Implementing PGRs in Soybeans

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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

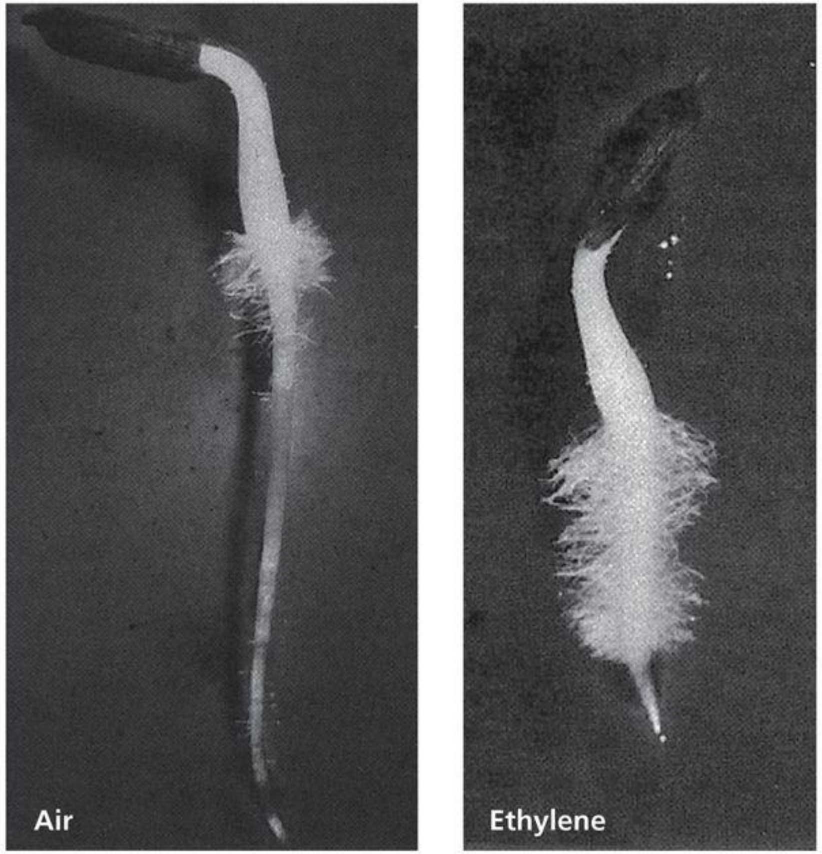
In this context, it’s easier to alter the genes of a soybean plant than it is to figure out how to gain a ROI from a PGR

What do we know about PGRs

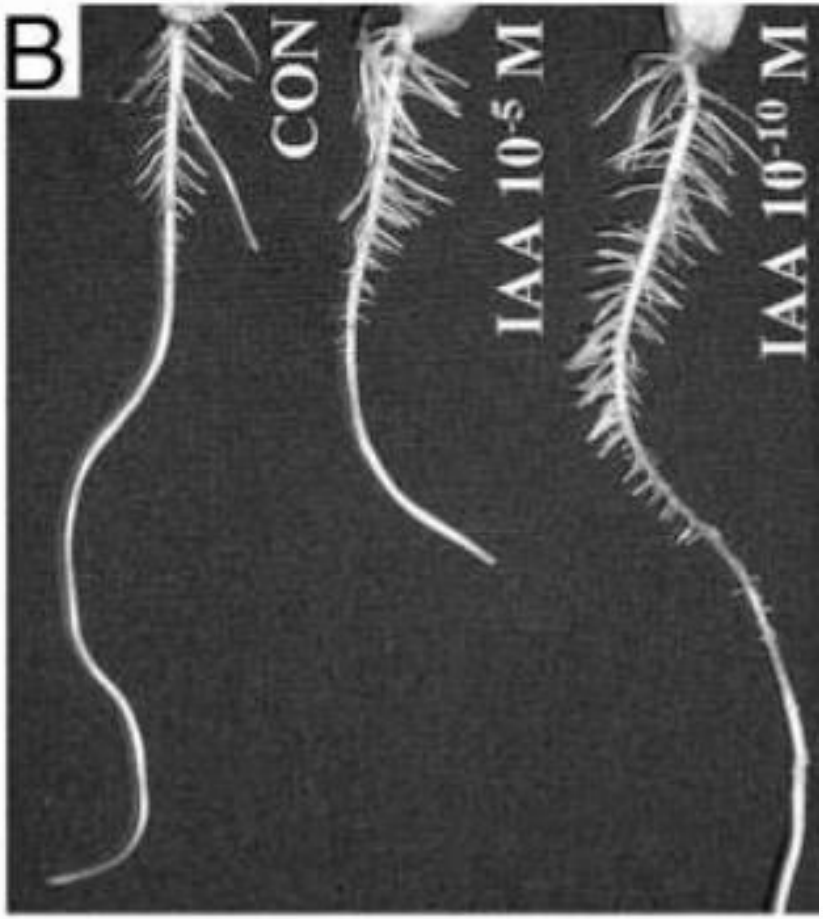
- The term Plant Growth Regulator (PGR) refers to synthetic hormones, not produced by the plant
- They are responsible for every plant function from breaking seed dormancy to maturing grain
- There are 5 main hormones
- There are many secondary hormones
- They may have varying responses based on the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

