Plant Growth Regulators

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Growth is an important factor of living organism defined as a permanent and irreversible change in size or volume of a living structure.

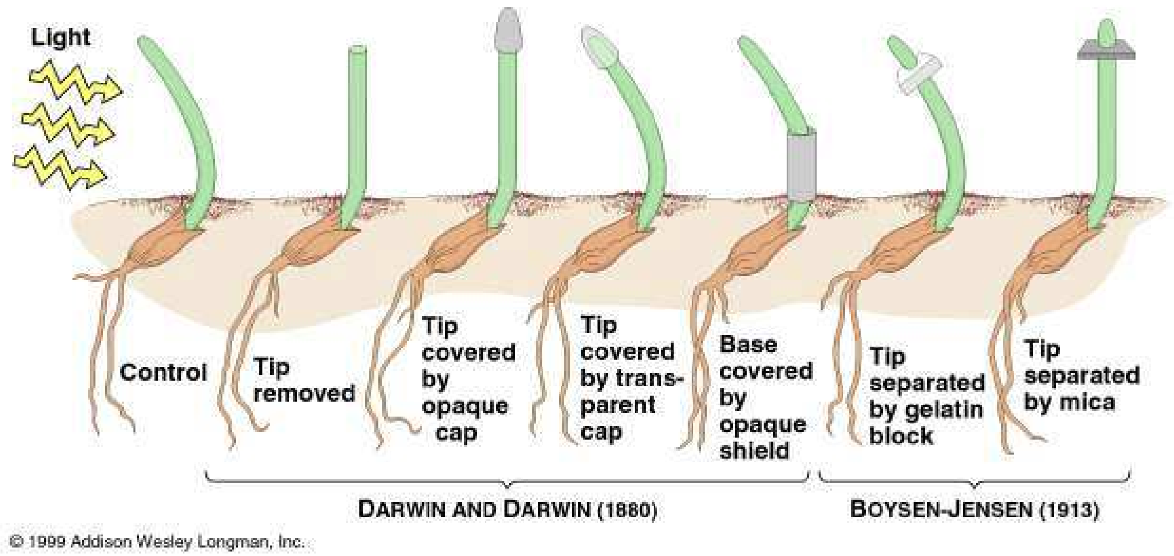
Growth is always seen in meristem present in stem tips and root tips, growth at this region referred as primary growth. Development in height and appendages are due to primary growth *i.e.*, meristamatic tissue growth. The development in size i.e., circumference by lateral meristems called secondary growth.

Growth Regulators: It is now recognized that all most all physiological activity of the plant is regulated by a variety of chemical substances called hormones. The term hormone was first developed by animal physiologists and defined as A chemical substance manufactured by a local group of specialized cells, which enters the blood stream and regulated the activity of distinct parts or tissues. Also, thought this may happen in plants and called as phytohormones or plant hormones and this phytohormones are regulators produced by plants which in low concentrations regulates plant physiological process. Hormones usually move within the plant from a site of production to a site of action.

The presence of growth regulating hormones in plants was first suggested by Julius Von Sachs in the later half of the 19^{th} century, when he reported that there were organ forming substances in plants i.e., flower forming substances, root forming substances, stem forming substances which were produced in the leaves and translocated downward in the plant. But he could not extracted organ forming substances. Hence work was not accepted by contemporary physiologists.

Charles and Francis Darwin in 1880 studied the effect of gravity and unilateral light on the movement of plants *i.e.*, trophic movements of plants. Darwin used canary grass (*Phalaris canariensis*) and he found that when he exposed the tip of coleoptiles to a unilateral source of light, the coleoptiles bend towards the light. But when either the tip of the coleoptiles cut or covered with tin foil to exclude all light from the area, the coleoptiles was insensitive to light and did not bend. In other words the decapitated coleoptiles or/and tip covered with tin foil did not bend because light was fully excluded to the tip.

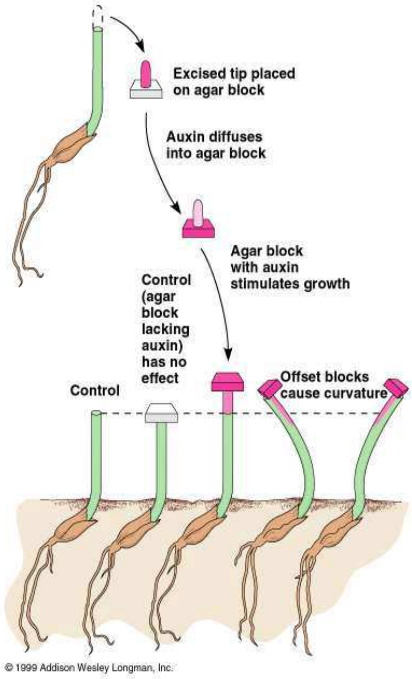
He suggested that plant growth might be under the control of special substances. He was able to demonstrate that the effects of light and gravity on the bending of roots and shoots are mediated by the tip. He concluded that when seedlings are freely exposed to a lateral light some influence is transmitted from the upper to the lower part causing the latter to bend. With respect to geotropism of roots he concluded that it is the tip alone which acted on and that this part transmits some influence to the adjoining parts causing them to cause downwards.



