Almond Plant Growth Regulation & Pest Protection Strategies

Lance Beem,
Beem AgroSciences

17th Australian Almond Conference

Pullman Hotel Melbourne, Albert Park, Victoria

November 8th - 10th, 2016

HOSTED BY:
The Almond Board of Australia

SUPPORTED BY:
Horticulture Innovation Australia Ltd

Lance Beem

President,

Beem Consulting/
Beem AgroSciences Corp USA

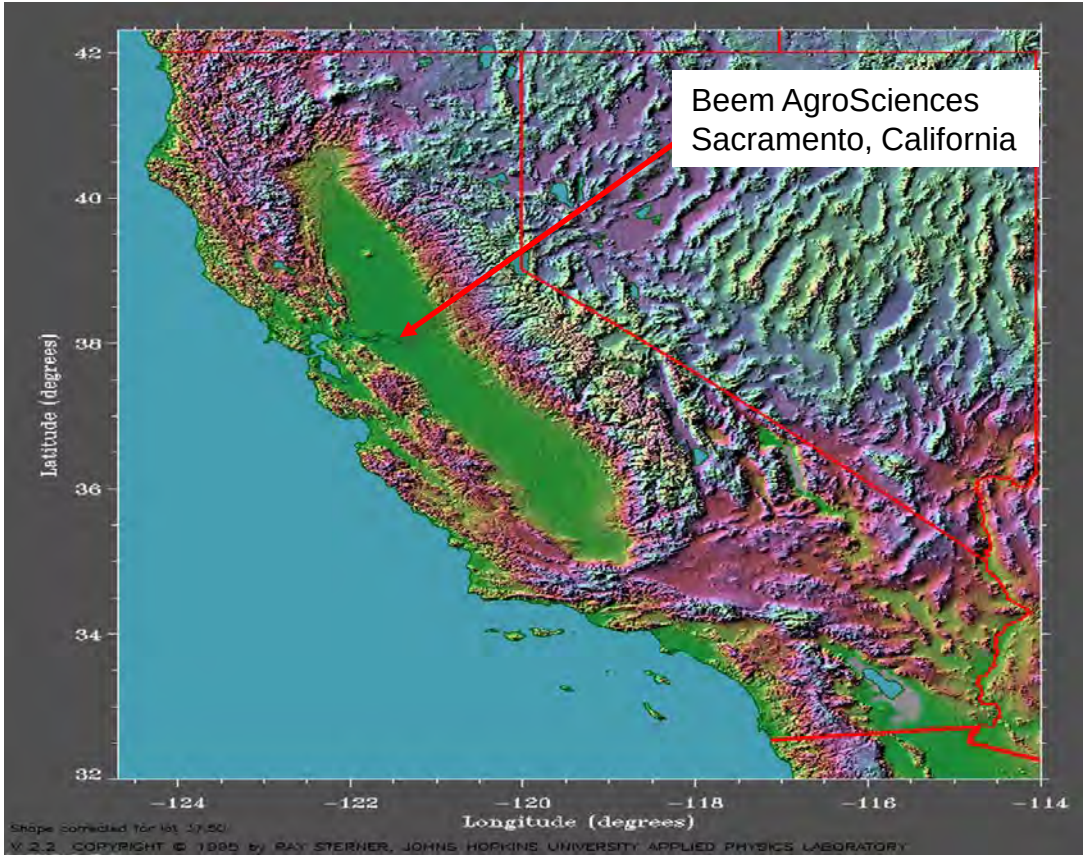
Lance's company Beem Agro Sciences conducts contract research, consulting and demonstrations focused on development of new pesticides, fertilisers, natural products and generally regarded as safe compounds. His business is designed to integrate conventional/and non-conventional plant regulation, nutrition and pest management practices. He has extensive expertise in herbicides, insecticides, fungicides, plant hormones, plant extracts, antioxidants, glycoside chemistry. He consults with large and small farmers, companies and individuals seeking registrations. Prior to beginning his own business, Lance was engaged by Stoller Enterprises for numerous years as a Market Development Manager in major and minor crops.

Presentation Outline

- Introduction of California Almond Production
- Introduction of Beem AgroSciences
- Plant Hormones in Almond Production (eg. Roots/Shoots/Bloom)
- Results of Research with Plant Growth Regulating Compounds in Almond Trials.

Introduction California Almond Production

California Almond Region



Almond Importance in California

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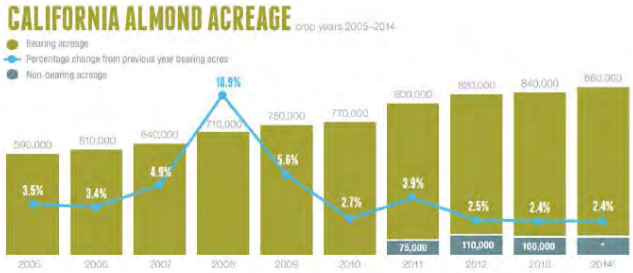
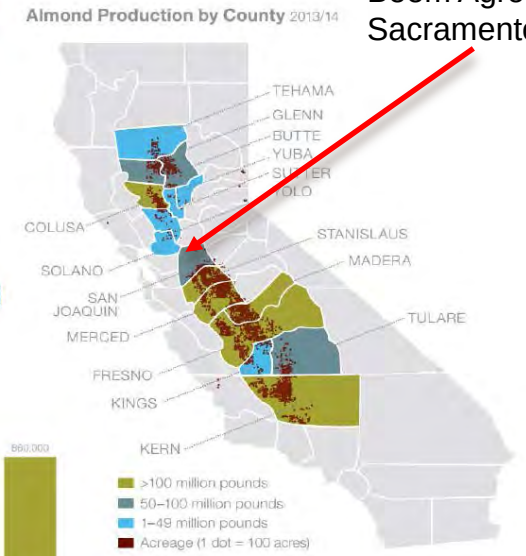
The Scope of the California Almond Industry

Almond orchards span 500 miles from north to south through California's Central Valley.

- 2014 total acreage: 1,020,000 A
- 2014 bearing acreage: 870,000 A
- 3 growing regions: North, Central, South
- 97,000 almond industry-related jobs generated in Central Valley, 104,000 statewide





Beem AgroSciences
Sacramento, California

100% of Almond Production in USA

Who We Are
Beem AgroSciences

Who and What We Do

Beem AgroSciences, Sacramento, CA

1.) 50% Conventional Product R & D

2.) 50% Organic Product R & D

3.) Trees, Vines, Vegetables, Specialty, etc.

Brief History

Almond Research Trials (1982-2016)

1.) Plant Growth Regulators

2.) Bio-Stimulants

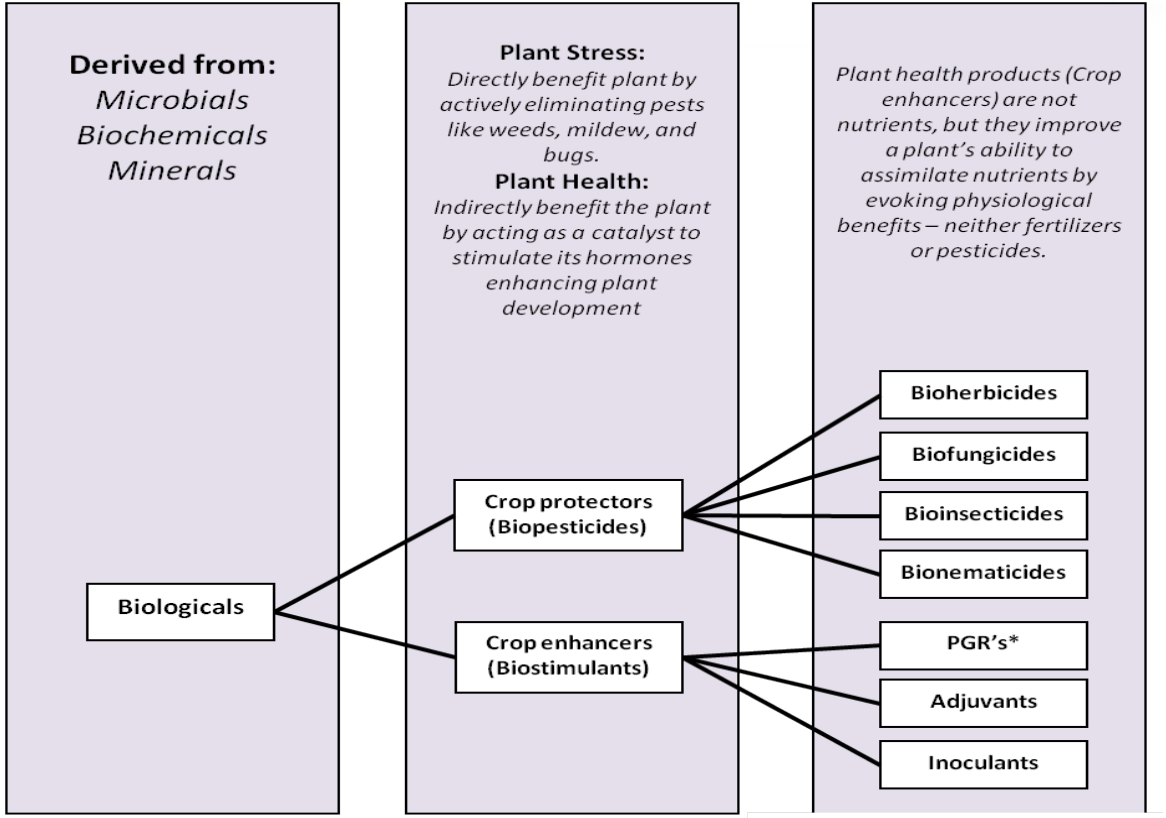
3.) Bio-Regulators

4.) Conventional & Bio-Pesticides

Beem AgroSciences Corp

1. Investigations into Pesticides, Plant Growth Regulators and Biologicals
2. Benefit Cost Analysis of Biologicals
3. Greenhouses & Research Farms
4. Replicated Field Trials & Grower Validation Trials.

Biological Plant Products



* PGR's = *Plant Growth Regulators*

REGISTERED BIOPESTICIDE ACTIVE INGREDIENTS BY GEOGRAPHY

Geography	Registered active ingredients	Date
U.S.	~400	*As of early 2013*
China	85	*As of 2011*
EU	79	*As of early 2013*
Brazil	26	*As of August 2011*
India	15	*As of 2008*

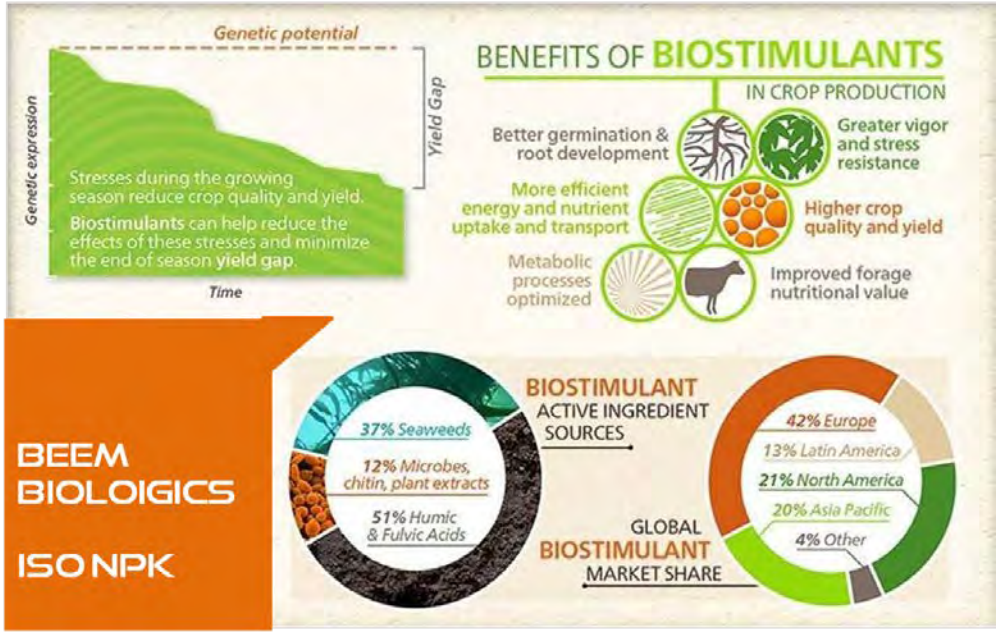
Source: U.S. EPA, Agrow Informa UK, Biopesticides: Pest Management and Regulation, Embrapa Environment, African Journal of

TIME AND COST INVESTMENT FOR FOUR AGRICULTURAL PRODCTS

Type	Time to Market	Cost of Development
Traditional chemical pesticide	10 years	$260 million
Genetically engineered trait	8-13 years	$140 million
Biopesticide	3 years	$8-15 million*
Biostimulant	1-2 years	$1.5-3 million