Roles of Primary Plant Hormones

Figure 22.16 Promotion of root hair formation by ethylene in lettuce seedlings



PLANT PHYSIOLOGY, 5e, Figure 22.16



Role of Secondary Plant Hormones

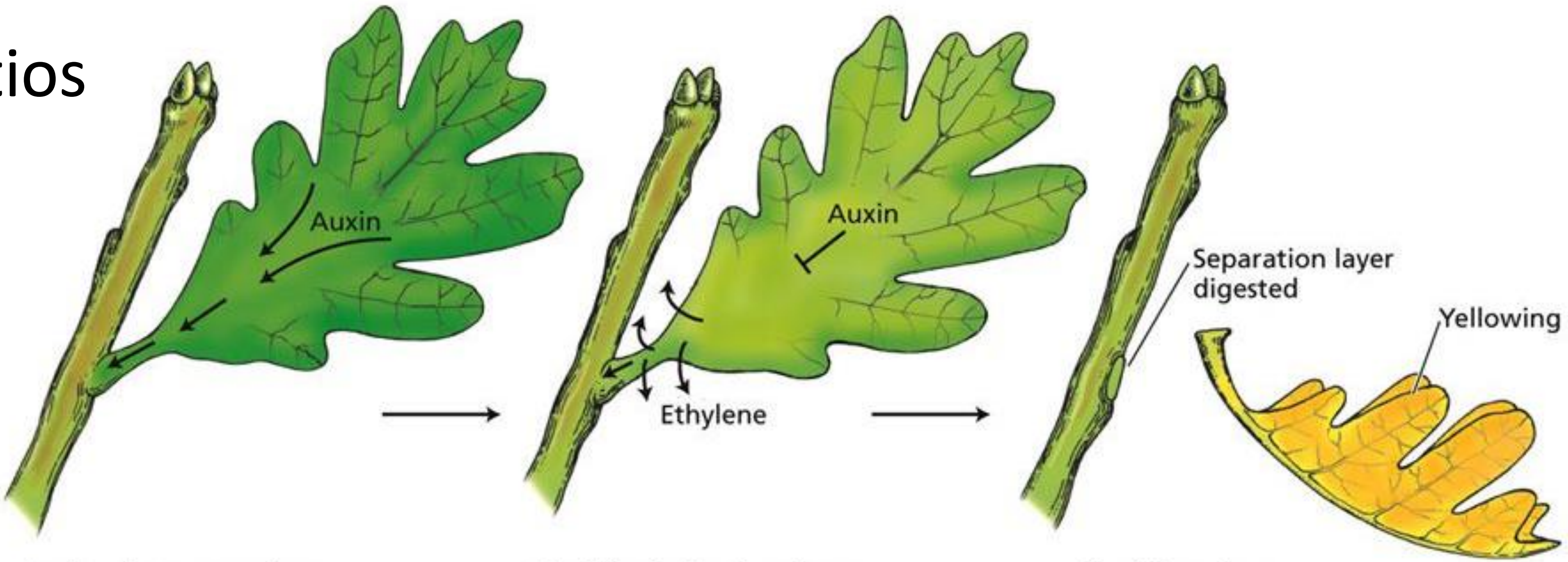
- Jasmonic Acid & Salycylic Acid
  - Plant defense, SAR
- Bassinosteroids
  - Stem elongation and cell division, & vascular differentiation
- Polyamines
  - Mitosis & meiosis, pollination/fertilization

S-adenosyl-methionine

- 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

	Too Much	Too Little	Balanced
AUXIN	•Distorted growth (phenoxy herbicide effect) •Inhibits elongation •May lead leaf fall	•Insufficient cell division & differentiation •Stunted root & shoot growth •Poor pollination, flowering •Poor sugar movement: poor grain/fruit sizing and quality	•Activates Ethylene (especially in roots) •Cell division/differentiation (w/cytokinin) •Signals movement of sugar to grain/fruit •Delays fruit senescence •Triggers wounding response
GIBBERELLIC ACID (GA)	•Promotes excessive vegetative growth •Antagonizes ABA effects •Reduce plant responses to stress •Inhibits flowering	•Stunted growth •Poor flowering •Poor grain/fruit sizing with potential abortion under extremes	•Promotes cell elongation/division and •flowering (long day plants and trees) •Breaks dormancy/initiates germination •Induces enzyme activity •Facilitates leaf and fruit senescence
CYTOKININ	•Promotes excessive vegetative growth •Prevents grain/fruit development when not in a balanced ratio with auxin	•Stunted growth •Premature senescence •Poor grain/fruit set	•Cell division/enlargement (with auxin) •Grain/fruit formation/sizing (with auxin) •Prevent senescence •Mobilizes nutrients/photosynthates
ABSCISIC ACID (ABA)	•Inhibits plant growth, photosynthesis •Counteracts the effects of GA and cytokinin •Induces premature dormancy •Reduces photosynthesis •Inhibits ripening	•Delayed plant maturity •Poor grain/fruit ripening •Increased susceptibility to drought and other stress •Poor harvested grain/fruit storability	•Abscission •Flowering (short day plants) •Stomatal closure during drought •Break dormancy (antagonizes GA) •Embryo development •Plant tolerance to stress
ETHYLENE	•Premature maturity/senescence •Premature leaf drop •Inhibits elongation (stunting) •Can lead to flower & fruit abortion	•Poor flowering/grain & fruit set •Poor grain/fruit sizing and quality •Delayed plant senescence	•Ripens grain/fruit •Initiates movement of sugar to grain/fruit for sizing and quality •Triggers senescence and abscission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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

