Stoller Enterprises

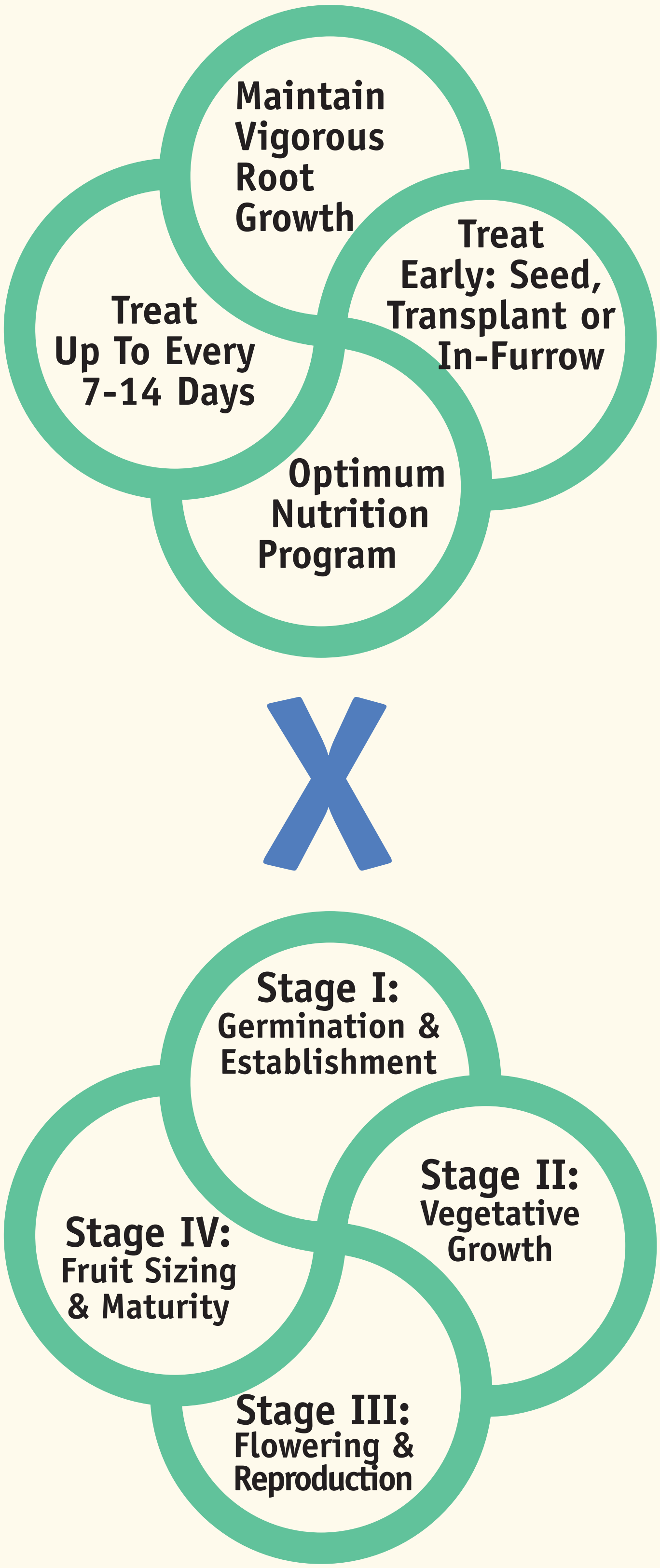
Crop Health Leader

CROP HEALTH GUIDE

Maximizing Plant Genetic Expression

Second Edition $15.00

Crop Health Therapy 4 X 4 Program



= Maximum Genetic Expression

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Contents

Harness The Power of Mother Nature

There are things in crop production we can see that we can control. For the things we can't see (inside the plant) and can't control (Mother Nature), what do we do?

Every producer understands the importance of good seed and genetics, good fertility, and good control of weeds, disease and insects. These are the things you can see and control! However, after all of these areas have been addressed, why do crop yield and quality often turn out to be unsatisfactory?

The Evolution of Crop Inputs for Reducing Plant Stress

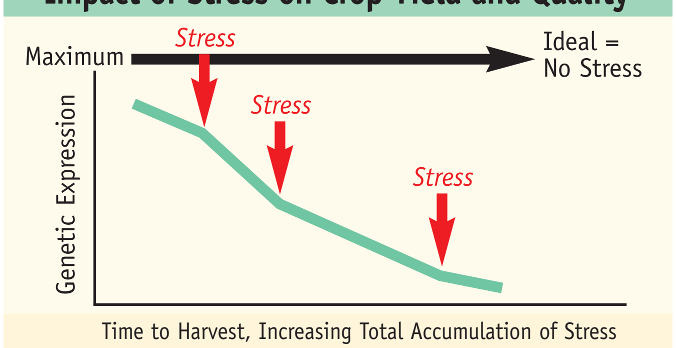
Interaction	*I. Crop Nutrition*	• Granular fertilizer • Liquid fertilizer • Micronutrients
Reaction	*II. Crop Protection*	• Herbicides • Fungicides • Insecticides • PGR's
Prevention	*III. Genetic Expression*	• Biotechnology • Crop Health Therapy

It is better to PREVENT plant stress than to REACT to existing plant stress that has already irreversibly reduced Genetic Expression.

Crop Health Therapy is a new and innovative technology for managing the things you can't see and can't control. Crop Health Therapy is based on the application of naturally occurring plant growth factors to increase crop genetic expression.

Genetic expression is compromised by stress, usually from unfavorable weather. Stress results in an imbalance between growth hormones (auxin, cytokinin and gibberillic acid) and stress hormones (ethylene and abscisic acid). This hormone imbalance tends to shift the movement of sugars predominantly to the upper part of the plant (apical meristem) resulting in uncontrolled vegetative growth. Excessive vegetative growth leads to weaker roots and decreases in fruiting part (fruit, seed, tubers, etc) number, size, uniformity and quality.

Impact of Stress on Crop Yield and Quality



Crop Health Therapy consists of treatments to maintain the appropriate hormone balance throughout the growing season to make plants more resistant to stress, thereby facilitating the expression of their full genetic potential in terms of enhanced yield and quality. Biotechnology and breeding provide the genetic potential, Crop Health Therapy helps to realize it.

Now producers can manage the things they can't see (inside the plant) and haven't been able to control (Mother Nature) for increased crop yield and quality.

What Is Crop Health Therapy?

Crop Health Therapy is based on the use of naturally occurring plant growth factors reintroduced to plants to support optimum growth when weather or other stress conditions cause hormone imbalance. Treatments consist of plant hormone-supporting nutrients and other hormone co-factors that work together to ensure optimum hormone balance and activity. The combination of these hormone co-factors are necessary for consistent and reliable crop responses under a wide range of unpredictable and variable conditions.

- Treatments are designed to provide specific hormone balance at key developmental stages for different crop types.
- Crop Health Therapy supports the plant's ability to withstand the stresses limiting optimum growth.

Why Use Crop Health Therapy?

The external factors that affect plant hormone balance are unpredictable and variable:

- weather
- crop cultivars and varieties
- soil type, condition and fertility
- tillage and agronomic practices
- pests

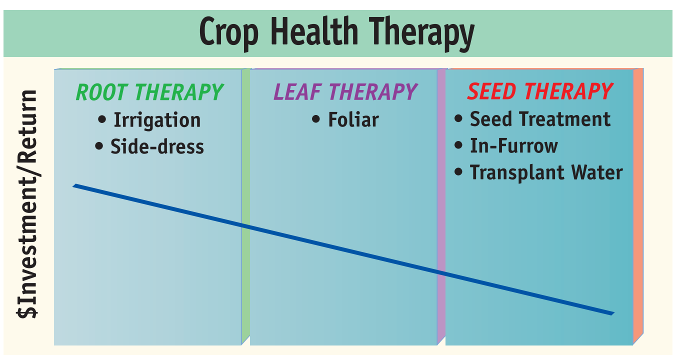
Crop Health Therapy Principles

1. Root tips serve as the "brains" of the plant growth control center, regulating all plant growth processes. Crop Health Therapy focuses on maintaining vigorous root growth throughout the life cycle of the plant.

2. Genetic expression is affected from the time the seed germinates or when perennial plants begin to grow. Treatment must start early at seeding, transplanting or just before plants break dormancy.

3. Root caps respond to the environment and signal the plant to absorb nutrients and produce hormones. Every 7-14 days the root cap cells die, are sloughed off, and must be replaced by new cells. Without this replacement process, there will be fewer roots and root tips with the capacity to synthesize plant hormones and control plant growth. For this reason, an optimal Crop Health Therapy program is based on continuing treatment every 7-14 days through to harvest. Soil and/or foliar treatments throughout the season will maintain and enhance the benefits gained from initial seed starter fertilizer, transplant or in-furrow treatment to minimize the impact of stress conditions.

There are three methods of treatment:



The rate of return is similar no matter what approach you use. However, the total amount of return is proportional to the total amount invested.

4. The "Law of the Minimum" in terms of nutrition plays a key role. The nutrient in shortest supply limits genetic expression during each stage of plant development. Plant hormones, supporting nutrients and other hormone co-factors work together to ensure appropriate hormone balance throughout the different growth stages of the plant. The appropriate combination of ingredients ensures consistent and reliable crop responses. Regular application of plant hormones in combination with supporting nutrients and other key hormone co-factors allows the plant to choose and use what it needs, when it needs it.