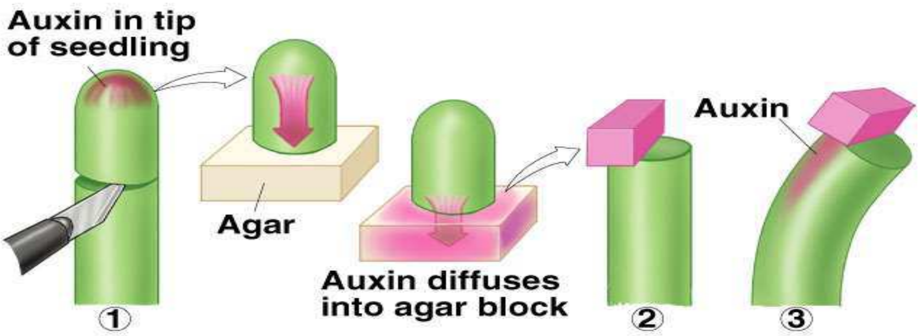
In 1920 Boysen-Jensen gave actual proof of the nature of plant growth regulators. When he decapitated coleoptiles few millimeters from the tip, put a gelatin plate on the stump, replaced the tip and illuminated the coleoptiles unilaterally above the incision, curvature towards the light progressed as in the intact coleoptiles. He also demonstrated that one could interfere with the normal phototropic bending of the plant by making a transverse slit halfway through the coleoptiles below the tip on the dark side of a unilaterally illuminated grass seedling and inserting a piece of mica in the slit. Inserting the piece of mica on the illuminated side of the seedling produced no such interference giving evidence that the stimulus fro bending passes down the dark side. There is no curvature.

Although Boysen-Jensen demonstrated that some substance, which originates in the tip, is responsible from the bending of unilaterally illuminated coleoptiles toward the light, he did not claim originally that this substance was a growth regulator.

Paal 1919 decapitated coleoptiles replaced the tip asymmetrically and discovered that the coleoptiles bent away from the side with the tip, even in dark, Paal’s experiments strongly suggested that there was a material substance transmitted from the tip which could stimulate growth of the cells below the tip



F.W.Went in 1928 replaced freshly cut coleoptiles tips on small blocks of agar for a measured periods (2h) and then placed the agar blocks asymmetrically on decapitated coleoptiles for 2 hours in dark. The coleoptiles exhibited a curvature similar to that obtained when coleoptiles tips were placed asynetrically on coleoptiles stumps. Went found that the degree of curvature of the coleoptiles is proportional to the amount of active substance in agar blocks.



Because of the use of Avena plant this bioassay is subsequently became known as the Avena curvature test.

Application of the Avena test to a great variety of substances led to the finding that human urine is rich in growth substances. Starting with 33 gallons of human urine Kogl and Haagensmith concentrated the hormone activity by employing a series of purification process. The activity of the products of each purification step was determined by Avena curvature test. After distillation in high vacume, the final step yielded 40 mg of crystals that had a specific activity 50,000 times of the original urine. The final product was given the name Auxin A (Auxentriolic acid). Using the same purification methods another active substance was isolated from the corn germ oil. This substance was found to be very similar in structure and activity to Auxin A and was given the name Auxin B. In the same tear still another substance was isolated from human urine and it is known today Indole-3-acetic acid (IAA).

Physiological effects of Auxins: Since the discovery of auxin and its identification as a growth hormone an enormous amount of literature has accumulated describing its effects on the growth of the plant. In some cases auxin is stimulatory, in other inhibitory and in still other cases a necessary participant in the growth activity of another plant hormone like Gibberellins and cytokinins. The involvement of auxins in plant physiology is

Cell elongation/ enlargement: May be due to increase the osmotic content of the cell, increased permeability to water, reduction in wall pressure, increase in wall synthesis or inducement of specific RNA and protein synthesis.

Callus formation/Cell division: Auxins support the cell division, promotes the differentiation of xylem and other fibers.

