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A REVIEW

Effect of plant growth regulators on crop production

Masina Sai Ram*, Sagar Maitra **and** Tanmoy Shankar
M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi (Odisha) India (Email: sairammasina52@gmail.com)

Abstract : Plant growth regulators are the naturally extracted or synthesised compounds which are used in smaller quantity to modify the hormonal activity in agricultural and horticultural crops. Though there effect was not totally revealed there was some significant works carried out to know the effect of growth regulators on agronomic crops they are now using in wide range of crops to alter different parameters such as plant height, canopy development, effective branching, flower imitation and improving yield. They also play a key role in dryland farming as some of the plant growth regulators are used in stress tolerance of the crops. Few research works are carried to know the effect of major plant growth regulators on cereals and pulses. The plant growth regulators like auxins, gibberellins, cytokinins and ethephon are the majorly used plant growth regulators in cereals and pulses to obtain optimum plant growth and to improve the yields.

Key Words : Plant growth regulators, Auxins, Gibberllic acid, Cereals, Pulse

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INTRODUCTION

Plant growth regulators are the compounds that effects the biological processes of plantsat lower concentrations. Any compound thatinfluence by increasing or decreasing the growth and productivity of the plant bychanging their biological processes are known as PGR (Fishel, 2006). When they are produced inside the plant, they are called plant hormones, but when externally they are used as both natural and synthetic compounds to play the same role as hormones they are called PGRs (Avery, 1937). Plant growth regulators (PGRs) or phytohormones are non-nutrias chemical substances generated spontaneously in plants. In reaction to their surroundings, all plants create hormones that regulate their growth, development and metabolism. Hormones are produced in a variety of areas, including roots, buds and leaves, and then transported to specific locations after connecting with certain receptors (Rademacher, 2015). Hormones impact plant responses to stress by controlling cell division, cell elongation, and cell differentiation. Only a few hormones have the potential to control plant growth. These hormones are found in low quantities in plant tissue, which makes isolating, identifying, and extracting sufficient amounts for laboratory studiesdifficult. Similar processes, such as the development and growth of buds, flowers, fruits, and roots, may be regulated by synthetic hormones Flasinski and Hac-Wydro (2014). As a result of these discoveries, synthetic hormone products are now being

***Author for correspondence:**
[1]Indian Institute of Rice Research, Rajendra Nagar, Hyderabad (Telangana) India

produced commercially, also known as plant growth regulators (PGRs).Plant growth regulators are frequently employed in agriculture, viticulture and horticulture to boost yields and ease of harvesting in non-ideal or stressful Harms and Oplinger (1988). Along with that these plant growth regulators are also having promisable effect on agronomic crops in various aspects such as improving yields, controlling the growth and crop canopy also they are major used in stress conditions to support the crop growth by altering some physiological and morphological conditions. Some of themajor growth regulators includes Auxins, Cytokinins, Gibberellins, Abscisic acid, Ethylene, Brassinosteroidsetc.

Important growth regulators used in crop production:

Auxins :

Although there are cases of auxin-induced cell division, auxins typically govern growth through cell expansion. They have the potential to function as both growth stimulators and inhibitors, causing various plant components (shoots, buds, and roots) to respond in different ways. The auxin-like herbicide 2,4-D, for example, induces cell expansion at low doses but inhibits or is harmful to cells at larger quantities. Auxins also promote cell differentiation, root formation on plant cuttings, and the development of xylem and phloem tissues.Auxins are phytohormones that are generated in the shoot and root apices and move from the apex to the elongation zone. Auxins stimulate plant development along the plant's longitudinal axis. Auxin is a word used by Morgan and Gausman(1966) to describe plant hormones that are particularly concerned with cell expansion or shoot development. The only auxin found naturally in plants is indole acetic acid (IAA). As a result, an auxin may be described as an organic molecule that stimulates growth (i.e., irreversible growth) along the longitudinal axis when given in low concentrations to shoots of plants that have been liberated as much as possible from their own inherent growth promoters. Other characteristics of auxins may exist, and they usually do, but this one is crucial (De wilde, 1971). They promote growth when applied at low concentrations while inhibiting growth at high concentration application. They are known for inducing plant cell expansion and stem elongation. They are also involved in the growth of plant branches and are linked to apical dominance.Auxins were considered to have only major function is to stimulate cell growth. However, further research has revealed that they are intimately linked to a wide range of functions. They operate as a stimulant in certain situations, an inhibitor in others, and a required participant in the growth activity of other phytohormones like gibberellins and cytokinins. The auxins (both natural and synthetic) have a part in a variety of growth processes.