What Is Genetic Potential and Genetic Expression?

Genetic Potential is determined by a plant's internal DNA structure from breeding and/or biotechnology.

Genetic Expression is the physiological manifestation of a plant's genetic potential and is determined by external factors from the time a seed germinates, a bulb or tuber sprouts, or when a perennial plant breaks dormancy all the way through to harvest.

Crop Health Therapy is designed to fortify plants against unpredictable and variable conditions!

The combination of ***genetic potential and genetic expression*** produces the resulting plant growth patterns, characteristics, yield and quality. It is estimated that, on average, growers actually harvest only 30% of a plant's genetic potential. Genetic expression limits harvests due to unpredictable and variable external stress factors.

Factors Influencing Genetic Expression

Genetic Expression =
Genetics (DNA) x Building Materials ÷ Stress

Genetics (DNA)	Building Materials	Stress
Breeding and Biotechnology	*Fertility (nutrition), Water, Sunlight*	*Weather, Tillage Practices, Soil Conditions, Diseases, Weeds, Insects* *Stresses Result in Hormone imbalance***

*** Plants measure and respond to their environment with plant hormones (also called PGR's, phytohormones or biostimulants).*

Crop Health Therapy ensures good hormone balance *throughout* the growing season to minimize the effects of stress.

What Hormones Do Plants Have?

There are five key hormones:

Growth Hormones
- Cytokinin: The Dispatcher
- Auxin: The Activator
- Gibberellic Acid (GA): The Sizer

Stress Hormones
- Ethylene: The Regulator
- Abscisic Acid (ABA): The Terminator

Plant hormones, nutrients and hormone co-factors regulate plant growth and reproduction much like hormones, nutrition and vitamins regulate growth in humans and animals.

Cytokinin: The Dispatcher

Cytokinin is the dispatcher hormone that ***signals*** the hormone events controlling cell division and differentiation:

1. Cytokinin is primarily produced in root tip meristematic tissue.
2. Cytokinin movement upward in the plant stimulates shoot formation and branching. New shoot tissues make auxin that is transported down the plant where it combines with cytokinin to cause cell division for new root tip growth:
   - The ratio of auxin to cytokinin determines the type of growth: more auxin = root growth, more cytokinin = shoot growth
   - Maintaining new meristematic root growth is critical for optimal development of the plant
3. Cytokinin acts to reduce senescence (aging) of the plant. The lack of cytokinin allows ABA levels to build higher in the plant. The synthesis or addition of cytokinin reduces the level of ABA in the plant enabling it to maintain its youthful vigor.
4. Since nitrate nitrogen is absorbed by the roots to synthesize cytokinin, a certain amount of nitrogen can be replaced by directly applying cytokinin with hormone co-factors.

Auxin: The Activator

Auxin is the hormone that ***activates*** and ***directs*** new cell division and food movement in a plant:

1. Auxin is primarily produced in new apical meristem tissue in the leaves. Auxin concentration in leaf tissue can be 1000 times higher than in root tips.
2. Auxin is responsible for cell division leading to active growth of the plant. If levels are insufficient cell division will cease, growth will stop, and flowers or fruit will abort (drop) leading to a lack of bud formation.
3. Auxin also directs the movement of photosynthates (food, sugar) throughout the plant. As the plant grows more vigorously and more auxin is produced in the leaves, the movement down to the roots increases. This directs more food from the roots to the upper part of the plant.
4. As the amount of auxin in the upper part of the plant increases and moves downward, it causes bud dormancy in both vegetative and reproductive buds.
5. As the plant reaches its most rapid and vigorous vegetative growth stage, the high amount of auxin transported down to the roots tends to inhibit cell division in the roots. This resulting loss in root vigor causes the plant to begin senescence (cell death).
6. After a plant begins senescence, auxin levels build in the fruiting buds and fruiting areas of the plant. This triggers an increase in the amount of ethylene and ABA in the fruit, grain, and storage cell tissues, which initiates ripening.

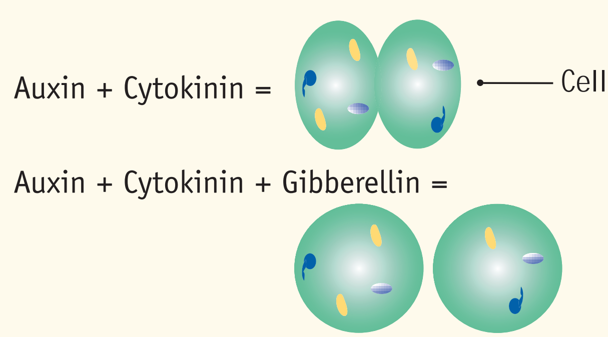
Gibberellic Acid (GA): The Sizer

Plants produce gibberellic acid to encourage cells to size and elongate:

1. GA occurs inside the cell and increases the sink of the cell to attract photosynthate (food, sugar) movement into the cell. Food is needed for energy and cell-building material to produce cell expansion (enlargement).

How The Growth Hormones Work Together

- Auxin and Cytokinin give birth to new cells.
- Auxin then directs food movement to the new cells and, with cytokinin, stimulates cell growth.
- GA, which is made inside the new cell, controls the rate of movement of food into the new cell and its size.



Cell Division: important for establishing the type and number of cells needed for normal plant development, vigorous growth and yield **quality**
Cell Sizing: important for root and shoot mass, and yield **quantity**

2. Auxin transport initiates the synthesis of gibberellic acid. This tends to size the cells and cause longer internode growth or stem elongation, which is very favorable for plants grown for leaf or shoot mass, but is not favorable for plants grown for fruit, seed and storage tissue parts.
3. Gibberellic acid is normally stored in the nodes where it increases cell sizing and the reproductive viability of the buds that occur from the nodes. This is why reproductive buds tend to form at nodes.
4. If gibberellic acid moves out of the nodes, the nodes become less productive, the seed or fruit at the nodes fail to set and may abort. In the absence of gibberellic acid, flowers, small fruit, or storage tissue may be aborted. GA also helps to break seed dormancy.
5. Gibberellic acid works opposite to ethylene and ABA. GA reduces the process of ripening and tends to keep plant tissue more youthful and vigorous.

Ethylene: The Regulator

Ethylene is a gas produced in the cells to regulate the movement of hormones. Ethylene comes in two forms:

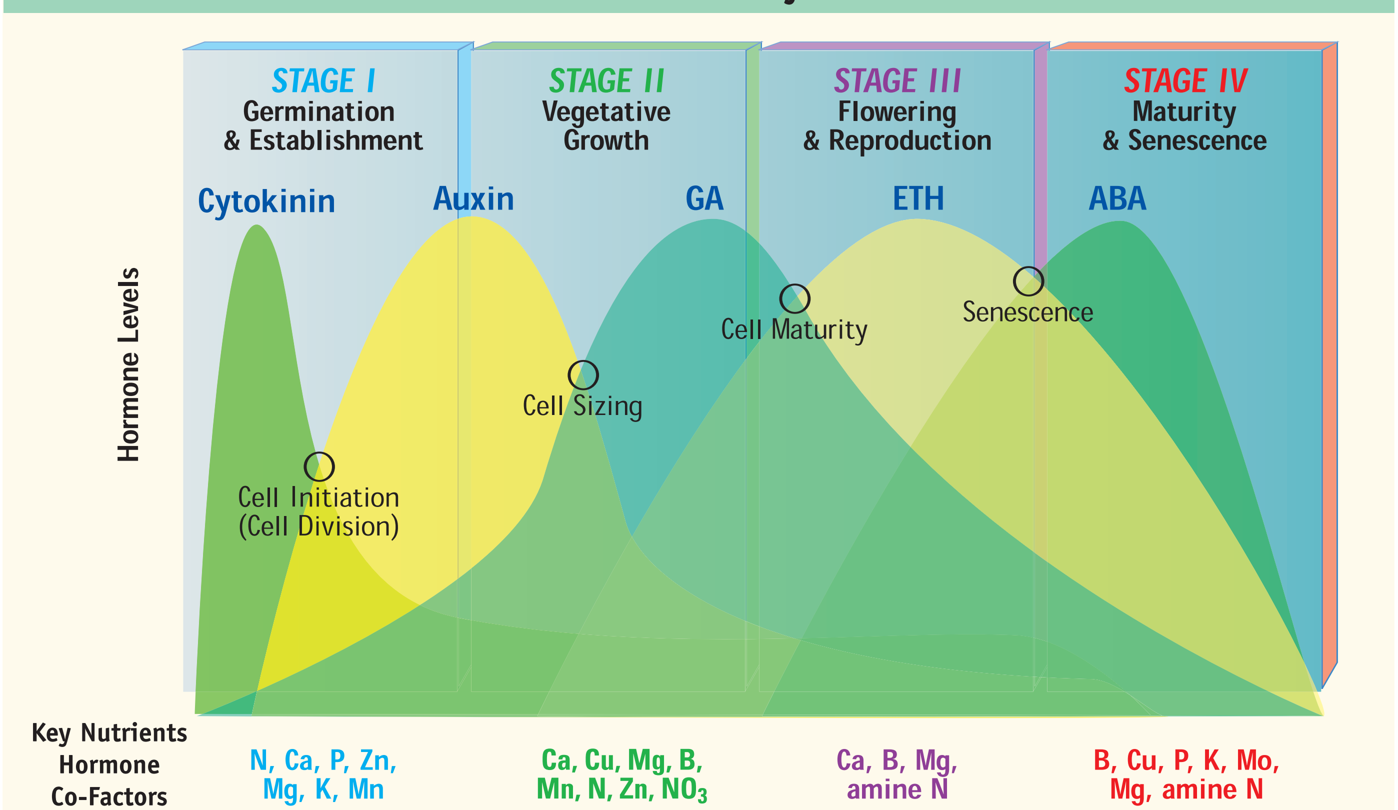
Regular Ethylene

1. Controls the movement of auxin from various cells within the plant. Without ethylene, all food movement would be directed towards new apical meristematic leaf tissue with little movement to the roots (storage tissue) or developing fruit.
2. Signals reproductive maturity and initiates flowering and fruiting.
3. Increases as the plant ages to initiate the ripening process. Encourages an increase in ABA to drive plant tissue (seed, fruit, and storage tissue) into dormancy. This facilitates senescence (the death of old cells) resulting in better storage shelf life of the harvested plant parts.