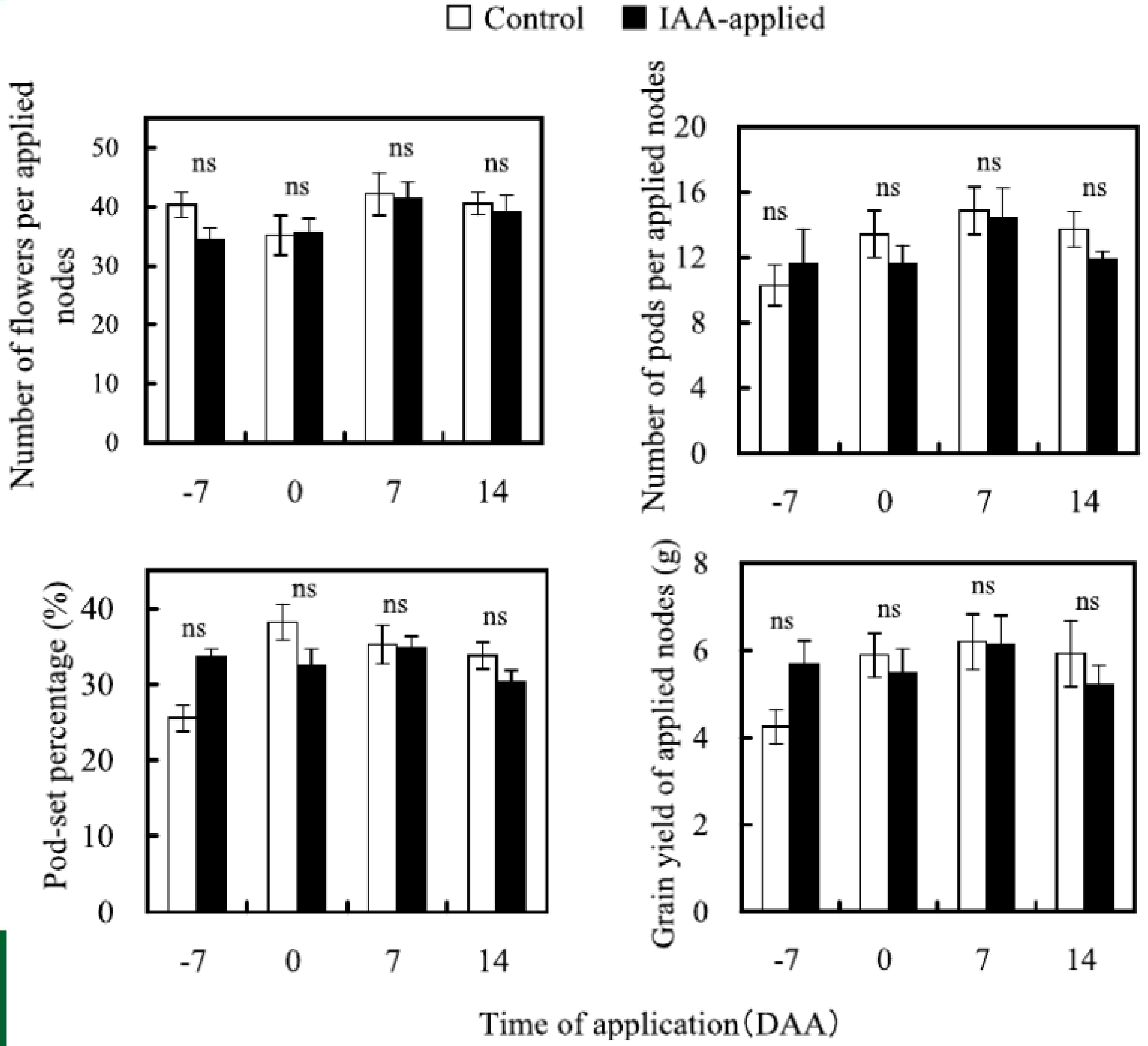
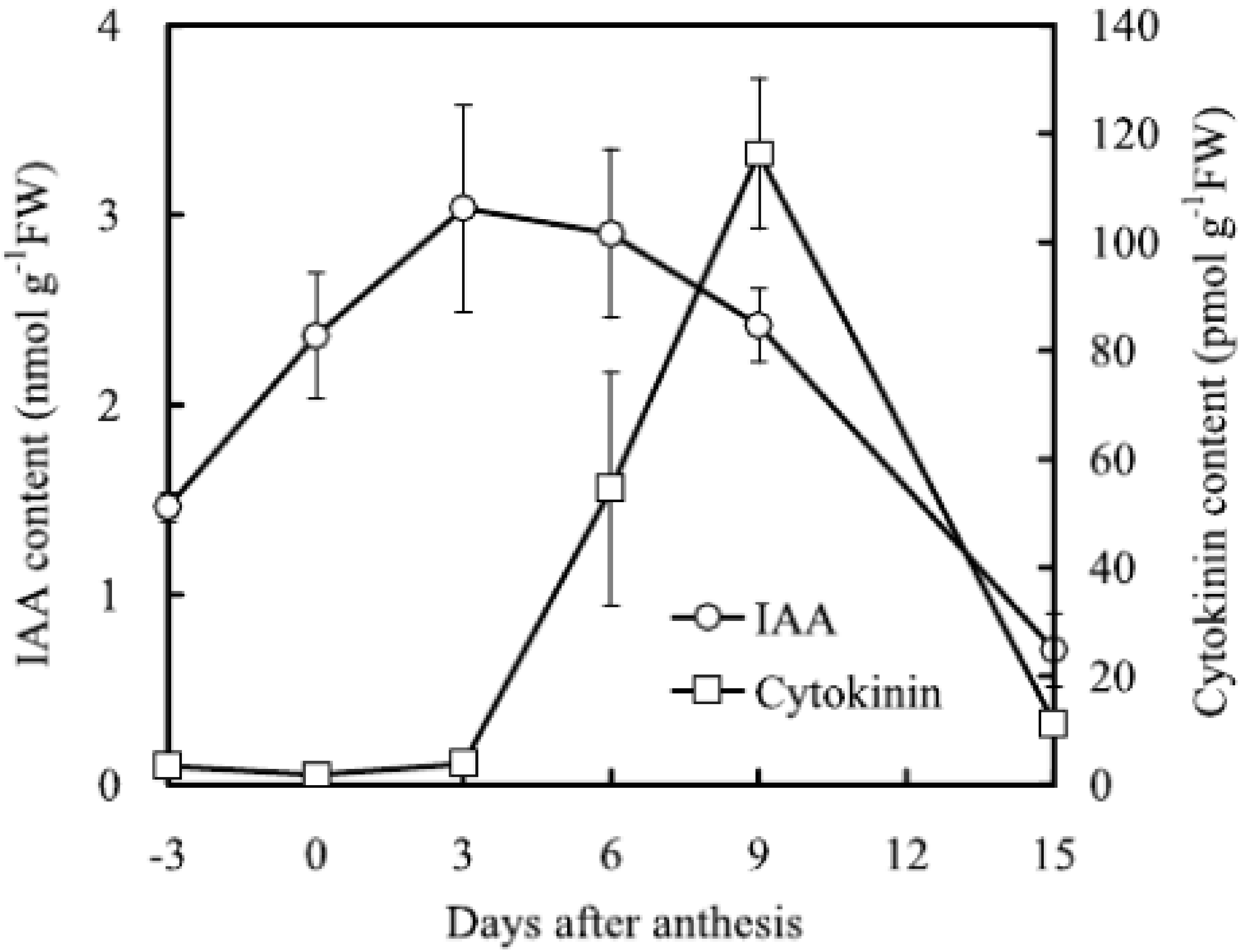


Fig. 4. Effects of IAA application on the number of flowers, pod-set percentage, number of pods and grain yield at IAA-applied nodes (Exp. 2, field, 2003). IAA was applied to racemes at intervals before and after anthesis. Values represent the mean ± SE (*n*=7). NS; not significantly different between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

Kaori Nonokawa, Makie Kokubun, Takayuki Nakajima, Teiji Nakamura & Ryuji Yoshida (2007) Roles of Auxin and Cytokinin in Soybean Pod Setting, Plant Production Science, 10:2, 199-206, DOI: 10.1626/pps.10.199

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).



