Stoller
Together we grow.

The World of Plant Hormones and their influence on Alfalfa Quality and Yield

A Corteva Agriscience Business

Agenda

- BIOLOGICALS/BIOSTIMULANTS OVERVIEW
- HORMONE BASICS & THEIR PURPOSE
- HOW HORMONES CAN IMPROVE ALFALFA YIELD & QUALITY

A Corteva Agriscience Business

BUILDING A BIOLOGICALS BUSINESS, TOGETHER

"We are pleased to officially welcome Symborg and Stoller employees to Corteva. We believe their knowledge and expertise, combined with Corteva's innovations capabilities, will come together to form a leading Biologicals Business ready to accelerate and grow with the rapidly expanding biologicals market."

-Chuck Magro, Chief Executive Officer, Corteva Agriscience

2023 AG BIOLOGICALS LANDSCAPE

The Mixing Bowl
CONNECTING INNOVATORS IN FOOD, AG & IT

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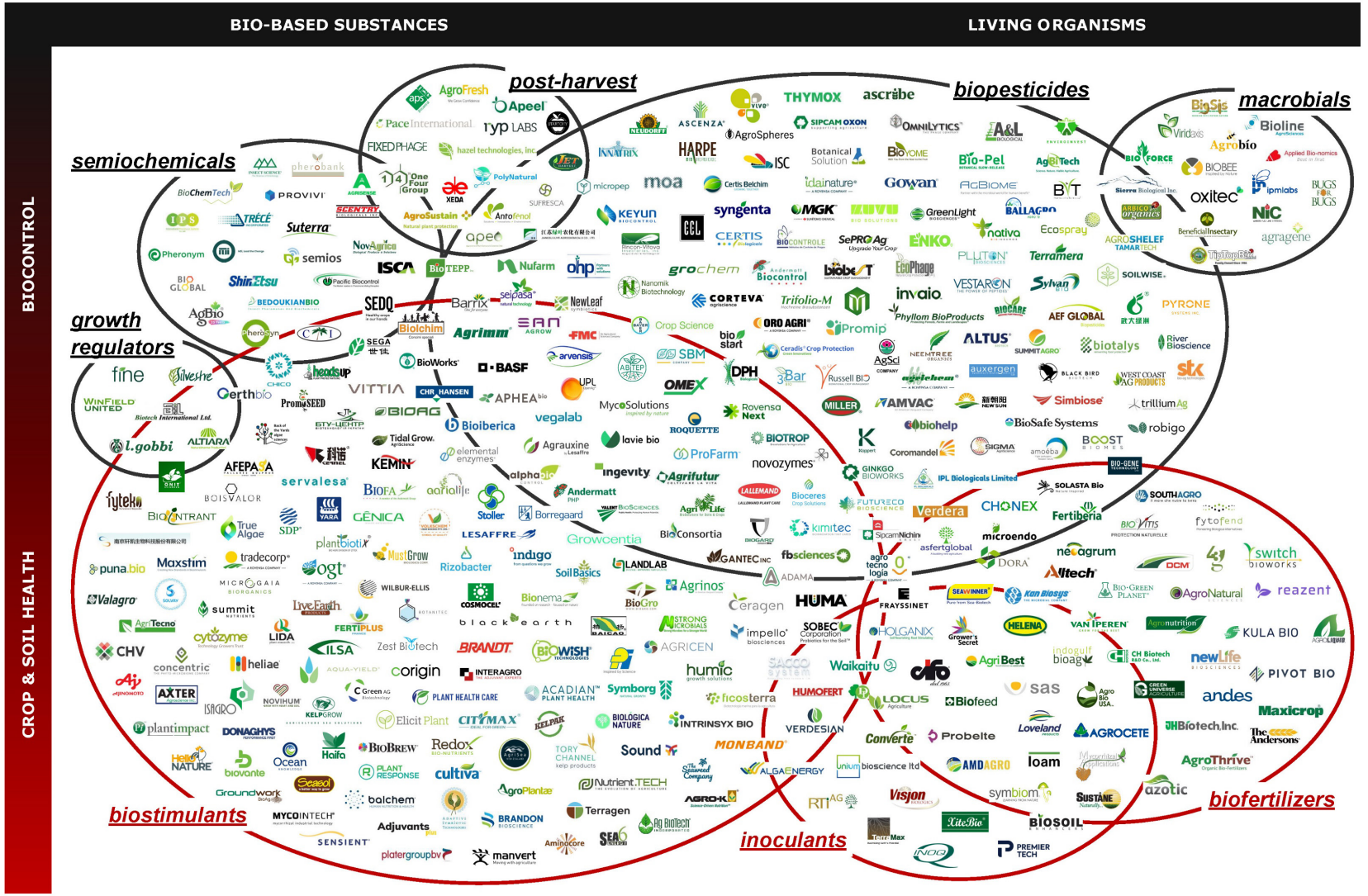
Together we grow.



Chris Taylor
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WESTERN GROWERS

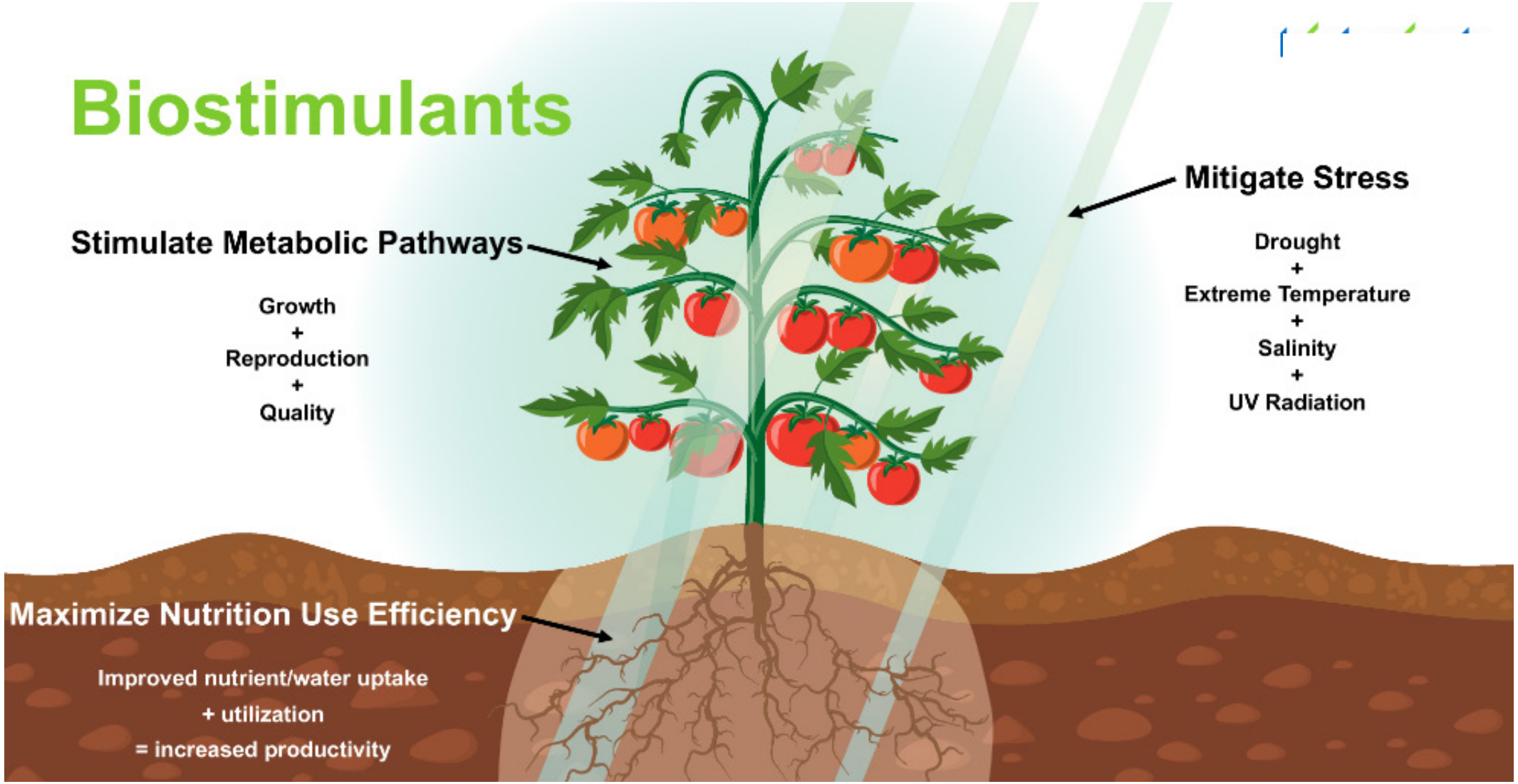
Companies appear on the landscape only once, although some may offer products in multiple segments. Overlapping areas are meant to imply this, however, logo positions are not necessarily indicative of any specific or limited product offerings.

What are Biostimulants?