Gibberellins :

Gibberellic acid is the most well-known gibberellin (*i.e.* GA_3). Gibberellins are plant endogenous growth hormones that are produced in response to various developmental or environmental stimuli Iqbal and Ashraf (2013). Gibberellins were first discovered in a fungus called "Gibberella," and since then, they've been found in a variety of plant regions with active development. Different gibberellins have been given names based on the sequence in which they were found (GA1-GA7). As a result of their direct impact on ribonucleic acid and protein synthesis in plants, gibberellins are known to govern stem internode elongation, grass leaf elongation, general cell elongation, and cell division in plant shoots. However, the exact method of action and site of biosynthesis of gibberellins remain unknown (Harms and Oplinger, 1988; George *et al.,* 2008; Hamayun *et al.,* 2010 and Kaur *et al.,* 1998). As a result, the plant exhibits stimulation in longitudinal growth that happens as a result of meristematic tissue formation. Gibberellins develop in this manner in response to light stimulation. The presence of significant quantities of gebberellins in pollen demonstrates that it is capable of controlling floral development and growth, as well as seed fertility Small and Degenhardt (2018). Direct administration of bioactive gibberrellins to an aberrant plant lacking viable pollen resulted in the production of normal flowers. This plant-produced growth hormone is also present in seeds and is important in breaking seed dormancy (Greipsson, 2001 and Zhang *et al.,* 2006). Gibberellins, when given externally to developing seeds, have also been found to have a role in breaking seed dormancy, even when the external circumstances are stressful, harsh, or unfavourable. Under the influence of gibberellins, the induction of hydrolytic enzymes and nutrients improves the growth potential of a developing seed. Given the slow germination and establishment of native plants, even a few days of seed germination has been shown to be beneficial in grass establishment Juska (1958). The usage of gibberellic acid for breaking seed dormancy is being explored by several ways before being evaluated for viability and germination of seed. This allows for a more accurate and thorough evaluation of seed quality Tuna *et al.* (2008). Gibberellic acid has also been shown to reduce or even reverse the effects of water stress on seed germination and seedling development. Furthermore, in the event of salt stress on soya beans, Gibberellic acid is known to alleviate the negative effects, which not only restores normal growth but also aids in subsequent development. A research found that GA3 prevents plants from growing and developing normally under salty environments by increasing membrane permeability and boosting nutrient absorption. GA3 modulates ion accumulation and partitioning in plant tissues when administered as a pre-sowing treatment (100 mg/l), resulting in a decrease of stress induced by increased osmotic pressure Iqbal and Ashraf (2013). Seed priming with GA3 (15 dS/m) increased plant biomass (dry weight), grain production, and plant height of spring wheat cultivars under salty conditions (150 mg/l) is done. Gibberellins have an impact on plant nitrogen metabolism because they enhance soil-derived nitrogen re-distribution Khan *et al.* (2002). When mustard cultivars were sprayed at concentrations and rates of 105 M and 600 L/ha, respectively, the vegetative portions and seeds showed enhanced nitrogen build up and hence increased nitrogen partitioning into seeds Khan *et al.* (2002). As a result, gibberellins might be an unique nitrogen-use efficiency product.

Cytokinins :

