Why is it that we can map the genome of corn, yet in 2019 we still can’t get a firm grasp on using Plant Growth Regulators in soybeans?

It’s **VERY** complicated

In this context, it’s easier to alter the genes of a soybean plant than it is to figure out how to gain a ROI from a PGR
What do we know about PGRs

• The term Plant Growth Regulator (PGR) refers to synthetic hormones, not produced by the plant
• They are responsible for every plant function from breaking seed dormancy to maturing grain
• There are 5 main hormones
• There are many secondary hormones
• They may have varying responses based on the development stage and specific part of the plant
Roles of Primary Plant Hormones

- **Auxin**
  - Primary growth hormone
  - Co-responsible for all cell growth and reproduction
  - Apical dominance

- **Gibberellic Acid**
  - Cell elongation

- **Cytokinin**
  - Cell division
  - Axillary bud activation

- **Abscisic Acid**
  - Stress response

- **Ethylene**
  - Root hair initiation and development
  - Senescence

**Figure 22.16** Promotion of root hair formation by ethylene in lettuce seedlings
Role of Secondary Plant Hormones

• Jasmonic Acid & Salicyclic Acid
  – Plant defense, SAR

• Bassinosteroids
  – Stem elongation and cell division, & vascular differentiation

• Polyamines
  – Mitosis & meiosis, pollination/fertilization

• Strigolactones, Peptide hormones, Nitric Oxide, Karrikins, Triacontanol...
What makes them so complicated

They work in ratios

**Leaf maintenance phase**
High auxin from leaf reduces ethylene sensitivity of abscission zone and prevents leaf shedding.

**Shedding induction phase**
A reduction in auxin from the leaf increases ethylene sensitivity in the abscission zone, which triggers the shedding phase.

**Shedding phase**
Synthesis of enzymes that hydrolyze the cell wall polysaccharides results in cell separation and leaf abscission.
What makes them so complicated

Overproduction of one can lead to negative results or the production of another

Auxin induced Ethylene biosynthesis
Ethylene induced Auxin biosynthesis
What makes them so complicated

- Root development
  - GA promotes root length, without branches
  - GA can induce IAA biosynthesis
  - IAA inhibits root length, but increases lateral root formation
  - With IAA, CYT increases cell number for growth
  - With IAA, ETH increases the development of root hairs
  - Root growth in inversely proportional to IAA concentration
<table>
<thead>
<tr>
<th></th>
<th>Too Much</th>
<th>Too Little</th>
<th>Balanced</th>
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<tr>
<td><strong>AUXIN</strong></td>
<td>• Distorted growth (phenoxy herbicide effect)</td>
<td>• Insufficient cell division &amp; differentiation</td>
<td>• Activates Ethylene (especially in roots)</td>
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<td>• Inhibits elongation</td>
<td>• Stunted root &amp; shoot growth</td>
<td>• Cell division/differentiation (w/ cytokinin)</td>
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<td></td>
<td>• May lead leaf fall</td>
<td>• Poor pollination, flowering</td>
<td>• Signals movement of sugar to grain/fruit</td>
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<td></td>
<td></td>
<td>• Poor sugar movement: poor grain/fruit sizing and quality</td>
<td>• Delays fruit senescence</td>
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<td></td>
<td></td>
<td>• Triggers wounding response</td>
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<td><strong>GIBBERELLIC ACID (GA)</strong></td>
<td>• Promotes excessive vegetative growth</td>
<td>• Stunted growth</td>
<td>• Promotes cell elongation/division and flowering (long day plants and trees)</td>
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<td>• Antagonizes ABA effects</td>
<td>• Poor flowering</td>
<td>• Breaks dormancy/initiates germination</td>
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<td>• Reduce plant responses to stress</td>
<td>• Poor grain/fruit sizing with potential abortion under extremes</td>
<td>• Induces enzyme activity</td>
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<td>• Inhibits flowering</td>
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<td>• Facilitates leaf and fruit senescence</td>
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<td><strong>CYTOKININ</strong></td>
<td>• Promotes excessive vegetative growth</td>
<td>• Stunted growth</td>
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<td>• Prevents grain/fruit development when not in a balanced ratio with auxin</td>
<td>• Premature senescence</td>
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<td>• Poor grain/fruit set</td>
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<tr>
<td><strong>ABSCISIC ACID (ABA)</strong></td>
<td>• Inhibits plant growth, photosynthesis</td>
<td>• Delayed plant maturity</td>
<td>• Abscission</td>
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<td>• Counteracts the effects of GA and cytokinin</td>
<td>• Poor grain/fruit ripening</td>
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<td>• Induces premature dormancy</td>
<td>• Increased susceptibility to drought and other stress</td>
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<td>• Reduces photosynthesis</td>
<td>• Poor harvested grain/fruit storability</td>
<td>• Break dormancy (antagonizes GA)</td>
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<td>• Inhibits ripening</td>
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<td>• Embryo development</td>
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<td><strong>ETHYLENE</strong></td>
<td>• Premature maturity/senescence</td>
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<td>• Premature leaf drop</td>
<td>• Poor grain/fruit sizing and quality</td>
<td>• Initiates movement of sugar to grain/fruit for sizing and quality</td>
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<td>• Inhibits elongation (stunting)</td>
<td>• Delayed plant senescence</td>
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<td>• Can lead to flower &amp; fruit abortion</td>
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What do we know about soybean?