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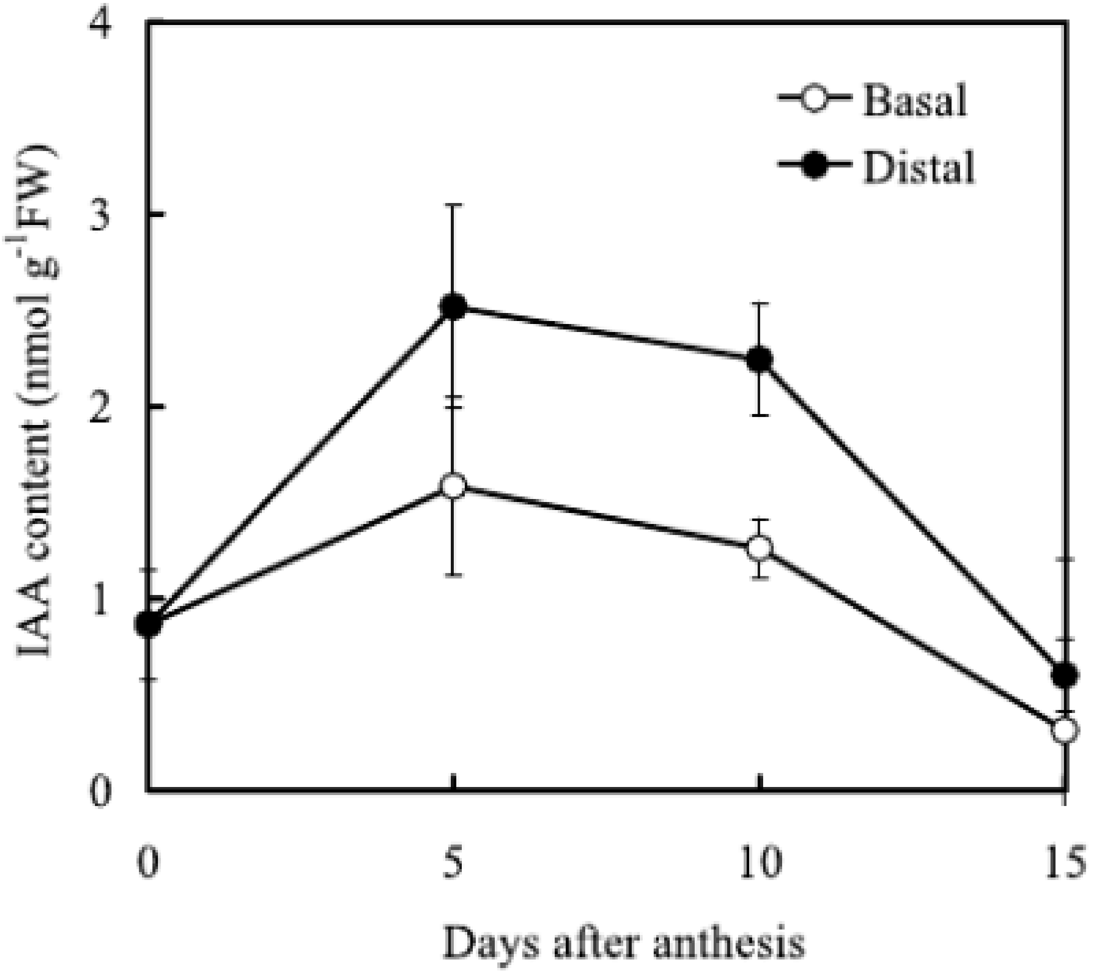