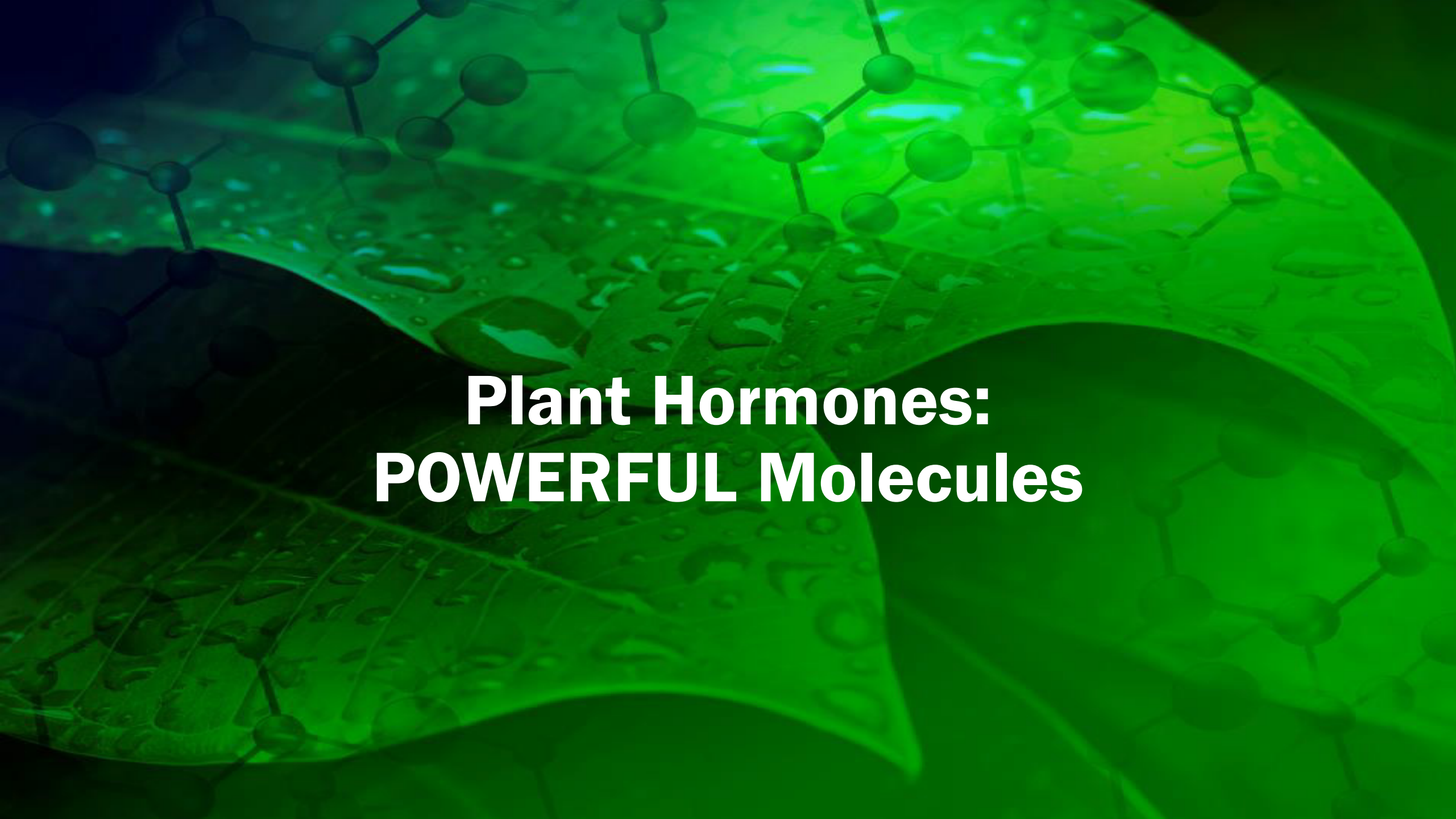
Pending USDA Biostimulant Definition

"A plant biostimulant is a substance(s), microorganism(s), or mixtures thereof, that, when applied to seeds, plants, the rhizosphere, soil or other growth media, act to support a plant's natural nutrition processes independently of the biostimulant's nutrient content. The plant biostimulant thereby improves nutrient availability, uptake, or use efficiency, tolerance to abiotic stress, and consequent growth, development, quality or yield."

Benefits of Biostimulants?

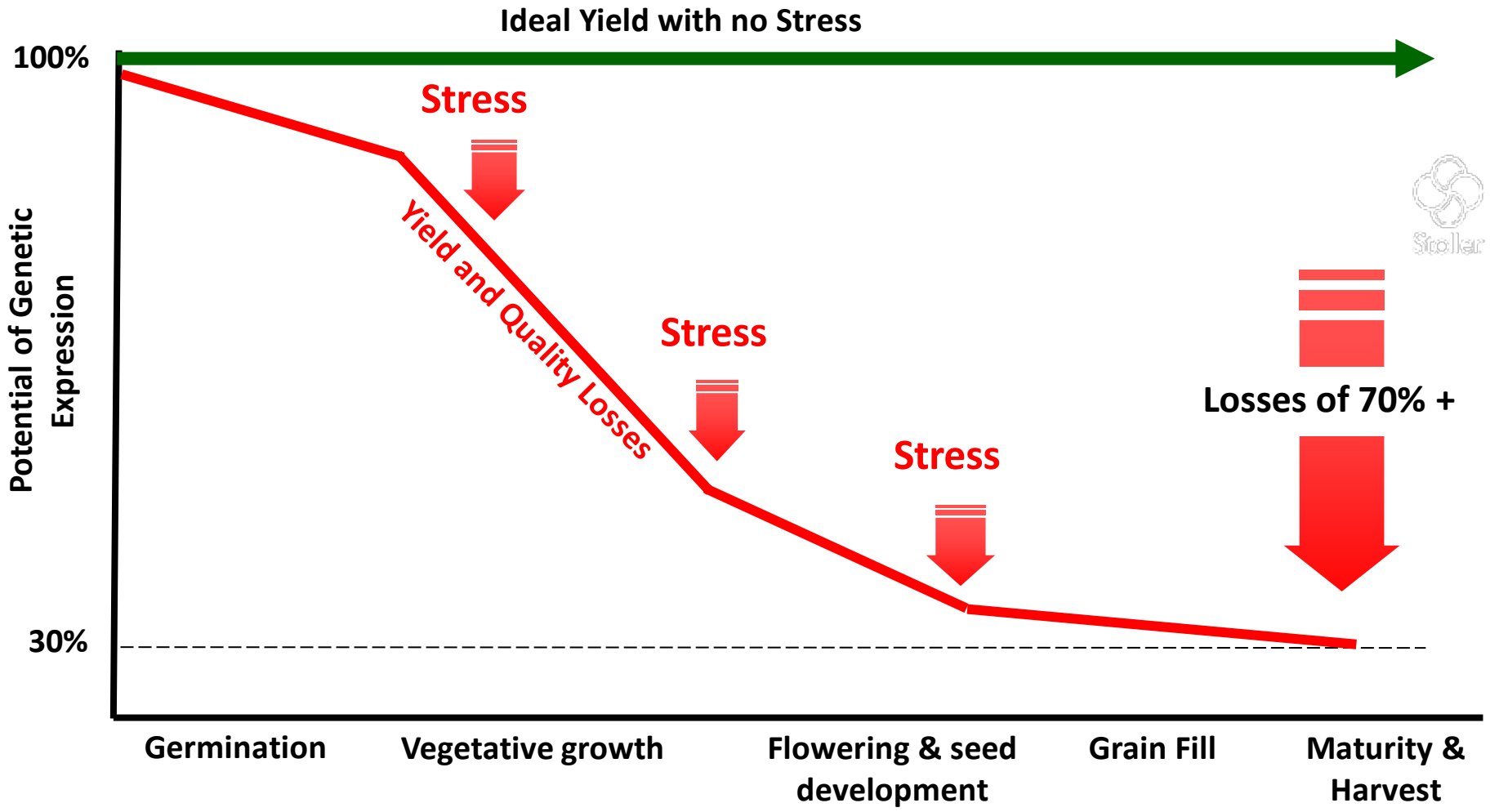


(Corteva, n.d.)



Plant Hormones: POWERFUL Molecules

Yield Potential and Farm Yield



- Moisture extremes
- Nutritional imbalance
- Hormonal imbalance
- Sunlight extremes
- Temperature extremes
- Weather damage
- Weed competition
- Herbicide damage
- Insect damage
- Disease damage
- Mechanical factors
- Overall Agronomics

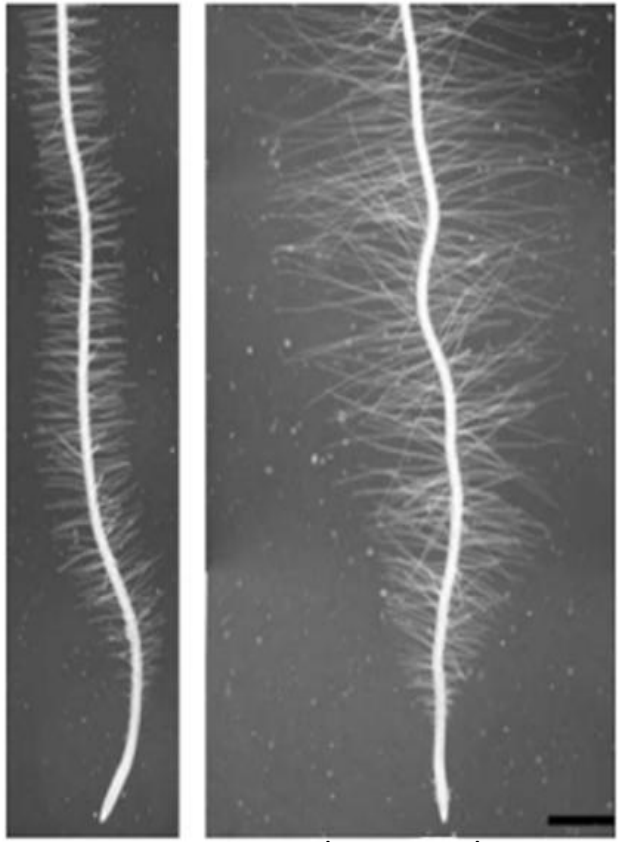
The Stoller Approach

The Roots are the “Brains” of the Plant

4 of the 5 major plant hormones are produced in the roots of the plant.

The Need:

- **Keep the roots actively growing**
- **Supplement to maintain hormonal balance**