The term cytokinins refers to all naturally occurring chemicals that have been shown to stimulate cell proliferation. Letham coined the phrase "cytokinin" (1963). They are also known to postpone the onset of senescence. Zeatin, the first naturally occurring cytokinin, was discovered in corn. Synthetic benzyladenine and kinetin are the most commonly dispersed cytokinins. They also playresponsible role in organ development, such as the production of leaves, fruit, buds, and branches. A phytohormone called "Cytokinins" is produced spontaneously by meristematic tissues and organs (*i.e.*, shoot apex, immature organs, root tips) of a growing plant Osugi and Sakakibara, (2015). There are around 20 cytokinins found naturally in plants. The direct influence of cytokinins on protein synthesis, which is known to be involved in mitosis, has a significant impact on plant cell division. In the absence of Cytokinins, the cell cycle has been seen to come to a halt George *et al.* (2008).In contrast to auxins, which are involved in apical dominance, cytokinins stimulate lateral plant development, which includes the formation of lateral shoots and lateral roots Rademacher, (2015). Cytokinins increase protein synthesis, amino acid transport, cell enlargement, cell division, and senescence, which promotes the production of shoots from internodes, choloroplast maturation, start of callus formation, spreading of thick roots, and release of buds in dormancy (Harms and Oplinger, 1988). As a result, cytokinins have an impact on a plant's whole life cycle. This phytohormone also regulates a plant's response to many stimuli, including water availability, light, nutrients, abiotic stressors, and biotic stressors. This modulation of response to stimuli occurs via protein synthesis signalling, cell degradation and increased production of protective enzymes such as antioxidants George *et al*. (2008). When synthetic or natural cytokinins were given to plants, they showed mobilisation of nutrients to a specific application site Werner *et al.* (2001). Direct administration of cytokinins to leaves, for example, resulted in a decrease in protein and chlorophyll breakdown. In the case of latent buds, cytokinin administration has been linked to early bud development Werner *et al.* (2001). As a result, cytokinins play a bigger part in the early vegetative phases of the plant and their impacts may be seen and measured in the developmental period when they're used. A balanced ratio of cytokinins and auxins must be applied to the plant. Auxins can limit cytokinin accumulation and cytokinins can influence auxin activity if a balance in the amounts of two hormones is not maintained George *et al*. (2008).

Abscisic acid (*ABA*) :

ABA are the growth regulators which regulatory influence on abscission and dormancy, they were previously known as Dormin or Abscisin. This hormone is widely distributed in higher plants and may be detected in a variety of organs and tissues (both old and young). ABA causes the leaves of a wide range of plants to abscise, as well as the fruits of some plant species. Seed germination is inhibited or delayed by ABA. A wide range of plant tissues and organs, including leaves, coleoptiles, stems, hypocotyls, and roots, are inhibited by ABA. It accelerates the breakdown of chlorophyll and induces senescence by leaf abscission, degeneration of excised leaves and leaf abscission. Abscisic acid integrates and controls stress signals and reactions during a variety of physiological changes and environmental circumstances Tuteja (2007). When plants are subjected to abiotic environmental stress, such as drought, low and high temperatures, salt, and flooding, ABA is biosynthesized, and ABA synthesis drives plant acclimatisation and stress tolerance (George *et al.*, 2008; Hamayun *et al*., 2010; Tuna *et al.*, 2008; Tuteja, 2007 and O'Brien and Benkova, 2013). Some phytopathogenic fungus, such as Botrytis cinerea and Cerosporarosicola, have been found to produce abscisic acid. Botrytis cinerea Rademacher (2015) is used to extract ABA for use as an external application to plants. When ABA is produced endogenously by plants, it reduces plant development and causes alterations in cellular membrane permeability, as well as water and nutrient absorption. ABA has the ability to regulate drought conditions by influencing stomatal conductance in leaves, which lowers total intercellular water loss and transpiration Rademacher(2015). Guard cells receive ABA signals for the closing of stomata directly for this function. In good conditions, ABA aids the plant in overcoming stressful situations and initiating the seed germination and development process Tuteja (2007). In the absence of abscisic acid, the plant fails to recover from environmental stress wilt, resulting in delayed growth and eventual mortality Tuteja (2007). Freezing tolerance and osmotic stress, leaf abscission, regulation of protein encoding genes, controlling ion and water uptake by roots, seed dormancy, protein and lipid synthesis for storage purposes, defence against pathogens, control of gene expression in developing embryos and during maturation, growth and morphogenesis of tissues are just a few of the other regulatory functions of ABA (Flasinski and Hac-Wydro, 2014; Small and Degenhardt, 2018 and Aguilar *et al.*, 2000). Plant tissues generate more abscisic acid in response to abiotic stress, which starts signals, activates signal pathways and regulates gene expression modification, resulting in plant adaptation to harsh environmental circumstances O'Brien and Benkova (2013). When abscisic acid is given topically to the plant in the form of a spray, the plant produces more of it (through -carotene and several enzymatic processes) to imitate stressful conditioned effects (Tuteja, 2007 and Watts *et al.,* 2000).

