses of these regulators in agriculture production for further ensuring food safety. Several techniques are used to detect the residue of these regulators such as LC-MS, HPLC, GC-MS, Immunoassays techniques (radioassay, enzyme-linked immunosorbent assay).

**Keywords:** Plant hormones; auxins; gibberellins; HPLC; GC-MS

## INTRODUCTION

The plant hormones are signalling molecules or the combination of chemicals which are present at very low concentration in the plants. These hormones affect mainly the growth, separation and development of plant, also influence the different processes, such as stomatal development. Darwin and Francis (1880) introduced the concept of plant hormones by the bending of plants towards the light and phenomena named as phototropism **(Davies, 2010).** The term "Phytohormones" was coined by Thiamann as an organic substance which is present naturally in the plants **(Thimann, 1963).** The term plant hormones is used for naturally occurring hormones in plants, whereas, the term plant growth regulators (PGRs) are a man-made compound or synthetically produced **(Kamiya, 2010**). Plant growth regulators has important role in plant developmental processes, which is associated with plant reactions to a wide scope of biotic and abiotic stresses. Plant hormones are also known to be firmly connected with fruit development and ageing **(Klee *et al*., 2011).** Hormones have confined site of synthesis and particular concentration, which transports through the circulation system to a target tissue, and the control of a physiological reaction in it **(Went *et al*., 1937).** PGRs are accountable for complete development and growth of the plants and also modulate the various plant cell processes (Tab 1). Plant hormone affects the growth, cellular division, and transcription etc. Different types of plant hormones are found till now are the auxins, the gibberellins (GAs), the cytokinins, ethylene, abscisic acid (ABA), jasmonic corrosive, the brassinosteroids, salicylic corrosive (SA), and the bioactive oligopeptides, (for example, CLE peptides). Recently, the new class of plant hormones was identified as strigolactones **(Roldan *et al*., 2008; Umehara *et al*., 2008).**
Plant source produce are used as spices and herbs (Sharma et al. 2016a; Sharma et al. 2016b) and also serve as source of vitamins (Kaushik et al., 2017, Sachdeva et al. 2015; Kaushik et al. 2015a), minerals (Kaushik et al. 2015b; Sachdeva et al. 2015; Rana et al. 2018). Cereals are the main economic crops from plants and several bakery products are prepared from them like cake (Saklani and Kaushik 2019), noodles (Kaushik et al. 2018) rusk (Lohan et al. 2019), cookies (Kumar et al. 2013) and so on. Most of the foods are originated from plants, therefore, use of synthetic hormones in plant foods is alarming and we have to control it.

### Classification of Plant Hormones

Plant hormones are classified into 2 broad categories (1) Growth Promoter (2) Growth Inhibitor. Growth promoters are those hormones which promote the growth of the plant by cell division, flowering, the ripening of fruits, etc. However, growth inhibitors are those molecules which inhibit the growth and development of plant and promote abscission. Growth promoters are further classified into 3 categories (i) auxin (ii) Gibberellin (iii) cytokinin. Ethylene and abscisic acid come under the category of growth inhibitor hormones (Figure 1).

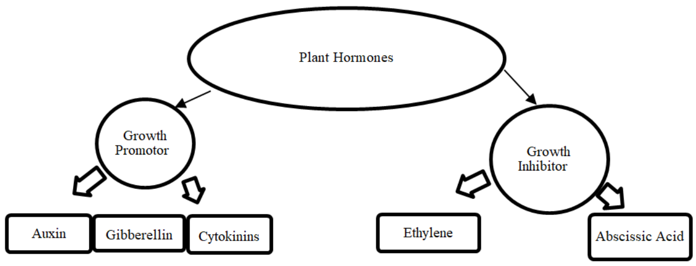



**Figure 1** Broad classification of plant hormones

These hormones play an important role in growth and development of plants **(Hazra *et al*., 2006)** affecting various attributes such as plant growth, flowering, fruiting, ageing, senescence, colour enhancement of fruits, prevention or promotion of stem elongation, leafing and leaf fall. Even a minute concentration of these hormones may lead to crucial growth changes in the plants.
The classes of plant hormones are discussed further:

### Auxin

The word auxins means to grow or to increase which mainly act with the development or the growth of the shoot **(Smit *et al*., 1931).** It is a natural substance which work as a growth promoter towards the longitudinal axis of the plant when applied in a lower concentration to the shoots **(Thimann, 1948).** Auxin was discovered by Darwin in 1880. It is the first class growth regulator. The major form of auxin present in plants is Indole-3-acetic acid or IAA. It is a naturally appearing hormone commonly present in a plant **(Davies, 1995).** Several compounds such as Indole-3-butyric acid, phenylacetic acid, and 4-chloro-IAA, also present in plants **(Davies, 1995).** Natural occurring auxins were isolated, purified, and their the chemical structures were identified; which were indole derivatives, Indole-3-acetic acid, IAA, Indole-3-acetonitrile, IAN, Indole-3-acetaldehyde, IA, Ethylindoleacetate, Indole-3- pyruvic acid, IPyA and Indole-3-ethanol (**Trewavas, 1991).** L-tryptophan via indole-3-pyruvic acid or tryptamine is mainly a precursor's molecule which help in the formation of IAA. Auxins combine with the alcohols, amino acids and sugars to produce the ester, amide or glycoside conjugates. With the help of this mechanism auxin stores in cells and with the metabolizing it helps in stabilizing the level of auxin which is present in the free form. In the conjugated molecules auxin was prevented from the oxidative breakdown or by the enzymatically released when it's required **(Bandurski et al., 1995).** 2, 4-dichlorophenoxyacetic acid and 1-naphthaleneacetic acid (NAA) is a synthetic auxin which mostly used as herbicides **(Davies, 1995).** For the formation of embryogenic tissue or to maintaining suspension cultures dicambra (3, 6-dichloro-o-anisic acid) and picloram (4-amino-3, 5, 6-trichloropyridine-2-carboxylic acid) are commonly used (Hagen et al., 1991). Leyser, 2006 reported IAA protein would bind with the auxin response factors (ARFs) and help in the inhibition of transcription of particular auxin response genes. Transport inhibitor response 1 (TIR1) was an auxin receptor which interconnects to Aux/IAA protein **(Kepinski et al., 2005; Dharmasiri et al., 2005). Woodward et al., 2005** reported that for the development and growth of plant the auxin persuade three groups of genes viz. Aux/IAA family, GH3 family, and small auxin-up RNA (SAUR) family. In Arabidopsis and Rice, it was observed that auxin with the GH3 genes shows the defense responses **(Zhang et al., 2007). Sachs, 1980** reported that in the plant the growth-regulating hormones were present and also suggested that there were an 'organ-forming substances' which produced in the leaves and moved downward in the plant body. **Darwin, 1880** an evolutionist, contemplated the impact of one-sided light on plant developments. While leading his examinations on canary grass (*Phanaris canariensis*), he found that if the coleoptile tip is given light from one side just (i.e., one-sided brightening), the tip would twist towards the light. Without light, be that as it may, no ebb and flow could be initiated. The material idea of the hormones was first definitively shown by a Dane, Peter Boysen-Jensen (1910). He previously cut off (or beheaded) the coleoptile tip a couple of millimetres from the apex and put a square of gelatine on the executed stump and eventually replaced the cut tip on the gelatine square. Upon one-sided brightening, the coleoptile flows towards the light **(Jensen, 1910).**

**Synthesis**

Biosynthesis of the auxin in a plant is the most complex. Several pathways are helping in the production of de novo auxin. Due to hydrolytic cleavage of the IAA-amino acids, IAA-sugar, and IAA-methyl ester IAA released from IAA conjugates **(Li *et al.*, 2008).** IAA synthesis basically takes place in leaf primordial or in developing seeds. It is synthesized from Tryptophan and Indole. IAA was moved from cell to cell, primarily in vascular cambium and the procambial strands, but in the epidermal cell also **(Davies, 2010).** In figure 2 the biosynthesis pathway of auxin showed by the two steps which play an important role in the development process.

Tryptophan (Trp)

(TAA family of amino transferases)

↓

Indole-3-pyruvate (IPA)

↓

(YUC family of flavin monooxygenases)

↓

IAA

**(Zhao, 2012)**

**Figure 2** Biosynthesis Pathway of Auxins

**Physiological Roles**

Auxin affects various factors such as:

a. Cell enlargement (Auxin plays an important role in stimulates cell expansion and stem growth).

b. Cell division (With the combination of cytokinin in tissue culture and cambium the cell division will be stimulated by the effects of auxin).

c. Vascular tissue differentiation (by stimulating the separation of phloem and xylem).

d. Root initiation (helps inactivate root initiation on stem cuttings, also help in the development of branch roots and segregation of roots in tissue culture).

e. Tropistic responses (it helps in bending the shoot and root towards the light and gravity).

f. Apical dominance (growth of the lateral bud represses by supplying auxin from the apical bud).

g. Leaf senescence (it is deferrals leaf senescence).

h. Leaf and fruit abscission (help in inhibition or promote the growth of fruit and leaf with the help of ethylene).

i. Fruit setting and growth, assimilate portioning (due to the effect of phloem transport there will be boosted in the movement due to the auxin).

j. Fruit ripening (its help in delaying the ripening process),

k. Flowering (it promotes the flowering), the growth of flower parts (its help inactivation) (Davies, 2014).