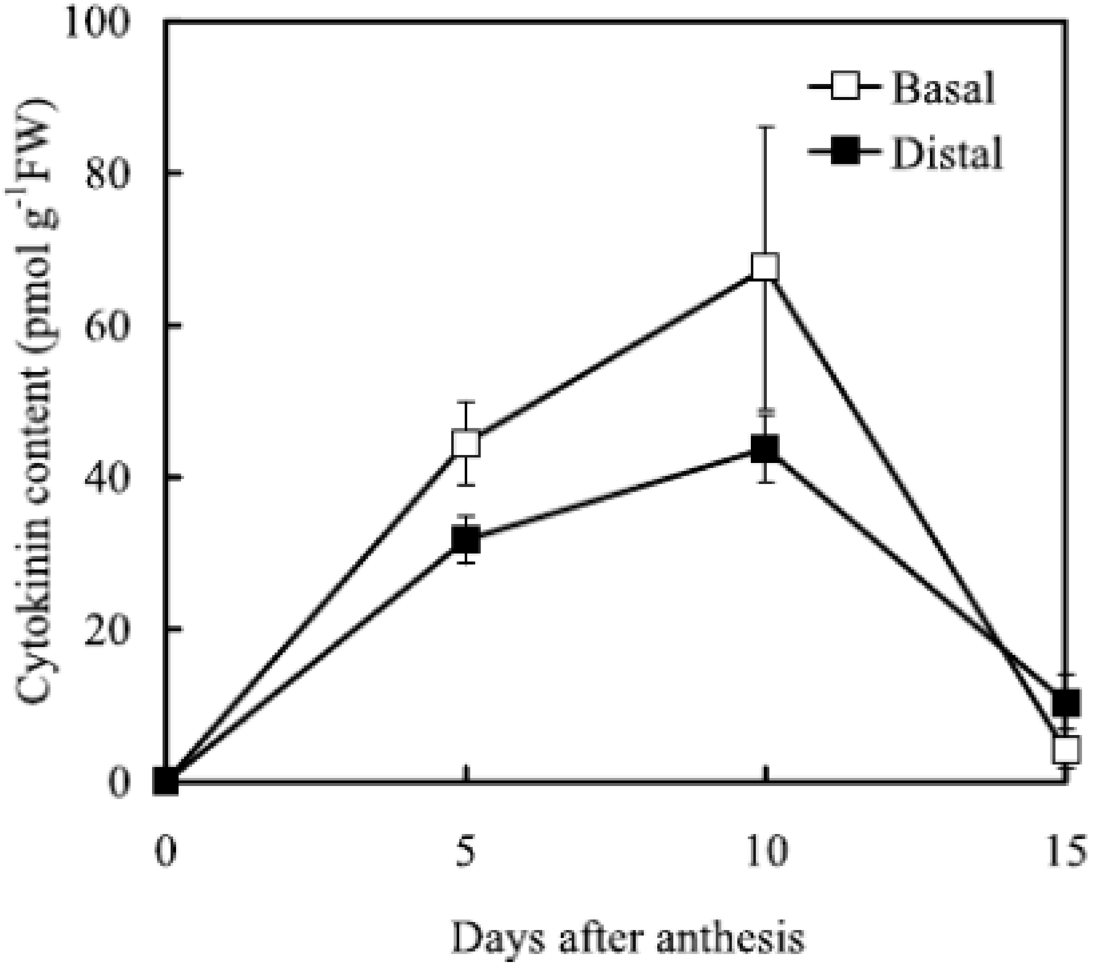

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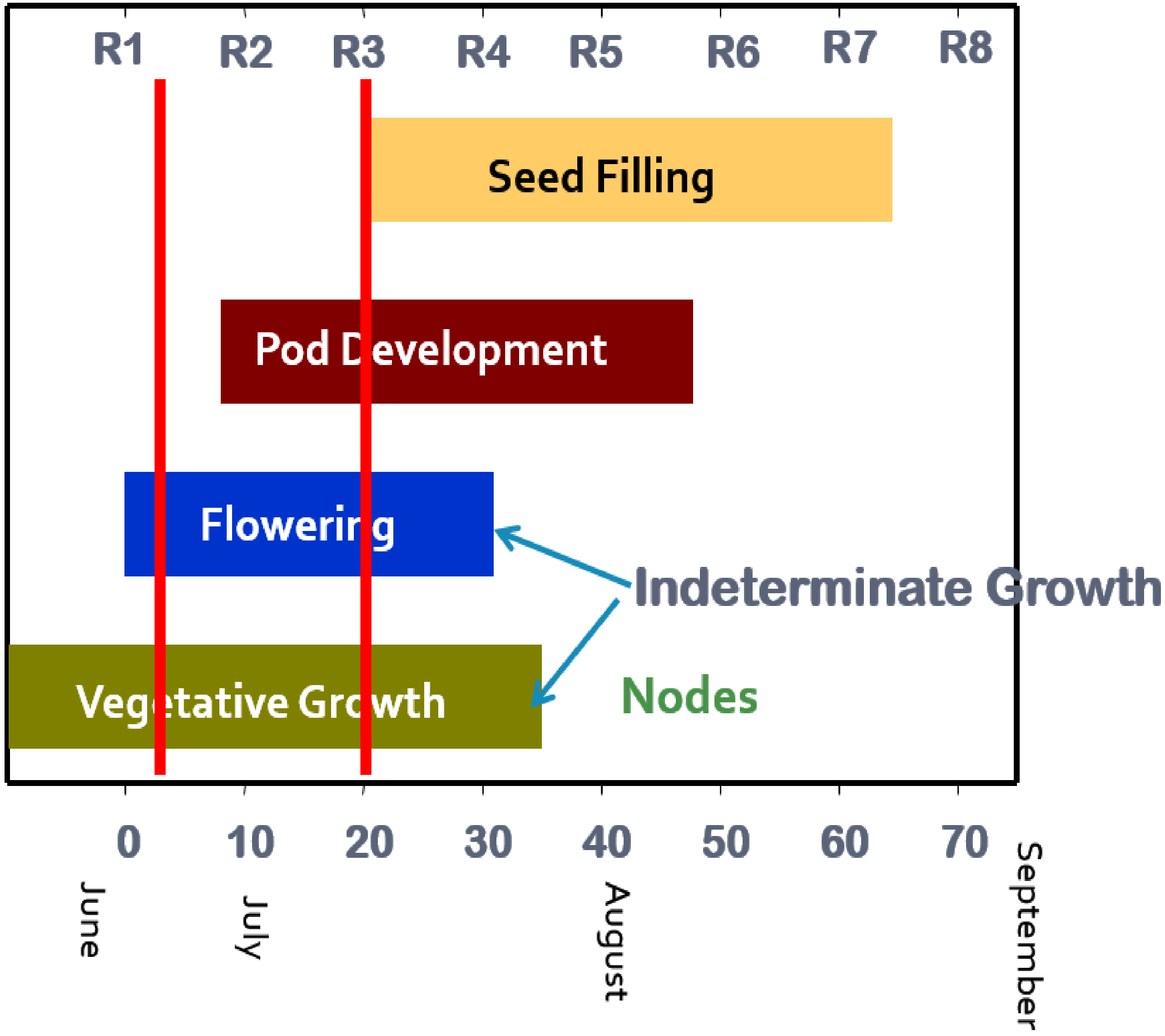
Timing is critical

- 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.