Phototropism: When a growing plant is illuminated by a unilateral light it responds by bending toward the light. The bending of the plant is caused by cells elongating on the shaded side at a much greater rate than the cells on the illuminated side. This differential growth response of the plant to light called Phototropism**.** it is caused by an unequal distribution of auxins. The higher concentration of the growth hormone being on the shaded side. This unequal distribution of auxin could be accomplished by light induced inactivation of auxin, lateral transport of auxin or inhibition of basipetal transport of auxin.

Geotropism: If an intact seedling is placed in a horizontal position it will respond to the earths gravitational field with a particular pattern growth. Growth of the stem under these circumstances will cause it to curve upward until it is vertical again and the root system will curve downward until it too s vertical again. Accordingly we refer to the stem as an organ which exhibits negative geotropism and to the root as an organ which exhibits positive geotropism. Like phototropism the geotropism response is controlled by unequal distribution of auxin but unlike phototropism gravitational pull instead of light is the influencing factor in geotropic auxin distribution.

The accumulation of auxin on the lower side of a horizontally placed stem cause an accelerated growth to occur on the out side causing the stem to curve upward. The horizontally placed root, however will exhibit a positive geotropic response even though auxin concentration on the lower side is higher. Roots are much more sensititive to IAA than stems and the concentration of IAA which stimulate cell elongation in stems are actually inhibitory to cell elongation in stems are actually inhibitory to cell elongation in roots. The accumulation of auxin on the lower side of a horizontally place would retard cell elongation on that side. The higher concentration of auxin in base of coleoptiles which makes coleoptiles to grow upwards for stem and downwards for roots. The root cap secrets abscissic acid will inactivate the auxins at root region. No abscissic acid in stem portion so it grows upwards or negatively geotrophic.

Apical dominance: The dominance of apical over lateral growth is seen in many species of plants, that the apical or terminal bud of many vascular plants was very active in growth, while the lateral buds remained inactive. The apical dominance might be because of large quantity of auxin produced at the terminal bud and transported through the stem.

Root initiation: The action of auxin in roots is similar to that in stems, but that the concentration of auxin stimulatory to stem growth are inhibitory to root growth. In other words roots are much more sensitive to auxin than stems and real stimulation of root elongation may be achieved if low enough concentration is used. The application of relatively high concentration of IAA to root not only retard root elongation but causes a noticeable increase in the number of branch roots. IAA in lanolin paste can be used to promote root formation in cuttings of economically useful plants EG., Exotic mulberry varieties.

In addition auxins induces abscission (immature falling of laves, fruits, flowers etc.,), stimulatory effect of respiration and parthenocarpy.

Gibberellins: Are another important kind of phytohormone which has found in 19^{th} century which had devastating effects on the rice economy of Japan. Japanese farmers noted that some plants were taller, thinner, and paler than their counterparts and sometimes were devoid of fruits and such plants they called as Bakanae disease or foolish seedling. Crop loss due to this disease as high as 40% were reported. During 1926 an extensive programme of research about the cause of bakanae disease was initiated. Japanese pathologists first demonstrated the connection between bakanae disease and the fungus called *Giberella fujikuroi (Fusarium heterosporum*). Sawada postulated that the disease may caused by something secreted by the fungus. This postulation supported by Kurosawa. He demonstrated that sterile filtrate of the fungus is capable of causing the symptoms of bakanae disease in normal/healthy seedlings. Finally in 1938 Yabuta and Sumuki were able to isolate the crystalline gibberellins. Brian *et.al*. imported fungi for investigation and to test the effect on healthy plants. Later West *et. al*., 1950 reported 3 gibberellins in higher plants. Later Cross *et. al*., 1961 identified 6 more gibberellins and named as GA1, GA2, GA3 … until now more than 80 gibberellins were discovered. They are present in very low concentration in plants *eg*., 100 sunflower buds can yield 0.001μg of GA.

Physiological Effects of Gibberellins: Gibberellins act similarly to IAA in that they promote cell elongation, induce parthenocarpy, promote cambial activity and induce the new RNA and Protein Synthesis In the following discussion we cover the influence of gibberellins on genetic dwarfism, light inhibited stem growth and mobilization of compounds during germination.

Genetic Dwarfism: One of the most striking properties of the gibberellins in their ability to overcome genetic dwarfism in certain plants. Genetic dwarfism is usually caused by the mutation of a single gene. This mutation may block in a metabolic pathway leading to the synthesis of gibberellins or some growth site involved in the biological activity of gibberellins. Generally this type of dwarfism causes a shortening of the internodes rather than a decrease in the number of internodes. For this reason when gibberellins is supplied to single gene dwarfism.