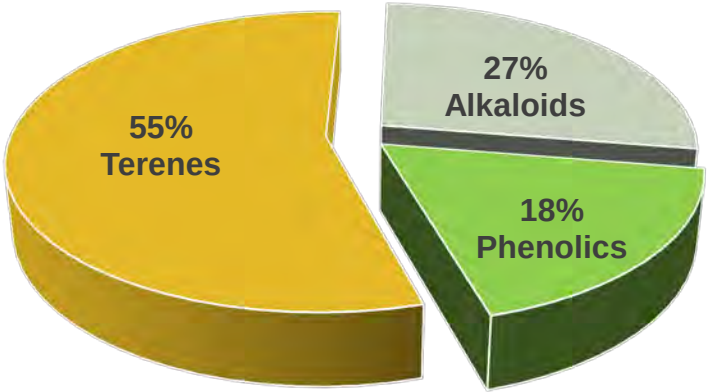
Source: CropLife America / ECPA study, CropLife International study 2011, BPIA, Marrone Bio Innovations

UNDERSTANDING How BIOSTIMULANTS Fit

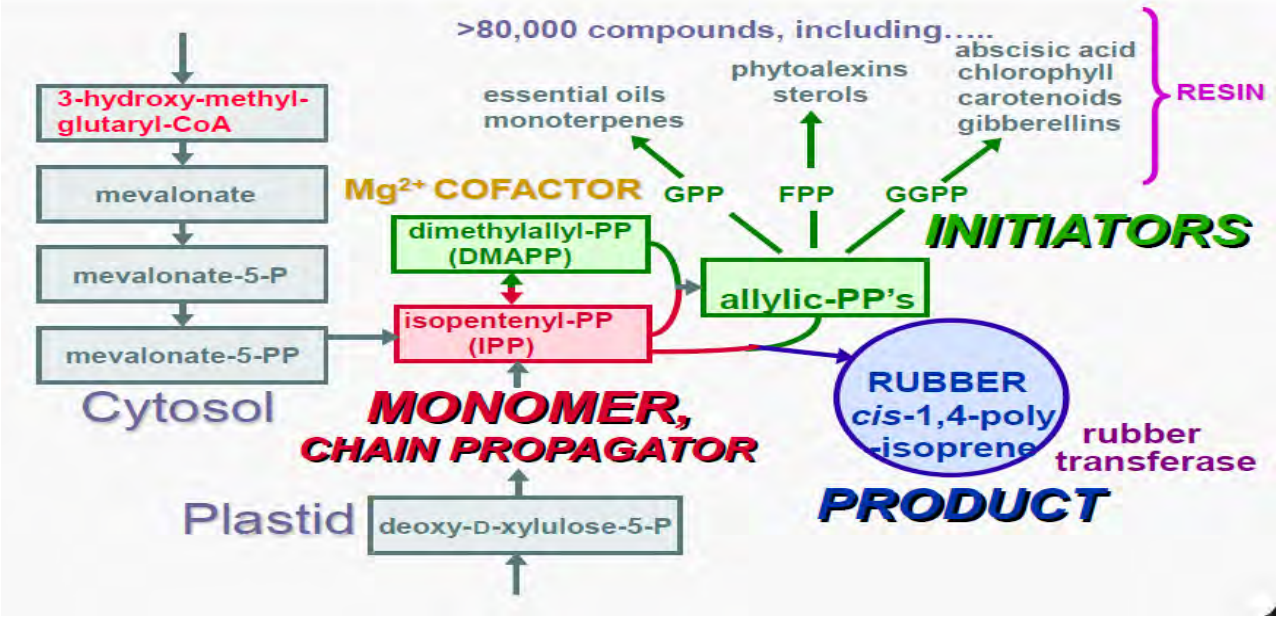


Biological Plant Products

It has long been known that the basic unit of most secondary plant metabolites, including terpenes, consists of isoprene, a simple hydrocarbon molecule. The term terpene usually refers to a hydrocarbon molecule while terpenoid refers to a terpene that has been modified, such as by the addition of oxygen. Isoprenoids are, therefore, the building blocks of other metabolites such as plant hormones, sterols, carotenoids, rubber, the phytoltail of chlorophyll, and turpentine.



Biological Plant Products

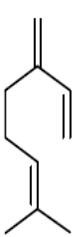


The Isoprenoid Pathway –
a plant based chemical factory

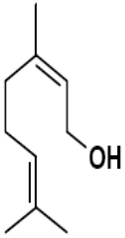
Biological Plant Products

Examples Isoprenes Molecules Interact with Plant Hormones

The isoprene units are always linked 1,4 and head-to-tail in terpenes (the preferred addition orientation even in mineral acid), but are often linked further in bizarre ways to produce rings. Oxygen functional groups are often included, as might be expected from hydrolysis of the pyrophosphate linkage. The diversity of compounds produced is amazing, but the pattern of one methyl group every fourth carbon reveals their origin. The simplest, monoterpenes, consist of 2 isoprene units. The stereoisomers of these simplest terpenes provide interesting illustrations of the stereospecificity of odor receptors; for example (+)-(*S*)-carvone is responsible for the odor of caraway and (-)-(*R*)-carvone the odor of spearmint.

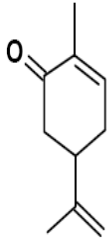


myrcene



geraniol

limonene



carvone

camphor

pinene

Plant Hormones In Almond Production

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What are Plant Hormones?

Chemical Messengers

Frits Went, 1903-1990

".....characterized by the property of serving as chemical messengers, by which the activity of certain organs is coordinated with that of others".

-*Frits Went and Kenneth Thimann, 1937*

Kenneth Thimann, 1904-1997

Frits Went image courtesy of Missouri Botanical Garden ©2010 Kenneth Thimann photo courtesy of UC Santa Cruz

Plant Hormones

Plant hormones regulate cellular activities (division, elongation and differentiation), pattern formation, organogenesis, reproduction, sex determination, and responses to abiotic and biotic stress.

Notholaena standleyi © 2008 Carl Rothfels

Old & New Plant Hormones

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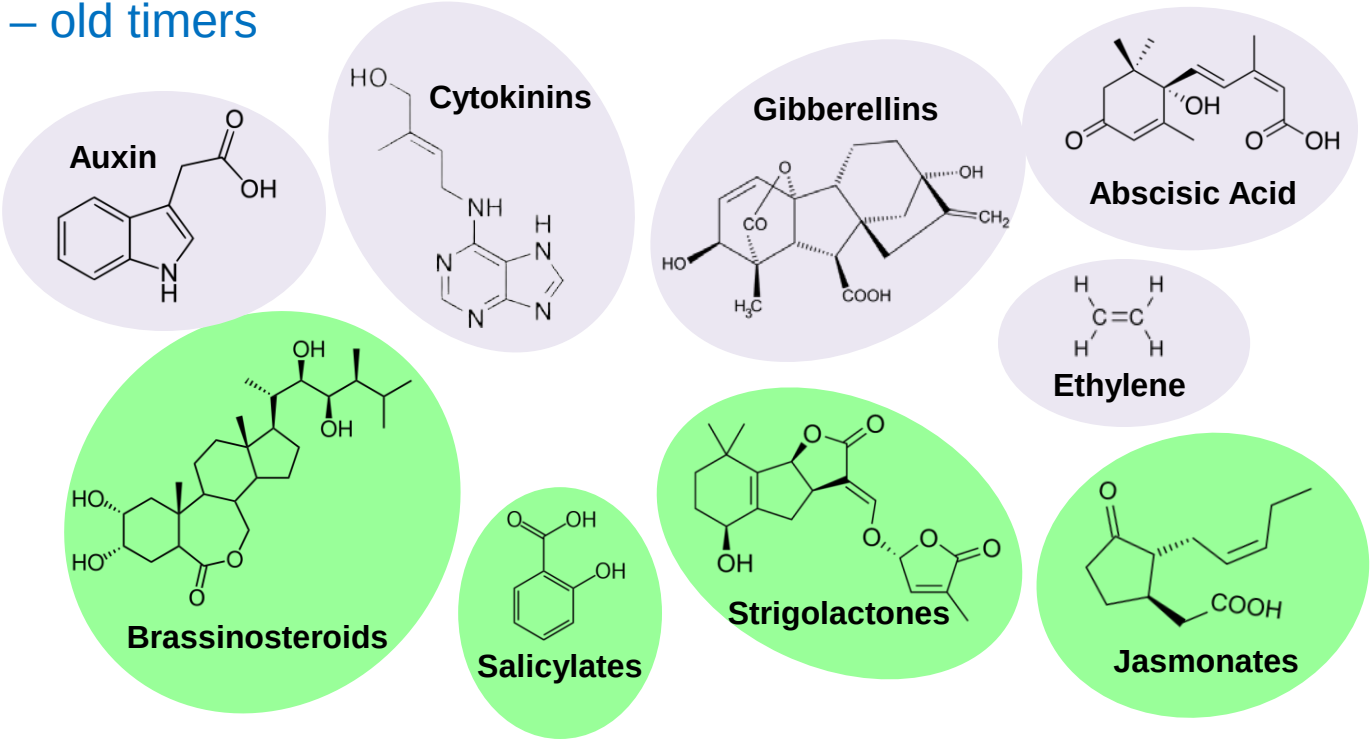
Chemical Messengers

– old timers



- newcomers

Plant Hormone Roles

How hormones work (*25% all plant genes*)

Hormonal control of vegetative development

- Auxin
- Cytokinins
- Strigolactones
- Gibberellins
- Brassinosteroids

Hormonal control of reproduction

- Ethylene
- Abscisic Acid

Hormonal responses to stress

- Salicylates
- Jasmonates

Cross-regulation of hormonal effects

Five Original Plant Hormones

Chemical Messengers

Growth Hormones
- **Auxin: The Activator**
- **Cytokinin: The Dispatcher**
- **Gibberellic Acid: The Sizer**

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

- Plant Hormones regulated Genes
- Plant Hormones respond to Environment.
- Plant Hormones are often Conjugated.
- Plant Hormones are often Eliminated Oxidation

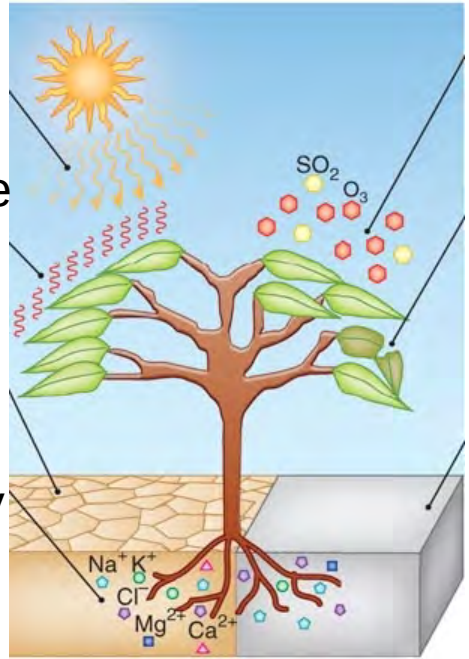
Hormonal responses > abiotic stress

Photo oxidative stress

High tempature stress

Water deficit, drought

Soil salinity



Air pollution

Wounding and mechanical damage

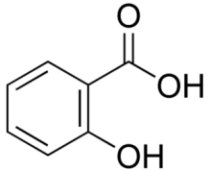
Cold and freezing stress

Plants' lives are very stressful.....

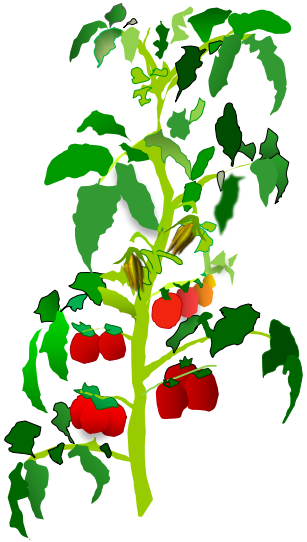
ABA and Ethylene help plants respond to stress.

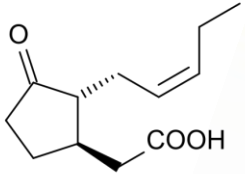
Hormonal responses > biotic stress

Bacteria, fungi, viruses – Biotrophic organisms



Salicylic Acid





Jasmonates

Herbivores – insects, other animals, fungi – Necrotrophic organisms

Photo credits: A. Collmer, Cornell University; Salzbrot.