Ethylene :

This is a simple gas generated in minute amounts by various plant tissues, and it acts as a strong growth and development regulator. They are abundant in physiologically developed fruits that are about to ripen. Ethylene is produced by plant tissues that play a function in plant growth control. Ethylene's ability to control plant growth and development is influenced by the amount of cytokinins, ABA, carbon dioxide, light, and auxins present in the plant. Ethylene regulates plant maturity and acts as an earning ageing hormone Schaller (2012). In certain plants, active cell division produces ethylene as a by-product, which regulates cell size. Plant biosynthesis of ethylene, which not only plays a role in auxinsynthesis but also in its metabolism and transport, has been linked to increased production of plant-derived auxins (Rademacher., 2015; George *et al.*, 2008 and Reinecke, 1999). Plant roots are said to produce more ethylene when cytokinin levels rise O'Brien and Benkova (2013). Regulation of cellular division, size and stolon development, blooming, fruit ripening, stimulation of root initiation, secondary metabolite modulation and overall plant growth are all major regulatory activities of ethylene in plants. Drought, salt, plant wounding, and toxicity are all environmental stressors that cause ethylene synthesis in plants (Hamayun *et al.,* 2010 and Rajasekaran and Blake, 1999). When ethylene accumulates in plants at high levels, it has a detrimental impact on the plant because it causes cellular membrane integrity to deteriorate and leaking through the membrane. As a result, the quantity of ethylene present in a plant may be used to assess plant stress. Ethylene is also known to control primary and secondary dormancy breakdown, as well as seed germination, under both stressed and normal circumstances Adkins and Ross (1981).

Brassinosteroids :

Hormones, which are steroids in nature, are produced by some plant types and are capable of controlling plant growth and development. "Brassinosteroids" is the name given to these steroid-based hormones Khripach *et al.* (2000). In plants, more than 60 distinct forms of this hormone have been discovered, but only 19 have been identified. Brassinosteroids are known to be discovered in plant tissue at extremely low quantities yet they are thought to be fundamentally present in the plant world. Brassinosteroids were shown to be active in rice and bean at concentrations of 0.5 ng and 10 ng in a research Rao *et al*. (2002). This implies that using low doses of this hormone to achieve targeted plant growth may be advantageous. Only 5–50 mg/ha of brassinosteroids can significantly improve agricultural plant growth when used exogenously. Because extracting biosynthesized brassinosteroids in tiny quantities is an expensive procedure, chemically manufactured analogues of biosynthesized brassinosteroids are presently being researched and patented. Brassinosteroids are present in the highest quantities in the plant's developing tissues (*i.e.*, shoots, roots) and reproductive organs, although their exact method of action in these areas is unclear. Brassinosteroids are reported to be secreted in greater quantities in shoots than in roots Clouse and Sasse (1998). Rhizogenesis, seed germination, blooming and senescence, as well as abscission and maturity, are all growth and developmental processes controlled by brassinosteroids. Basic cellular activities such as nucleic acid and protein synthesis, cellular fission, and cell elongation are all influenced by brassinosteroids. Furthermore, they have a function in regulating fatty acid (including membrane integrity) and amino acid composition, as well as enhancing product translocation, in order to maintain a balance among other phytohormones. Brassinosteroids allow plants to resist abiotic and biotic stress, enhance fruit quality and quantity, improve fertilisation, boost aboveground biomass, and reduce their growth cycle Small and Degenhardt (2018).

Effect of plant growth regulators:

Effect of plant growth regulators on cereals :