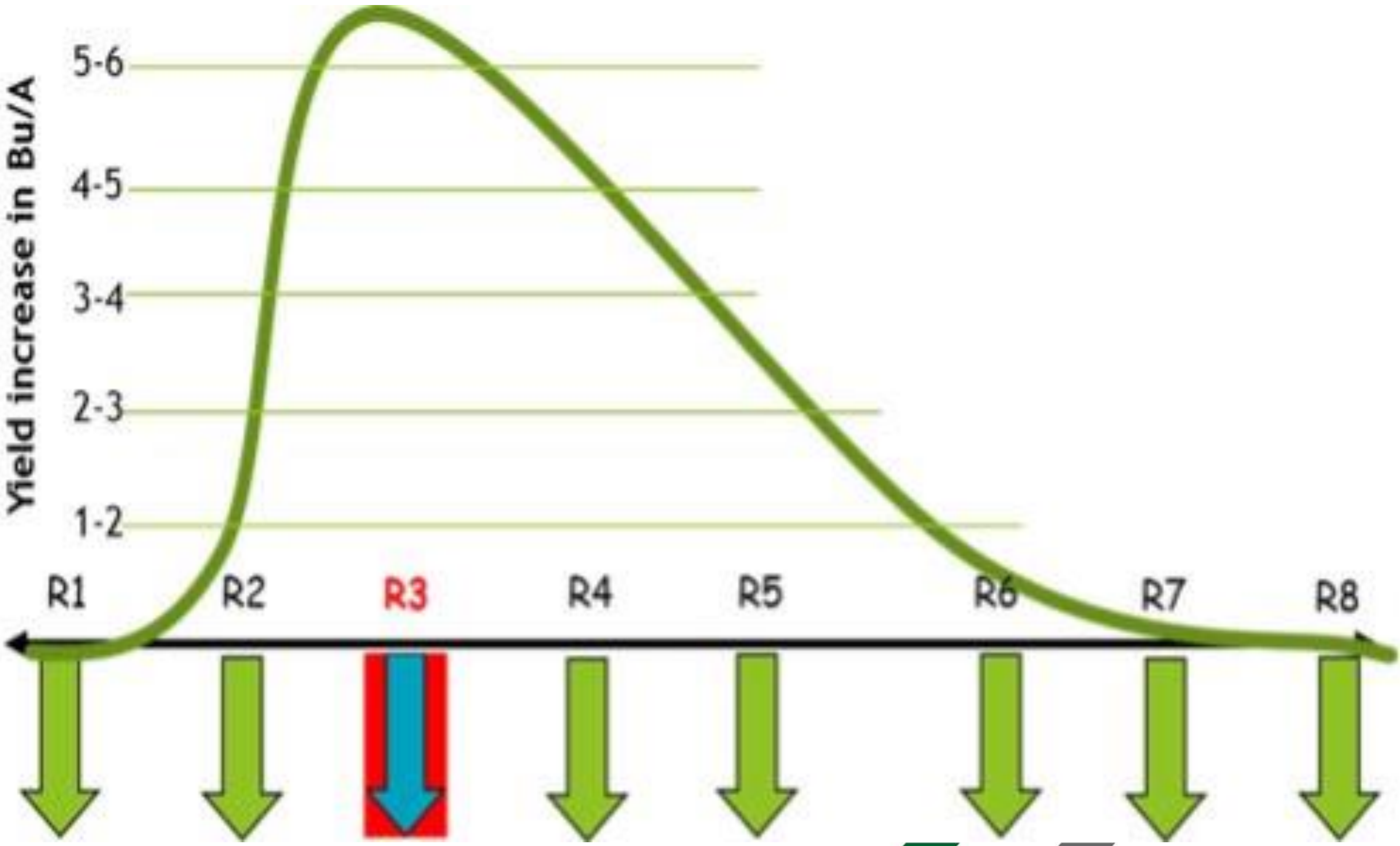
Where to focus

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



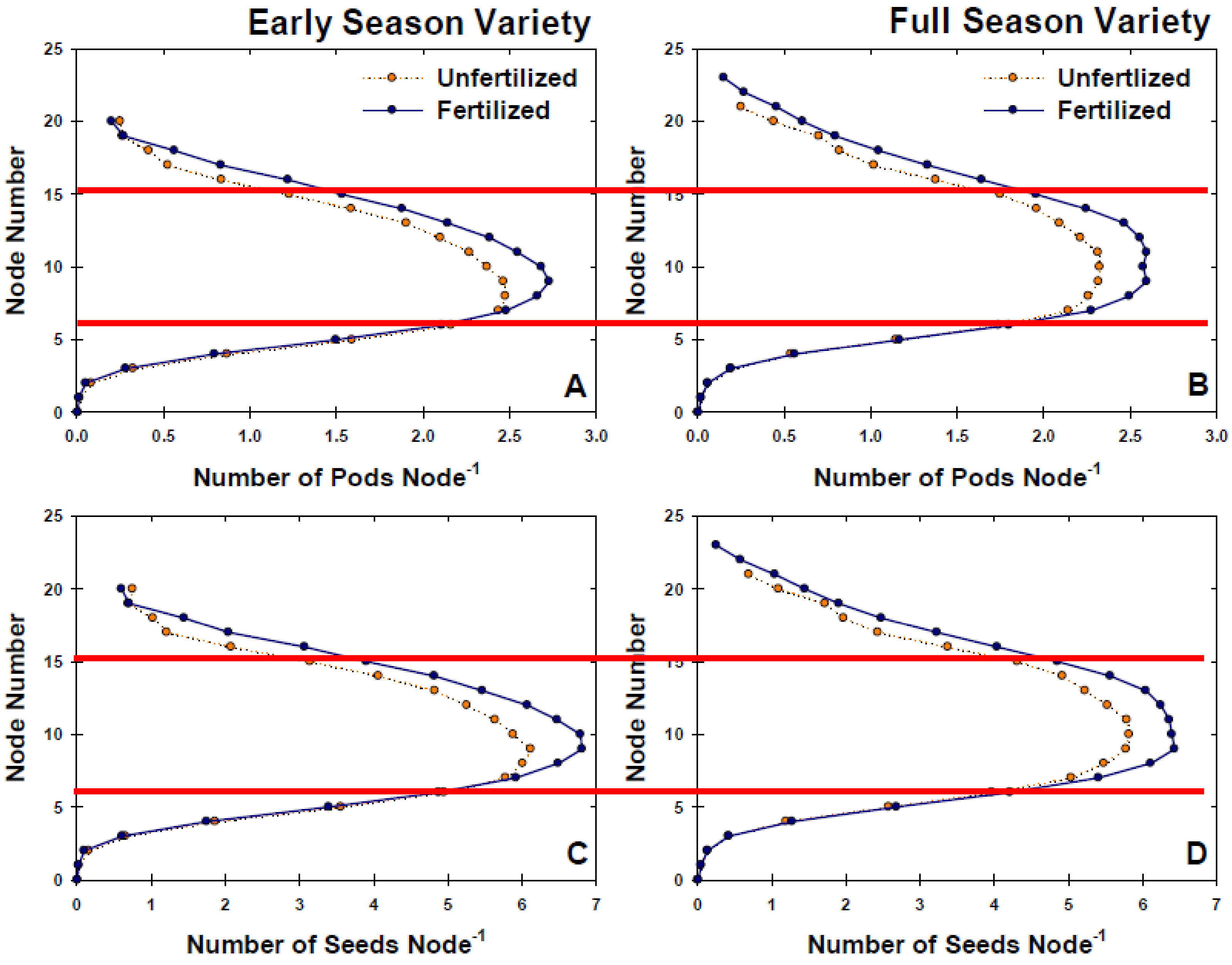
Where to focus

- 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



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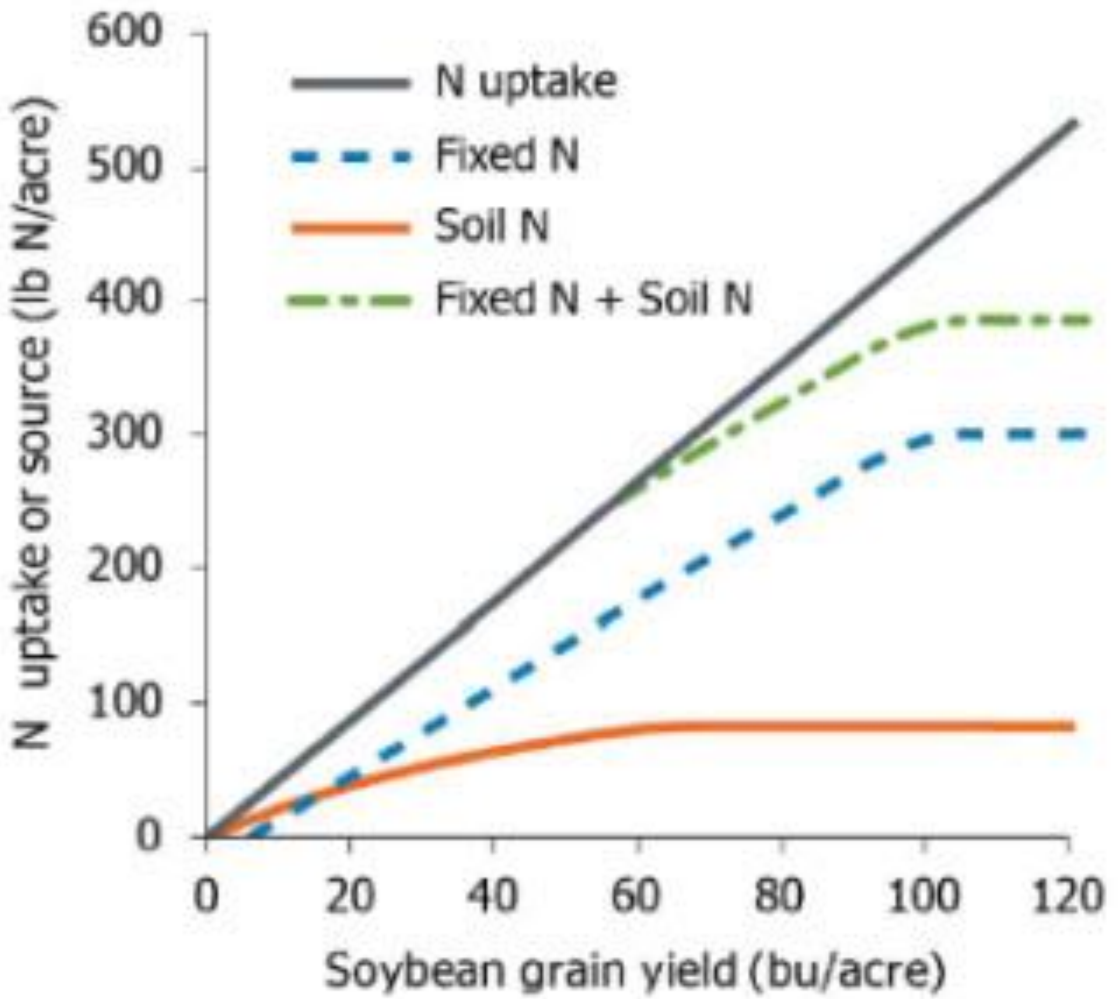
What can you do?

