Role of Growth Substances in Conservation Agriculture

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Conservation agriculture (CA) integrates ecological management with scientific agricultural production. CA promotes minimal disturbance of the soil by tillage (zero tillage), balanced application of chemical inputs (only as required for improved soil quality and healthy crop and animal production), and careful management of residues and wastes. CA Promotes application of fertilizers, pesticides, herbicides, and fungicides in balance with crop requirements. CA methods can improve the efficiency of input, increase farm income, improve or sustain crop yields, and protect and revitalize soil, biodiversity and the natural resource base. In short, CA methods enhance natural biological processes of the plant above and below the ground.

Plant growth substances have key role in different physiological processes related to growth and development of crops. It is obvious that changes in the level of endogenous hormones due to biotic and abiotic stress alter the crop growth and any sort of manipulation including exogenous application of growth substances would help for yield improvement or at least sustenance of the crop. The principles of CA can be well protected by judicious use of plant growth hormones. Plant growth hormones are organic substances produced naturally in the higher plants, controlling growth or other physiological functions at a site remote from its place of production, and active in minute amounts.

Hormones usually move within plant from a site of production to site of action. Phytohormones are physiological intercellular messengers that are needed to control the complete plant lifecycle, including germination, rooting, growth, flowering, fruit ripening, foliage and death. In addition, plant hormones are secreted in response to environmental factors such as abundance of nutrients, drought conditions, light, temperature, chemical or physical stress. Hence, levels of hormones will change over the lifespan of a plant and are dependent upon season and environment.

Traditionally five major classes of plant hormones are listed: auxins, cytokinins, gibberellins, abscisic acid and ethylene. However as research progresses, more active molecules are being found and new families of regulators are emerging; one example being polyamines such as putrescine or spermidine. This classification is based partially on the chemical structure and partially on the commonalities of plant physiological effects that certain substances exhibit. Members of one class may not relate from a structural point of view to another.

Auxins for instance include not only many indole 3-carboxylic acid derivatives but numerous phenylacetic acids as well. Most cytokinins (such as zeatins) are derivatives from adenine but still differ widely in their chemical structure. Hence, the mechanism driving action may be different in each case and likewise each specific activity will differ also. This is demonstrated by the range of optimal concentrations required for different factors which spans many decimals (0.001 – 100 mg/L).

The general functions of different phytohormones are given in the following table.

Class	Function(s)	Practical uses
Auxins	Shoot elongation	Thin tree fruit, increase rooting and flower formation
Gibberellins	Stimulate cell division and elongation	Increase stalk length, increase flower and fruit size
Cytokinins	Stimulate cell division	Prolong storage life of flowers and vegetables and stimulate bud initiation and root growth
Ethylene generators	Ripening	Induce uniform ripening in fruit and vegetables
Growth inhibitors	Stops growth	Promote flower production by shortening internodes
Growth retardants	Slows growth	Retard tobacco sucker growth

AUXINS

Auxin is the active ingredient in most rooting mixtures. These products help the vegetative propagation of plants. On a cellular level auxins influence cell elongation, cell division and the formation of adventitious roots. Some auxins are active at extremely low concentrations. Typical auxin concentration ranges from 0.01 to 10 mg/L.

Cell elongation: Auxin causes cell elongation by loosening of cell wall. The rigid cell wall becomes softened and its plasticity (irreversible capacity to stretch) increases. The loosening of cell wall begins due to dissolution of cell wall material, breaking of chemical bonds between cellulose and other wall materials, and fresh synthesis of new cell wall material and its incorporation into existing cell wall. The loosening of cell wall decreases the wall pressure (WP) which is equal to turgor pressure (TP). This action causes greater uptake of water and increase in the size of vacuole; and cell stretches.

Rooting of cuttings: When high concentration of auxin is applied to root, it not only retards root elongation but causes a remarkable increase in the number of branch roots. Application of IAA + linolin paste to the severed end of a young stem initiates the rate of root formation and develops large number of roots. This aspect has its commercial value.

Apical dominance: The suppression of the emergence of lateral buds by the presence of shoot apex is called apical dominance. It occurs due to auxin produced in the shoot tip, which is transported downwards basipetally and reaches to the axillary buds. The concentration of auxin in the lateral bud becomes supra-optimal which retards the growth of lateral buds into branches.