Plant Hormone Roles

How hormones work (*25% all plant genes*)

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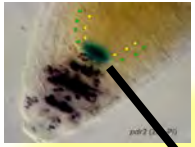
Cross-regulation of hormonal effects

Plant Hormone Transport

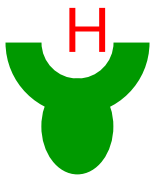
Chemical Messengers



Hormones: Synthesis, transport, perception, signaling and responses

Production of active hormone → **Conjugation**

Transport



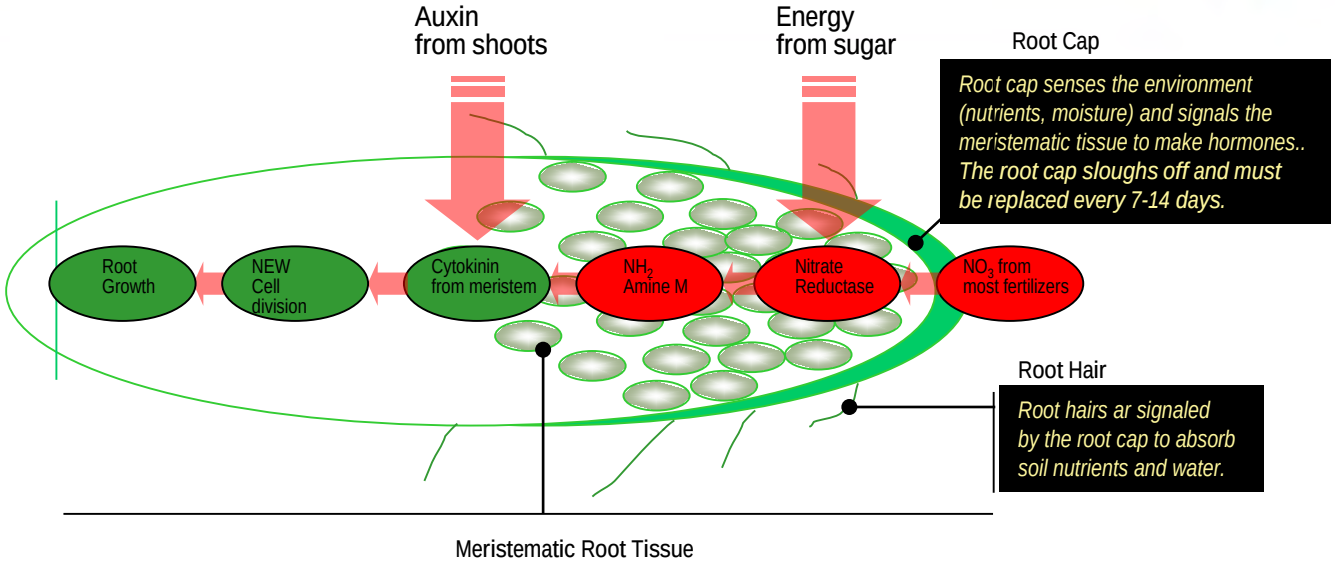
Binding to receptor

Signal transduction

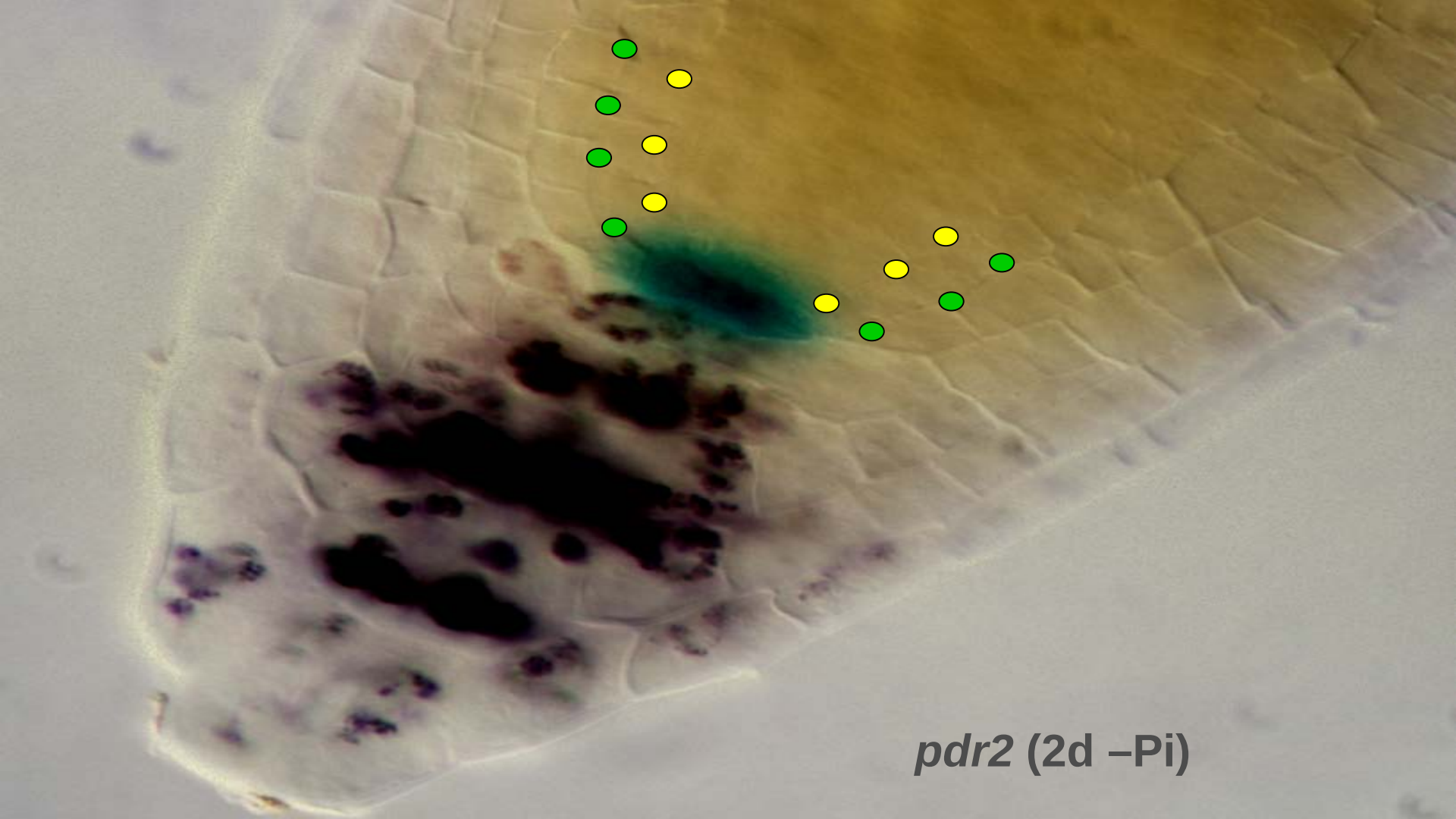
Downstream effects

Downstream effects

Root Tips “Brains” Of The Plant



Meristematic root tissue responds to the root cap to produce hormones (cytokinin, giberellic acid, & abscisic acid), which together with auxin from the shoots, maintain cell division for root tip growth. If the root tips die, the plant’s “brain” dies and it looses its ability to control hormone cycles and nutrient availability. The plant will loose vigor and eventually die. It is important to feed and maintain a healthy root system.

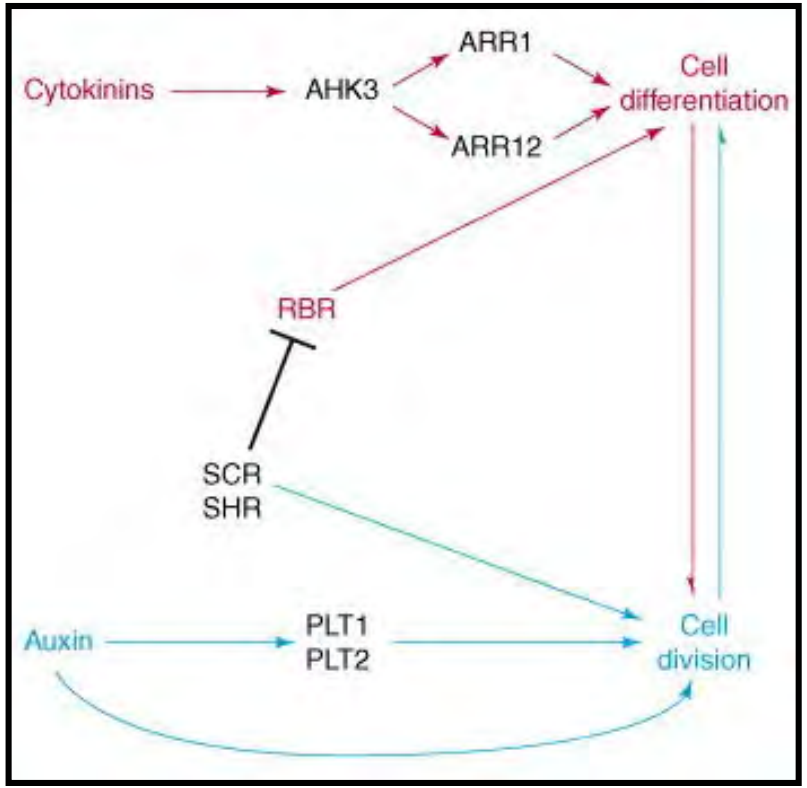

pdr2 (2d –Pi)

Regulatory Network Controlling Root Meristem Size and Activity

Elongation Zone

Division Zone

Stem Cell Niche



Dello-Ioio et al. (2008) Curr Opn Plant Biol 11:23-27

Root Tips “Brains” Of The Plant

Almond Lifecycle:

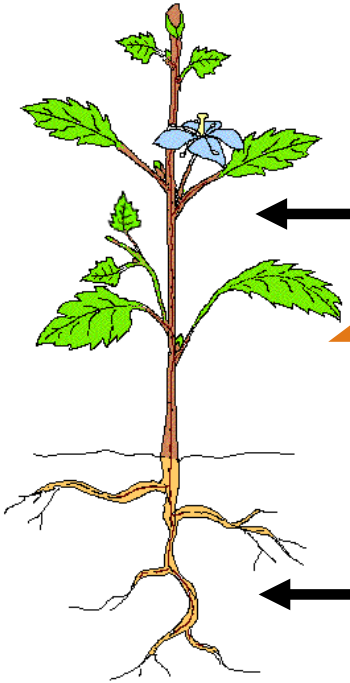
Roots are a high source of Cytokinins

You should think twice about planting conditions

Cytokinin Hormone

Internal C:Nitrogen Levels

Regulating N_2 influences rooting success cuttings

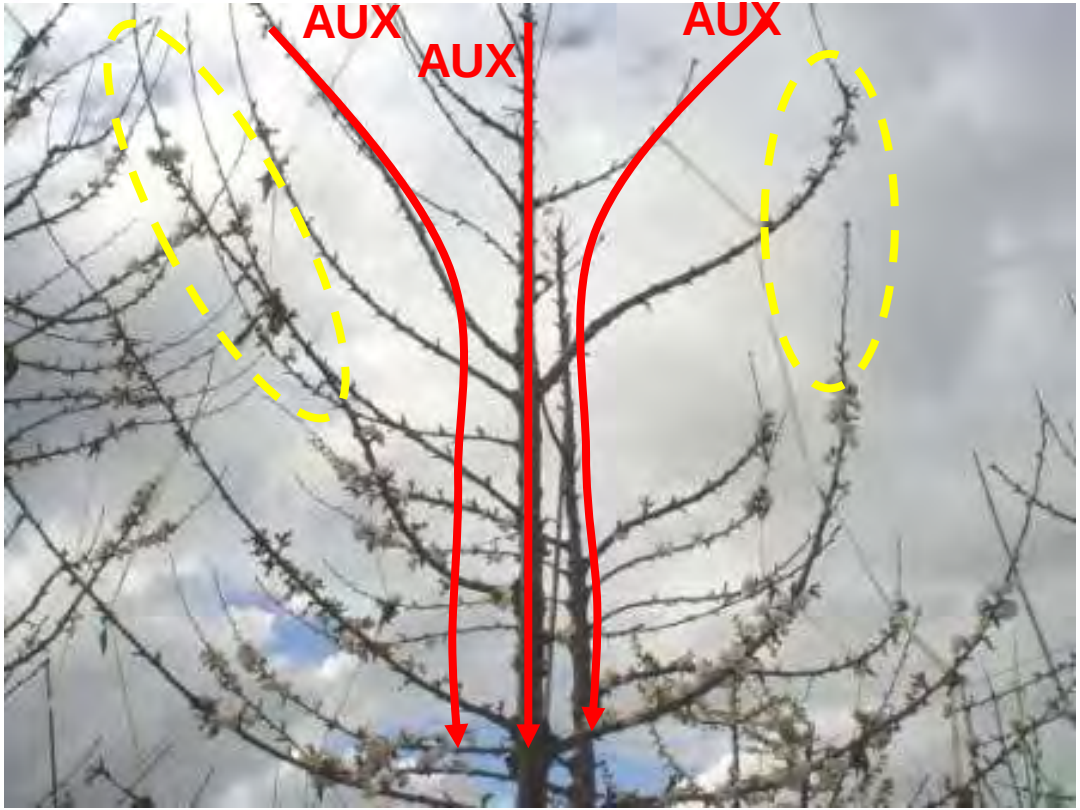


Increased shoot growth

Cytokinin moves up from the roots to stimulate new vegetative shoot growth

High levels of N_2 in the soil: Ammonia (NH3) or Nitrate (NO3).