Stress Ethylene

1. Produced under stress conditions as a signal for the plant to synthesize protectant proteins to help overcome moderate stress.
2. In excess, stress ethylene will cause premature senescence and cell death.

Plant Hormone Cycles



Any imbalance in these hormone cycles at any time can irreversibly reduce genetic expression.

Abscisic Acid: The Terminator

Abscisic acid is responsible for cell maturity and the termination of cell growth:

1. ABA is made primarily in roots and moves rapidly up to the shoots under any kind of stress:
   - closes leaf surface stomata to preserve moisture
   - reduces auxin levels
   - inhibits cell division in shoots but not in the roots
   - causes seed dormancy
2. ABA promotes ripening, abscission, and seed dormancy.
3. If the plant fruiting parts fail to ripen, there can be premature sprouting of grain and tubers and the storage quality/shelf life of harvested plant tissue may be severely affected.

Why Are Plant Hormones and Hormone Balance So Important?

Plant hormones affect virtually all aspects of plant growth. Understanding how hormones work and how they can be manipulated provides the ability to overcome many of the stress factors limiting plants' natural growth cycles and genetic expression. Plant hormones are present in different levels at different development stages in the life cycle of the plant. They must be available in sufficient quantities throughout the life cycle of the plant to maximize genetic expression.

The processes described in the various plant growth stages may be going on simultaneously in different parts of the plant, particularly in continuous, multiple-fruiting or indeterminant crops. Plant hormones must be constantly synthesized and regulated by the root tip cells of the plant. Maintaining and prolonging healthy root tip growth is critical to the optimal hormone balance needed for maximum genetic expression.

Other Factors Affecting Hormonal Balance

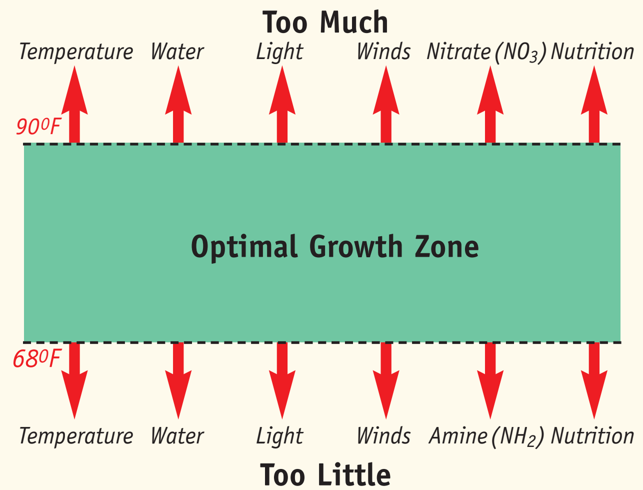
Plant hormone levels change in response to either abiotic or biotic stress for two primary reasons:

- Root caps monitor the environment and communicate these changes throughout the rest of the plant by changing the amounts of hormones present in the tissues. This process is known as "signaling."
- Enzymes that manufacture hormones have an optimum operating temperature. Hormones cannot be made effectively at very high or very low temperatures.

What Causes Hormonal Imbalance?

ANY STRESS CONDITION:

1. Abiotic Stress: adverse weather conditions, high nitrogen levels, soil salinity, soil compaction, etc
2. Biotic Stress: disease, insect, nematode or weed pressure, herbicide carryover/damage, etc



Different stresses affect the cells in different ways, including:

- Membrane disruption and alteration
- Increase in damaging oxidizing agents
- Decrease in the ability of proteins to function properly

The end result of all these different effects, however, is almost always an imbalance in hormones. Generally, auxin and cytokinin (the growth hormones) fall to levels that are too low, and ethylene and ABA (the stress hormones) rise to levels that are too high.

Plant hormone levels are also affected by co-factors:
Nutrients act as catalysts in hormone synthesis and perception. The ability of the roots to absorb nutrients from the soil depends on the pH of the soil and the presence of chelating agents that help keep the nutrients in a form the plant can absorb.

Anti-oxidants reduce oxygen radicals to protect cell membranes, enzymes and DNA, minimizing cellular damage and stress.

Polyamine Complexes stabilize cellular structures, and increase nutrient availability and efficiency.

N-HIB Technology increases the amount of the energy-efficient amine nitrogen (NH_2). N-HIB provides improved nitrogen use efficiency which maintains hormone balance for control of rank vegetative growth and increased sugar availability. N-HIB also helps remediate high soil salinity and compaction, further contributing to the maintenance of hormone balance.

Nutrient Co-Factors and Hormone Balance

Nutrients are involved in the synthesis of hormones, the perception of hormone levels and needs, and also impact the length and degree of hormone activity. Nutrients (particularly chelated nutrients), in combination with other hormone co-factors, work together to provide better hormone balance and activity in the plant. The appropriate nutrient and hormone balance results in a more consistent and optimized response to hormone applications under a wide range of unpredictable and variable conditions.

Organic Chelation

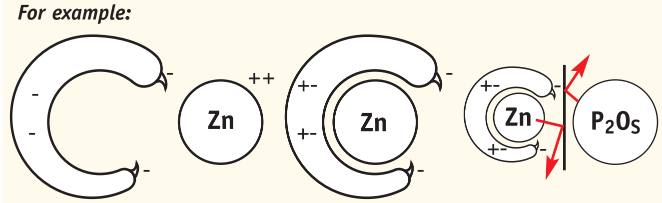
Stoller patented chelation technolgy does more than just chelating micronutrients. This technology stimulates plant growth independent of the micronutrients in the formulation.

Hormone Co-Factor	Key Support Role in Maintaining Hormone Balance
Amine Nitrogen (NH_2)	More energy-efficient, plant-useable nitrogen form for controlled shoot growth, increased sugar.
Boron	Enhances cell wall strength reducing oxidative breakdown of auxin, thereby increasing auxin levels and corresponding auxin effects including increased sugar movement into harvestable fruiting parts.
Calcium	Structural component of cell walls/involved in hormone-signaling pathways and regulation of auxin transport contributing to increased disease resistance and sugar movement into harvestable fruiting parts.
Cobalt	Decreases ethylene production by preventing the binding of the necessary components in ethylene biosynthetic enzymes.
Copper	Structural component of the ethylene receptor required for appropriate plant response to ethylene. Consequently, plays an important role in maintaining hormone balance and in ripening. Also plays a role in the conversion of nitrogen into protein and amino acids.
Magnesium	Structural component of chlorophyll, a co-factor for synthesis of many enzymes, pumps nutrients into the roots and sugars out of leaves thereby supporting and enhancing hormone activity.
Manganese	Acts in energy utilization, photosynthetic electron transfer, nitrogen and auxin metabolism.
Molybdenum	Co-factor for the enzymes that function in auxin and ABA biosynthesis; also has anti-oxidant properties.
Nitrate Nitrogen (NO_3)	Triggers cytokinin synthesis by root tips for cell expansion, shoot growth.
Phosphorus	Regulates hormones for healthy root growth, functions in energy transfer, sugar movement, disease resistance.
Potassium	Regulates sugar transport, water uptake & hormone synthesis for cell expansion.
Zinc	Integral for auxin synthesis, genetic expression, cell membrane integrity, energy transfer.

Why Are Chelated Micronutrients Important?

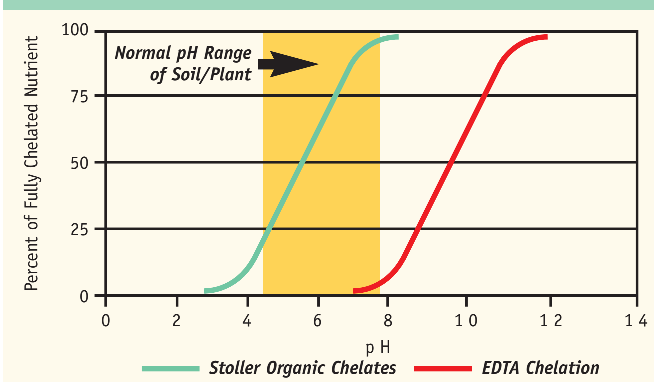
Chelation results from a binding reaction between a chelating agent and a positively charged micronutrient ion which creates a "molecular claw."

For example:



The claw holds and protects the micronutrient from being tied up by negatively charged particles and precipitating out in the soil or in spray tank mixtures with starter fertilizers or other components. The strength of the claw (Log K Value) determines how long the micronutrient chelate remains water soluble and available to plant roots or leaves.