Fruit size: Exogenous application of auxin can alter fruit size and the period of maturity in plums, pineapples and fig. Auxin can increase the size of these fruits and rate of maturity. Auxin application stimulated growth of strawberry fruits also.

Abscission: Abscission is the shading, detachment, separation or dehiscence (a specialized type of abscission) of plant parts, that is, organs, other structures, or tissues. Applying IAA to explant systems usually retards abscission.

Herbicides: The most widespread commercial application of auxins as herbicide is well known. Auxins like (2,4-dichlorophenoxy) acetic acid (2,4-D) and (2,4,5-trichlorophenoxy) acetic acid (2,4,5-T), which act as herbicides when used in large doses. Dicotylendonous weeds are particularly sensitive to very high auxin level. Some of the most valuable and widely used selective herbicides in the weed control are auxins, particularly the phenoxyacetic acid analogous (e.g., 2,4-D, 2,4,5-T and McPA).

Methods of application

Lanolin is a soft fat prepared from wool and is a good solvent for auxins. The paste prepared with the fat and auxin in a suitable proportion sticks firmly and the auxin does not dry, thereby maintaining a constant concentration of the compound in contact with a treated organ. A suitable paste for induction of rooting from stem cutting is prepared by dissolving IAA and IBA in lanolin at concentrations of 0.01 to 0.05 per cent. For parthenocarpy and fruit-set higher concentrations of 0.1 to 0.5 per cent paste have been recommended. The technique has limited value for practical application under field conditions and is commonly used for laboratory experiments. It helps to obtain a clue for the theoretical and practical significance of a particular compound on a physiological process.

GIBBERELLINS

Gibberellins are derivatives of gibberellic acid. They are natural plant hormones and promote flowering, stem elongation and break dormancy of seeds. There are about 100 different gibberellins, but gibberellic acid (GA_3) is the most commonly used form. Gibberellins are fundamental to plant development especially with respect to the growth of stems. Low levels of gibberellins will prevent plants from reaching their natural height. Gibberellin synthesis inhibitors are extensively used in grain production to keep stems artificially short: shorter and thicker stems provide better support and resist weather conditions better too. Gibberellins are particularly effective at breaking seed dormancy and at speeding up germination. Seeds that are difficult to germinate are frequently treated with gibberellic acid solutions.

Cell division: It has been argued that GA can promote growth of plants by affecting either cell expansion or cell division or both. It must be emphasized that cell division alone cannot result in growth of organisms. Cell division contributes to growth by producing more cells which can undergo expansion. The effect of GA_3 on cell division can be readily accounted by an effect on cell cycle.

Floriculture: GA_3 is also used to thin approximately 60% of the flowers because almost every flower tends to set, resulting in a tightly packed cluster. The physiological basis for grape flower thinning by GA is unknown, but could be due to pollenicidal activity. The result of adequate thinning almost appears excessive, but with two subsequent applications of GA, berry size is increased by 60%. GA_3 also inhibits flowering on several stone fruits. In young sweet and tart cherries, GA_3 is applied to prevent excessive flowering to minimize the competitive effect of early fruiting on vegetation growth.

Fruit characters: GA_3 has been used in the seedless table grape industry since 1960 to manipulate three physiological events; rachis cell elongation, flower thinning, and berry enlargement. The effect of delayed fruit senescence by GA_3 has also been exploited in the citrus industry. More recent results suggest that GA_4 may promote apple flowering.

Protection against plant pathogens: Recent laboratory studies have shown that GA_3 application significantly reduces the number of probes and egg fecundity of the fruit fly due to increased exposure to toxic peel oils contained in the juvenile rind. If this effect is manifested in the field, a high level of resistance may preclude the need for post harvest treatment with an insecticide / larvicide. The commercial uses of gibberellins are listed in the following table.