**Gibberellins**

Gibberellin was discovered incidentally by the Japanese farmer in the 20th century where he saw that some rice plant have abnormal growth as compared to the normal plant. This abnormal growth is known as "bakanae" diseases, which mean foolish seedlings. This disease is caused by a chemical which is secreted by fungus, called *Gibberella fujikuroi* **(Sawada, 1912). Kurosava,** 1926 practically supported that bakanae disease shows that healthy rice seedlings symptoms from the sterile filtrates of the fungus. Later on, this substance was isolated in the crystalline form which helps in promoting the growth of the plant and its name as Gibberellins **(Yabuta *et al.*, 1939).** Gibberellins are the bigger cluster of tetracyclic diterpenoids, ent-gibberellane ($C_{20}$) or 20-nor-ent-gibberellane ($C_{19}$) carbon skeletons which help in the plant life cycle at various points such as seed germination, stem elongation, root growth, leaf expansion, trichome development, flowering and fruit development **(Rose *et al.*, 1997).** Gibberelline or gibberellic acid is a widely obtainable compound in plant containg primarily stem elongation properties **(Davies, 2014).** It is the second growth regulator extracted from Fungus. **Lance *et al.*, 1976b** reported for the callus growth endogenous GAs is major compound. **Fry *et al.*, 1980** reported addition of the GA help in promoting the growth of shoots in meristem and shoot cultures. It was reported in, 2001 that in bacteria, fungi and vascular plant 126 different categories of GAs were identified. But from these categories only least compound contains the GA4 and GA1 which shown the elicit biological response in plant **(Hedden *et al.*, 2000).** For the rise of cell elongation GA1 was the most active gibberellins and GA3, GA4 (mixture), GA7 used more in plant culture as compared to other GAs. In seeds of grasses and cereals, gibberellins play a major role in introducing the hydrolytic enzymes such as α-amylase and protease and also help in endosperm mobilization **(Klerk, 2007).**

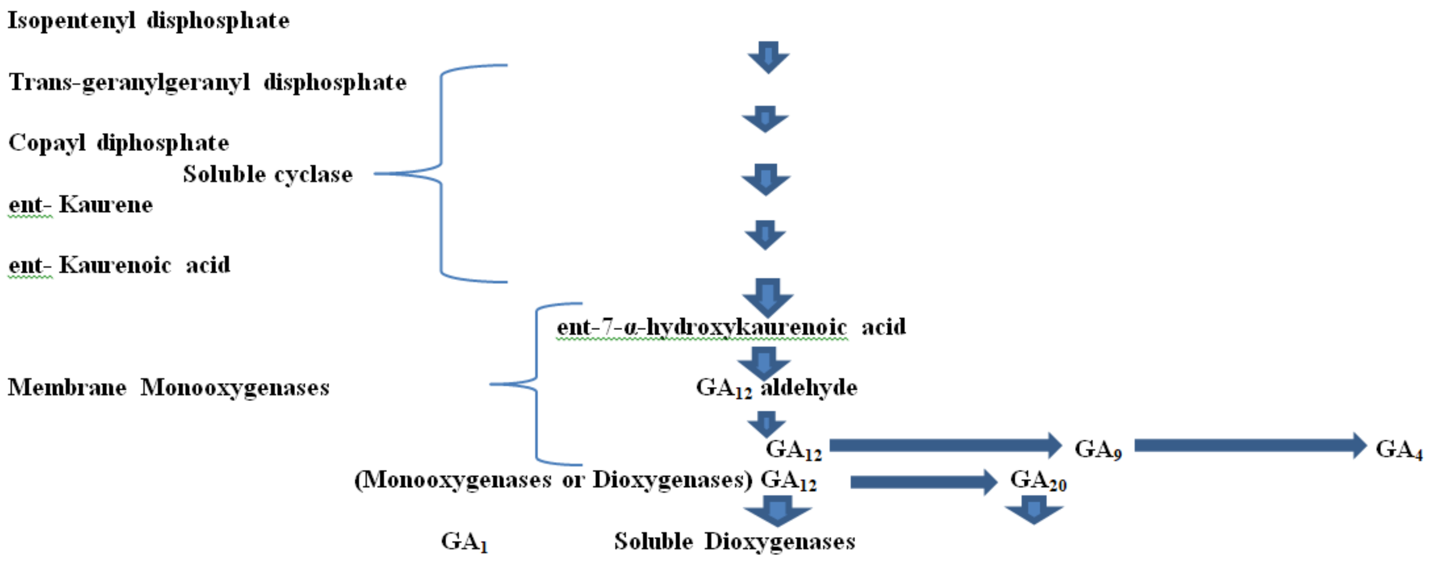
**Synthesis**

Biosynthesis of gibberellins is a very complex mechanism. It contains mainly three steps:

(i) Isopentenyl diphosphate will produce the ent-kaurene in plastids,

**(ii)** Conversion of ent-kaurene by the monooxygenase membrane into GA12 aldehyde ( this conversion contains the various steps such as hydroxylase and oxidase),

**(iii)** In cytoplasm bioactive C19-GA is form and deactivate of as shown in figure 3 **(Olszewski *et al.*, 2002).**




(Olszewski *et al*., 2002)

**Figure 3** Biosynthesis pathway of Gibberellin

**Kasahara *et al*., 2002** reported that geranylgeranyl diphosphate (GGPP) was also responsible for the formation of GA in Arabidopsis seedlings by the mevalonate-independent pathway. Due to this pathway, it is seen that there will be rapid growth of tissues, shoot apices, root tips, developing anthers and seeds. In phloem and xylem, it seemed that GAs transported mainly but GA1 is an important bioactive compound which would be restricted **(Davies, 2014).**

**Physiological Role**

Gibberellin responsible for the:

- **a.** Stimulating the cell division and cell elongation which prevents the genetical dwarfism
- **b.** Promote stem growth ( by hyper elongation of stem which causes by GA1)
- **c.** Functions in the modulation of bolting (stem elongation for long day cause by GAs)
- **d.** Flowering, helps in the production of parthenocarpic fruit
- **e.** Spread germination (required cold or light to persuade germination)
- **f.** Regulate production of enzymes during germination (by activation of α-amylase for the germination of cereals grains) break seed dormancy. For the media culture, GA3 acid was an important ingredient at the low densities **(Stuart *et al*., 1971).** It also reported that GA3 has a similar nature as comparing the auxin when it added in culture media, if it used in higher concentration there was a change in the growth of the callus cells **(Beasley, 1977).**

**Cytokinins**

Cytokinins are another class of growth promoter's hormones. Cytokinin defined as a chemical which has the ability to promote cell division in various plant organs **(Skoog *et al*., 1965).** Another scientist named as Fox (1969) described that cytokinins as a chemical which is made up of 2 adenine group in which one hydrophilic group with of high specificity and one lipophilic group without the specificity. The first existence of cytokinins was reported by Gottlieb Haberlandt (1913) who observed that non-dividing parenchyma cells of potato can promote to division in the presence of phloem sap from various plant species. He indicates that a soluble material present in phloem was responsible for the promotion of cell division**. Overbeek *et al*., 1941** reported that cell division is also achieved by the addition of certain natural products like coconut milk to mineral medium containing auxin. Later on, the factor that promoting cell division was identified by Skoog **(Miroslav, 2015).** Experiments with tobacco stem pith tissues showed that auxin was capable of inducing mitosis unaccompanied by cytokinesis **(Naylor *et al*., 1954).** Kinetin was the first cell-division-stimulating factor which was isolated in 1955 from the yeast DNA. In presence of auxin Kinetin has more power to promote cell division. In later years, many other compounds isolated that promoting cell division **(Miller *et al*., 1955).** Kinetin was not regarded as natural plant hormone because it was the second class oxidative product of DNA **(Hall *et al*., 1955; Barciszewski *et al*., 1997).** Carlos Miller turned his attention to immature maize kernels, which is a rich source of a cell division factor and demonstrated that it is a purine-like compound closely related to kinetin **(Miller, 1961).** The natural cytokinin was isolated from the kernel of maize named as Zeatin **(Letham 1963c, 1966).** Synthetic cytokinins such as 6-benzyl amino purine (BAP), 6-(benzyl-amino)-9-(2- tetrahydropyranyl)-9H-purine (PBA), 1, 3-diphenylurea, thidiazuron (TDZ), etc. (**Kaur *et al*., 2018**). The richest sources of kinins are fruits and endosperm. Active substance that promotes cytokinin also present in Coconut milk and corn. Cytokinins stimulate cell division and responsible for secondary growth of stems and roots, in the juice of tomato and apple, pear floral extracts **(Powell *et al*., 1964; Kende, 1964).**

**Biosynthesis**

Synthesis of Cytokinins takes place in root tips and developing seeds by way of biochemical modification of Adenine.