- 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

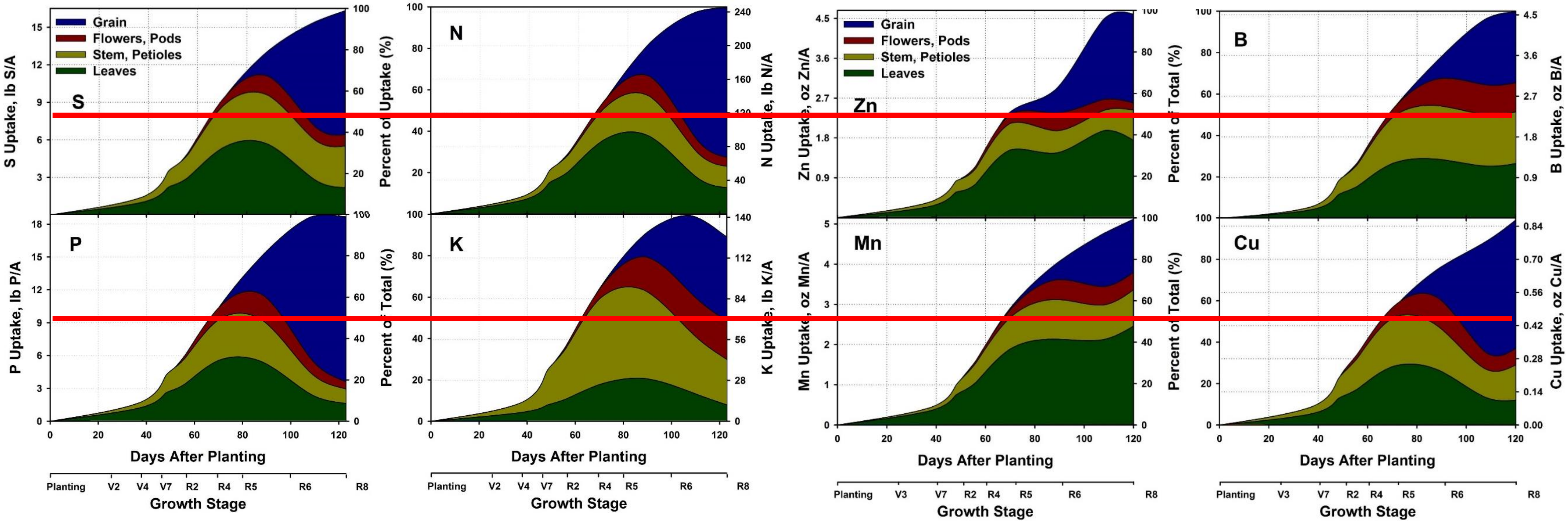
- As an example, a generalized N budget for soybean, shows that non-fertilizer sources of N can typically supply enough to grow ~60 bu/acre
  - High yielding soybeans need:
    1. Late N fertilizer
    2. Better N production from nodules
    3. Higher N mineralized from the soil