CYTOKININS

Cytokinins promote cell division, stimulate shoot proliferation, activate gene expression and metabolic activity in general. At the same time, cytokinins inhibit root formation. This makes cytokinins useful in culturing plant cell tissue where strong growth without root formation is desirable. Natural cytokinin hormone levels are high during maximum growth periods of mature plants. In addition, cytokinins slow the aging process in plants. Concentrations of cytokinin used in crops vary between 0.1 and 10 mg/L

Physiological effects: Externally applied CK's are known to exert spectacular effects on the growth and development of plants and excised plant tissue. Exogenous CK's have also a pronounced effect on stimulation of cell enlargement in cotyledons of diverse species and on leaf disc. They have been found to substitute for light in some cases, e.g. CK's can induce germination of light sensitive seeds. Pigment [β-cyanin] synthesis in cotyledons of *Amaranthus* seedling, chlorophyll synthesis in detached yellow leaves and etiolated cotyledons, chloroplast development and opening of stomata, reduction of leaf senescence and release of lateral buds by apical dominance by CK application are some instances which found commercial use. CK can also induce nutrient mobilization and recently have been found to influence unloading of phloem derived photosynthate into cytoplasm of bean seed coats.

Seed germination and early seedling development: CK's are important in seed germination. Thus the endogenous CL's would appear to be one of the key factors in the initiation of radicle growth. Endogenous CK appears to be important in reserve mobilization in germinating seeds, particularly in dicots. The most dramatic and well-studied response to CK's in immature seedlings is cotyledon expansion in dicots.

Chlorophyll synthesis : Another important effect of CK's is their ability to stimulate chlorophyll synthesis and accelerate chloroplast differentiation in the detached cotyledons in light.

Practical uses : The mixture of GA_{4+7} and BA is used to induce the extension of apple calyx lobes for the increased size and length / diameter ratio associated with a high calyx lobes for the increased size and length / diameter ratio associated with a high quality 'Red Delicious' apple fruit. The mixture is used in the promotion of flowering of Chrysanthemum under non-induce conditions. Recently, promising results were reported for thinning of apples with BA alone or in combination with carbaryl. Another cytokinin-like compound currently under development which also thins apples is 2-chloropyridylphenylurea (CPPU).

ABSCISIC ACID

Abscisic acid (ABA) is a plant growth inhibitor and an antagonist of gibberellins. It induces dormancy, prevents seeds from germinating and causes abscission of leaves, fruits, and flowers. High concentrations of abscisic acid can be induced by environmental stress such as drought. Elevated levels of abscisic acid will eventually induce dormancy, when all non-essential processes are shut down and only the essential metabolism is maintained in guard cells. ABA has been found in many higher plants tissues like roots, stems, buds, leaves, fruits and seeds. It has also been found in phloem and xylem sap and in nectar.

Plant water relations: As the water potential decreases there is marked increase in permeability of chloroplast membranes to ABA. The ABA synthesized by and stored in chloroplast then diffuses into mesophyll cytoplasm and moves from cell to cell through plasmodesmata to the guard cells where it induces stomatal closure. ABA applied via the transpiration stream to leaves affected photosynthesis both via stomatal closure and via a direct effect on carbon fixation.

Dormancy: Dormancy of potato tubers is positively correlated with the concentration in them of growth inhibitors, identified as ABA. ABA plays an important role in developing seeds by inhibiting vivipary. In the case of immature seeds, several evidence indicates that ABA prevents precocious germination (vivipary) of the developing embryo.

Abscission: ABA, applied externally tot he intact plant accelerates the abscission of the mature fruits of grape, olive, citrus and apple and the flowers of grape but only promotes leaf abscission at very high concentrations (2-4 mM). There are two peaks in the endogenous level of ABA in developing cotton fruits, the first coinciding with the dropping of immature fruits, the second with the final dehiscence of mature fruits.

Tuberization: ABA appears to be involved in the process of tuberization. Externally applied ABA has also been shown to promote the formation of these tubers in Dahlia and Jerusalem artichoke.

Senescence: ABA may also be involved in senescence and ripening processes. Externally applied ABA accelerates the senescence of detached leaves; however, its effects on the senescence of leaves still attached to a healthy plant are minimal. Externally applied ABA accelerates the ripening of young fruit; moreover, there is a rise in the level of endogenous ABA during the ripening of strawberries and grapes.

Resistance to frost damage: ABA may also be involved in increasing the resistance of temperate – zone plants to frost damage; the external application of ABA has been shown to increase the frost hardiness of many crops.

ETHYLENE

Ethylene is unique that it is found only in gaseous form. Indeed, ethylene is an organic compound consisting of carbons and hydrogens, and is produced within a plant. Ethylene promotes epinasty, prolification, root formation and abscission and inhibits growth and anthocyanin formation of morning glory seedlings. It induces ripening, causes leaves to abscess and promotes senescence. Plants often increase ethylene production in response to stress and before death. Ethylene concentrations fluctuate with the seasons while playing a role in inducing foliage and ripening of fruit.