**Physiological Role**

Cytokinins are capable of promoting the growth and development of the plant in the presence of auxin. It promotes cell division **(Skoog *et al*., 1957).** The process of cell division completes in 3 steps (1) DNA synthesis, (2) mitosis and (3) cytokinesis. **Patau *et al.* 1957** found that IAA is involved in DNA synthesis (first step of cell division) and mitosis (2nd step) and cytokinesis is controlled by kinetin. When justified ratio or concentration of IAA and kinetin are used together, the response of growth is much more. **Gan *et al*., 1996** reported that cytokinin also helps to delay in leaf senescence. Kinetin also encourages cell elongation. This type of promotion has been observed in tobacco pith cultures after the treatment of kinetin **(Glasziou, 1957),** in tobacco root and also in bean leaf tissues. Kinetin has the ability to stimulate as well as inhibiting root development. Initiation and development in stem callus cultures were observed by **Skoog, 1957**, when kinetin and IAA were used together in the root. Also have the capability of preventing seed dormancy in Lettuce, tobacco, white clover, and carpet grass.

**Ethylene**

It is the simplest hydrocarbon with molecular formula $C_2H_4$ that effects the growth and development of a plant **(Mattoo *et al*., 1991; Abeles *et al*., 1992).** It's a naturally produced hormone with two basic Carbon gaseous regulators **(Janssenn *et al*., 2018).** Also responsible for the ripening of fruits and organ abscission, and thus has great commercial importance in agriculture. The Germany city was lightened by the "illuminating gas" lamp in the 1800s. After that they put these lamp in their home and they observed that the plants which grow near to lamps had short thick stems, cause more abscission of leaves. **Neljubow, 1901** observed that when "illuminating gas" was burned and ethylene was produced that falling of leaves, abnormal growth of plants that were growing near the lamps and also noted that 0.06 ppm of ethylene showed these effects. Japanese Department of Agriculture received a report and requested that oranges and bananas cannot be stored together because oranges produced something and that something - caused premature ripening of the bananas. This 'something' was identified as ethylene by R. Gane in 1934.Presence of ethylene also seen in fungi (*Penicillium digitatum* and *Alternaria citri*) and certain parts of plants (leaves, flowers and mature fruits). **Pratt *et al*., 1969** confirmed that ethylene was a naturally occurring in plants so called as Phytohormones or natural plant hormone.

**Biosynthesis**

Ethylene produced from angiosperms plants (beans, rice, wheat), but a huge amount of ethylene released from the root, the shoot apical meristem, nodes, senescing flowers, and ripening fruits. Biosynthesis of ethylene is occur in two steps (i)methionine is converted into S-adenosylmethionine (ii) then conversion of S-adenosylmethionine into 1-amino-cyclopropane-1-carboxylic acid (Stimulated by high auxin concentration and also a precursor of ethylene) and then ethylene is produced as shown in figure 4. Synthesis of ethylene is decreased when the plant found to be in pure $CO_2$.

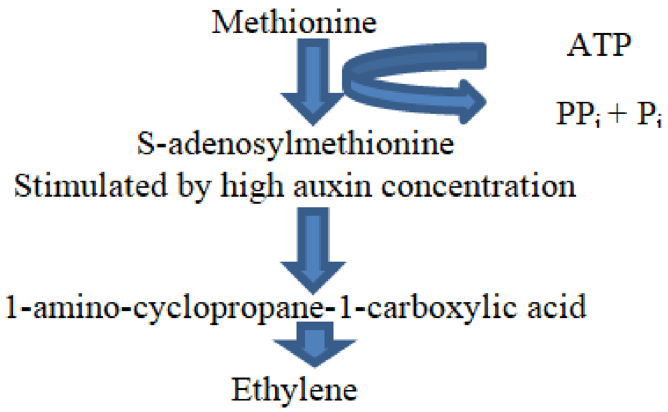



**Figure 4** Biosynthesis pathway of ethylene

**Physiological Roles**

Ethylene affects the dormancy, fruit ripening, root hairs, seed germination (activate), inhibit auxin transport, Leaf abscission, shoot growth and also stimulation of femaleness in dioecious flowers **(Davies, 1995; Mauseth, 2014; Raven, 1992; Salisbury *et al*., 1992).**

**Abscisic Acid**

**Addict, 1963** discovered the fifth phytohormone which is termed as abscisic acid (ABA). Abscisic acid (ABA) was one of the major inhibitor hormones which were naturally present in the plant. **Addicott *et al.*, 1992** given " abscising II" first name to the abscisic acid due to the controlling properties of abscission of cotton bolls. It also plays an important role in bud dormancy, so it was coined as "dormin" by Philip Wareing and on another hand study of abscission of flower and fruits was conducted by the Van Stevenickv. **A**fter several studies, plant physiologists were decided to name this compound "Abscisic acid" **(Salisbury *et al.*, 1992)**. This also known Stress hormone because it has the ability to increase the tolerance of plant in stress condition. It also plays an important role in the inhibition of auxin-promoted cell wall. ABA is a mixture of isomers and a cleavage product of carotenoids –xanthophylls **(Zeevart, 1999).** It has the ability to regulate the transpiration water loss and leaf growth when this stress hormone moves from xylem to root and then another part of the shoot. It helps to regulate the plant's growth viz. seed maturation, dormancy, seedling growth, and stomatal behaviour. With the combination of different plant hormones such as ethylene, jasmonic acid, ABA shows effective properties against the insect wounding and also show the plant response against the environmental stress **(North *et al.*, 2007).** Abscisic acid (C15) is inactivated by the two processes (i) ABA inactivation by oxidation and (ii) by conjugation with monosaccharides as shown figure 5:

**Biosynthesis**

ABA present in the angiosperms and gymnosperms and it is synthesised from the carotenoids. There will be the conversion of glyceraldehyde-3-phosphate via isopentenyl diphosphate and carotenoids in roots and mature leaves. It moved nonpolar like gibberellins and cytokinins and there would be no synthetic abscisic acids available **(Klerk, 2007; Davies, 2014).**

**Abscisic acid ($C_{15}$)**

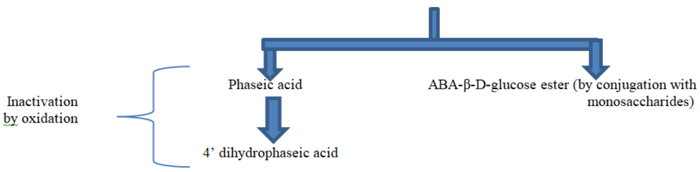



**Figure 5** ABA inactivation

**Physiological Roles**

a. It induces abscission and dormancy.
b. Inhibits seed development and germination of seed.
c. Helps during water stress (increasing the hydraulic conductivity).
d. Regulates stomatal closing (reducing transpiration, increase ABA and reduce the stomatal size)
e. Induces storage protein synthesis in developing seeds
f. Help in seed maturation, growth of bud and inhibits shoot growth, but help in endorsing leaf abscission and senescence by other Phytohormones, have the ability to maintain and introducing the effects of ABA on dormancy of seeds
g. Prevent in gene transcription by the wounds by increasing the ABA level
In case of cereal grains germination it prevent from the effect of gibberellin on the α-amylase synthesis and also help in slow down the cell elongation **(North *et al.*, 2007; Davies, 2014).**

**Table 1** Plant Growth Regulators and its classes

| Plant Growth Regulators | Classes |
|---|---|
| Auxin | 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 |

**Effect of plant growth regulators on growth, development and yield of plant**

**Kaur *et al*., 2018** reported that Plant Growth Regulators or PGRs synchronize physiological process in the crops like ripening, rooting, growth, flowering, sprouting. PGRs has a quick impression on vegetative and the yield of crops having advantages such as environment-friendly and less time consuming to serve the plants. The vegetable production is upgraded after the implementation of growth regulators and the implementation of different PGRs on the fruits and vegetables were also considered in the research. Utilization of Plant Growth Regulators in the fruits and vegetable production found to be valuable for yield and yield supplying characters of distinct crops.

**Effect of ethylene**

**Saltveit 1998** studied the effect of ethylene on the quality of fresh fruits and vegetables. Ethylene affects the development, growth and storage life of various fruits and vegetables. It is basically
Used to ripen the fruits by purposive exposure. He also reported that ethylene causes adverse effects on the development, senescence and ripening processes.

**Effect of gibberellin and auxin (IAA, NAA)**

**Surendra *et al*., 2006** reported that when GA3 used in different concentrations (25 and 50 ppm) a significant increase in plant heights was observed.
**Gravel et al., 2007** reported that Indole acetic acid (IAA) affected the development by *Pythium ultimum* in tomato plants. IAA on the tomato plant impacts the development of P. ultimum symptoms. The intensity of the symptoms induced by *P. ultimum* inside rhizosphere of the plant was increased at the low level of IAA (0-0.1 µg $ml^{-1}$) whereas, at higher level (10µg $ml^{-1}$) there would be a reduction of this symptom.
In okra it has been observed that GA3 used at 15 mg/l and 45 mg/1 resulted with higher percentage of seed germination, stem girth, number of branches, number of leaves per plant, early flowering and plant height, number of internodes, intermodal length, respectively **(Patil *et al*., 2010).**
**Dhage *et al.*, 2011** revealed in its treatment that GA3 at 150 ppm showed the effective result for plant height (107.74 cm), intermodal length (3.1 cm), required a minimum number for first flowering (39 days) and at 100 ppm it showed that maximum branches number (3.53) in okra.
At GA3 50 ppm showed the effective result [that the tallest plant (89.0 cm), longest petiole (29.0
cm), number of leaves (49.0 per plant), leaf area (29.7 cm2), number of branches (5.5 per plant), fresh weight (84.5 g/plant) and dry weight (10.9 g/plant)] which was similar with G2 (NAA 50 ppm) but, showed minimum result with G0 (control fresh water) **(Mehraj *et al*., 2015).**
**Samapika *et al*., 2015** reported that treatment in cucumber with the combination of different Phytohormones (NAA 100 ppm and GA3 20 ppm) showed a better result in growth parameters i.e. vine length (cm), number of primary branches per plant and number of leaves per plant as compared to control and other applied treatments.
**Kaur *et al*., 2018** reported that Plant Growth Regulators or PGRs synchronize physiological process in the crops like ripening, rooting, growth, flowering, sprouting. PGRs has a quick impression on vegetative and the yield of crops having advantages such as environment-friendly and less time consuming to serve the plants. The vegetable production is upgraded after the implementation of growth regulators and the implementation of different PGRs on the vegetables