Auxin Movement



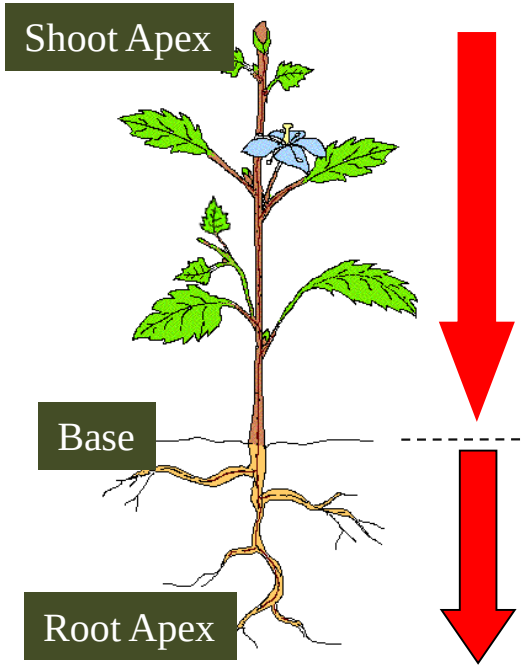
Auxins are made daily in the meristem of the buds & shoots of almond trees & move downward at a speed of approximately 20 cm an hour.

There are 100,000 more auxin in the shoot tips than root tips. But without auxin in root tips there would be no plant growth.

Both labeled sugar and auxin move rapidly through the plant at velocities of ca. 16-20 cm h(-1) with closely similar, exponential profiles.

Plant Hormone Movement

Auxin movement- "Polar"



In shoots:

Auxins move basipetally

(apex to base)

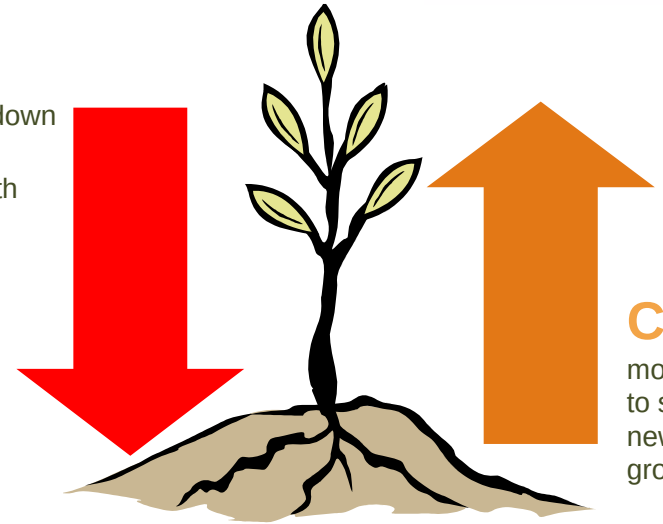
In roots:

Auxins move acropetally

(base to apex)

Vegetative Growth

Auxin moves down from the shoots to stimulate root growth



Cytokinin moves up from the roots to stimulate new vegetative shoot growth

Where auxin and cytokinin meet, vegetative buds are formed.

Vegetative buds are differentiated into reproductive buds by ethylene and GA. Ethylene and GA synthesis are stimulated by a *higher auxin to cytokinin ratio*.

Hormone Balance

Auxin + Cytokinin stimulate **cell division** giving birth to new cells

Cell Division: is important for establishing the type and number of cells needed for normal plant development, vigorous growth and yield **quality**

Plant Hormone Roles

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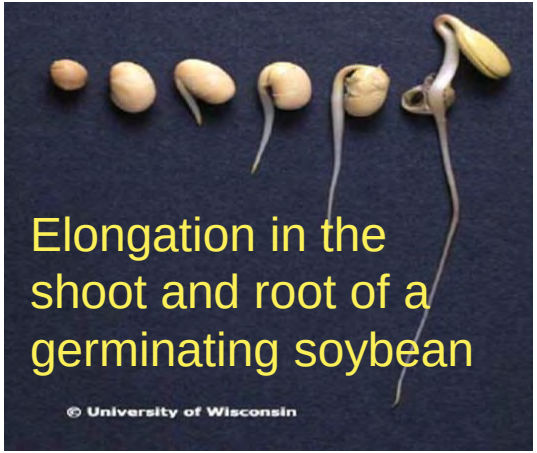
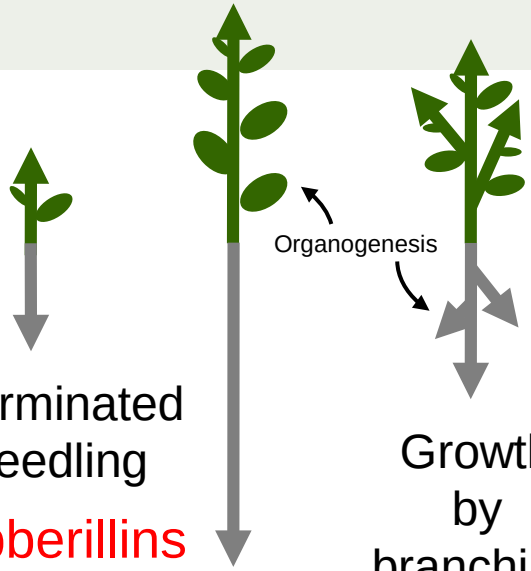
Cross-regulation of hormonal effects

Hormones: Growth Stages

Balance of Hormones = vegetative growth: elongation, branching and organogenesis

Gibberillins





Germinated seedling

Gibberillins

Growth by elongation

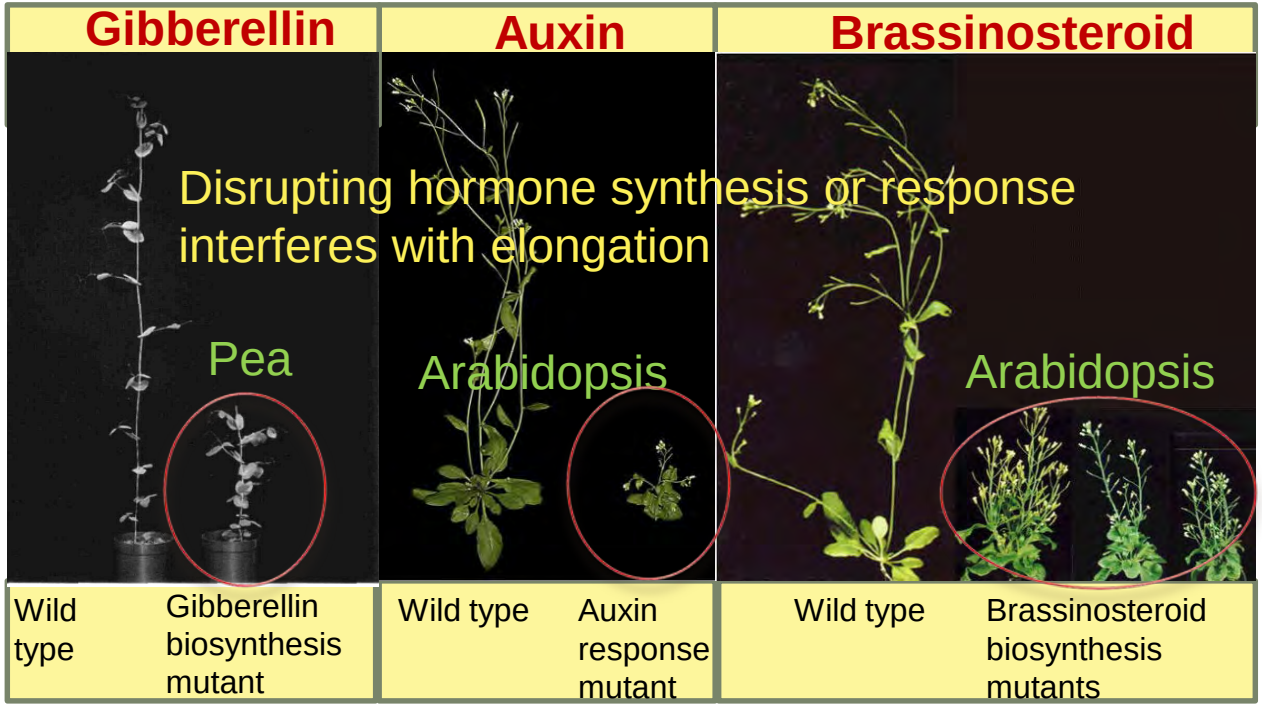
Growth by branching

Cytokinins

Photo courtesy of Shawn Conley

Stress Generate Oxidation Plant Hormone Activity

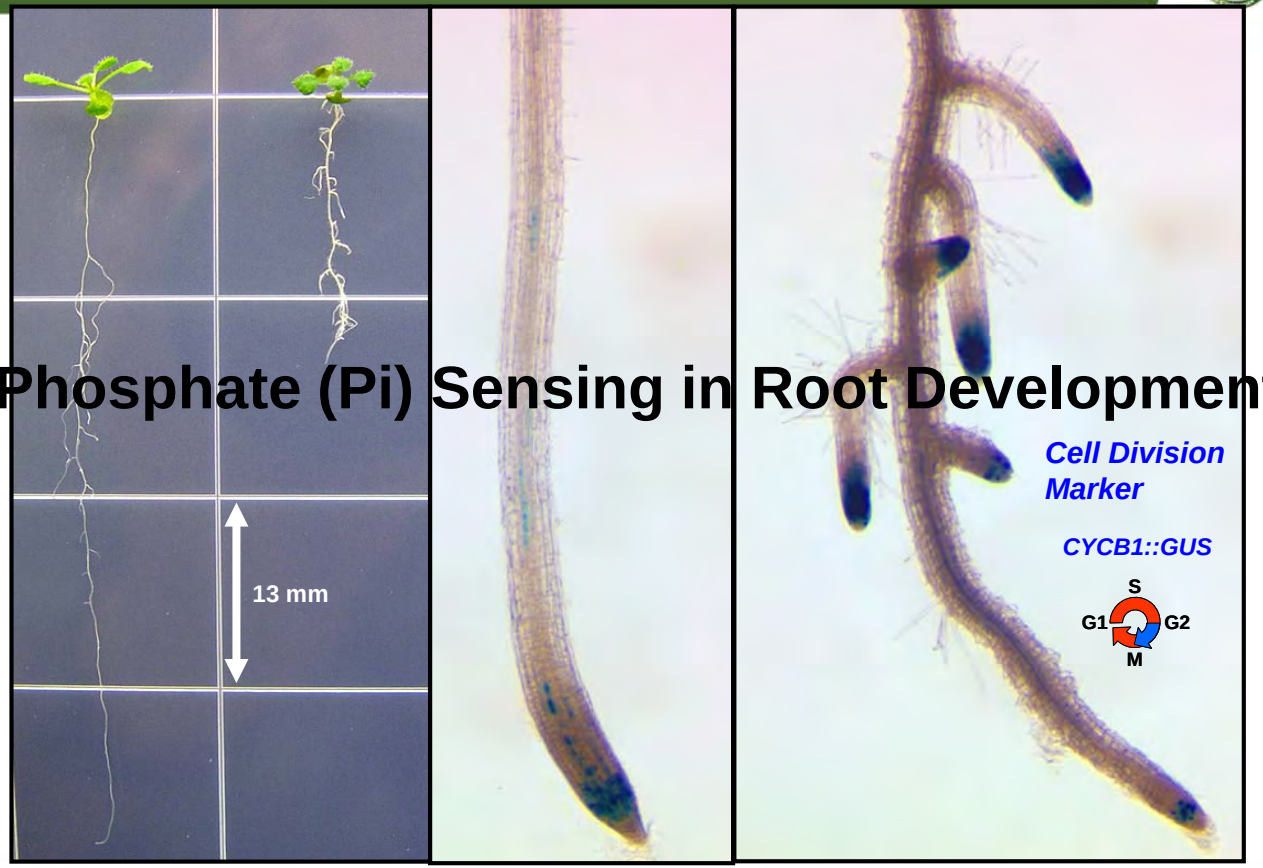
Hormones: Deficencies



Lester, D.R., Ross, J.J., Davies, P.J., and Reid, J.B. (1997) Mendel's stem length gene (*Le*) encodes a gibberellin 3β-hydroxylase. Plant Cell 9: 1435-1443.;Gray WM (2004) Hormonal regulation of plant growth and development. PLoS Biol 2(9): e311; Clouse SD (2002) Brassinosteroids: The Arabidopsis Book. Rockville, MD: American Society of Plant Biologists. doi: 10.1199/tab.0009