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

Salvagiotti, F., K.G. Cassman, J.E. Specht, D.T. Walters, A. Weiss, and A. Doberman. 2008. Nitrogen uptake, fixation, and response to fertilizer N in soybeans: A review. Field Crops Res. 108:1-13(adapted).

Nutrient Uptake and Partitioning



R.R. Bender, J.W. Haegele, and F.E. Below. 2015. Nutrient uptake, Partitioning, and Remobilization in Modern Soybean Varieties, Agron. J. 107:563-573, DOI: 10.2134/agronj14.0435

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

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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

Locus Identifier	AnnotationAnnotationAnnotationAnnotationAnnotation	FUNCTION	MEGAFOL F
AT4G10270	wound-responsive family proteinwound-responsive family protein	STRESS wound	62
AT3G10040	transcription factortranscription factortranscription factor	STRESS anoxia	46
AT3G02550	LOB domain protein 41 / lateral organ boundaries domain protein 41	STRESS biotic eFP	33
AT4G33070	pyruvate decarboxylase, putativepyruvate decarboxylase, putative	STRESS anoxia	25
AT2G37870	protease inhibitor/seed storage/lipid transfer protein (LTP) family prot	STRESS salt eFP	18
AT5G09520	hydroxyproline-rich glycoprotein family protein	HORMONE ABA eFP	17
AT4G33560	similar to wound-responsive protein-related [Arabidopsis thaliana] (TA	STRESS wound	16
AT1G77120	ADH1 (ALCOHOL DEHYDROGENASE 1); alcohol dehydrogenase	STRESS anoxia	14
AT2G47780	rubber elongation factor (REF) protein-related	STRESS salt eFP	10
AT5G04120	phosphoglycerate/bisphosphoglycerate mutase family protein	METABOLISM	10
AT5G62520	SRO5 (SIMILAR TO RCD ONE 5); NAD+ ADP-ribosyltransferase	STRESS cold wound eFP	8
AT5G13900	protease inhibitor/seed storage/lipid transfer protein (LTP) family prot	HORMONE ABA eFP	8
AT1G76650	calcium-binding EF hand family protein	STRESS cold eFP	8
AT1G52690	late embryogenesis abundant protein, putative / LEA protein, putative	STRESS osmotic eFP	7
AT4G16780	ATHB-2 (Homeobox-leucine zipper protein HAT4); DNA binding / trar	STRESS cold eFP	7
AT4G36610	hydrolase, alpha/beta fold family protein	HORMONE ABA eFP	7
AT1G02930	[AT1G02930, ATGSTF6 (EARLY RESPONSIVE TO DEHYDRATION	STRESS drought	6
AT5G07010	sulfotransferase family proteinsulfotransferase family protein	STRESS wound eFP	5
AT5G59320	LTP3 (LIPID TRANSFER PROTEIN 3); lipid binding	STRESS osmotic salt eFF	5
AT2G43620	chitinase, putativechitinase, putativechitinase, putative	STRESS osmotic eFP	5
AT1G72360	ethylene-responsive element-binding protein, putative	HORMONE ETHYLENE	5
AT3G13310	DNAJ heat shock N-terminal domain-containing protein	STRESS heat	5
AT5G45340	CYP707A3 (cytochrome P450, family 707, subfamily A, polypeptide 3	STRESS cold wound eFP	5
AT3G23170	similar to ATBET12 [Arabidopsis thaliana] (TAIR:AT4G14450.1)	STRESS cold eFP	5
AT1G19250	FMO1 (FLAVIN-DEPENDENT MONOOXYGENASE 1); monooxygen	STRESS biotic	5
AT2G34390	[AT2G34390, NIP2;1/NLM4 (NOD26-LIKE INTRINSIC PROTEIN 2;1)	STRESS anoxia	5
AT5G40590	DC1 domain-containing proteinDC1 domain-containing protein	HORMONE ETHYLENE e	4
AT5G22460	esterase/lipase/thioesterase family protein	STRESS osmotic eFP	4
AT3G02480	ABA-responsive protein-relatedABA-responsive protein-related	STRESS osmotic eFP	4
AT2G43570	chitinase, putativechitinase, putativechitinase, putative	STRESS osmotic eFP	4
AT2G47770	benzodiazepine receptor-relatedbenzodiazepine receptor-related	STRESS osmotic eFP	4
AT5G66400	RAB18 (RESPONSIVE TO ABA 18)	STRESS osmotic	4
AT4G37770	ACS8 (1-Amino-cyclopropane-1-carboxylate synthase 8)	HORMONE ETHYLENE	4
AT5G13580	ABC transporter family proteinABC transporter family protein	TRANSPORT	4
AT5G54490	PBP1 (PINOID-BINDING PROTEIN 1); calcium ion binding	HORMONE AUXIN	4
AT3G21720	isocitrate lyase, putativeisocitrate lyase, putative	METABOLISM	4
AT5G50260	cysteine proteinase, putativecysteine proteinase, putative	HORMONE ABA eFP	4
AT5G10230	ANN7 (ANN7, ANNEXIN ARABIDOPSIS 7); calcium ion binding / cal	HORMONE ABA eFP	4
AT4G33550	lipid bindinglipid bindinglipid bindinglipid bindinglipid binding	HORMONE ABA eFP	4
AT2G22510	hydroxyproline-rich glycoprotein family protein	HORMONE ABA eFP	4

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

IF

- 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

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People...Products...Knowledge®...

Thank You