Effect of pH on Stoller Organic Chelates vs EDTA Chelates



Stoller Organic Chelation vs EDTA Chelation

Problem	Cause	EDTA Chelation	Organic Chelation
Leaf burn	Inorganic salts	Up to 32% sodium chloride	NO inorganic salts
Limited plane bio-availability	Average soil/leaf pH <8.0	100% chelation @ pH12.0, Lower Log K Values, Less effective at normal pH's	100% chelation @pH 8.1, Higher Log K Values, very effective at normal pH
Leaf penetra-tion/uptake	Waxy leaf cuticle	Inorganic components NOT miscible in wax, will not penetrate waxy cuticle	Organic components are miscible in wax, will penetrate waxy cuticle
Wash-off potential	Rain, excessive moisture	Repelled by leaf surface	Attracted to hydrophobic leaf surface
Damage to equipment	Corrosiveness of formulation	Can be corrosive	Non-corrosive
Precipitation in mixtures with high P or other micronutrients	Weak chelate bond (low stability Log K values)	Lower stability values: may not mix well with high P or other liquid micronutrients	High stability values, NO mixing problems with P or other liquid micronutrients
Environmental	Persistence	Persistent, solubilizes environmental contaminants	Biodegradable, NO inorganic components

Polyamine Complex and Hormone Balance

The Polyamine Complex is a proprietary Stoller formulation consisting of organic, plant-based ingredients. These ingredients support hormone functions by stabilizing cell structures to:

- protect DNA/RNA
- reduce ethylene
- facilitate protein synthesis
- enhance root formation and elongation
- increase auxin availability
- improve disease resistance
- promote pollination and flower initiation
- slow down aging
- maintain bioavailability of micronutrients

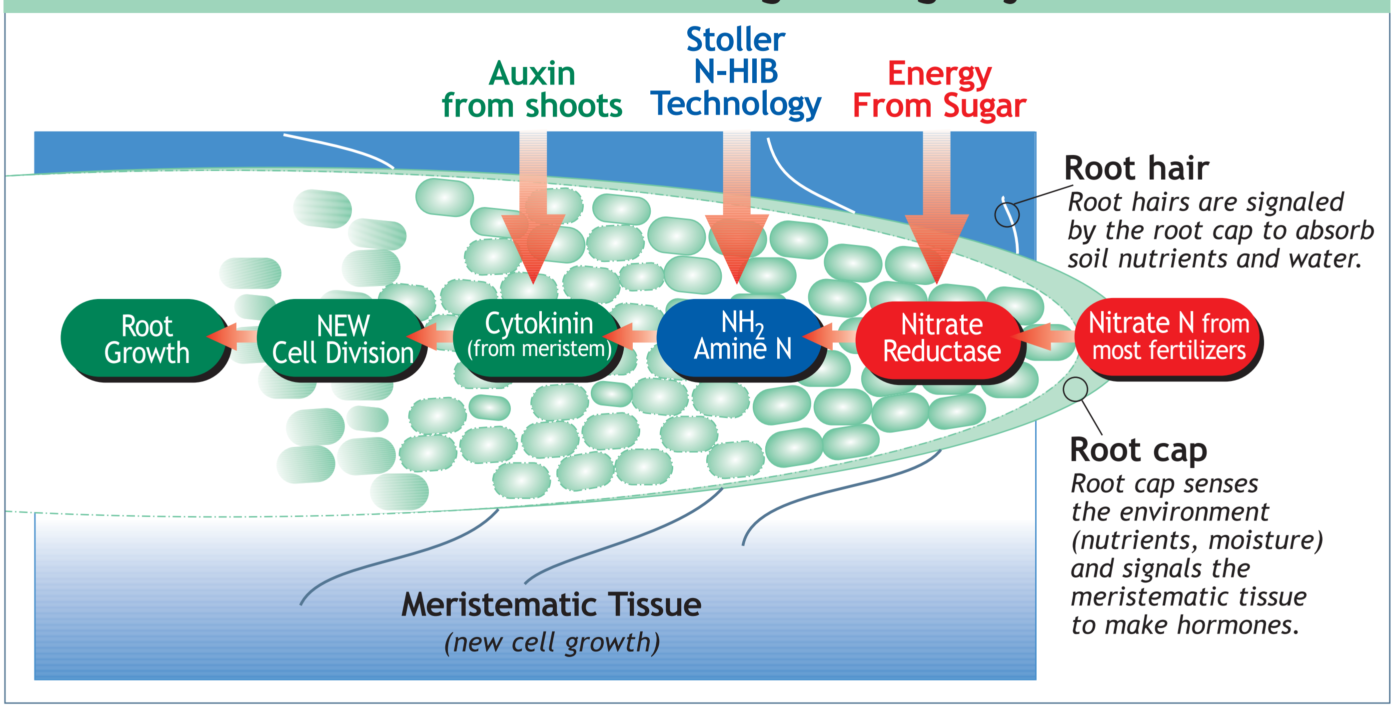
Anti-Oxidants and Hormone Balance

As a byproduct of respiration, oxygen radicals exist in virtually all plants and animals. All organisms that exist in oxygen containing environments perform aerobic respiration to release energy from stored carbohydrates. During this process, oxygen is consumed and converted to water. In a cyclical process, the water is broken down into oxygen, protons, and electrons. The electrons are used to harness the energy from sunlight during photosynthesis, and the harnessed energy is stored as carbohydrates (sugar).

Occasionally during photosynthesis and respiration, oxygen is released before its conversion to or from water is complete, resulting in oxygen radicals. Oxygen radicals damage cells by disrupting cell membranes, inactivating enzymes and damaging DNA, resulting in increased stress ethylene levels. These are typical symptoms of aging and stress.

Consequently, the fewer oxygen radicals that are present in the plant, the healthier the plant will be. Reduced stress maintains cell integrity which enables plants to maintain the hormone balance needed for maximum genetic expression. Antioxidants support hormone balance because they bind with harmful oxygen radicals to keep them from damaging cell membranes, proteins and DNA. Antioxidants also eliminate these signals for increased stress ethylene production, which maintains a balance between the growth hormones (auxin, cytokinin and GA) and stress hormones (ethylene, ABA) to ensure continued optimum plant development.

Amine versus Nitrate Nitrogen Usage By Plants



N-HIB Technology, Amine Nitrogen and Hormone Balance

Three forms of nitrogen are applied to crops:

- nitrate (NO_3)
- ammonium (NH_4) – converted by bacteria into nitrate
- urea (amine NH_2) – converted by "urease" soil enzymes into ammonium N, then into nitrate N

All three forms are absorbed by the plant, primarily in the nitrate form (90%). The nitrate form is very mobile in water and can be leached with water movement. On the soil surface, up to 30% of nitrate can be converted into the ammonium form which will volatilize. Nitrate N is absorbed by the root and transported up to the leaf. Nitrate in the leaf cannot be used by the plant until it is converted to the amine form. The amine N can then be used by the plant to make protein and other building blocks needed for maximum genetic expression. The nitrate N must be changed into amine N (NH_2) by the plant enzyme "nitrate reductase." This conversion occurs if the plant is functioning normally but uses up valuable plant energy reducing sugar availability for fruiting parts.

Some of the Nitrate N absorbed by the root is used to make cytokinin, which communicates nitrogen availability to the rest of the plant. This communication causes a rank vegetative growth response to provide the photosynthetic energy needed to manufacture the enzyme "nitrate reductase." High levels of nitrate in the plant can be toxic, and high amounts of nitrate in the leaves interferes with ABA and auxin synthesis. ABA and auxin are necessary to increase cell membrane permeability, allowing movement of sugar out of the leaves to the harvestable fruiting parts of the plant.

Stoller's proprietary N-HIB technology maintains urea in the amine form by inhibiting "urease" enzyme activity. This allows the plant to bypass the step of converting nitrate N into amine N thereby conserving sugars for movement into fruiting parts. N-HIB technology permits:

- lower urea usage rates of up to 50% due to reduced losses of nitrogen to leaching or volatilization and more efficient plant use
- control of rank vegetative growth since less leaf mass is required to generate the photosynthetic energy used up by the "nitrate reductase" enzyme for converting non-useable nitrate NO_3 into useable amine NH_2
- increased plant sugar availability for fruiting part sizing, soluble solids, specific gravity, brix and etc. This is due to the increased amount of photosynthetic energy available to make sugar as well as increased ABA synthesis to facilitate sugar movement out of leaves to the fruiting parts.

Remediation of Soil Salinity

N-HIB technology also helps to counteract high soil salinity. The salinity tolerance of crops varies but all plants are negatively affected by salinity at some point. Soil salinity is a problem when the level of salts (primarily sodium) is high enough to restrict water uptake by root hairs and/or have a direct toxic effect on plants. High sodium levels in plant root zones can lead to elevated levels of ethylene and ABA (the stress hormone) resulting in dehydration, reduced turgor and ultimately cell death. Cell membrane integrity is reduced as sodium displaces calcium resulting in reduced water and nutrient uptake. Sodium will also reduce protein synthesis and alter hormone balance and activity.