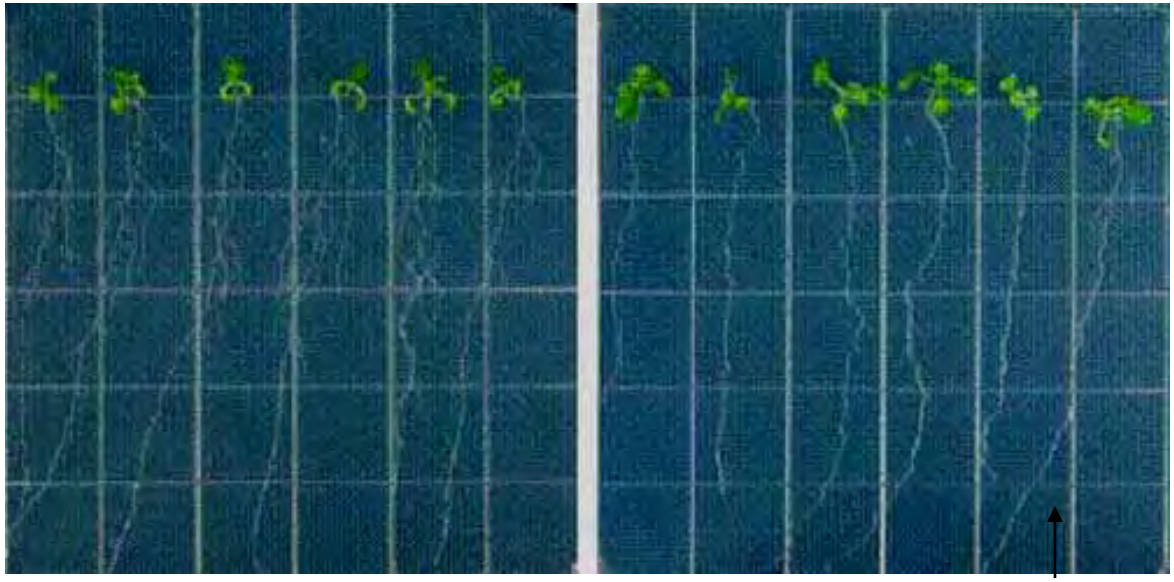
Phosphorus Reduction

Phosphate (Pi) Sensing in Root Development



+Pi -Pi +Pi -Pi

Increasing Ethylene



low nitrates

high nitrates

Proper Auxin to Cytokinin ratio

Increases Ethylene

Nitrate Reductase Enzyme

Sugar Mover at 0.01% increased root hair formation in Arabidopsis

Roles of Auxin

Auxins – promote adventitious rooting

Effect of the "rooting hormone", Auxin = IBA, on hardwood cuttings of the tropical legume, *Inga fueillei*

Plant Hormone Manipulation During Almond Bloom

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Brassinoids, Gibberillins & Cytokinin During Almond Bloom

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PGR Almond Pollen Tube/Fruit Set

The effect of three plant bioregulators on pollen germination, pollen tube growth and fruit set in almond [*Prunus dulcis* (Mill.) D.A. Webb] cvs. Non Pareil and Carmel

- Segundo Maita[a, b],
- Carlos Sotomayor

Show more

http://dx.doi.org/10.1016/j.ejbt.2015.07.004

Cytokinins =KN
Gibberellins = GA3
Brassinosteroids = BL

PGR Almond Impact on Pollen Tube

Percentage of pollen germination in vitro on Non Pareil and Carmel almond cultivars after 4 h, in the presence of Plant Bio-Regulators in the 2013 and 2014 growing seasons.

Table 1.

Treatments	cv. Non Pareil		cv. Carmel	
	2013	2014	2013	2014
Control	90.0 d	90.9 c	89.2 c	91.9 b
BL 10 mg L^{-1}	95.3 a	97.7 a	95.5 ab	95.1 a
BL 30 mg L^{-1}	92.4 cd	94.4 abc	92.6 bc	94.0 ab
BL 50 mg L^{-1}	91.0 d	91.4 bc	90.4 c	93.6 ab
GA_3 10 µL L^{-1}	90.9 d	91.3 bc	92.4 bc	94.3 ab
GA_3 30 µL L^{-1}	92.6 bcd	95.2 abc	96.7 ab	94.8 ab
GA_3 50 µL L^{-1}	95.1 ab	96.6 ab	96.9 a	95.1 a
KN 10 µL L^{-1}	90.7 d	92.8 abc	92.9 abc	92.8 ab
KN 30 µL L^{-1}	92.0 cd	94.5 abc	93.3 abc	94.3 ab
KN 50 µL L^{-1}	94.1 abc	95.9 abc	94.4 abc	94.7 ab

Means followed by the same letter are not statistically different according to the Tukey-Kramer test ($p \leq 0.05$).

PGR Impact on Almond Pollen Tube

Pollen tube length in Non Pareil and Carmel almond cultivars after 8 h, in the presence of Plant Bio-Regulators in the 2013 and 2014 growing seasons (values in µm).

Table 2.

Treatments	cv. Non Pareil		cv. Carmel	
	2013	2014	2013	2014
Control	937.1 f	945.0 h	917.7 e	921.3 g
BL 10 mg L^{-1}	1067.4 b	1078.8 b	1117.0 c	1100.1 e
BL 30 mg L^{-1}	1032.6 c	1043.0 d	1059.7 d	973.1 f
BL 50 mg L^{-1}	963.9 e	971.6 f	921.3 e	964.0 f
GA_3 10 µL L^{-1}	977.0 e	971.7 f	1183.0 b	1144.6 d
GA_3 30 µL L^{-1}	1000.0 d	997.7 e	1199.4 b	1168.1 c
GA_3 50 µL L^{-1}	1100.6 a	1096.0 a	1226.6 ab	1183.5 b
KN 10 µL L^{-1}	942.0 f	947.3 h	1198.4 b	1179.9 bc
KN 30 µL L^{-1}	965.1 e	960.6 g	1212.5 ab	1186.2 b
KN 50 µL L^{-1}	1056.8 b	1066.9 c	1243.4 a	1215.9 a

Means followed by the same letter are not statistically different according to the Tukey-Kramer test ($p \leq 0.05$).

PGR Impact on Almond Fruit Set

Percentage of fruit set in Non Pareil almond cultivar at 60 days after full bloom, with Plant Bio-Regulators treatments at two phenological stages (2013 and 2014).

Table 3.

Treatments	Pink Bud		Fallen Petals	
	2013	2014	2013	2014
Control	17.1 d	16.7 d	15.6 c	16.5 c
BL 10 mg L^{-1}	24.6 ab	22.3 bcd	21.7 abc	22.6 ab
BL 30 mg L^{-1}	22.5 abcd	19.2 cd	19.5 abc	20.4 abc
BL 50 mg L^{-1}	22.1 abcd	18.9 cd	17.8 bc	16.7 bc
GA_3 10 µL L^{-1}	23.7 ab	26.2 ab	19.8 abc	22.5 abc
GA_3 30 µL L^{-1}	27.1 a	28.0 ab	26.2 a	22.7 ab
GA_3 50 µL L^{-1}	18.0 cd	22.7 bcd	20.6 abc	19.8 abc
KN 10 µL L^{-1}	20.1 bcd	22.7 bcd	22.1 ab	19.8 abc
KN 30 µL L^{-1}	23.5 abc	24.8 abc	23.7 ab	25.6 a
KN 50 µL L^{-1}	25.8 ab	31.0 a	22.1 ab	24.0 a

Means followed by the same letter are not statistically different according to the Tukey–Kramer test ($p \leq 0.05$).

Plant Hormone Roles

How hormones work (*25% all plant genes*)

Hormonal control of vegetative development

- Auxin
- Cytokinins
- Strigolactones
- Gibberellins
- Brassinosteroids

Hormonal control of reproduction

- Ethylene
- Abscisic Acid

Hormonal responses to stress

- Salicylates
- Jasmonates

Cross-regulation of hormonal effects

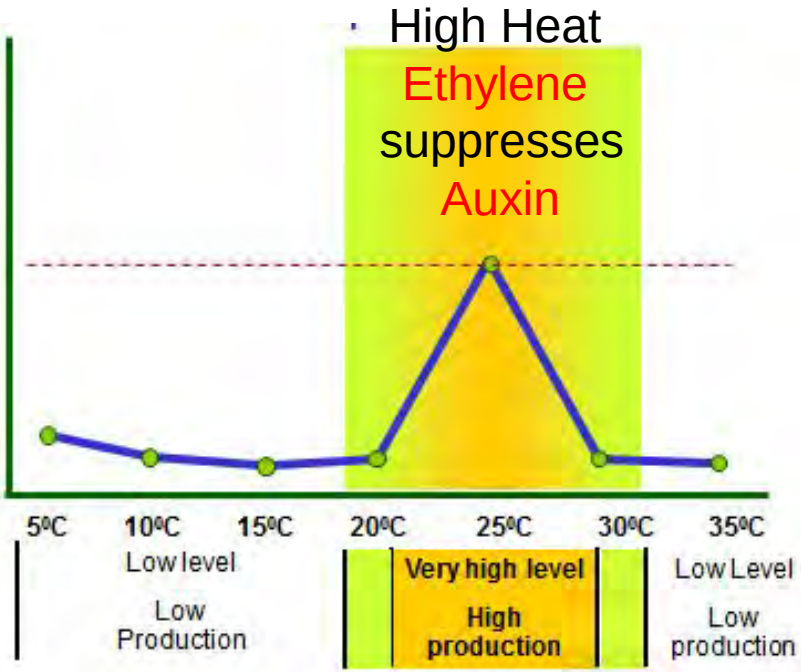
Temperature and Pollination

Problems from adverse temperatures are due to a lack of growth hormone production in the plant

Auxin levels

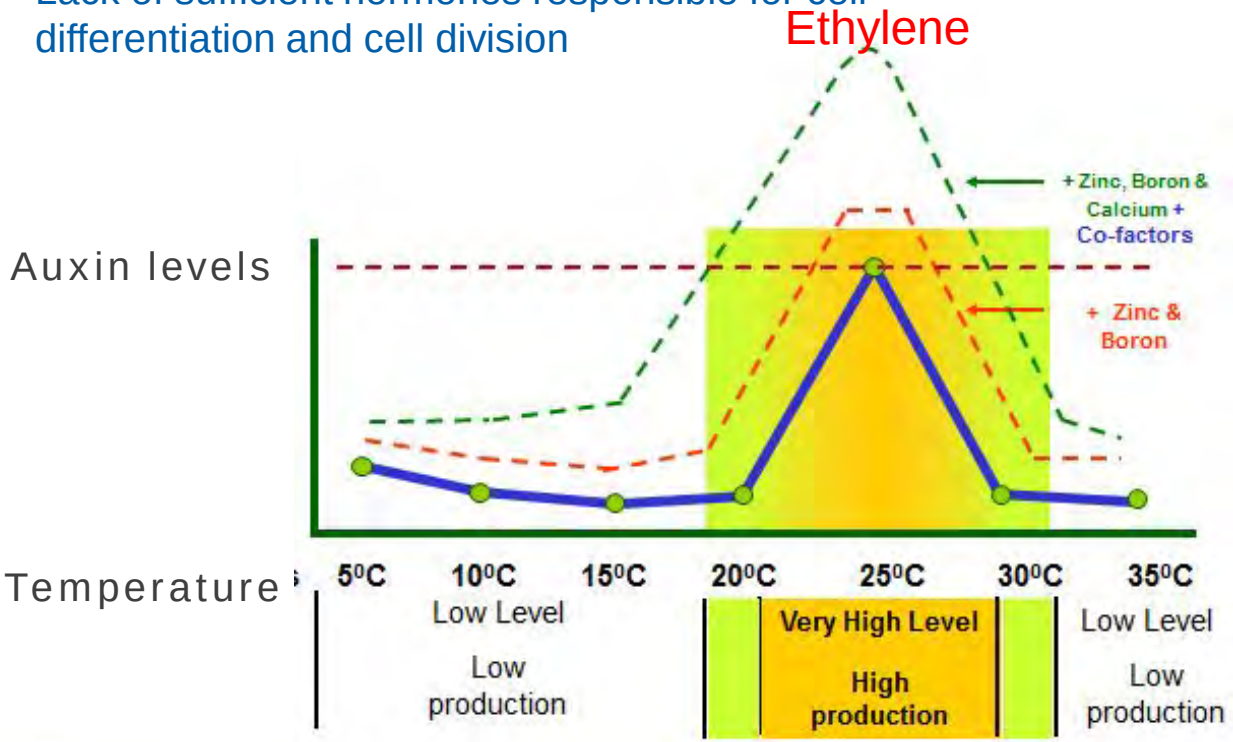
Pollination vigour

Temperature



Reducing poor pollination

Lack of sufficient hormones responsible for cell differentiation and cell division



What is Ethylene?