Stress and ethylene production: Plants when subjected to stress produce ethylene. Such stresses may be disease, radiation, mechanical wounding and chemicals. Generally it is accepted that ethylene hastens abscission and auxin delays it. Also, abscissic acid (ABA) enhances the abscission of some plants as a third abscission regulator.

Chlorophyll degradation: Degreening does not occur during exposure to ethylene in the peel of satsuma mandarin fruits, but does by exposing the ethylene-treated fruits to air. Chlorophyllase enzyme is responsible for degradation of chlorophyll in plants. Its activity is low during exposure to ethylene and during the first 6 h of the subsequent exposure to air.

Germination: Germination of a number of plant species is enhanced by ethylene. So there are some efforts to apply ethylene releasing compounds in combination or prior to application of herbicides to increase the effectiveness of the herbicide treatment. Even the application of ethylene as a gas seems promising.

Flowering: Cucumber and melon normally produce male flowers earlier than female flowers. Ethylene stimulates the early production of female flowers. Often male flower formation is completely inhibited following ethylene treatment. Treatment of plants with Ethephon has the same effect. Female flower induction in Cucurbitacae is of commercial interest to achieve an earlier harvest and a yield increase. Ethylene applied at a certain time of pollen development causes male sterility.

Fruit ripening: Ethylene gas is widely used commercially for ripening a variety of climacteric fruits and decoloring non-climacteric citrus fruits. However, the use of ethylene-releasing compounds to effect this response is confined to relatively new crops, and normally when they are used as a preharvest application.

GROWTH RETARDANTS

Plant growth retardants are defined as synthetic organic chemicals that cause a retardation of cell division steps in pathways of hormone biosynthesis without evoking substantial growth distortions. Plant growth retardants have significant uses in agriculture and horticulture. These retardants evoke several biochemical and physiological alterations, including suppression of key steps in gibberellin synthetic pathway.

Several growth retardants are available which are active in a broader range of plant species than most retardants known hitherto. These include tetcyclasis (BAS-106); triazoles such as uniconazole (S-3307; XE-1019), paclobutrazole (PP^{333}, Cultar), triapenthenol (RSW-0411) and BAS-111; pyrimidines eg. Flurprimidol (EL-500) and 4-pyridines such as inabenfide (CGR-811). There are other ‘old time’ retardants also and these include AMO-1618, CCC, Phosphon-D, C-111, B-Nine and Maleic hydrazide.

OTHER PLANT GROWTH REGULATORS

Jasmonic acid

Jasmonic acid (JA) JA is a fatty-acid-derived plant hormone that is similar in overall structure to physiologically active small molecules from animals called prostaglandins. In plants, jasmonic acid is firmly associated with pathogen defense pathways. The physical stimuli of certain insects can trigger the synthesis of JA, which then functions to increase expression of genes involved in defending the plant. Microbial and viral pathogens can also trigger JA synthesis.The study of JA-mediated events in the plant cell are of interest to plant pathologists who wish to engineer transgenic plants that are disease-resistant

Salicylic acid

Salicylic acid (SA) is a phenolic phytohormone and is found in plants with roles in plant growth and development, photosynthesis, transpiration, ion uptake and transport. SA also induces specific changes in leaf anatomy and chloroplast structure. SA is involved in endogenous signaling, mediating in plant defense against pathogens.[3] It plays a role in the resistance to pathogens by inducing the production of pathogenesis-related proteins.[4] It is involved in the systemic acquired resistance (SAR) in which a pathogenic attack on one part of the plant induces resistance in other parts. The signal can also move to nearby plants by salicyclic acid being converted to the volatile ester, methyl salicylate.

Polyamines

Polyamines are unique as they are effective (and are applied) in relatively high concentrations. Typical concentrations range from 5 to 500 mg/L. Polyamines such as putrescine or spermidine influence flowering and promote plant regeneration

Brassinolides

It is a sterol, much like estrogen and testosterone (which function as sex hormones in animals) critical for normal plant growth and development. It plays roles in stem elongation, leaf development, pollen tube growth, vascular differentiation, seed germination, photomorphogenesis, and stress responses.