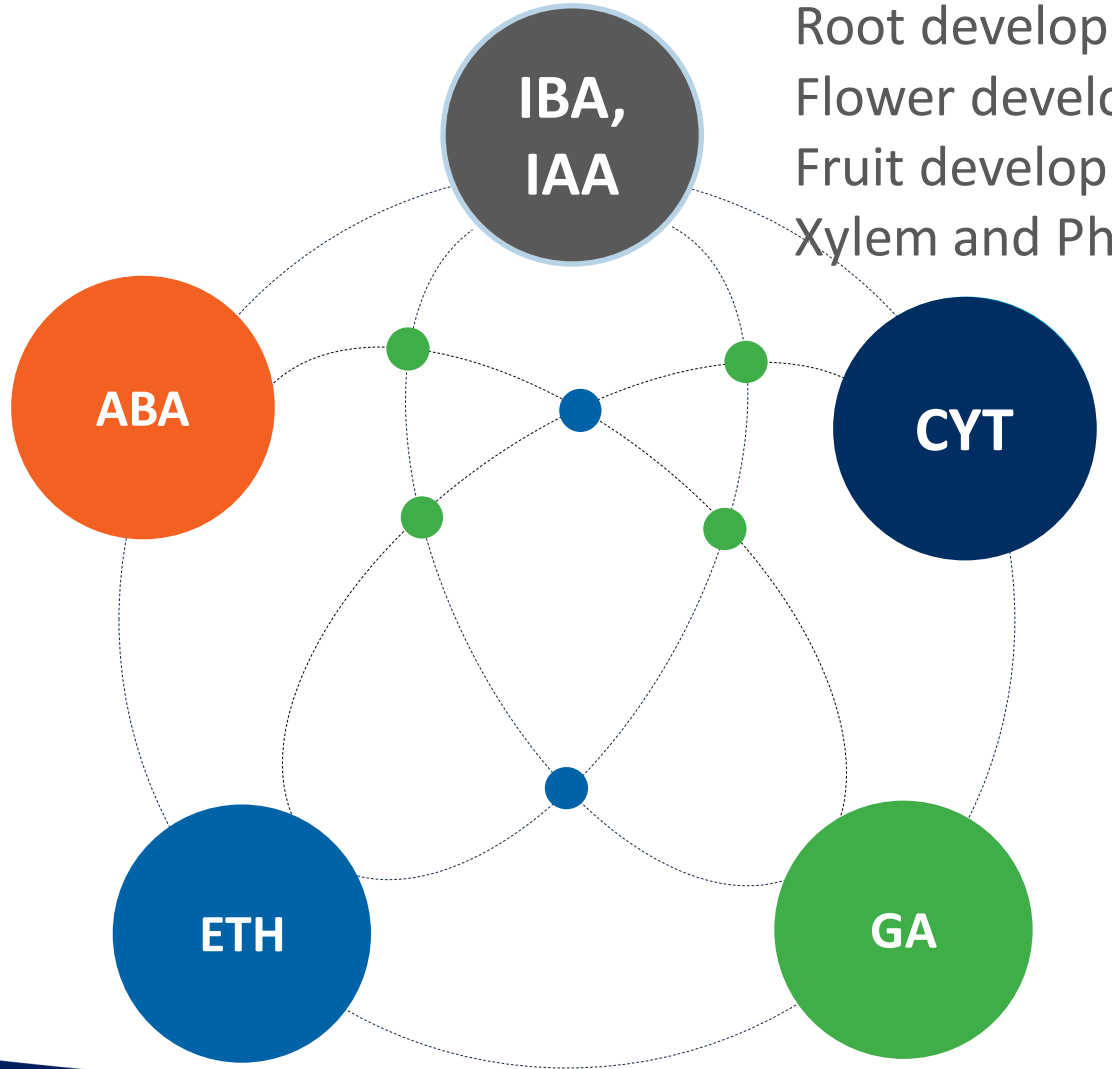


New root tips last 7-14 days

Five Major Plant Hormones

Abscisic Acid
Stomatal regulation
Seed dormancy
Promotes ripening

Auxin
Root development
Flower development
Fruit development
Xylem and Phloem Formation

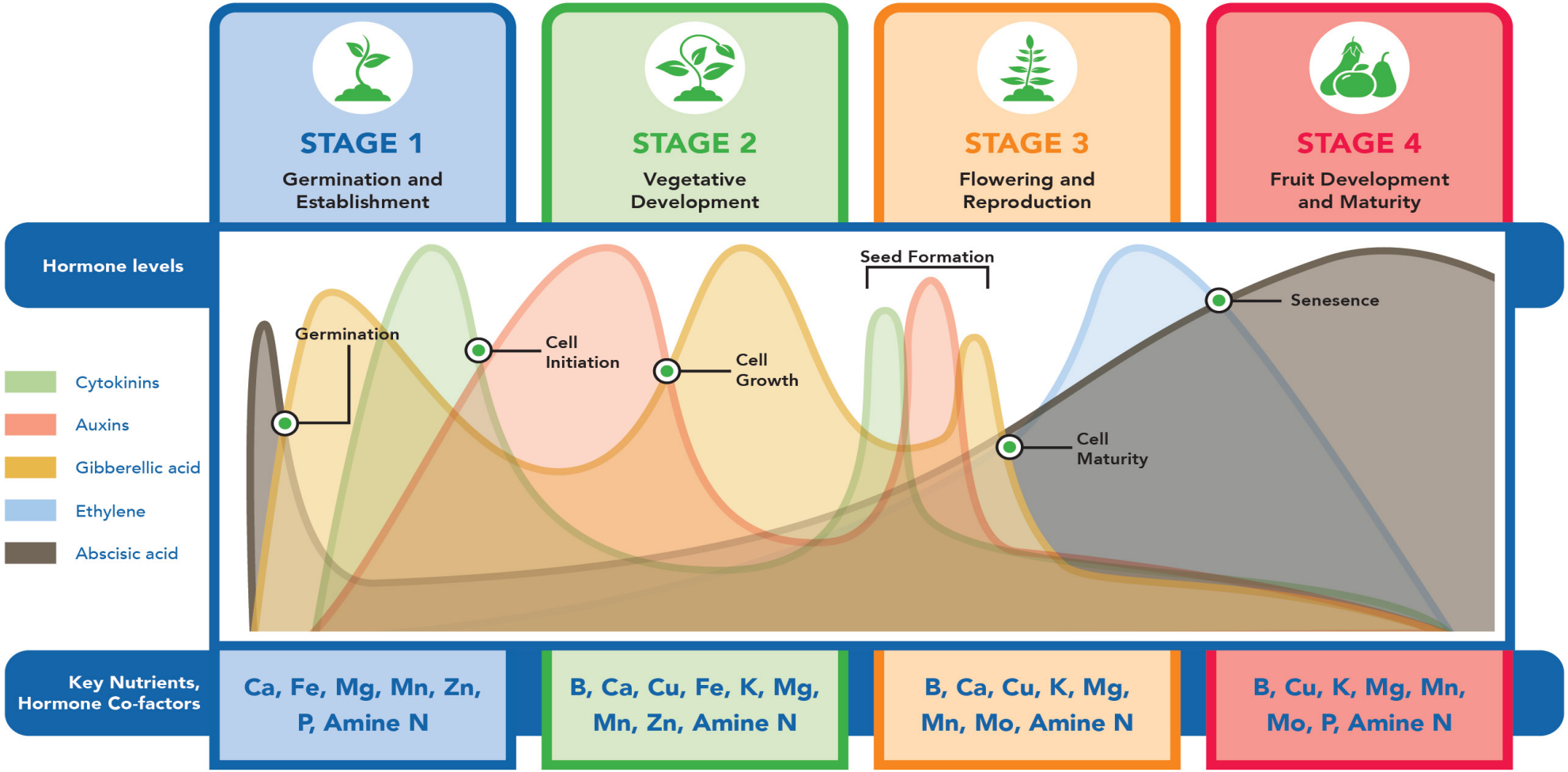


Cytokinin
Cell division
Lateral branching
Reproductive growth

Ethylene
Gaseous form
Promotes ripening
Stress hormone

Gibberellin
Cell elongation
Induces germination
Fruit sizing

The Stoller Plant Hormone Model



U.S. Patent #8,207,091 B2 (2012)

Hormone Co-Factors

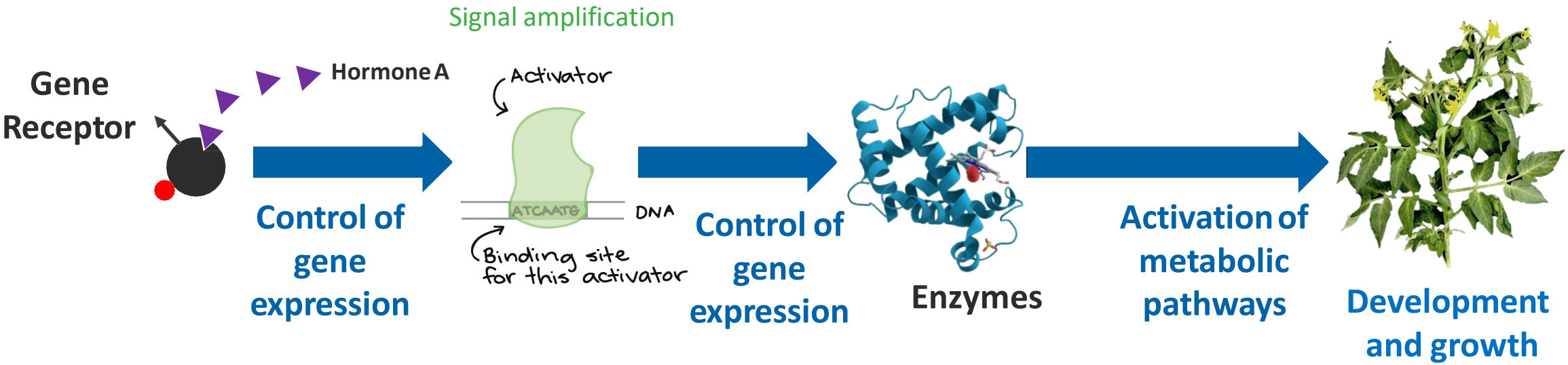
Amine Nitrogen (NH_2)	More energy-efficient, plant-useable nitrogen form for controlled shoot growth, increased sugar.
Boron	Enhances cell wall strength reducing oxidative breakdown of auxin, thereby increasing auxin levels and corresponding auxin effects including increased sugar movement into harvestable 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.

Hormone Co-Factors

Magnesium	Structural component of chlorophyll, a co-factor for synthesis of many enzymes, pumps nutrients into the roots.
Manganese	Acts in energy utilization, photosynthetic electron transfer, nitrogen and auxin metabolism.
Molybdenum	Key element 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.