The cereals have been detected in plant growth regulators such as gibberellins, auxin, cytokinins and abscisic acid. Several plant hormones have been discovered to influence seed germination in cereal plant species (Nickell, 1982). Gibberellins stimulate the principal occurrence of breaking seed dormancy. PGR mainly help in that regulate the stomata closing during moisture stress, chemicals that make a water-barrier film layers over the lower and upper surfaces of leaves in plants and reduces the plant growth and increase the root to shoot ratio to minimise water consumption by the plants (Elankavi *et al*., 2009). In major cereals like maize and rice ABA helps in seed-filling and it is directly related to the yield of the crop (Qin *et al.,* 2013). The increased seed filling rate in superior seeds is mainly owing to higher ABA content than inferior seeds and ABA has significant effects on top and lower seed filling in rice (Zhang *et al.,* 2012). Also the growth regulators effect positively in crop logging some studies says that the application of uniconazole and ethephon can reduce lodging and protect plants from various stresses (Tripathi *et al.,* 2003). In rice Foliar application of Gibberellic acid in early stage shown increase in inter-node length but during the later stage there is no significant variation in inter-node length after 2nd and 3rd application (Gavino and Abon, 2008). In rice yield attributes and yield were observed superior with foliar application of GA3 (200ppm) (Bora and Sarma, 2006). In wheat and barleysome of the growth parameters like leaves/plant, plant height and tillers/plant were found to be improved in application of 100 and 200ppm naphthalene acetic acid (NAA) (Jahan and Adam, 2013). In rice the use of different plant growth regulators considerably increased seed yield by application of GA3 and NAA. This application of PGR also significantly affected the yield components as well (Tiwari, 2011). In rice and maize GA3 also increased the yield components, yield and harvesting index of the crop. Some studies also show that gibberellin application during the pollination stage improved the yield of Zea mays (Stuart and Cathey, 1961). Both the PGRs (CCC and ethephon) have been used to reduce plant height significantly compared to non-application in winter wheat Dahnous *et al.* (1982) The PGR treatment plants (CCC or ethephon) showed greater yields of grain compared with control plants. Although the use of both PGRs boosted grain output, this growth in yield was the consequence of greater spikes m^{-2}due to a higher tiller survival in CCC treating plants (Acharya *et al.*, 1990).

Effect of plant growth regulators on pulses :

Generally Pulses are effected from low germination percentage due to abiotic factors such as soil salinity, sensitivity to moisture regime etc. Application of PGR can help in overcoming these stresses and increasing the germination percentage of seeds Hoque *et al.* (2002). The research says that the brassinolide application (0.4 ppm) significantly increased green gram germination with maximum germination percentage of (100 %). It also resulted in higher seedling growth (1.43 cm) and relative root elongation (134.5 %). In general, brassinolides are known to enhance seed germination and cause elongation of hypocotyls, epicotyls and peduncles in dicots Chang and Cai (1988); Dong *et al.* (1989) and Hayat *et al.* (2003). Akbari *et al.* (2008) reported that application of gibberelic acid (GA3) showed significant improvement in green gram germination and yield attributes in saline conditions. Chauhan *et al*. (2009). The GA3 application for pea done by Thomson *et al.* (2015), revealed that the vegetative growth had been early completed and plants had better feed after application of the growth regulator. However, after application of the growth regulator, delayed maturity was also observed in chickpea, Upadhyay (2002). With kinetin application and equivalent to higher grain/pod, plant pod, stover yield and seed yield. Ganiger *et al.* (2002) found the effect of [GA3 + abscisic acid (ABA)] on different characters of black gram and confessed that (1.0 ppm) application resulted in significantly higher number of leaves per plant and leaf area index (LAI) at all growth stages, which ultimately lead to higher number of pods per plant and seed yield. Similar result was obtained in soybean (*Glycine max* L.) with 2, 3,5-tri-iodobenzoic acid application. This helps in stimulating photosynthesis due to higher assimilative area production which helps in ensures better growth, development and higher yield. Parmar *et al.* (2012) said that the GA3 (20 ppm) applied at 20 and 40 days after sowing (DAS) significantly increased number of leaves per plant in green gram. Application of mixtures of abscisic acid (ABA) and gibberellic acid (GA3) promoted flower bud initiation and flowering in long-day plants (kamuro *et al*., 2001). Application of NAA @ 20 ppm in black gram was effective in improving the increase relative chlorophyll content and photosynthesis Reddy *et al*. (2009). Rao *et al*. (2002) observed that application of 1.25 ppm Tricontanol (TRIA), 0.2 in chickpea resulted in high flower setting and seed yield.Tripathi *et al.* (2003) determined the effect of growth regulators on flower drop, growth and yield of pigeon IAA @ 25 and 50 mg litre-1, Kinetin @ 5 and 10 mg litre-1 and NAA @ 25 and 50 mg litre -1was done twice at 35 and 75 DAS resulted in improving flower production and pod setting in pigeonpea.

Conclusion :

Plant growth regulators are having a major role in crop production but the utilization of specific compounds for cereals and pulses are yet to be revealed. Though different plant growth regulators are effective in stress tolerance of cereals and pulses they are not much using in commercial agricultural practices due to lack of awareness on application of plant growth regulators. Along with proper nutrient management practices the use of growth regulators should be included in cultural practices with proper norms so that it helps in improving crop productivity.

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