- Ethylene is a natural plant hormone that affects many processes
  - Nut/Fruit Set
  - Flower Development
  - Fruit Ripening
  - Flower/Fruit Abscission

Plant Health Regulating Compounds During Almond Bloom

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Valent Anti-Etyhlene PGR Use During Almond Bloom

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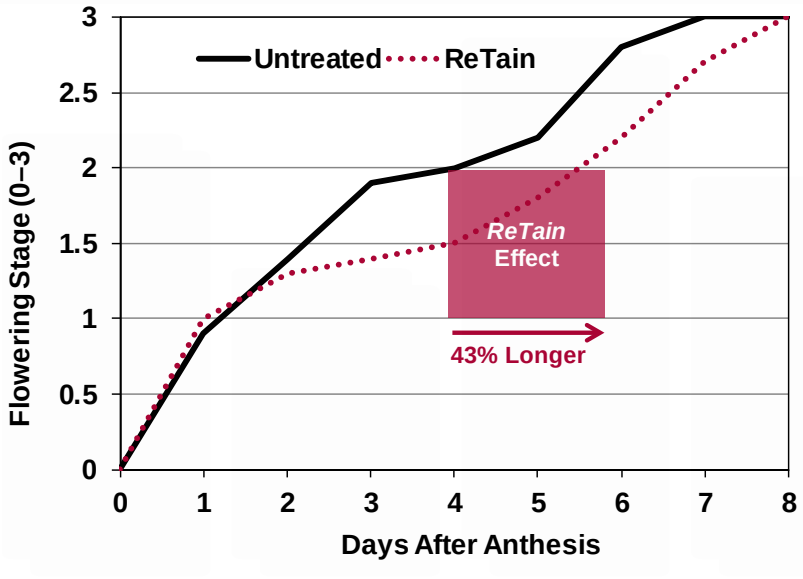
How Does ReTain Work in Almonds?

- ReTain reduces ethylene evolution in almond flowers and delays flower and stigmatic senescence. This effect results in flowers being viable longer, which allows more time for pollination to occur. Increasing set and potential yield.

How to Use ReTain on Almonds

Use Rate	1 water-soluble pouch/A (333 grams)
Application Method	Ground (air blast sprayer)
Timing	From 10% bloom to petal fall (recommended timing: 30–60% bloom)
REI / PHI	12 hours / 0 hours (none required)
Rainfastness	8 hours after application
MRLs	No residue restrictions for export markets

ReTain Extends Pollination Period



ReTain effectively delayed bloom senescence in almonds, thus improving the chances for pollination by 43%

Source: Valent

ReTain Extends the Pollination Period

Trial Location: Firebaugh, CA
ReTain applied on 2/17/16, 1 bag/A in 100 gpa
Pictures taken on 2/23/16 (6 DAT), Variety: Monterey

ReTain effectively delayed bloom senescence in almonds, thus improving the chances for pollination by 43%

Source: Valent

Replicated Commercial Trials

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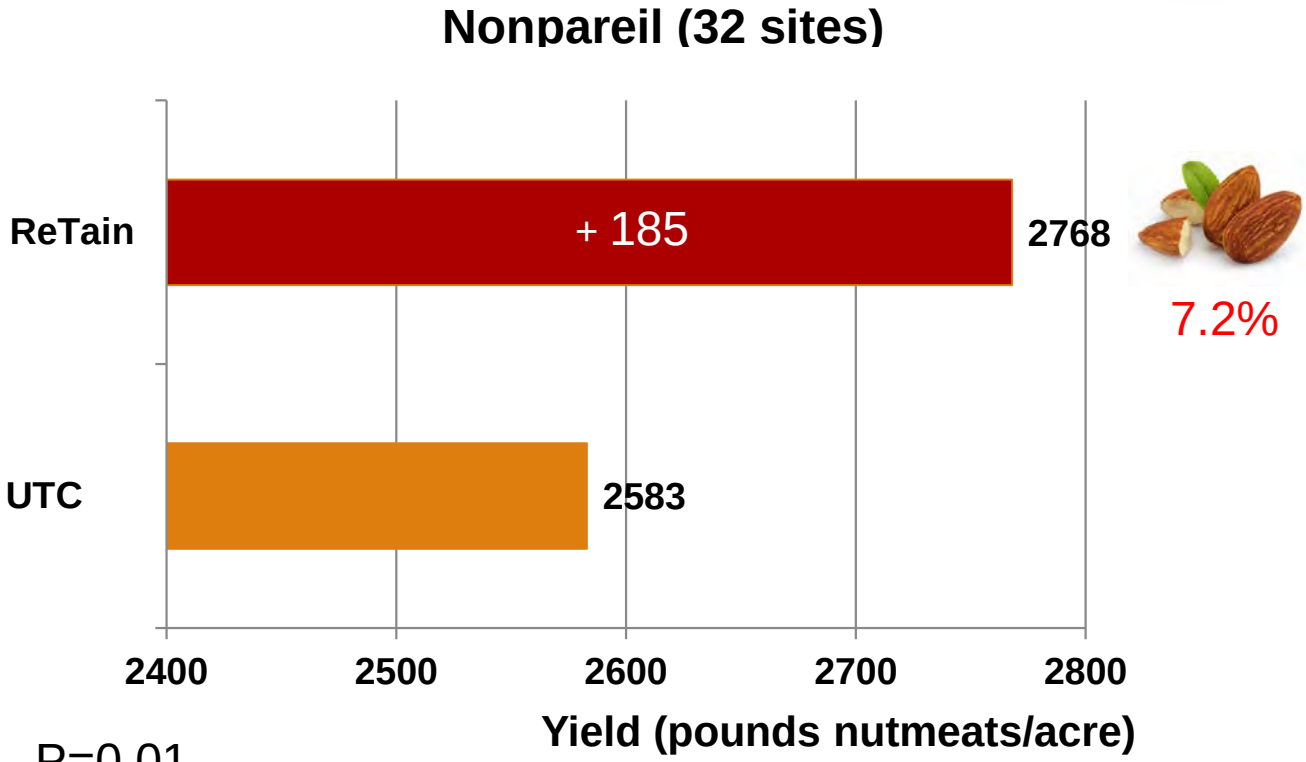
(2014-2016)



7.2%

P=0.01

What is Ethylene?

- Ethylene is a natural plant hormone that affects many processes
  - Nut/Fruit Set
  - Flower Development
  - Fruit Ripening
  - Flower/Fruit Abscission

Bayer & BASF Fungicides During Almond Bloom

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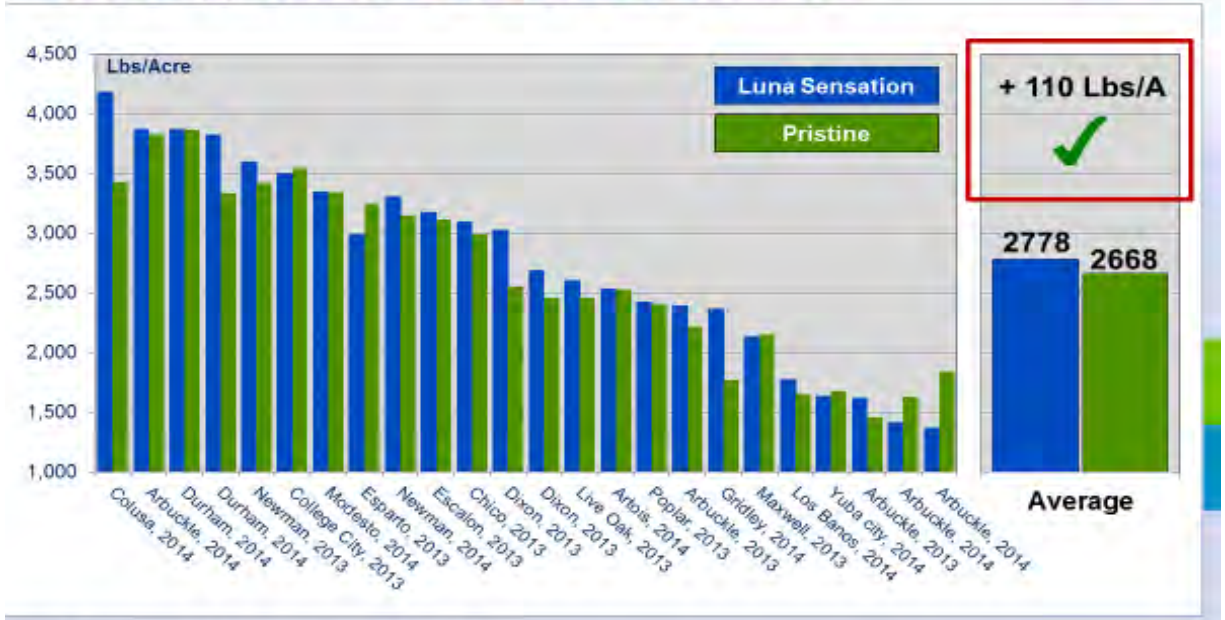
Suppresses Ethylene, Increases Mitocondria

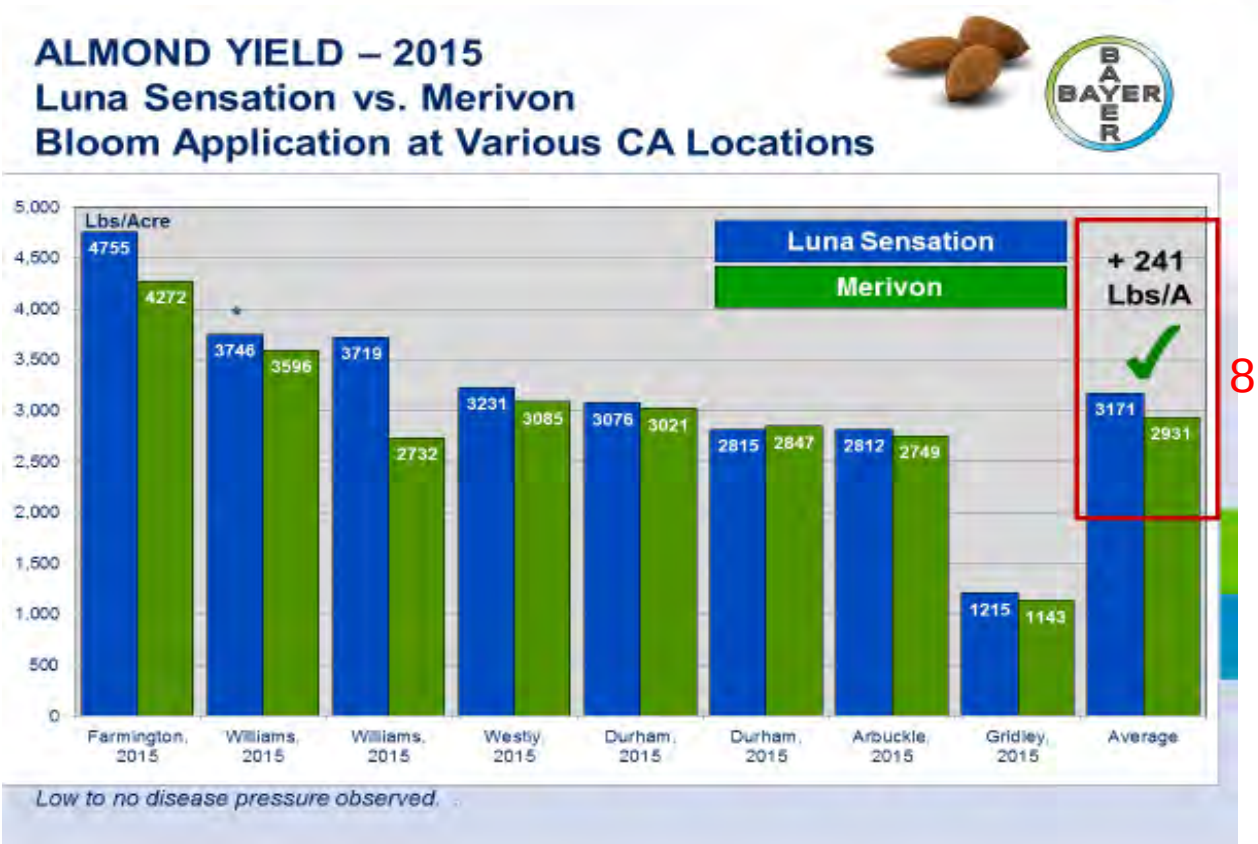
ALMOND YIELD – 2013 and 2014
Luna Sensation vs. Pristine
Bloom Application at Various CA Locations



4.1%

No disease pressure observed at any site.