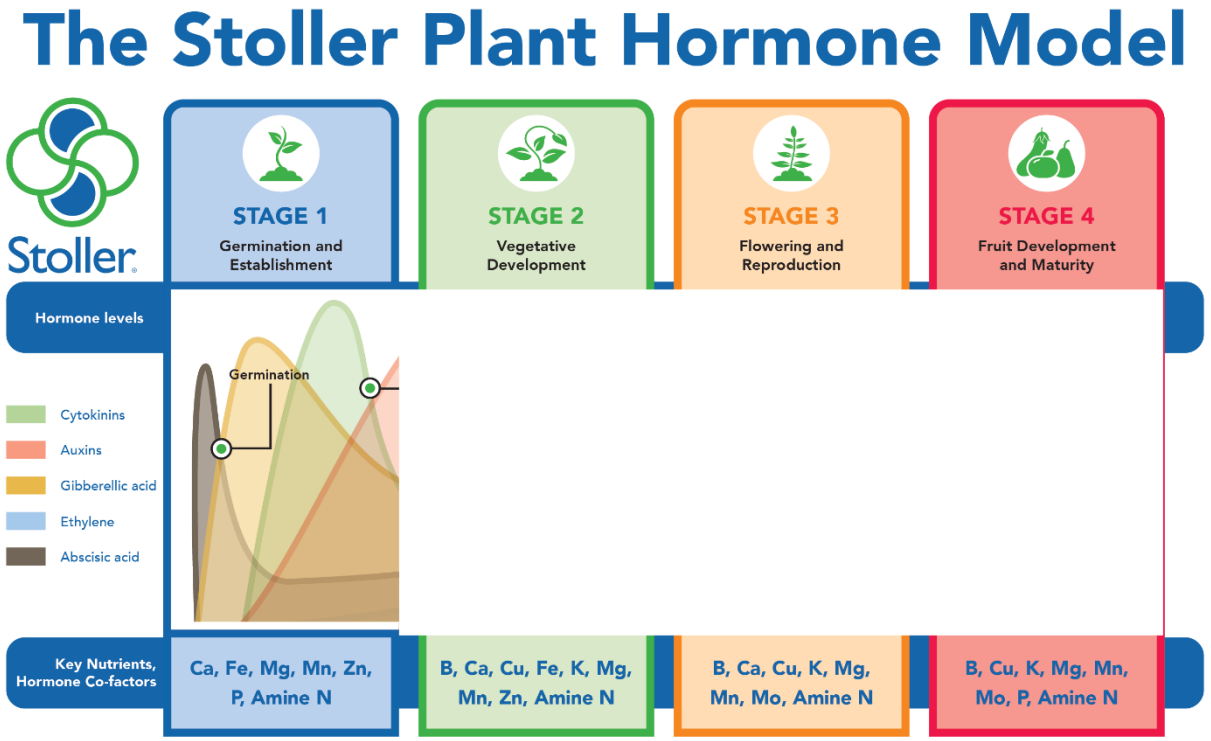
Hormone Signaling

Plant hormones control every aspect of development and growth since they regulate the production of enzymes that activate metabolic pathways



Stage 1: Germination and Establishment

- ABA is needed for dormancy and keeps the seed dormant until planting or the perennial plant dormant until budding
- As the soil warms and with moisture present, ABA decreases and GA increases, signaling germination
- As the root emerges, cytokinin is produced and moves upwards, promoting vegetative growth

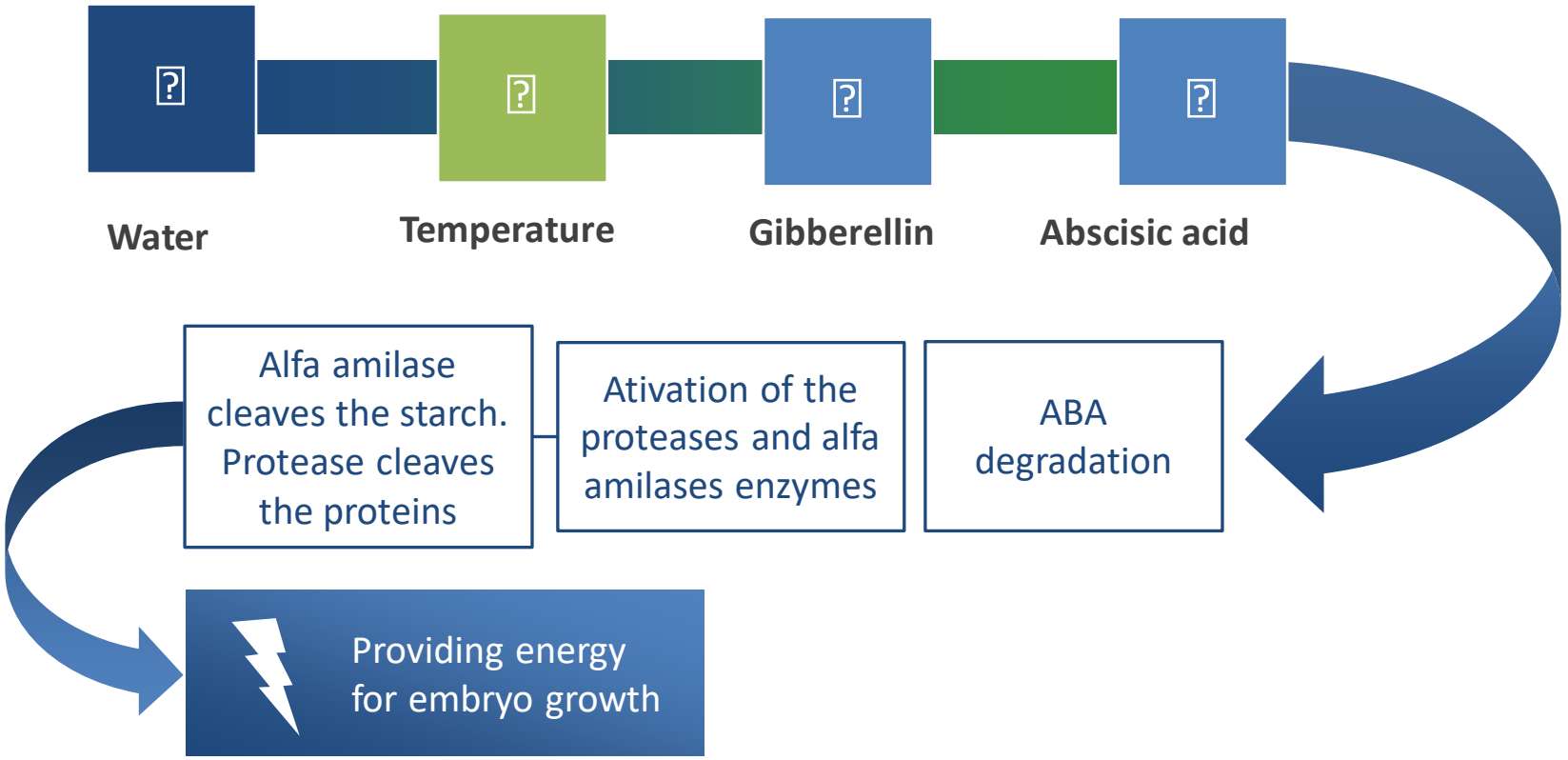


Method for improving growth and crop productivity of plants by adjusting plant hormone levels, ratios and/or co-factors.

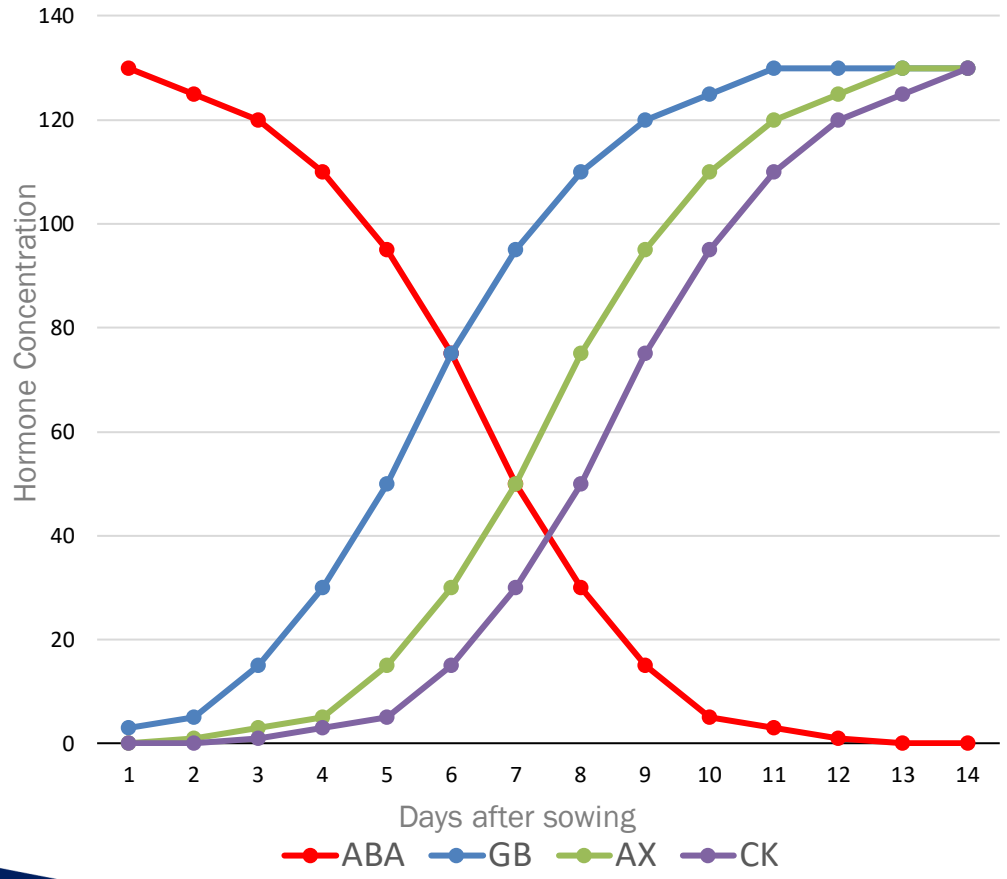
U.S. Patent #8,207,091 B2 (2012)