were also considered in the research. Utilization of Plant Growth Regulators in the vegetable production found to be valuable for yield and yield supplying characters of distinct vegetable crops.

Fruit yield was increased by using the GA3 at different concentration (25 and 50 ppm) as compared to other applied treatment **(Surendra *et al*., 2006b).** In tomato, it observed that when it was treated with 80 ppm GA3 and 100 ppm NAA, the maximum fruit yield (483.6 q/ha and 472.2 q/ha) was obtained reported **(Prasad *et al*., 2013).** 2% DAP was sprayed at 35 and 70 days after the transplanting in green chilli, observed that minimum days required for the fruit set (25 days), highest length (6.32 cm) and diameter (6.32 mm) of the fruit, number of fruits per plant (142.32), total fruit yield (31.31 t/hectare**) (Singh *et al*., 2015)**. In treatment of tomato different hormones combination used are GA3, NAA and 2, 4-D at specific concentration (GA3 at 30 ppm, NAA at 30 ppm and 2, 4-D at 5 ppm) showed an effective result by increase the weight of fruit and increases total yield up to 523 q/h in tomato **(Tomar *et al*., 2016). Singh *et al*., (2005)** reported that as GA rates increased the plant height, number of branches per plant, plant spread, stem girth, leaf area, and yield per plant and yield per hectare increased.

**Effect of formaldehyde**

Effect of formaldehyde on some post-harvest qualities and shelf life of mango, litchi and oyster mushroom was studied by **Antora *et al*., 2018**. They reported changes in texture, color, and weight loss were assessed during the storage of samples which were treated with unrelated concentrations of formaldehyde solutions i.e., 0%, 1%, 5% and 10% for a period of 15 minutes. These samples were observed at every another day and loaded in transformed airspace. Hence, no advantages were developed over the control after served with unrelated concentrations of formaldehyde on the served samples of litchi and mango. Rather, fruits went for rapid degradation. Higher the mass of formaldehyde faster was its degradation. No remarkable change in weight loss of the fruits was noticed. However, treated mushrooms showed enlarged shelf-life and earned an elastic texture. The study concluded that formaldehyde is not an applicable preservative to magnify the shelf-life and post-harvest quality of fruits and vegetables.

**Effect of oxytocin on fruits and vegetables**

**Chandravathi *et al*., 2016** carried out a study based on detection of oxytocin which is a schedule H drug, normally used in fruits and vegetables to increase its size. It is difficult to identify the difference between a normal grown crop and one treated with oxytocin thus by using a wireless sensor, the presence of oxytocin in the fruits and vegetables can be easily detected. This technique can amplify comprehension of surviving examination, advanced novel systems through which oxytocin may work and refine prediction regarding oxytocin pharmacotherapy. This technique can be applied in the field of production of milk and in the field of Agriculture. In this Study, detection of oxytocin in bovine skim milk at very low concentrations is done by a sensitive EIA which is based upon the second antibody coating technique.

In this study, five different fruits and vegetables (pumpkin, watermelon, cucumber, bottle gourd, and brinjal) were used as a sample. A new sensitive solid phase extraction (SPE) - LC-MS/MS ESI technique was established with a satisfactory complete analytical performance resulted in the estimation of oxytocin in fruits and vegetables. **(Satpathy *et al*., 2011)** described this method as selective, sensitive and precise with a limit of quantification which was ranging between 0.039-0.050 ng. The samples were collected from the Agricultural Produce Marketing Committees of Delhi, India in which the concentrations of oxytocin were below the decision limit (CCα). The oxytocin spiked vegetables cooked at 110° C for a period of 30 minutes reduced its concentration level by 88 % for the bottle gourd and by 64 % for the pumpkin. The results were found below the decision limit and negligible for the investigated market samples. Thus from this study, it was found that oxytocin content in the samples was low and not observed after the cooking.