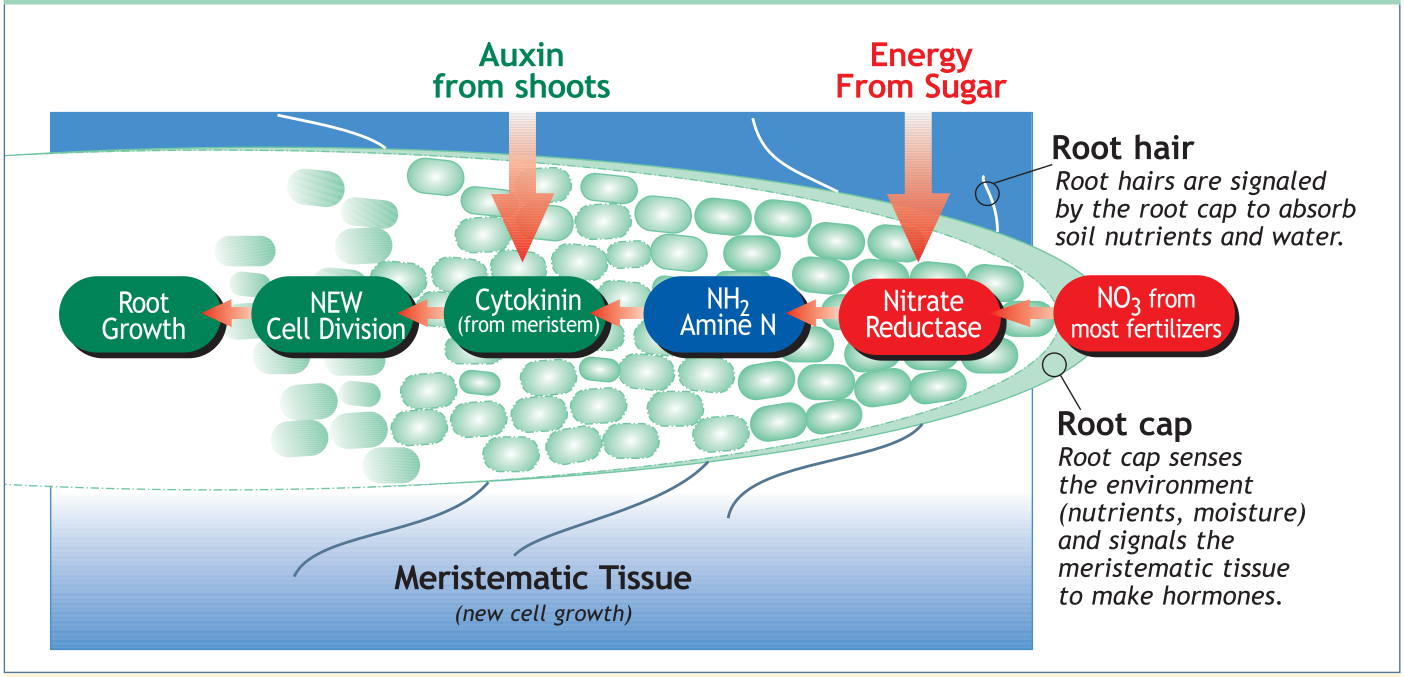
A plant's ability to extract and use water from the soil is similar to the effect that salts have on the boiling and freezing points of water: salty solutions will have a higher boiling or lower freezing temperature than non-saline water. More energy is required to turn the water into steam or ice when salts are present. The same is true for plants. Plants must use more energy to separate and absorb water tightly bound to soil particles by high sodium content.

Sodium salts can only be extracted from soil by leaching or mechanical removal. The N-HIB calcium and N-HIB magnesium have a stronger attraction to clay particles and tie up binding sites, leaving more sodium free and unattached in the soil water solution. With adequate rainfall or irrigation, the free sodium will be leached out of the plant root zone and roots can expand more easily and vigorously to absorb the relatively non-mobile micronutrients required for optimum hormone balance.

Alleviation of Soil Compaction

Because of its comparatively large size, single electric charge and hydration effects, sodium tends to cause physical separation or breakdown of large, porous soil particles into smaller, less porous particles, resulting in soil compaction. When excess sodium ions are present, the forces binding clay particles are disrupted. Repeated wetting and drying causes saline soils to reform and solidify into a cement-like soil. N-HIB calcium has the opposite effect on soil structure because it tends to cause soil particles to bind together. Increases in the number and size of pores between

Root Tips: The Brains Of The Plant



Meristematic root tissue responds to the root cap to make cytokinin primarily, which together with auxin and sugar from the shoots, maintains cell division for root tip growth. If the root tips die, the plant's "brain" dies and it loses its ability to control hormone cycles and nutrient availability. The plant will lose vigor and eventually die. It is important to feed and maintain a healthy system.

soil particles reduces soil compaction so roots can grow more vigorously and absorb more of the nutrients required to maintain optimum hormone balance.

Plant Growth Stages

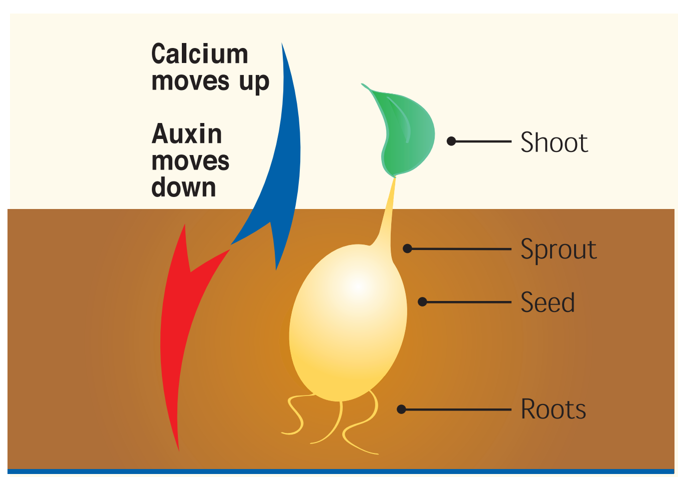
Stage I: Germination & Establishment

Maximizing plant genetic expression begins with seed germination, the establishment of a vigorous root system, fast and uniform emergence. If these processes are hindered by stress or lack of nutrients, maximum genetic expression is compromised for the rest of the growing season and cannot be regained.

A planted seed is in a state of dormancy due to high ABA levels. For germination to occur, the level of ABA must be reduced or the levels of auxin and GA must be increased. If soil conditions are too wet or dry, this hormone shift cannot take place and the seed will require external application of auxin and GA or supporting co-factors either as a seed treatment, in-furrow application or through irrigation.

The size and vigor of an emerging seedling (sprouting tuber, bulb or perennial plant coming out of dormancy) depends on the amount of cell division taking place in the newly developing root tips. The root tips manufacture cytokinin but need auxin from new shoot growth to maintain cell division needed for root tip growth and healthy plant development.

Roots move calcium into the new leaf tissue, causing auxin to move from new shoots in the opposite direction down into the developing root hairs. This is how roots acquire the auxin needed for cell division.



Why Is Root Tip Growth So Important?

Through signals transmitted by calcium and certain proteins, roots control the nutritional and hormonal balance for the whole plant. Root caps, which are replaced every 7-14 days, direct the manufacture of hormones and the absorption of water and nutrients. As root hairs absorb nutrients that are in the soil solution, they will deplete the nutrient supply without a consistent availability of soil moisture to solubilize and transport nutrients to the root hairs. Since soil moisture conditions are rarely consistent, the plant must continuously grow new root hairs into areas with optimal soil moisture conditions.

Solutions for Healthy Roots

Under drought conditions, roots no longer have adequate amounts of auxin and cytokinin to conduct normal cell division. The root system is affected in much the same manner when temperatures are too hot or cold.

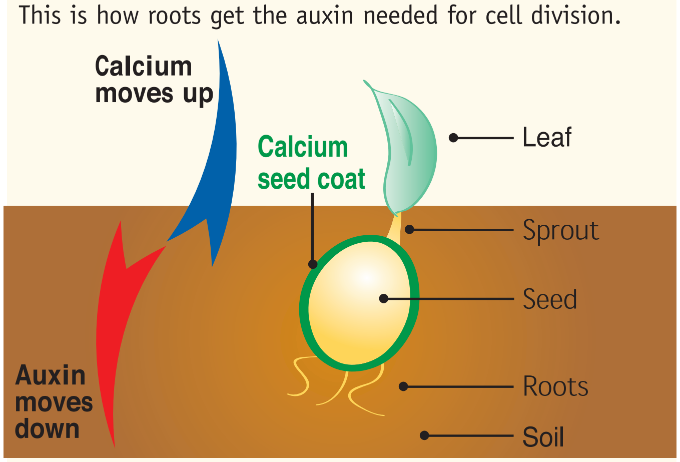
In flooded conditions the soil is deprived of oxygen and the roots can no longer breathe. They become dysfunctional or die. Since it is impossible to repair old, damaged roots, new root tips must emerge from the buds that are in the crown. This process requires sufficient amounts of cytokinin.

Typically, soil conditions provide enough nutrients to maintain plant health even when roots are affected by stress conditions. What looks like an apparent nutrient deficiency is generally caused by the roots' inability to generate new root tips to absorb these nutrients. This lack of cell division in the root tips is a result of a hormone imbalance caused by insufficient auxin and cytokinin.

Because most nutrients are absorbed by new root tip tissue (the root hairs), it is just as important for a plant to maintain a healthy hormone balance to keep continuous root tip growth as it is for the plant to have nutrients available in the soil. Without adequate root growth, the plant will not be able to absorb sufficient nutrients, even with very fertile soil or high soil analysis conditions.