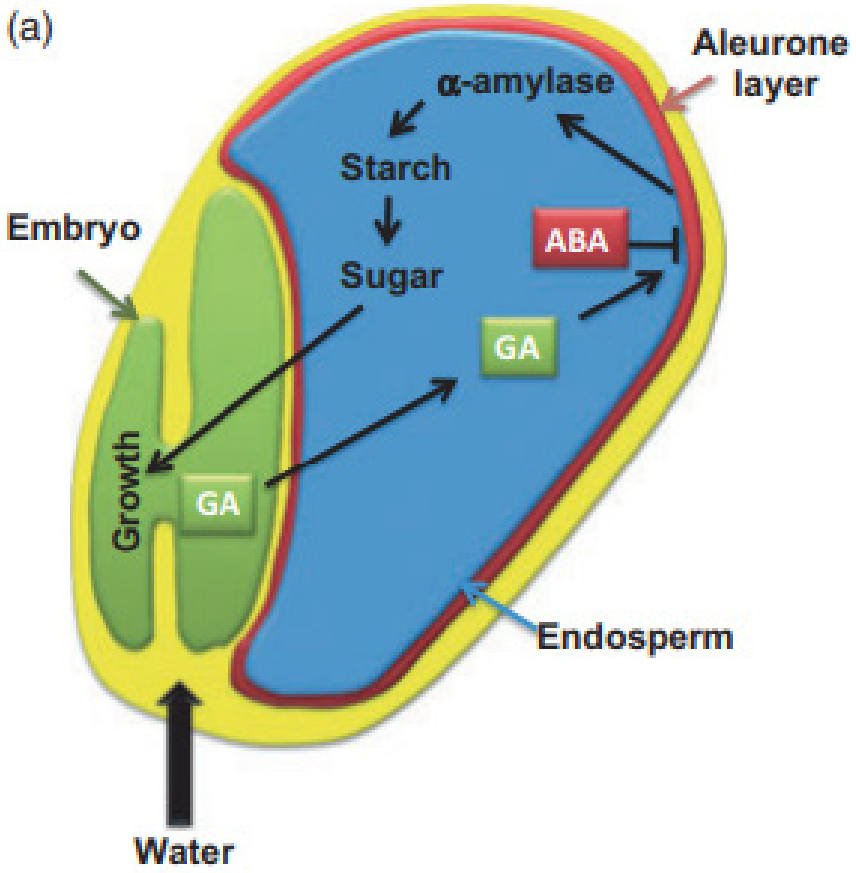
Germination

The driving factors of seed germination

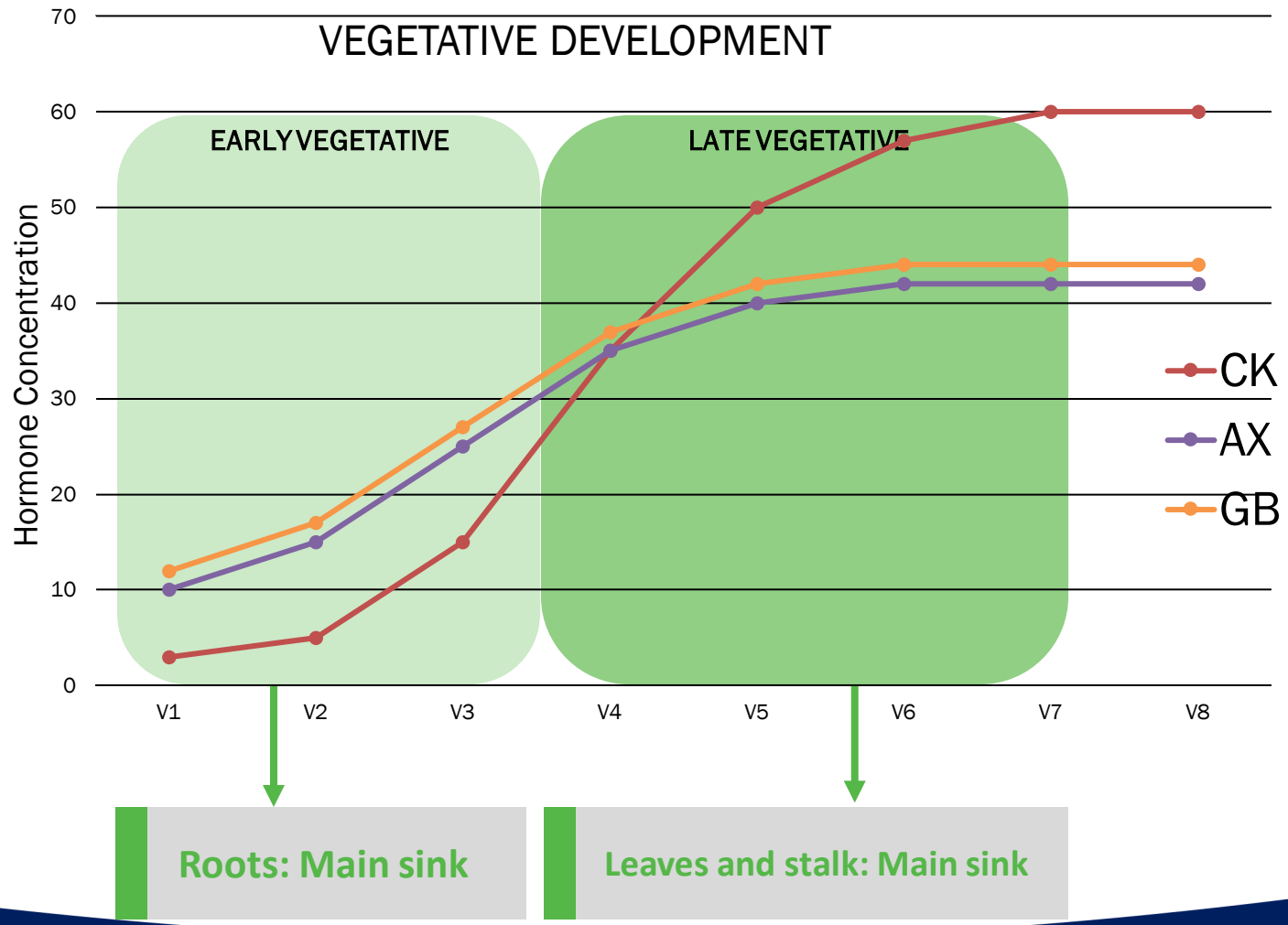


HORMONE DYNAMICS WHEN GERMINATION STARTS

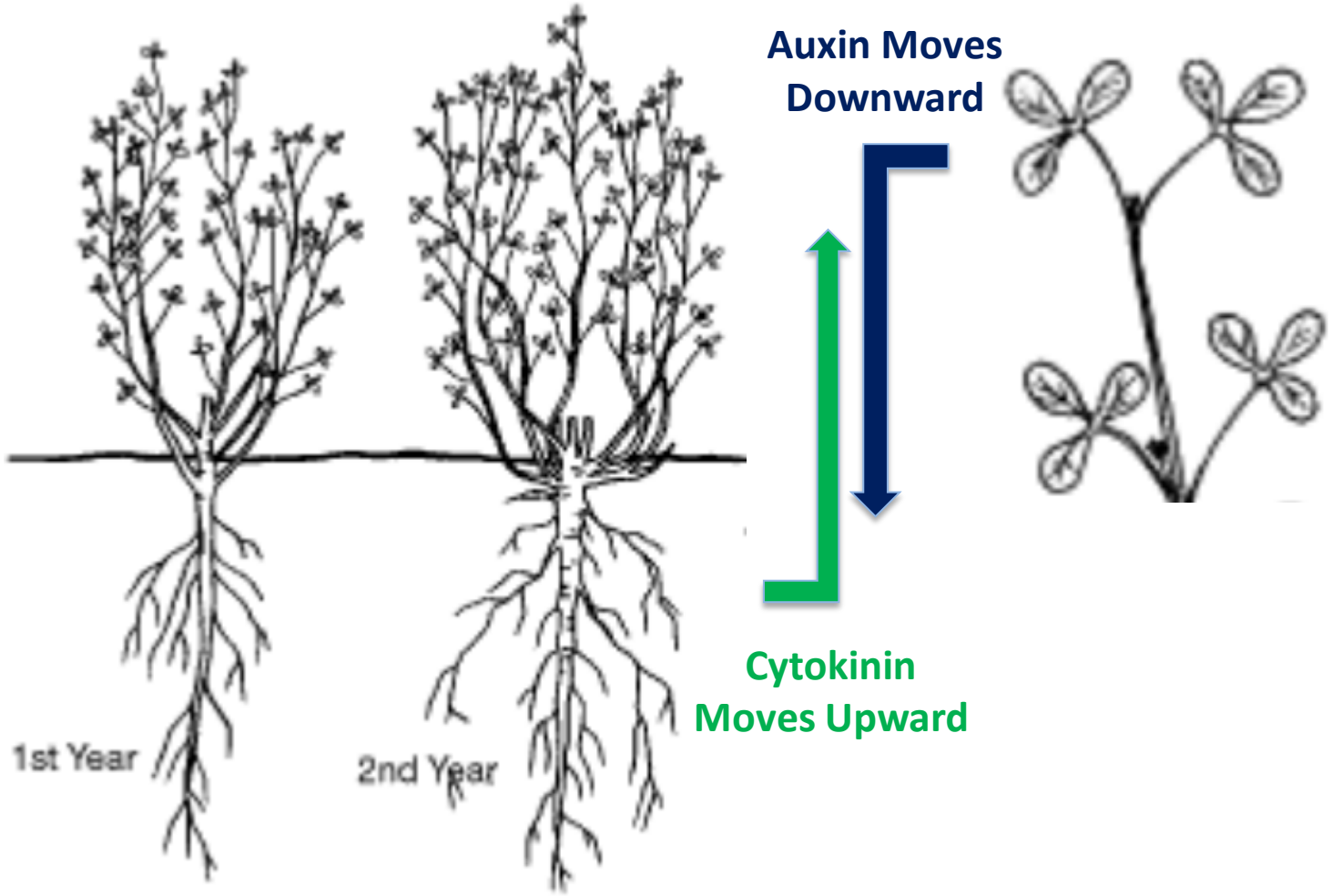


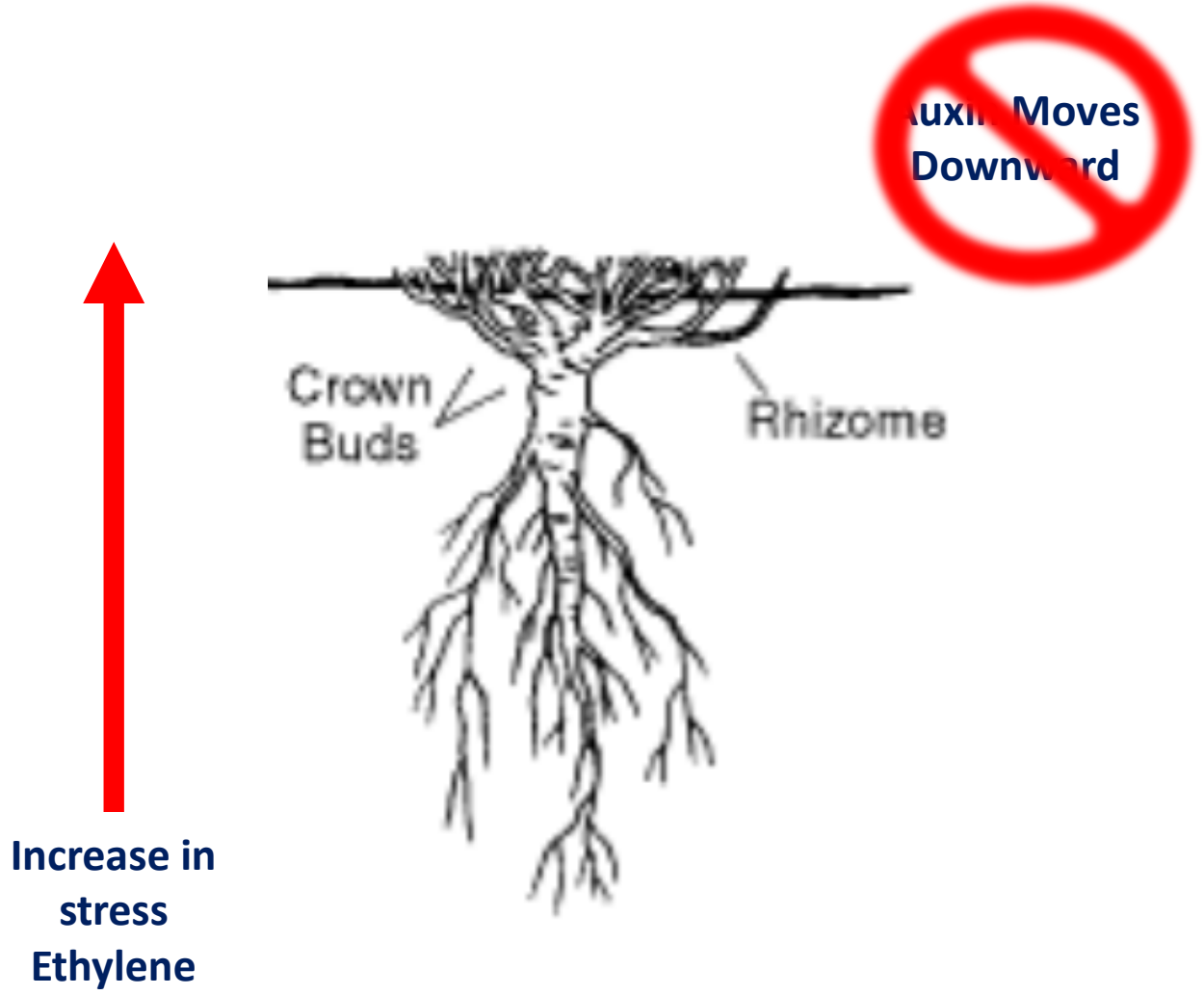


VEGETATIVE HORMONAL DYNAMICS

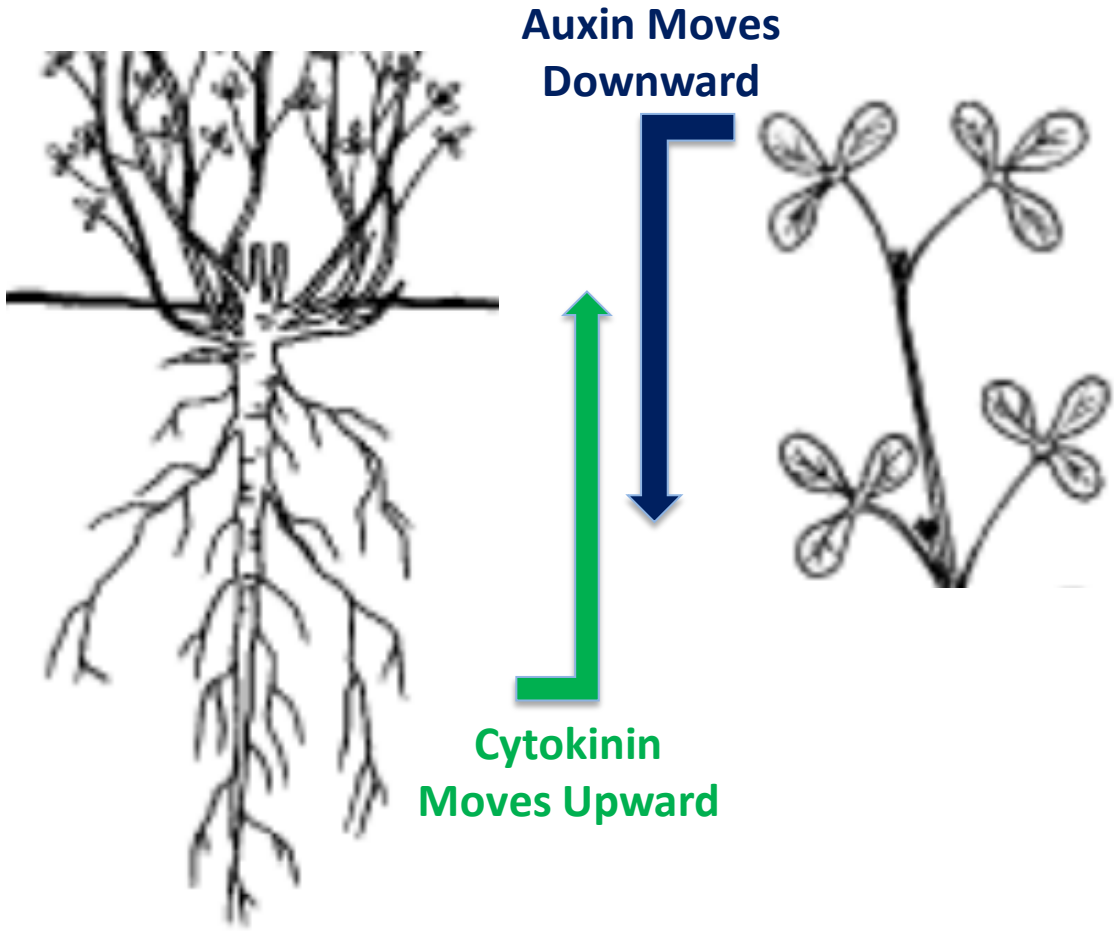


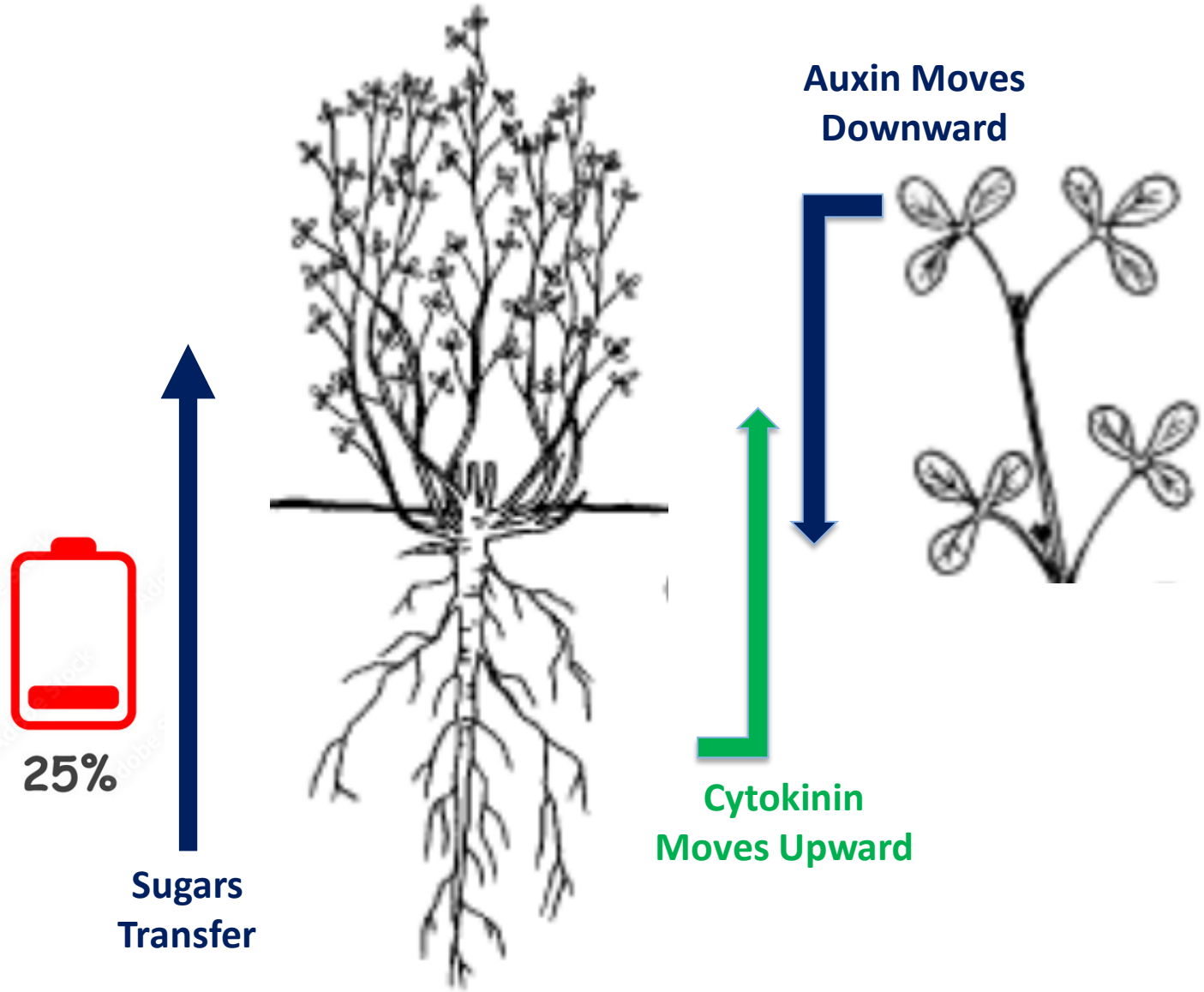