Maximagro is a formulation based on Brassinolides that enables crops/ plants to overcome inefficiency barriers by triggering vital physiological process leading to higher crop yields. Maximagro is readily absorbable and assailable from making it very effective as a foliar spray. It is a miscible liquid with a recommended dose of 0.05 to 0.1 liter per hectare for Apple, Chilli, Sunflower, Tea, Cotton, Onion, Tomato, Okra, Vegetables, Grapes, Mango, Citrus Sweet orange, Flowering plants and Annual flowering plants. The advantages of using brassinolides include,

- Encourages growth, yield and improving quality.
- Promoting fruit's enlargement and increase the percentage of fruit setting
- Increasing weight of fruits
- Cold and drought resistance
- Disease resistance
- Differentiation in tissue culture
- Reduce the harmful effect of fungicides, herbicides and pesticide
- Increase in seeds and germination percentage
- When applied 10-15 days before harvesting, it increases the natural preservation value
- Reduces fruit dropping and flowering

Nitrobenzene

Nitrobenzene is a combination of nitrogen and plant growth regulators, extracted from Sea weeds. Nitro benzene produce best results in combination of plant growth regulators, which have capacity to increase flowering in plant and also prevent flower shedding. Yield contributing characters like plant height increase bys 8-10% and number of branches per plant increase by 15-20%. Four sprays of nitrobenzene during 40,55,80 &105 DAS improve the yield up to 40 %.

Seaweed products

Seaweed extracts have been proven to accelerate the health and growth of plants. The actions of it are many. Being of biological origin, seaweed extracts have tremendous applications in conservation agriculture. Seaweed stimulates beneficial soil microbial activity, particularly in the pockets of soil around the feeder roots resulting in a substantially larger root mass. where the beneficial fungi and bacteria known as "mycorrhizae" make their home. This area of the soil is known as the "rhizosphere." The rhizosphere activity improves the plants ability to form healthier, stronger roots. Having many actions it also enhances the plants own natural ability to ward off disease and pests.

A good example has been observed that aphids and other types of sap feeding insects generally avoid plants treated with seaweed. At the same time it works within the soil to make more nutrients available to the plant. The rhizosphere forms a nutrient food bank for the plant it can draw on in times of stress. Another action seaweed has on the roots in the rhizosphere is due again to the increased mass and depth of the roots the plant is able to draw more moisture from the soil increasing the drought tolerance level. The root mass also allows the plant to more effectively absorb and use fertilizers that are applied to the plant and soil. The overall stronger root structure may help plants physically resist certain types of root diseases.

Seaweed enhances photosynthesis via increasing a plants chlorophyll levels. Chlorophyll is what gives plants their green color. By upping the level of chlorophyll the plant is able to efficiently harness the suns energy. Along with this seaweed contains a complex range of biological stimulants, nutrients, and carbohydrates. To date more than 60 different types of nutrients in seaweed have been confirmed. However seaweed in itself is not a plant food, rather it is classified as a "bio-stimulant."

Seaweed extracts contain natural plant growth regulators (PGR) which control the growth and structural development of plants. The major plant growth regulator is auxins, cytokinins, indoles and hormones. The PGRs in seaweed are in very small quantities generally measured in parts per million. It only takes a very small amount of these to do the job. Indole compounds help the development of plant roots and buds.

Seaweed types and uses

Three types of seaweed are used in the manufacture of most seaweed digests: *Ascophylum nodosum*, *Ecklоniamaxima* and *Durvillea potatorum* (Australian bull kelp). Both *Ascophylum* and *Durvillea* have been studied extensively. The local seaweed, *Durvillea,* has much to recommend it, as the basis of a liquid seaweed formulation. *Durvillea* grows in the clean waters of the Southern Ocean and is remote from most sources of pollution. It grows prolifically and large quantities are washed up on beaches. Its single disadvantage is that it is somewhat more difficult to hydrolyse than *Ascophylum*.

Liquid seaweed affects plant growth because it contains substances that are generally referred to as plant growth regulators, plant hormones, plant growth enhancers or trigger compounds. The list of scientifically documented observed effects includes increase in nutrient uptake, yield, shelf life of fruit, frost tolerance, chlorophyll production, resistance to fungal attack and sucking insect attack, rachis stretch (grapes), fruit set, and germination, delay in senescence and decrease in water stress due to drought and salinity.