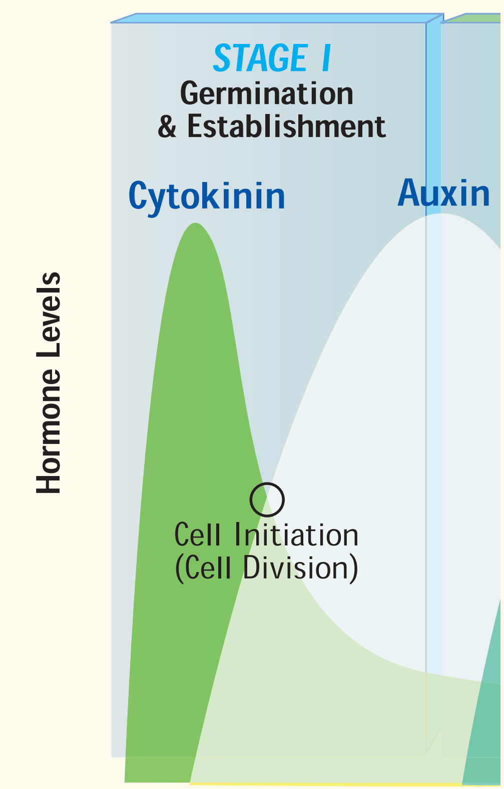
Establishing Seedling Vigor

Roots move **calcium up** from the seed coat into the new leaf tissue which causes **auxin to move down** from new shoots in the opposite direction into the developing root tip. This is how roots get the auxin needed for cell division.



One of the primary purposes of calcium inside the plant is to encourage movement of auxin between plant tissue.

Stage I: Germination and Establishment



Key Nutrients Hormone Co-Factors	N, Ca, P, Zn, Mg, K, Mn

Effects of Crop Health Therapy During Germination And Establishment

- Facilitate earlier planting
- Increase germination rate
- Enhance uniform plant emergence
- Produce a more consistent plant type throughout the crop
- Improve seedling vigor
- Control number of sprouts from tubers/rhizomes
- Improve transplant vigor and stress tolerance
- Establish healthy root system/increase root biomass
- Counteract high soil salinity, compaction, acidity/alkalinity
- Counteract hot/dry soil conditions
- Counteract cold/wet soil conditions
- Increase disease resistance
- Increase insect resistance

Stage II: Vegetative Growth

Vegetative top growth (shoots, leaves) is controlled by the rapidly developing roots. New leaf meristematic tissue provides auxin to the roots, maintaining a balance with the cytokinin for continued cell division in the root tips.
When vigorous root growth occurs (from high levels of amine nitrogen or cytokinin), the roots require more auxin from the leaves. In response the plant will produce new vegetative growth to supply the roots with the auxin needed to maintain growth of new root caps every 7-14 days.

Vegetative Growth and Temperature

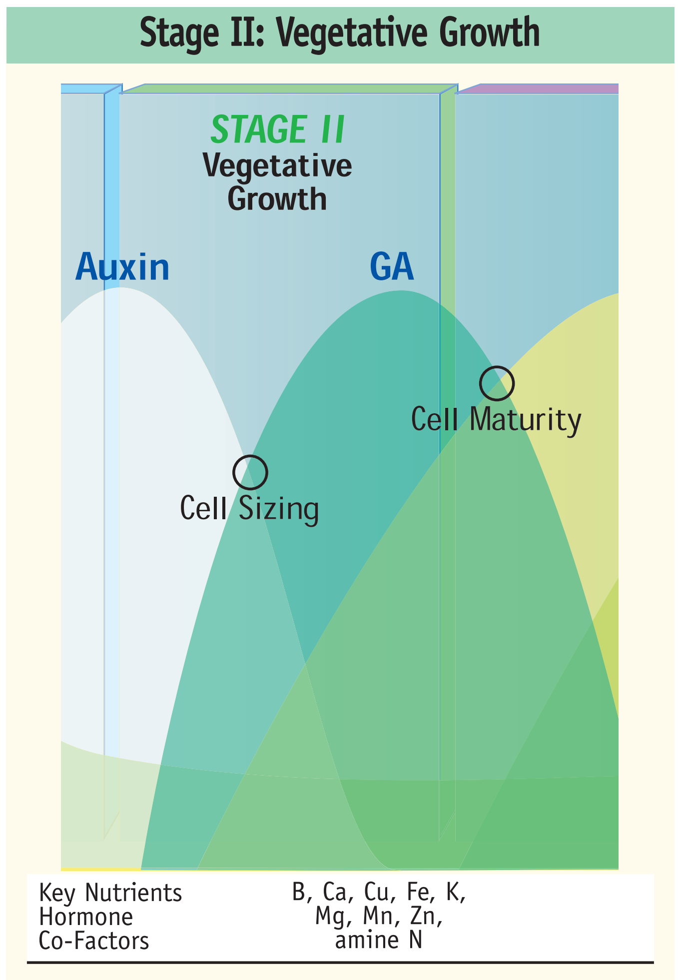
When temperatures are above 90^{0}F (31^{0}C) or below 68^{0}F (20^{0}C) the enzyme activity needed for hormone production becomes limited and cell division is impaired. During temperature extremes, additional hormones and/or hormone co-factors must be externally applied or cell division and growth will stop.

Vegetative Growth and Water

Roots cannot obtain adequate oxygen in conditions of excessive rain. The amount of cytokinin available for cell division is limited and cell division becomes abnormal. Since this lack of oxygen kills the roots, new roots must be forced out of the root crown. Externally applied cytokinin and/or co-factors support the development of new root growth.

In dry conditions where roots cannot provide adequate moisture to plant tissue, cellular water is reduced and wilting conditions occur. ABA levels rise and cause leaf surface stomata to close to prevent water loss. Stomatal closure also prevents carbon dioxide exchange and decreases photosynthesis. When wilting conditions are present, a combination of plant hormones and hormone co-factors can be applied to maintain cellular respiration, enabling the plant to continue to produce inter-cellular water.

The direction of root growth is also important. A plant with a hormone imbalance will have more shallow, lateral root growth. A plant with proper hormone balance will have more downward root growth. Downward root growth is extremely important as the plant's first line of defense against drought or other stress conditions



Vegetative Growth In Monocot Plants

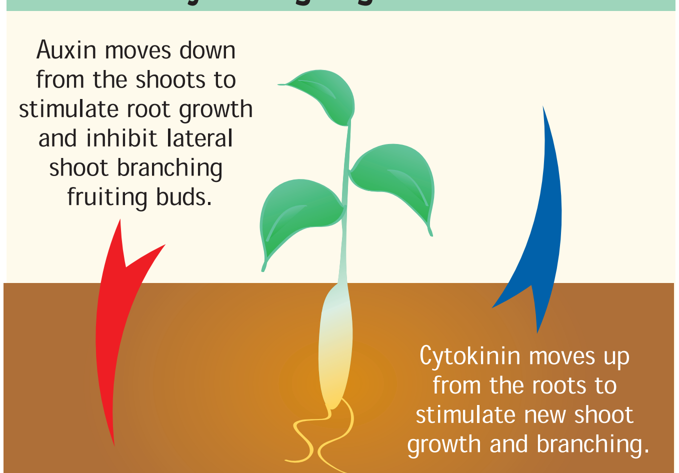
(cereal grains, corn, grass, rice)

In monocot plants the growing point comes only from the crown. By the time the growing point is 14 days old it has differentiated into leaves and potential seed parts. As the growing point moves up the inside of the stem, the leaves and the growing point are exposed. This continues in sequence until the seed head and tassel emerge. The growing point (bud) can be damaged as it travels from the crown up the plant. This is a function of cell division (the balance between auxin and cytokinin). Stress conditions can affect the hormone balance and the cell division process, altering the appearance of both the leaves and seed head or cob. The size of the leaves, the size of the stalk, and the size of the seed head or cob is primarily due to the expansion of the new cells, which is controlled by GA, the hormone responsible for cell sizing.

Vegetative Growth In Dicot Plants

In dicot plants most of the new tissue develops off the main stem or plant branches. Every plant node on either the stem or branches has a potential budding point where fruiting pods or fruiting parts can form. These fruiting points then develop fruits and seeds. The number of buds activated to become a fruiting part is related to the balance between auxin and cytokinin. Stress conditions can affect the hormone balance and the cell division on the buds, which will alter the number, viability and quality of the fruiting parts.

Hormone Movement and Activity During Vegetative Growth



Root and Shoot Growth

Auxin
Cytokinin > Cell Division
GA — Cell Sizing

Where auxin and cytokinin meet, buds are formed:
A. Vegetative buds: higher cytokinin to auxin ratio
B. Reproductive buds: higher auxin to cytokinin ratio

The Fruiting Part Wins If...

1. There are a lot of fruiting parts.
2. The fruiting parts have more seed (= more auxin).
3. Shoot growth is slower.

The number of fruiting parts is determined before pollination and early fruit development.

Vegetative Shoot Growth Wins If...

1. There is excessive vegetative growth.
2. There is little fruit.
3. There is seedless fruit (less seed = less auxin).
4. There is excessive Nitrogen.

Slow down vegetative growth by applying Boron and Molybdenum +/- a balanced mixture of auxin/cytokinin/GA.