Suppresses Ethylene, Increases Mitocondria



8.2%

Stoller's Anti-Oxidant Nutrient Flower Power

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Flower Power

- Flower Power™ is a complex micronutrient and antioxidant with growth enhancing co-factors resulting in increased fruit set and crop yield.
- Flower Power increases Auxin, the hormone that dictates pollination, in every flower for stronger pollination. Poor pollination is a common problem on many perennial trees, vines, bushes, and multiple fruiting crops resulting in lower yields.

Flower Power

- Boron 3.8%
- Copper 0.1%
- Molybdenum 0.02%
- Zinc 5.0%
- Proprietary Co-Factor

Nutrients and hormonal activity

- B - Boron reduces IAA oxidase.
- In other words, it increases the half-life of IAA. This is extremely important in the pollination stage.
    - If temperatures are too hot
    - If temperatures are too cool
    - If soils are too dry
- Boron deficiencies will cause poor pollination and physiological problems with seed formation in any crop.

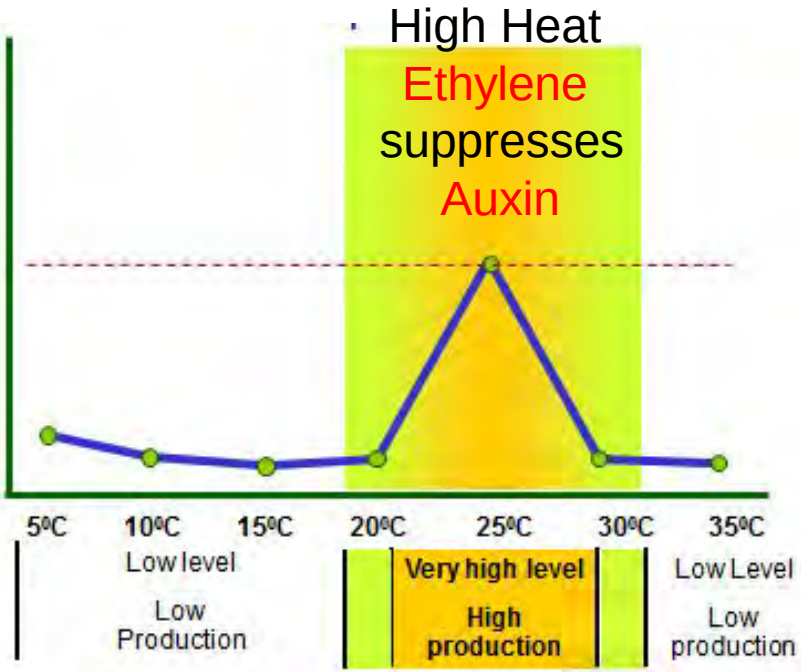
Temperature and Pollination

Problems from adverse temperatures are due to a lack of growth hormone production in the plant

Auxin levels

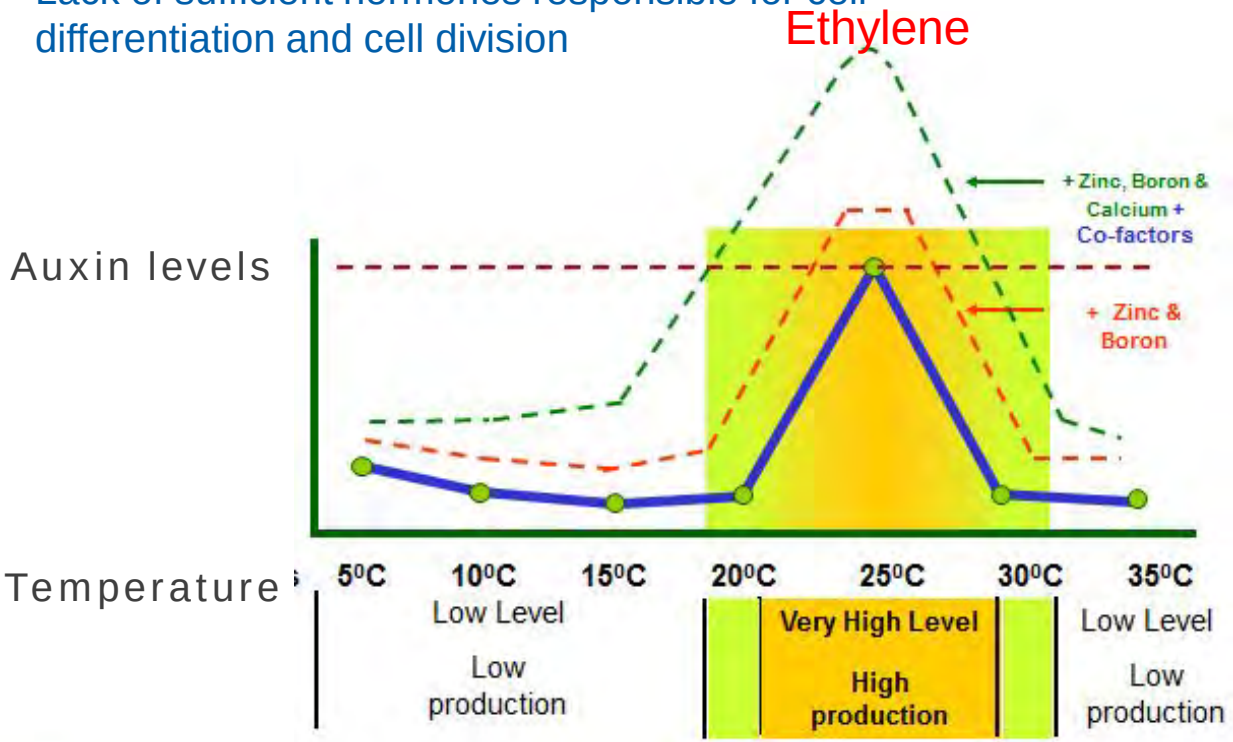
Pollination vigour

Temperature



Reducing poor pollination

Lack of sufficient hormones responsible for cell differentiation and cell division



Nutrients and hormonal activity of plants

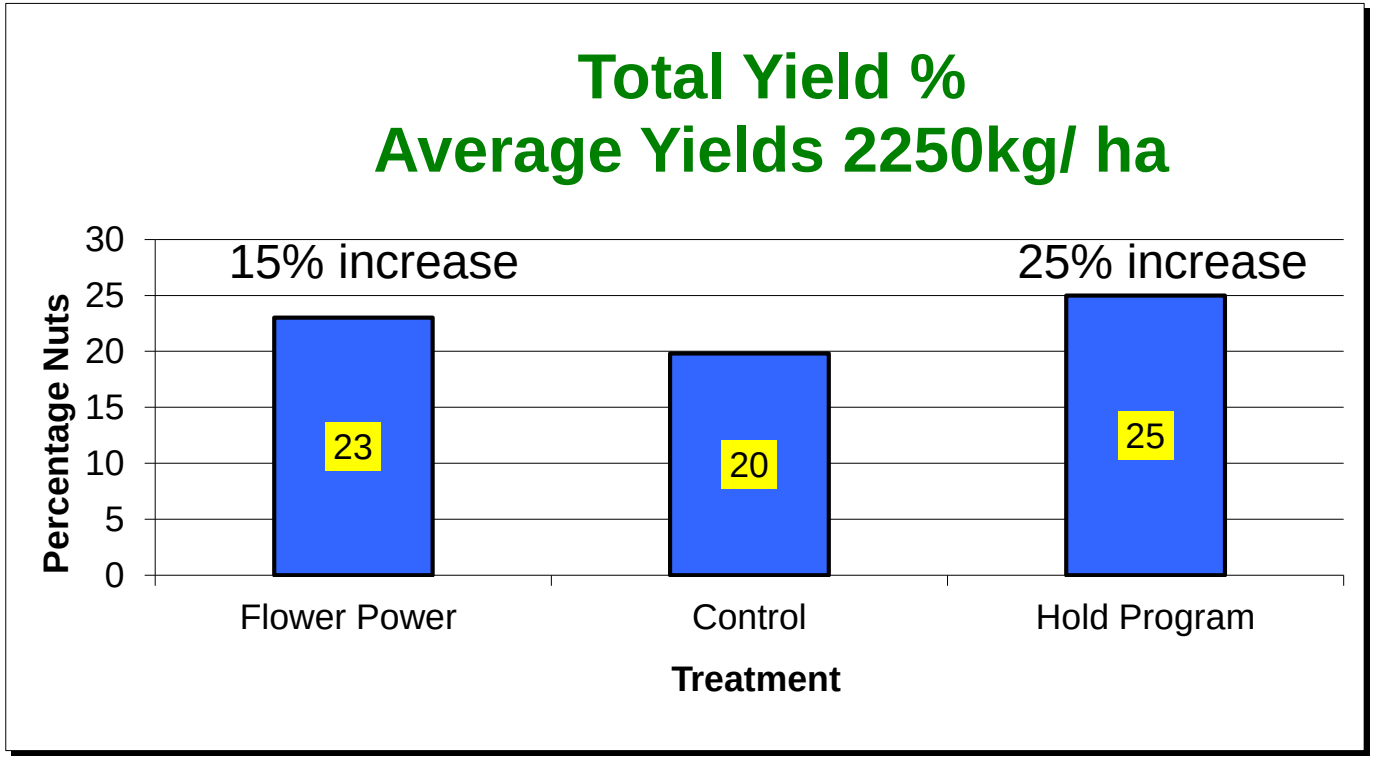
- Zn - Zinc is necessary to convert Trypthophan to Auixn = IAA. The lack of Indole Acetic Acid in new plant tissue (new leaves) inhibits cell division and causes new leaves to become yellow and small.

Almond Trees

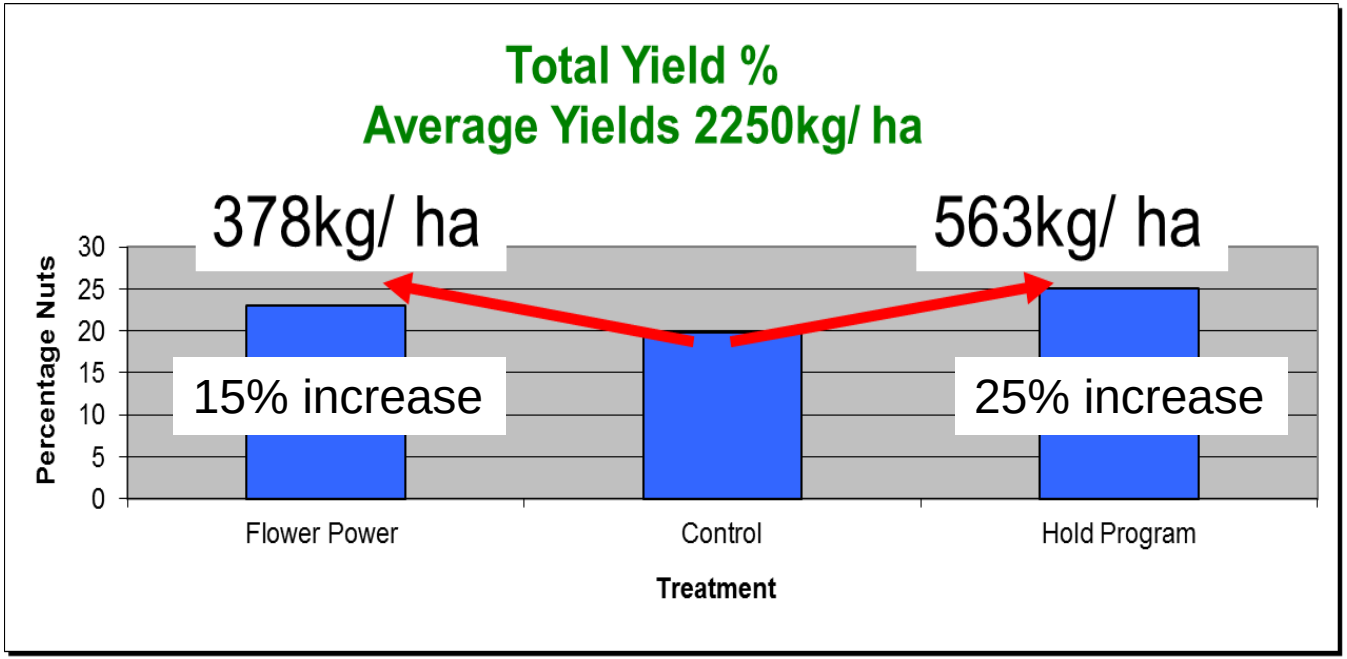
Treatments:

- Hold Program – X-Press at 4 litres/ ha + Action 5 at 4 litres/ ha
- Flower Power at 2.5 litres/ ha and SETT at 2.5 litre/ha
- Control