Fourier- Transform Infrared Spectroscopy (FT-IR) used for rapid, high-throughput screening potential and quantitative determination of adulteration in orange juice. Experiments were undertaken in triplicate and about 41 samples were obtained. Level of adulteration is quantified with the help of Partial Least Squares Regression (PSLR) and Principal Components-Discriminant Function Analysis (PC-DFA). **Ellis *et al*., 2016** showed that with help of this technique, the quantification and discrimination between three sugars present in orange juice to disguise adulteration through dilution was identified. Further, it was concluded that the combination of FT-IR and PSLR helped in the prediction of adulteration present in orange juice with great accuracy.

To enhance milk production from animals and increasing the growth rate of fruits and vegetable oxytocin is used as an adulterant. The estimation of oxytocin level in fruits and vegetables, High-Performance Thin Layer Chromatography or HPTLC is proved to be a reliable, safe and cost-effective technique. **Rani *et al*., 2013** carried out the standardization of HPTLC method for the estimation of oxytocin in the edibles which was based upon the simulation parameters of the stationary phase (Silica gel), mobile phase (MeOH: Ammonia) having pH 6.8 and the saturation time (5 minutes). By testing its limits of detection, accuracy, repeatability, quantification, precision, and linearity the method was validated. Thus it was concluded in this study, that this proposed method is specific, rapid, simple, and economical and was successfully used in the quantity and quality checking of oxytocin level in the edibles such as fruits and vegetables. In this study samples of milk, fruits and vegetables were used in which maximum adulteration was observed in the samples of vegetable, whereas, it was found that maximum amount of the oxytocin was present in the watermelon (75.25 μg/Kg) and the lowest amount of oxytocin was present in the sample of milk ( 39.10 μg/kg).

The potential role of neuropeptide hormone Oxytocin in Cancer was summarized by **Lerman *et al*., 2018**. In this study, special importance on prostate cancer was given, where it encourages cell proliferation. The study suggested that Oxytocin may have severe effects on the level of hormones, cell types, interactions of various hormones in the microenvironment. The study also concluded that there is more need for future research on oxytocin in relation to cancer.

**Effects of plant hormones on human health**

Plant hormones also affect the human health by affecting human gut microbes or food intake which causes a several harmful diseases such as diabetes (it caused more by the synthesis of ABA hormones in human and by retinoic acid), inflammatory bowel disease (IBD), gestational diabetes and cancers **(Lin *et al.*, 2011).** By releasing of insulin it affects the glucose homeostatsis and glucose uptake (**Magnone *et al.*, 2015).** Cell division is also affected by the dietary plant hormones. Releasing of proinflammatory interleukins showed the anti-inflammatory properties by intake of GAs **(Reihill *et al.*, 2015).** Immune system should be affected by the secretion of microbial compounds due to the diet which contains the microbes **(Maslowski *et al.*, 2011).**

**Different plant hormone analysis methods**

There are several methods which are used for the analysis of plant hormones such as Nuclear magnetic resonance spectroscopy (NMR) (provided the complete structural information i.e. identification of sugar location in conjugate hormones). **Muller et al., 2002** reported that GC-MS/MS mass spectrometry (MS) (used for the quantification and identification of the plant hormones) High-Performance Liquid Chromatography (HPLC) (by segregating the mixture of compounds and target the hormones by solid-phase extraction technique), combination of HPLC and ESI-MS also used (with the positive and negative electrospray ionization-tandem mass spectrometry) to identify the complex structural compound. Solid-phase extraction (SPE) (by anion-exchange retention with DEAE-cellulose sorbent i.e. diethylaminoethyl cellulose) **(Astot *et al.*, 2002),** electrochemical techniques (by pH and solution medium electrochemical behavior is affected) **(Li *et al.*, 2002).** Biosensors are also used now a days for the analysis of plant hormones (the high sensitivity, real-time detection and continuous dynamic monitoring). Radioimmunoassay (RIA) and enzyme linked immunosorbent assay (ELISA) used for the determination of plant hormones (by the particular Ab-Ag binding property) **(Yong *et al.*, 2002).**

## CONCLUSION

The plants contain several natural plant hormones which showed effective results in plant growth and development. PGRs are capable of increasing fruit size, height of plant, flowering and also improve the crop production. But the residue of these adulterant and PGRs in fruits and vegetables have health effects such as diabetes, inflammatory bowel disease (IBD), gestational diabetes and cancers. However, human health is a first priority, therefore, there is need to detect plant growth regulators in agriculture production. Several techniques are used for the detection of PGRs residue in agriculture product include HPLC, LC-MS, GC-MS and NMR.

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