Effects of Crop Health Therapy During Vegetative Growth

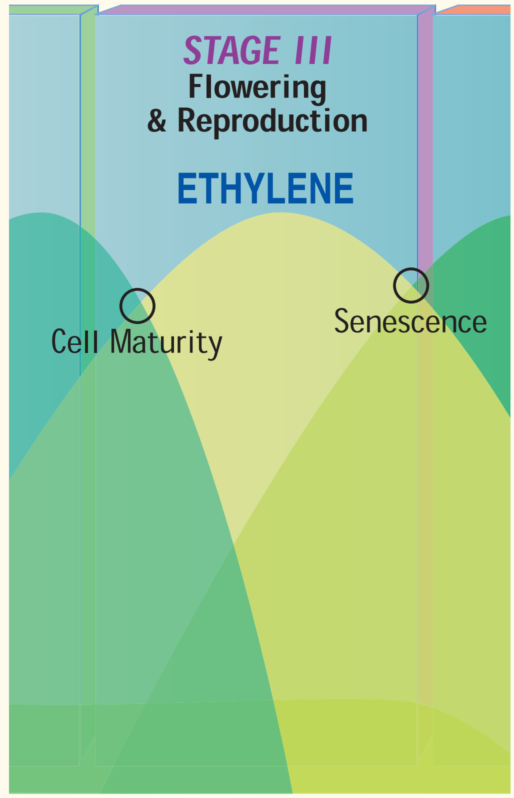
- Reduce tillers or number of shoots
- Increase branching/shoot number
- Reduce internode length
- Enhance drought resistance
- Enhance survival in flooded/waterlogged fields
- Increase plant tolerance to heat stress
- Increase plant resistance to freezing
- Improve plant recovery from frost damage
- Reduce effects of herbicide or other plant damage
- Increase insect resistance
- Increase stem/stalk diameter
- Expand leaf area and biomass
- Increase nutrient efficiency
- Increase protein content and quality of green tissues
- Improve digestibility and feed value
- Improve storage quality of silage, allow storage of higher moisture forage
- Maintain plant vigor for multiple harvests/seasons

Stage III:
Flowering and Reproduction

Auxin is needed to stimulate ethylene production and initiate flowering. Auxin also plays a role in pollen tube growth. Plants cannot synthesize enough auxin during high temperatures. Inadequate auxin results in flower abortion, fruit/seed drop, and physiological disorders at the time of flowering and fruit/seed set. Supplementing the plant with auxin and/or co-factors that help boost auxin availability, such as boron, calcium, molybdemum, and zinc, will help alleviate these problems.

Vigorous Roots: A stronger, shorter flowering period
Poor Roots: A longer, weaker flowering period

Stage III: Flowering & Reproduction



Key Nutrients Hormone Co-Factors	B, Ca, Cu, K, Mg, Mo, amine N

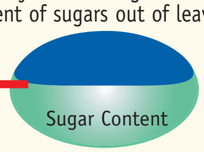
Effects of Crop Health Therapy During Flowering & Reproduction

- Shorten time to flowering/force flowering
- Increase number of flowers/fruiting positions (increase the number of reproductive buds)
- Increase bud strength/viability
- Increase pollination (pollen tube growth, transfer of pollen into stigma)
- Reduce flower and fruit abortion

Temperature and Sugar Movement

The difference between daytime and nighttime temperatures also has an effect on the movement of sugars out of leaves into fruiting parts.

Phloem Loading with Sugar is Weak



- GA dominant
- Respiration high
- Cell elongation
- = **Sugar "Sink"**

HIGH daytime/HIGH nighttime temperatures (>90°F) = Reduced Auxin Production

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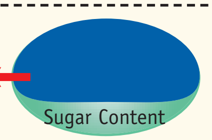
Phloem Loading with Sugar is Strong

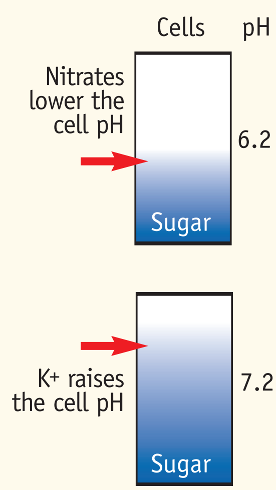


- Auxin dominant
- Respiration low
- Cell division
- = **Sugar "Source"**

HIGH daytime/LOW nighttime temperatures (68-89°F) = Normal Auxin Production

GA dominance increases cell "SINK": sugar stays in vegetative cells.
Auxin dominance increases cell "SOURCE": flow of sugar out of leaf towards fruiting parts

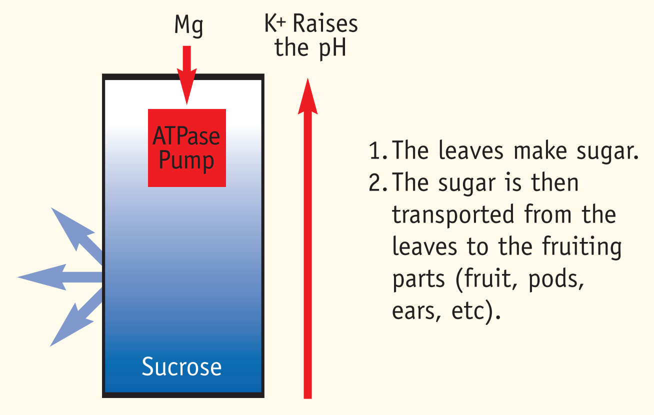
Effect of N & K On Sugar Movement



1. Nitrogen lowers the pH in the cell which reduces movement of sugar out of the cell.
2. All nitrogen should be applied well before fruiting parts start to size.

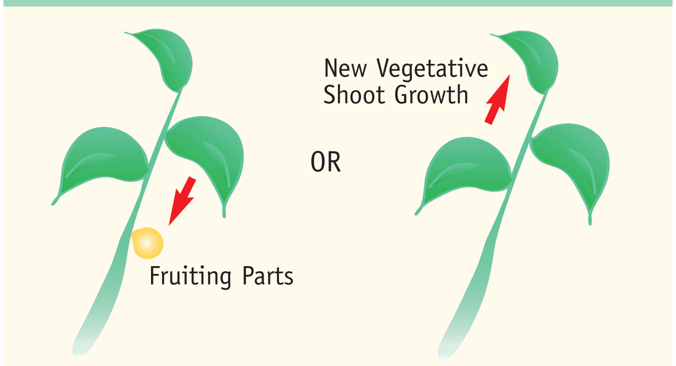
1. Potassium in the cell raises the pH thereby increasing sugar movement out of the cell.
2. Most of the K^+ should be applied at early sizing of fruiting parts.

The Discharge of Sugar From Vegetative Cells



Magnesium is the fuel that runs the ATPase pump.

Where Does The Sugar Go?



Natural competition exists between fruiting parts and new vegetative shoot growth for food (sugar from photosynthates).

Stage IV: Fruit Sizing and Maturity

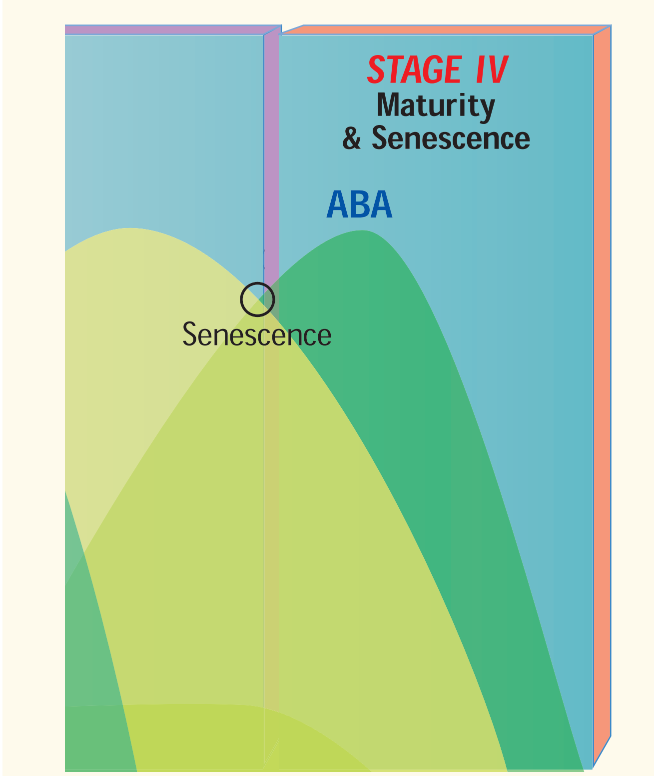
Understanding how hormones affect the plant is important for increasing yield, soluble solids/sugar content, and optimal/uniform sizing of fruiting parts (fruit, seed, pods, ears, other harvested storage tissues).

Auxin is made early in the fruiting part development process beginning at flower formation. Auxin moves out of the developing fruiting part, causing the plant to release more sugars to send to these developing bodies targeted for harvest. If auxin is not produced because of temperature extremes, sugars will not move out of the leaves into the new fruiting parts for sizing or quality enhancement.

When fruiting parts (fruit, seed, tubers, pods, ears, storage tissues) begin to form, an abundance of sugar (photosynthates) ensures that adequate amounts of starch are deposited in the tissues to be harvested. These sugars enter the fruiting parts from the stalk or stem. Sugar movement from the leaves into the stalk or stem should begin at least 2 weeks before the fruiting parts begin to form. The initial sugar supply (photosynthates) determines the number of fruiting parts that will survive during the development period. Normally 30%-50% of the fruiting parts are aborted in this phase due to lack of sugar transport into the embryo.