• Critical YIELD functions
  – Stand establishment
  – Root development (including nodulation)
  – Development of nodes
  – Development of photosynthetic capacity
  – Development of reproductive structures
  – Maintenance of reproductive structures

| Pods / Acre | X |
| Seeds / Pod | X |
| Weight / Seed | |
What do we know about soybean?

• ~25% of blooms become pods
  – Environmental / Nutritional stress during reproductive development
  – Evolutionary adaptation
  – Long reproductive period
  – Lots of opportunity to encounter favorable conditions
Soybean Production Meeting

• Current status as it relates to key yield projects
• Sunlight / Energy status
• Water / Nutrient status
• Prioritization of resources
• Likely to abort flowers
• Less likely to abort pods
• Once a project is scrapped it cannot be reinitiated
• Additional resources can be added to current projects
Timing is critical

Fig. 4. Effects of IAA application on the number of flowers, pod-set percentage, number of pods and grain yield at IAA-applied nodes (Exp. 2, field, 2003). IAA was applied to racemes at intervals before and after anthesis. Values represent the mean ± SE (n=7). NS; not significantly different between control and applied plots at $P<0.05$. 

Timing is critical

Fig. 1. Changes in the endogenous concentration of IAA and cytokinin (t-ZR equivalent) in racemes during reproductive development of soybean plant (Exp. 1, field, 2004). Racemes were samples for analysis at intervals before and after anthesis. Values represent the mean ± SE (n=6).

Timing is critical

Timing is critical

• Within individual racemes, the pod set percentage of basal flowers is considerably higher than that of distal ones. This phenomenon appears to be associated with the endogenous levels of cytokinin; the basal flowers contain a higher percentage.

• This doesn’t take into consideration that racemes at different nodes will begin flowering at different times, or that the plant will simultaneously be in several reproductive & vegetative stages.
Where to focus

- Flowering typically begins at 5\textsuperscript{th} or 6\textsuperscript{th} node for normal planting dates
- Highest yielding nodes start at 7\textsuperscript{th} node
- There is less internal competition for earlier flowers
- There is longer time to maturity for earlier flowering nodes
Where to focus

• Our internal trials show the greatest response to fungicide management at R3
• It is better to be slightly late than early
• This is in the absence of white mold as a disease concern
Where to focus

• Nodes 7 - 15

• Middle of the canopy makes the most grain

• “Top crop” not as impactful as people might think
What can you do?

• Manage what you can manage
  – Take care of the fundamentals
    1. Manage crop nutrition
    2. Protect the crop from pests
  – Target PGR applications to times when there are fewer growth stages
    1. Planting, Vegetative, later Reproductive
  – Target times critical to yield
    1. Develop canopy/node count
    2. Maintain photosynthetic capacity
  – Hope the unmanageable factors don’t show up late
Manage crop nutrition

• As an example, a generalized N budget for soybean, shows that non-fertilizer sources of N can typically supply enough to grow ~60 bu/acre
  – High yielding soybeans need:
    1. Late N fertilizer
    2. Better N production from nodules
    3. Higher N mineralized from the soil

Which other nutrients have late season need without a reasonable chance of attaining and/or remobilizing them?
What are my options?

• Plant Growth Regulators
  – Products with hormones in the ingredients list

• Strobilurin fungicides (group 11)
  – Research has documented impacts on hormone pathways

• Biostimulants
  – Non-PGRs that impact plant development, often through use of plant extracts
What are my options?

• PGRs & Fungicides
  – Set amount of plant hormone, may or may not be ideal for current development
  – Use of fungicides for plant health can be effective, but may not be good IPM

• Biostimulants
  – Little regulation or oversight regarding claims or product quality
  – Can be more adaptive in stimulating plant development
Megafol

- Megafol genomic activity was assessed on all 25,000 mapped gene sequences of the Arabidopsis plant.

- This list shows a partial list genes upregulated after application of Megafol.

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What are my options?

- Why might products not work consistently?
  - Not the right mix or rate of PGRs
  - Not the right timing for the product based on growth stage
  - Missed application window
  - Not the limiting factor, fundamentals not met
  - Product isn’t what it claims to be
Application timing

• Early season (Pre R1)
  – Plants naturally produce high levels of IAA
  – Overcoming stress, environmental and pesticide metabolism

• Late season (R3)
  – Managing plant stress
    1. Increasing ABA
    2. Managing crop nutrition
  – Increasing time in photosynthesis
    1. Increasing IAA
Plant hormones act in a balance with other plant hormones
The ratio for desired response is dependent on growth stage
Soybeans are often in multiple growth stages
All of this can be superseded by plant stress

It’s no wonder we haven’t been able to gain consistent results
IF WE

• Manage crop nutrition
• Target the type of response we want to the type of product we apply
• Target applications to times when the plant will have a more uniform response
• Target reproductive applications for growth stage of key yield producing nodes

We’ll give ourselves the best chance to see positive ROI from this valuable management tool
Thank You