Light Inhibited stem Growth: When you comparing the stem growth of an etiolated plant (dark-grown) with that of a light grown plant will immediately conclude that light has an inhibitory effect on stem elongation. Application of gibberellins to certain plants growing in the light will greatly increase their stem growth. The ligh causes inhibition of stem growth by lowering the level of available gibberellins in the plant. This inhibition is overcome by applying exogenous gibberellins to the plant.

Parthenocarpic: Auxins not only the growth hormone capable of inducing parthenocarpy. Gibberellins are also have the capacity to produce parthenocarpic fruits or gibberellins are also induces parthenocarpic fruit set. In many cases gibberellins show higher activity than the native auxin in this respect.

Seed Germination: Gibberellins plays an essential part in the germination of cereal grains by mobilizing the storage compounds during germination.

Cytokinins: Haberlandt 1913 noticed soluble substance in the pith of potato tubers which processes the capacity to induce the cell division. Bonnor 1939 isolated the traumatic acid from bean fruits which can induce the meristamatic activity, when a tissue is injured. Similar kind of work was done by so many workers in tissue culture experiments. Skoog 1948 worked on the stem internode culture of tobacco plant. He analyzed the effect of auxin in the inter node culture. He noticed insufficient development of cell culture, after addition of soluble substance of potato pith he noticed normal development.

Miller *et. al*., 1955 isolated another substance from yeast and named as kinetin. It was effective in induction of cell division in very low concentration. Subsequent to its discovery, many analogous of kinetin, active in promoting cell division were synthesized.

Physiological Effects

In promotes cell division, cell enlargement, root initiation and growth, morphogenesis, apical dominance and breaking dormancy.

Ethylene: The importance of this was analyzed and reported about 75 years ago in plant physiology. It attracted the attention of plant physiologists due to promoting effect of fruit ripening activity. This ethylene is quite different in nature i.e., it is volatile. In the normal physiological temperature ethylene is a gas and compared to auxins, gibberellins, cytokinins and abscissic acid. Minute quantities of ethylene can cause dramatic change in the physiological activities of plant. It influences on fruit ripening, geotropism and epical dominance either alone or in concert with auxins. Also, ethylene is released from incomplete combustion of carbon like wood, coal, petroleum products *etc*.,

Physiological effects: In most fruits the rate of respiration will undergo sharp rise and fall near the end of development. This phenomenon was called climacteric rise. The term climacteric has been adapted universally. Before ethylene was identified as a natural plant product, it was noted with some surprise that ripening fruit gave off some volatile substance which accelerated ripening of other fruits stored nearby. This substance was soon identified as ethylene. Ethylene is present in very small amount but there is about a hundred fold increase just before or during climacteric. Finally application of ethylene to unripe fruit will bring on a premature climacteric and accelerate ripening thus it has been finally established that ethylene is a fruit ripening hormone.

Geotropism: A number of investigators found that low concentration of IAA and other auxins induce ethylene formation in the fruits, stems, flowers, roots and leaves of all plants. The possibility exists that most inhibitory effects of high concentration of auxin are due to excessive amount of ethylene being formed in the presence of abnormal quantities of auxin. *Eg*., in the intact plant a positive geotropic curvature is caused by the lateral movement of auxin to the side of a horizontally placed root; curvature occur because cell elongation on the lower side of the root is inhibited by the accumulation of high concentration of auxin. According to Burg and Burg this inhibition is not directly due to auxin but is actually caused by ethylene formed in response to the relatively high concentration of auxin. This conclusion is supported by the fact that CO_2 a competitive inhibitor of ethylene action, considerably reduces geotropic curvature in pea roots without inhibiting their overall rate of elongation.

Apical dominance: Ethylene is powerful inhibitor of bud growth and in this respect it may have a controlling influence on apical dominance inhibits root growth, swelling of stem, flowering of plant *etc*.,

Abscissic acid: This totally inhibits the growth f tissue so it can be called as growth inhibitor, inducing the promotion of senescence, retardation and inhibition of growth, promotes dormancy in buds and seeds.

Hemberg 1949 by using dormant potato he extracted abscissic acid and he noticed retarded growth or inhibition of growth. When he applied this on Avena coleoptiles and he concluded that it is an dormancy promoting substance. To break this he took extracts from non dormant potato and applied on same coleoptiles, he noticed the growth of the seedling.

Osborne 1955 extracted the abscissic acid using leaves of bean plant this cause premature dropping of young leaves and named it as dormin and abscission II from cotton seeds.