The Language of the Alfalfa Plant


1st Year
2nd Year
Auxin Moves Downward
Cytokinin Moves Upward

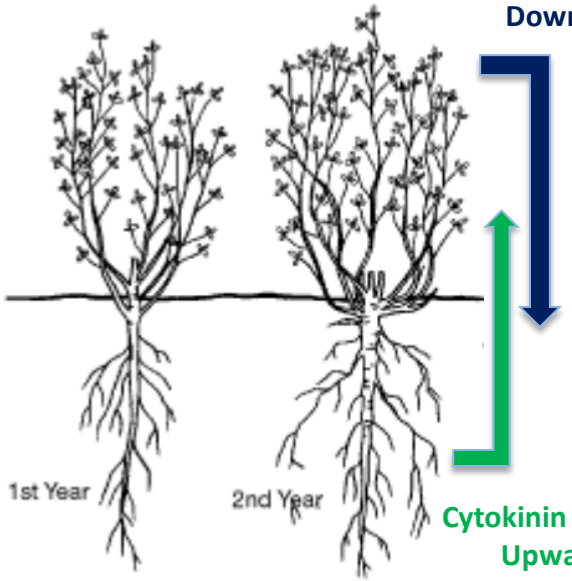

Auxin Moves Downward
Crown Buds
Rhizome
Increase in stress Ethylene

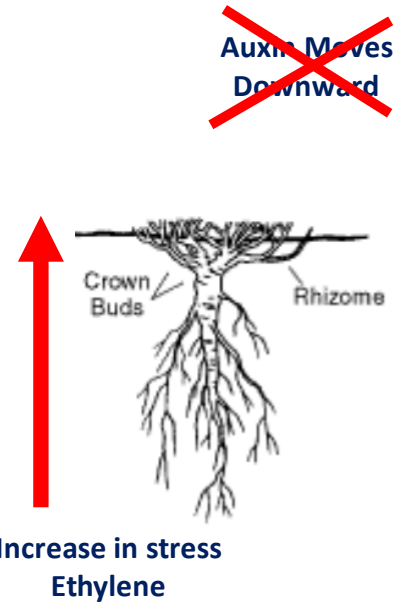
8-14 days after cutting the plant supplies enough auxin so that root growth continues