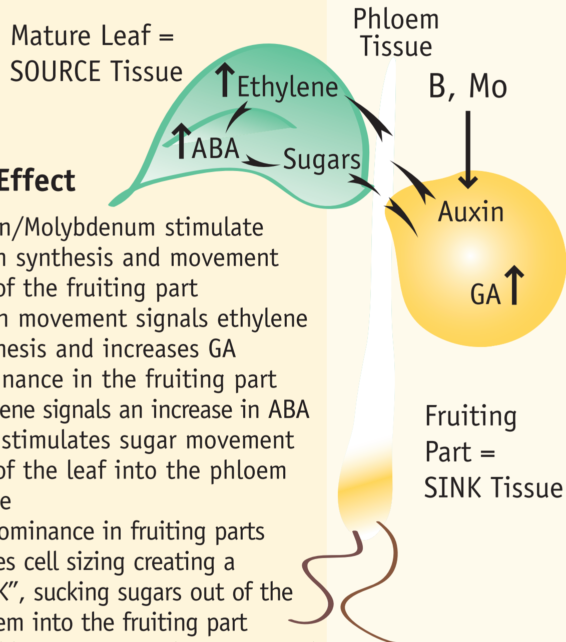
Fruiting part sizing depends on cell division and cell sizing. Under extremely dry conditions the seed size will tend to be small due to lack of auxin and GA. Under such conditions the seed accumulates ABA which terminates both cell division and cell sizing. The difference between daytime and nighttime temperatures also has a great impact on fruiting part sizing. Supplementing with and/or stimulating the plant to produce and move auxin helps ensure the desired fruiting part sizing under these conditions. If conditions during fruiting part formation are continually wet and the plant has an abundance of nitrogen, cell division and cell sizing will continue to such an extent that there is not enough ABA to terminate cell sizing and drive the fruiting part into dormancy and maturity. Under these conditions fruiting parts will sprout before they are harvested or while in storage

Stage IV: Fruit Sizing & Maturity



Key Nutrients Hormone Co-Factors	B, Ca, Cu, Fe, K, Mg, Mn, Zn, amine N

Hormones and Sugar Movement



The Sink Effect

1. Boron/Molybdenum stimulate auxin synthesis and movement out of the fruiting part
2. Auxin movement signals ethylene synthesis and increases GA dominance in the fruiting part
3. Ethylene signals an increase in ABA
4. ABA stimulates sugar movement out of the leaf into the phloem tissue
5. GA dominance in fruiting parts causes cell sizing creating a "SINK", sucking sugars out of the phloem into the fruiting part (i.e. like a sponge soaking up water)

Physiological Disorders Of Harvested Fruiting Parts

Most physiological disorders occur during the cell division period before fruiting bodies (fruit/pods/ears, etc) start to form during the cell expansion period. If there are too few cells available for expansion, then physiological disorders will appear as the fruit starts to size. Foliar application of cytokinin with boron and calcium will alleviate the physiological disorders associated with this period.

Highest Yields

As a plant ages, new root growth greatly decreases due to an overabundance of auxin migrating from the large vegetative mass at the top of the plant down to the roots. As a result, the amount of auxin exceeds the amount of cytokinin needed to balance it for continued cell division. Excess auxin inhibits cell division in the new root tips causing premature senescence (early death). Stems that brown prematurely are an indication of excess auxin, while green stems at harvest are indicators of continuing healthy root growth which leads to higher yields. To ensure maximum yields, cytokinin and auxin levels must be balanced.

Crop Health Therapy for Fruit Sizing and Maturity

Stoller Crop Health Therapy positively affects cell division of small fruiting parts, promotes a strong sink effect to promote sugar movement to inflorescence, flowers and fruit/seed instead of new vegetative growth. It also maintains calcium in the new flower, inflorescence and fruit part tissues for reduced physiological disorders, enhanced quality and prolonged storage shelf life.

- Better manage fruit thinning
- Reduce alternate-bearing syndrome
- Reduce physiological disorders/maintain cell division
- Move sugars from leaves to storage tissues and increase soluble solids/sweetness
- Decrease protein content in grains
- Increase protein content of grains
- Size up fruit, seed, tubers, storage tissues
- Enhance harvested fruit, seed, tuber, storage tissue quality
- Get more uniform size fruit, seed, tubers, storage tissue
- Improve or hasten ripening, fruit color
- Delay ripening
- Delay plant senescence
- Extend and enhance harvest period and maintain high yields for multiple harvests
- Increase harvested quantity and yields
- Increase storage shelf life
- Reduce respiration/breakdown during storage
- Reduce early sprouting from grain, bulbs and tubers

Plant Hormone Co-Factor Benefits

Hormone Co-Factor	Key Benefits
Polyamine Complex	Assists hormone activity by stabilizing cell structure and activity
Anti-oxidant	Reduces oxidative stress for prolonged cell life; supports cytokinin activity
Organic Chelation	Superior nutrient availability for enhanced protein function and hormone balance
Amine Nitrogen (NH_2)	More energy-efficient N form for controlled shoot growth, increased sugar
Boron	Enhances cell wall strength, auxin levels, sugar transport into seed/fruit
Calcium	Facilitates hormone function, healthy cell walls and disease resistance
Copper	Regulates hormones for enhanced vegetative growth and ripening
Magnesium	Pumps nutrients into the roots, sugars out of the leaves, enhances hormone activity
Manganese	Regulates auxin levels, energy transfer, photosynthesis & frost resistance
Molybdenum	Stimulates the synthesis of auxin and ABA; has anti-oxidant properties
Nitrate Nitrogen (NO_3)	Triggers cytokinin synthesis for cell expansion, shoot growth
Potassium	Regulates sugar transport, water uptake & hormone synthesis for cell expansion
Zinc	Integral for auxin function, genetic expression, cell membrane integrity, energy

Summary

Genetic potential and good cultural practices help build the photosynthetic factories (the vegetative cells) needed for genetic expression in yield and quality. However, plants are exposed to a variety of stresses during the growing season that reduce genetic expression.

During stress, respiration is necessary to keep cells alive in order to produce the sugars, or plant food, from photosynthesis needed for normal, healthy plant growth. This means that the growth hormones auxin, cytokinin and gibberellic acid must remain active, in adequate supply and appropriate balance throughout the growing season until ripening and maturity is desired. Crop Health Therapy, employing hormone co-factors such as organically-chelated micronutrients, amine complexes, anti-oxidants and N-HIB technology and, in some cases, the hormones themselves, helps ensure that optimum hormone cycles remain in balance to counteract the effects of stress on the plant. This ensures that photosynthesis and resulting sugar production are maximized.

Once the sugar has been produced and stored in the leaves, the movement of sugar from the leaves to the storage/fruiting part tissue determines yield and quality. This requires a reversal in the usual flow of sugar from the leaves up to the apical meristem at the top of the plant due to loss of control by the roots towards the end of the growing season (apical dominance over the roots during senescence). Consequently, most plants are only harvested at approximately 30% of their genetic potential. Crop Health Therapy helps reverse this normal flow where sugar now moves from the leaves down to fruiting parts resulting in significantly enhanced yields and quality.

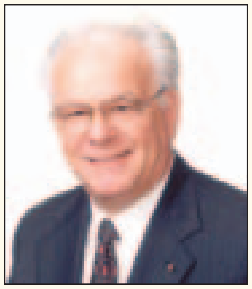
The four key steps to effectively using Crop Health Therapy are:

1. Maintain vigorous root growth until harvest
2. Begin treatments immediately with seed, in-furrow, transplant water or starter fertilizer treatment at seeding or break in dormancy
3. Eliminate any possible limiting factors:
   - nutrients (organically chelated)
   - amine complexes/anti-oxidants/N-HIB hormone co-factors
   - growth hormones, if needed
4. Maintain Crop Health Therapy treatments up to every 7 to 14 days until harvest

StollerUSA: The Company

"The only thing that is more valuable than the product we sell you, is the knowledge that we empower you with. Seeing is Believing!"

- World leader in development and sales of Crop Health products since 1970
- Worldwide headquarters in Houston, Texas
- Products distributed in more than 50 countries
- Dedicated to helping producers find ways to naturally enhance a plant's potential through genetic expression
- Pioneered the use of acid fertilizers
- Leader in developing unique chelated forms of micronutrients with advanced plant availability
- Spearheading research and development in the new area of Crop Health Therapy based on natural plant hormones



JERRY STOLLER

Founder, owner, CEO for the Stoller Group
Recognized global authority on plant nutrition
Renowned innovator and teacher
Worldwide crop production experience
Leader in plant hormone modeling

CONSULTING PROJECTS:

Public and private sector commissions:
Crop production in Jamaica
Coffee production in Central America
Palm oil production in Malaysia
Potato production in Canada
China project sponsored by Cargill

PROFESSIONAL

Board of Directors, The Fertilizer Institute

AFFILIATIONS:

American Society of Agronomy
Soil Science Society of America
Crop Science Society
American Horticulture Society
1998 Entrepreneur of the Year for the Retail-Wholesale Industry (Southwest Region)
Plant Growth Regulation Society of America
Western Plant Growth Regulation Society of America

Relevant Stoller Patents

Issued:

Amine chemistry and micronutrients
Amine chemistry and boron
Chemistry and use of ReZist (SAR) for disease resistance and enhancement of root growth
Use of amine nitrogen and calcium to inhibit diseases

Pending:

Use of plant hormones for insect and disease resistance
Use of plant hormones applied to the roots of plants to manipulate and enhance physiological growth characteristics

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