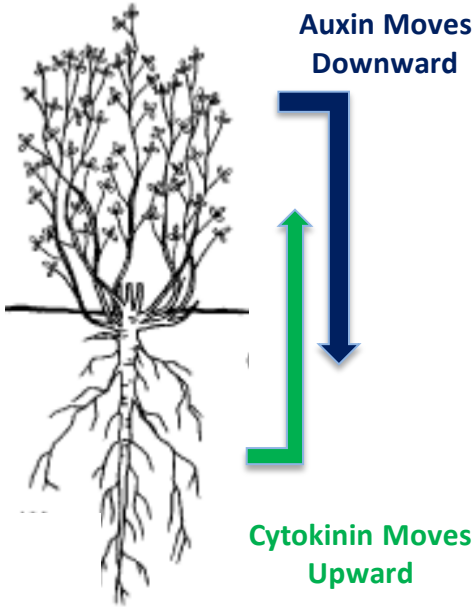

Auxin Moves
Downward
25%
Sugars
Transfer
Cytokinin
Moves Upward

The Language of the Alfalfa Plant





14-18 days after cutting the plant supplies enough auxin so that root growth continues



Alfalfa Quality Parameters

- More than 95% of plant dry matter comes from photosynthesis from the leaves.
- Alfalfa leaf cell walls are highly digestible, more leaves to stems improves forage quality.
- Leaf retention
- Minimizing heat stress

Cytokinin

INCREASING PHOTOSYNTHESIS

Photosyntheis Maintenance

- Chlorophyll synthesis
- Chloroplast development
- Rubisco activity
- Senescence delay

Translational researches on leaf senescence for enhancing plant productivity and quality

Guo, Yongfeng; Gan, Su-Sheng

Journal of Experimental Botany , Volume 65 (14) – Jun 16, 2014

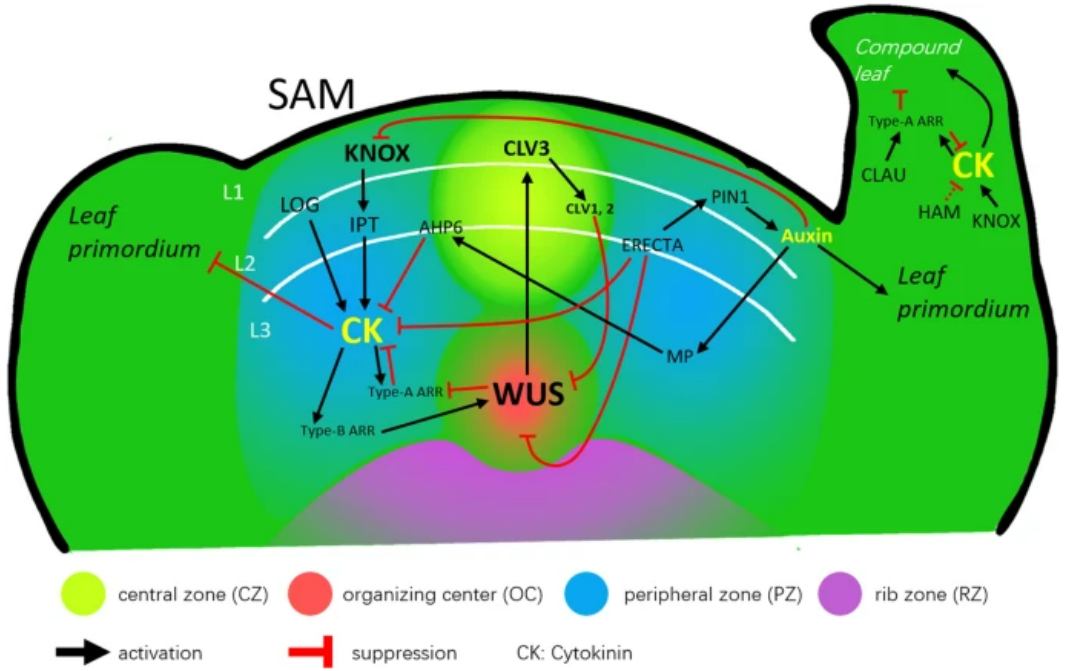
thus delays senescence (Noodén, 1988). The foliar application of nitrogen and phosphorus slows down the senescence of wheat plants (Benbella and Paulsen, 1998*a*). The plant hormones ethylene, abscisic acid (ABA), jasmonic acid (JA), salicylic acid (SA), auxin, and brassinosteroids (BR) are believed to be inducers/promoters while cytokinins and polyamines are antagonists of senescence (Gan, 2003; Jibran *et al.*, 2013).

Plant senescence could be delayed by either suppressing senescence-promoting hormones such as ethylene or overproducing senescence-inhibiting cytokinins (Gan, 2003; Jibran *et al.*, 2013). Suppressed expression of two genes encoding for ethylene biosynthetic enzymes, ACC synthase (Oeller *et al.*, 1991) and ACC oxidase (John *et al.*, 1995; Aida *et al.*, 1998), led to significantly reduced ethylene production and

Cytokinin

PRE-REQUISITE FOR LEAF INITIATION

Fig. 2: Schematic diagram of cytokinin (CK) regulation of leaf primordium initiation.



Cells in the shoot apical meristem (SAM) are arranged into the L1, L2, and L3 layers and four distinct zones: the central zone (CZ), peripheral zone (PZ), organizing center (OC), and rib zone (RZ). KNOX is expressed in almost the entire SAM. KNOX positively regulates the synthesis of cytokinins and keeps their levels high. Cytokinins promote the expression of WUS through signal transduction and transcription factors, which maintain a high cell division rate in the OC. ERECTA blocks the effect of cytokinins and promotes the transport of auxin. In areas with higher auxin concentrations, the leaf primordium begins to form. In the early stage of leaf development, KNOX, which is highly expressed in the marginal blastozone, changes the leaf morphology by promoting cytokinin synthesis to form compound leaves. Solid lines indicate direct relationships that have been confirmed; dashed lines represent potential mechanisms. The abbreviations are as defined in the text

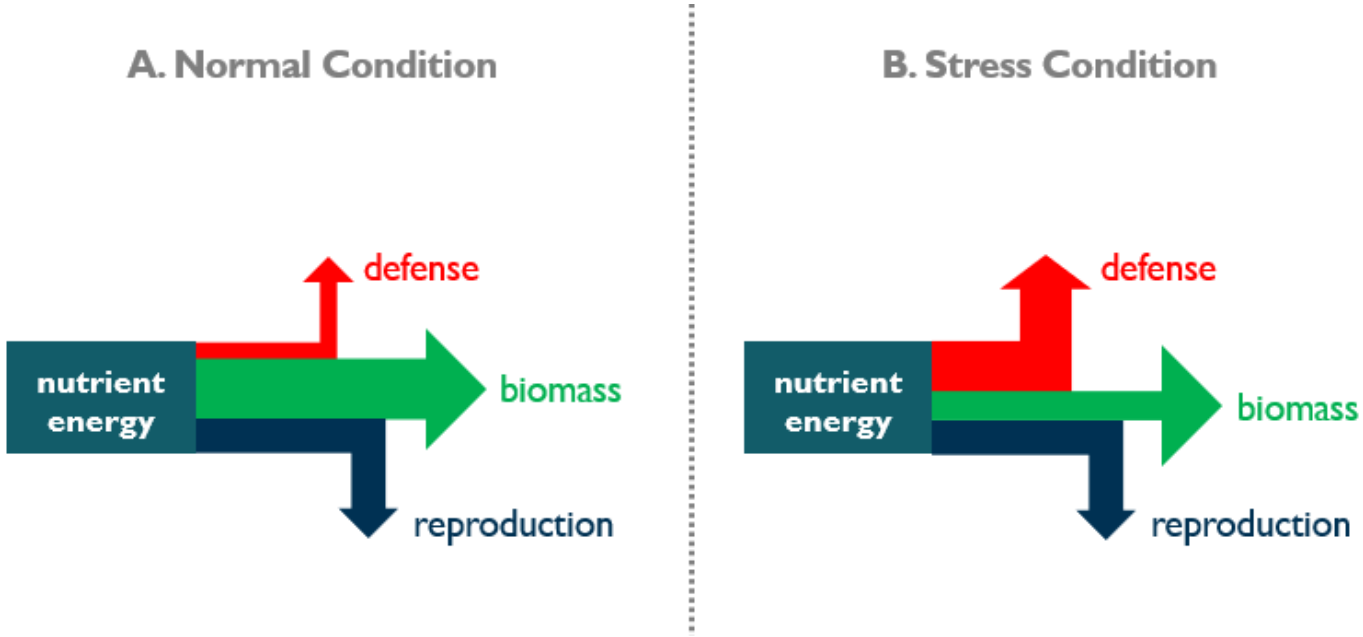
Cytokinin

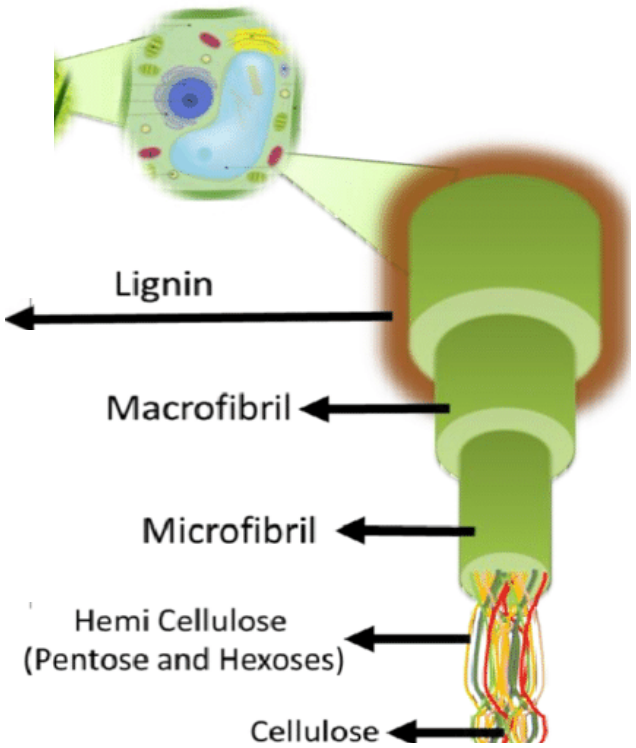
COMPOUND LEAVES- 5 LEAFLETS

Cytokinin

MITIGATE HEAT STRESS

- Cytokinin degrades during high heat events
- Stress ethylene increases
- Increased levels of lignification occurs





Lignin: the Building Block of Defense Responses to Stress in Plants

Yadav, Shalini; Chattopadhyay, Debasis
Journal of Plant Growth Regulation , Volume 42 (10) – Oct 1, 2023

The response of a plant to an adverse situation is a complicated process encompassing hundreds of genes. Plants' lignin content has been found to change in response to a variety of biotic and abiotic stressors, allowing them to adapt with the environment. In this review, we attempt to highlight

Nutrients for increased Quality and yield

MOLYBDENUM/IRON- INCREASING PROTEIN LEVELS & AIDING IN NITROGEN FIXATION

COBALT- FOR NODULE ACTIVITY, LEG HEMOGLOBIN THAT TRANSPORTS AND REGULATES OXYGEN LEVEL INSIDE OF THE NODULE. INHIBITING ETHYLENE LEVELS

CALCIUM, BORON, ZINC, MANGANESE & COPPER- INCREASING PECTIN AND FIBER

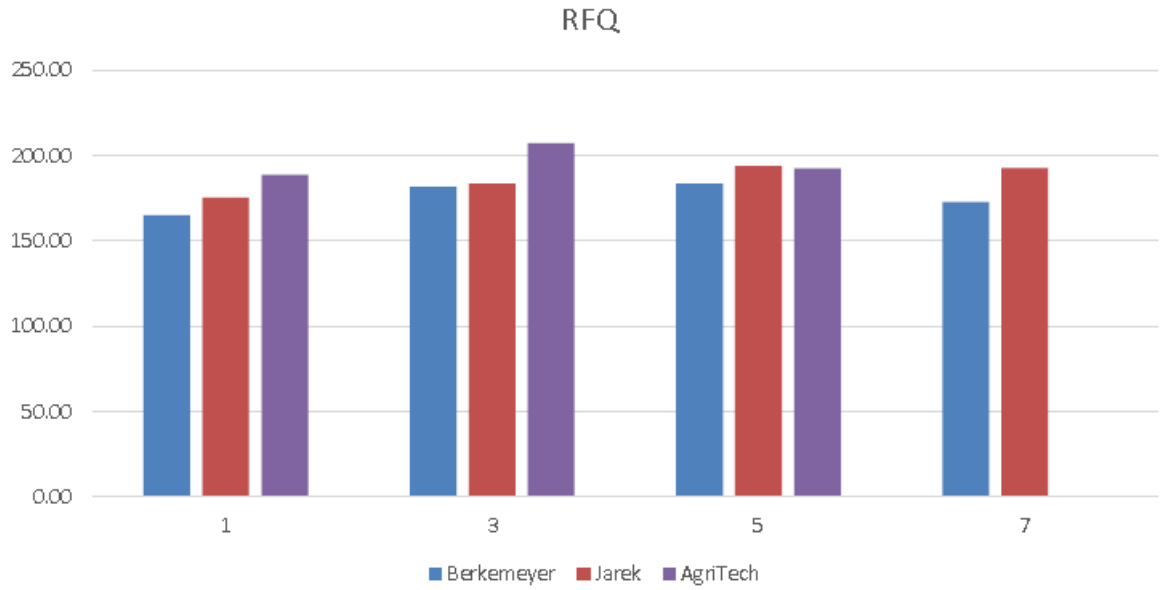
Alfalfa Trials

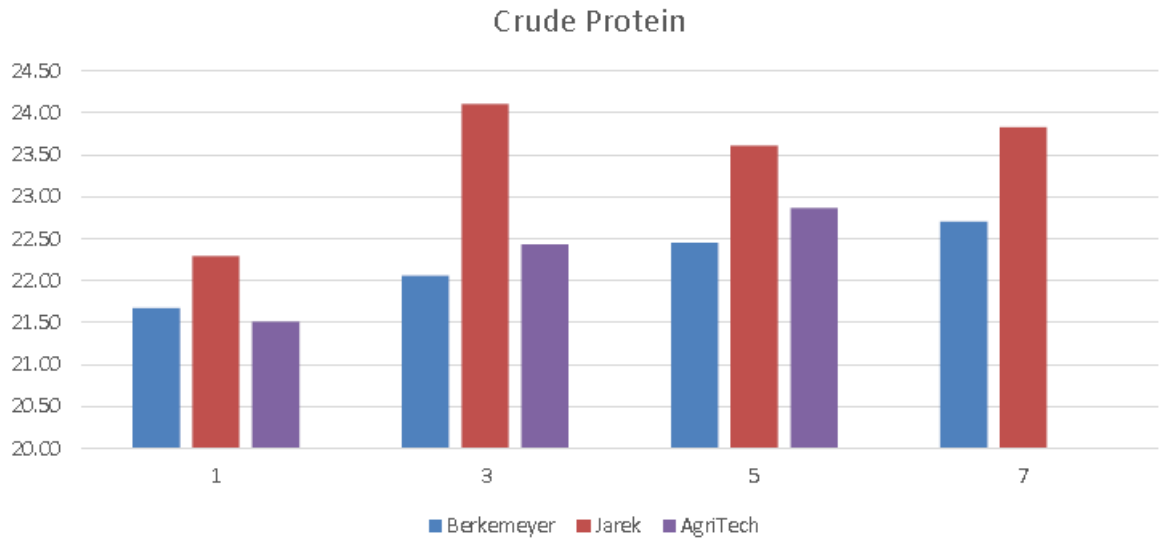
7-10 DAYS AFTER CUTTING
1- GROWER STANDARD PRACTICE

3- CYTOKININ PRODUCT AND NUTRITIONAL

5-HORMONAL PRODUCT & NUTRITIONAL

7-BIOSTIMULANT PRODUCT & NUTRITIONAL





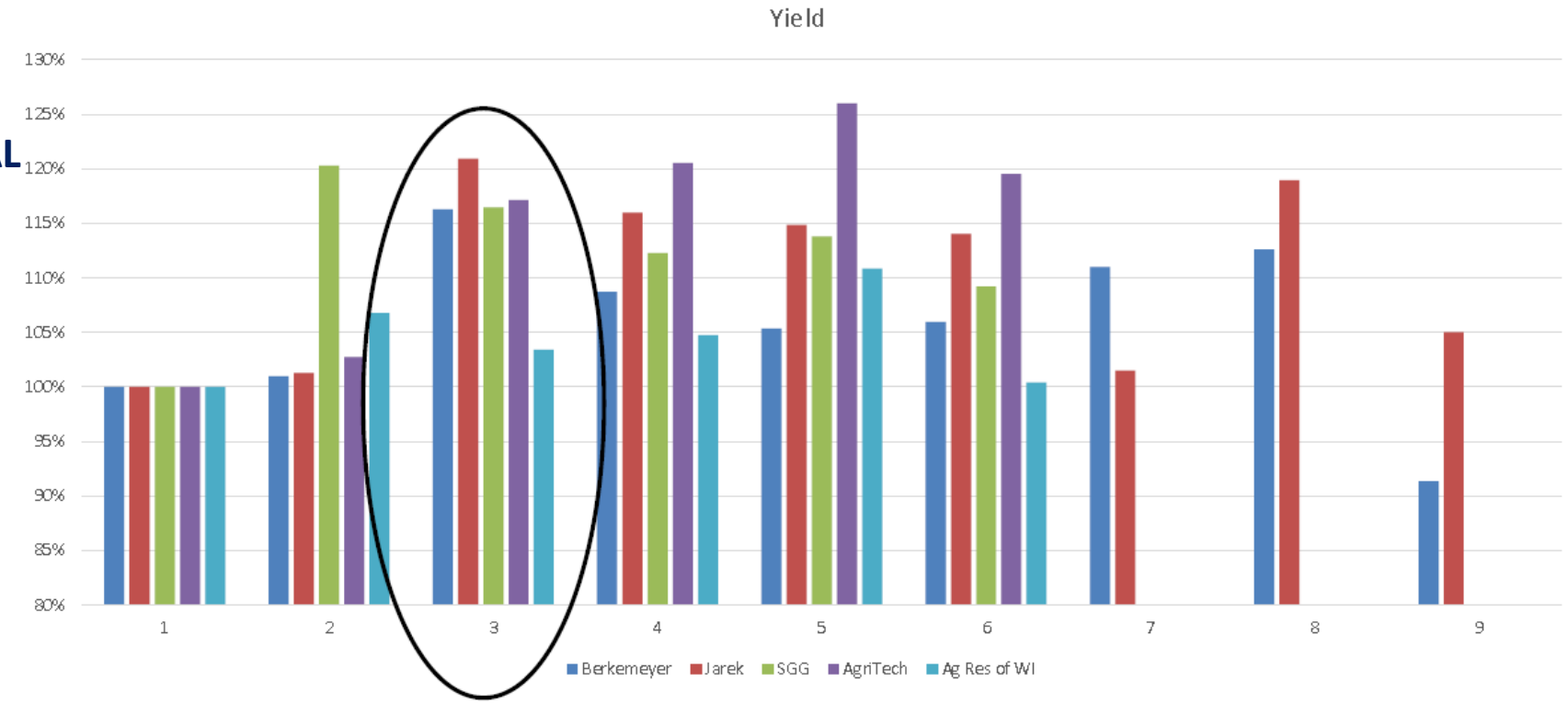
14.5 point increase in RFQ in treatment 3 with also increases in crude protein

Alfalfa Trials

TREATMENT 3 WITH THE STOLLER CYTOKININ PRODUCT & NUTRITIONAL PERFORMED THE BEST OVERALL

AVERAGE .73 TON/ACRE INCREASE OVER THE CONTROL

$105/AC INCREASE



Cytokinin

- IMPROVED QUALITY
- IMPROVED YIELD
- IMPROVED PLANT HEALTH

Stoller
Together we grow.

Thank you!

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