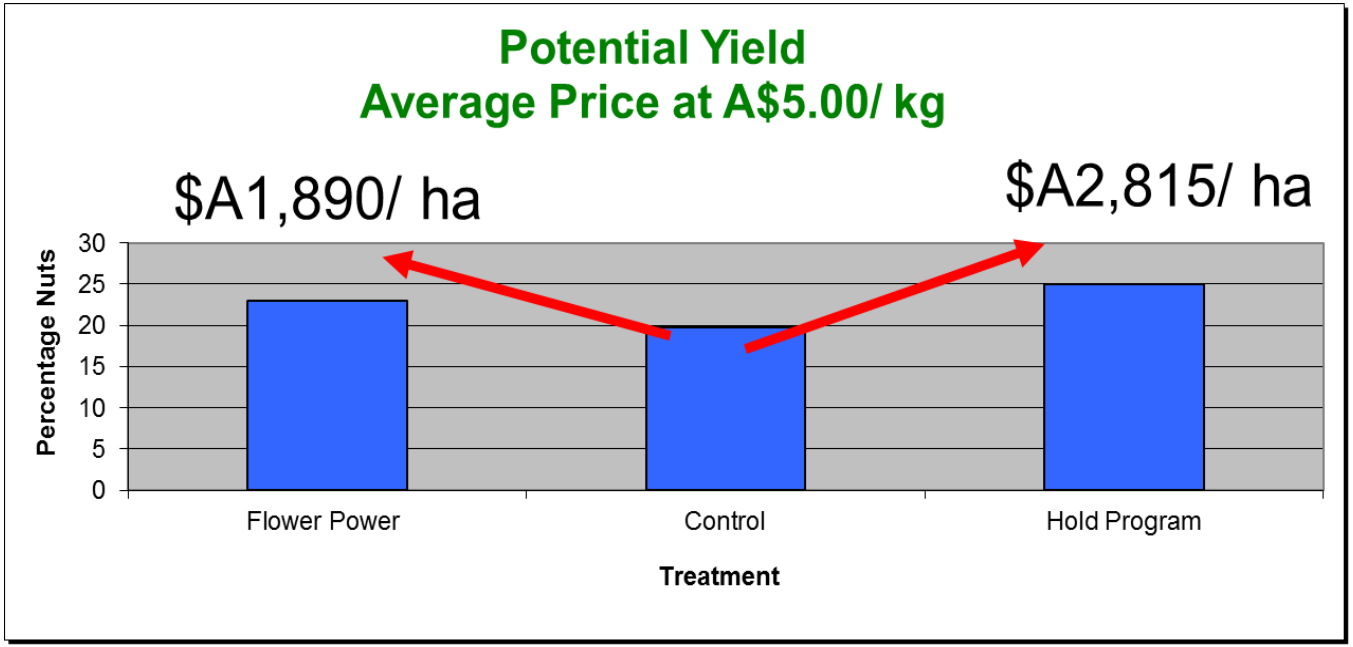
Almond yield increases



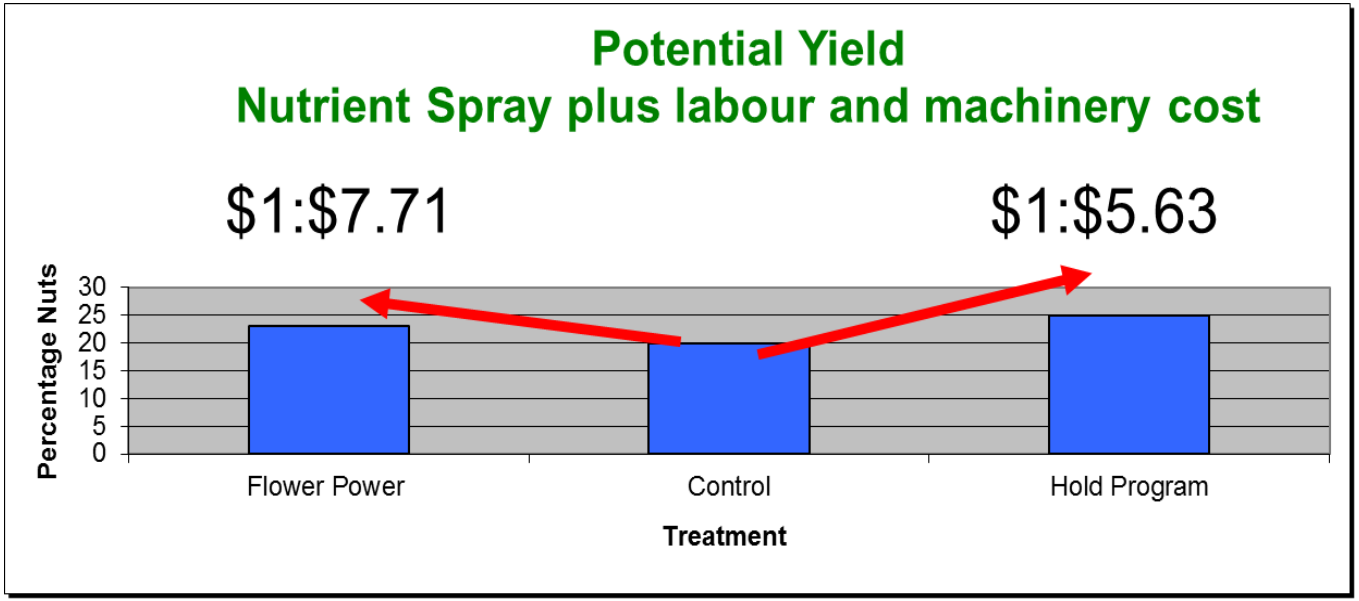
Almond yield increases



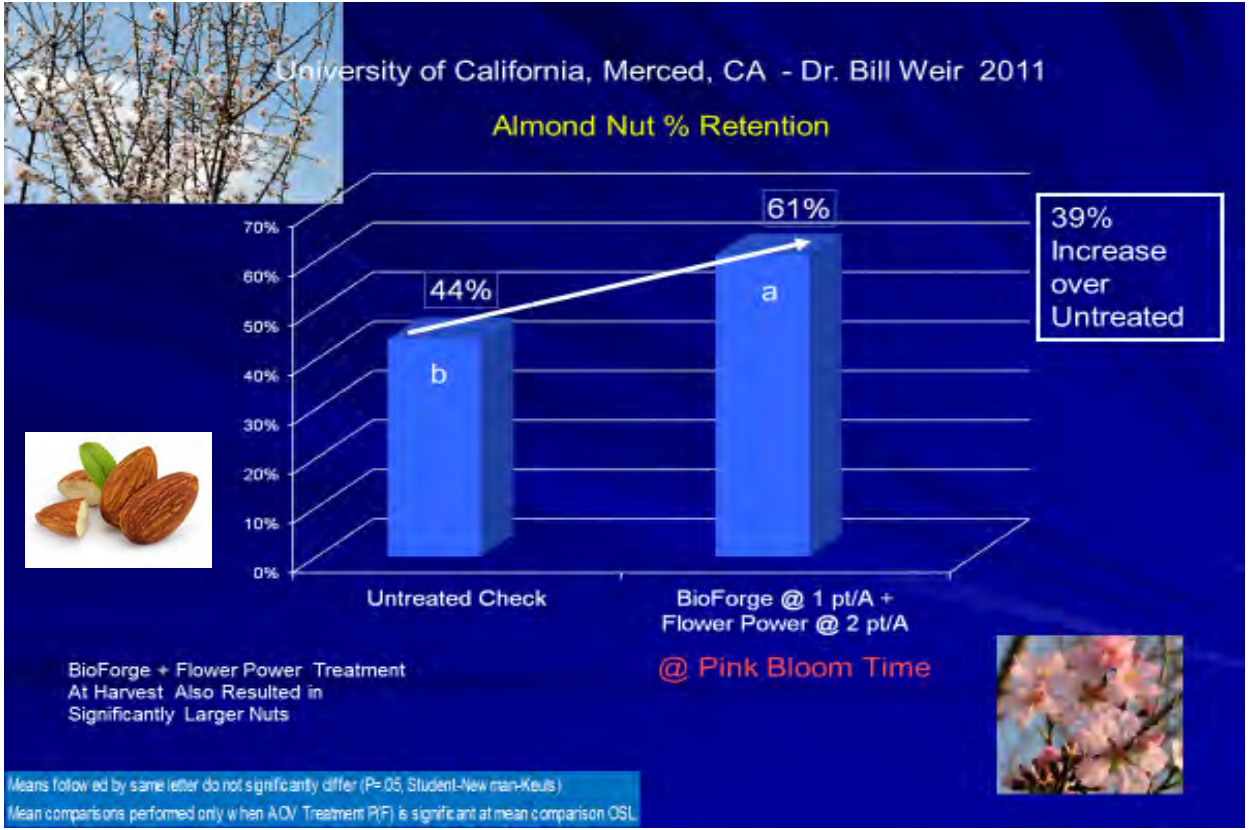
Almond yield increases



ROI almond yield increases



Flower Power Almond Trial Calif.



Stoller’s Sugar Mover

Sugar Mover Analysis

- Sugar Mover
- Boron 10%
- Moly 0.13%

- Plus Stoller's Co-Factors which enhance Auxin & Cytokinin Balance in Fruit Buds

Sugar Mover Analysis

- Redirects plant food (sugar, carbohydrates, metabolites) from the apical meristems in the leaves to the buds, fruit and roots
- Shorten internode length
- Used to increase sugar levels and bulking prior to harvest

Stoller’s Sugar Mover Trials
Walker Flat, South Australia

17th Australian Almond Conference

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Stoller®
Unleashing The Power Of Plants

Sugar Mover Trial Aim

- Increase Flower Bud Development for the following season in Almonds.
- Increase yield by 15% in the following years harvest.
- Can be applied with current spray program, compatible with fungicides.

Stoller's Sugar Mover Trial

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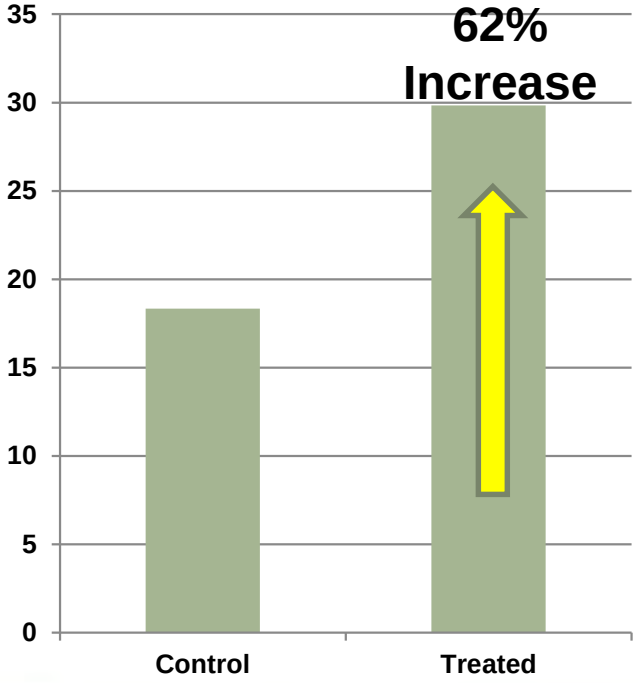
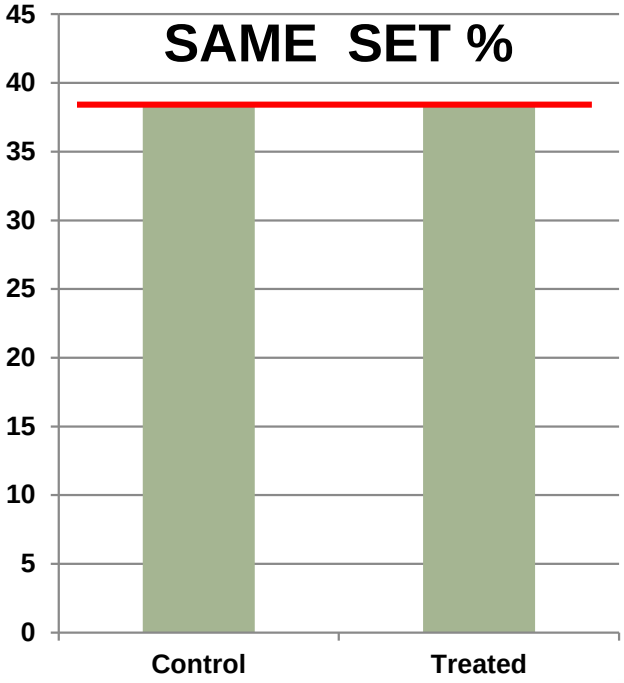
Buds per metre stem



Flower set %



Trees without Sugar Mover

Trees with Sugar Mover

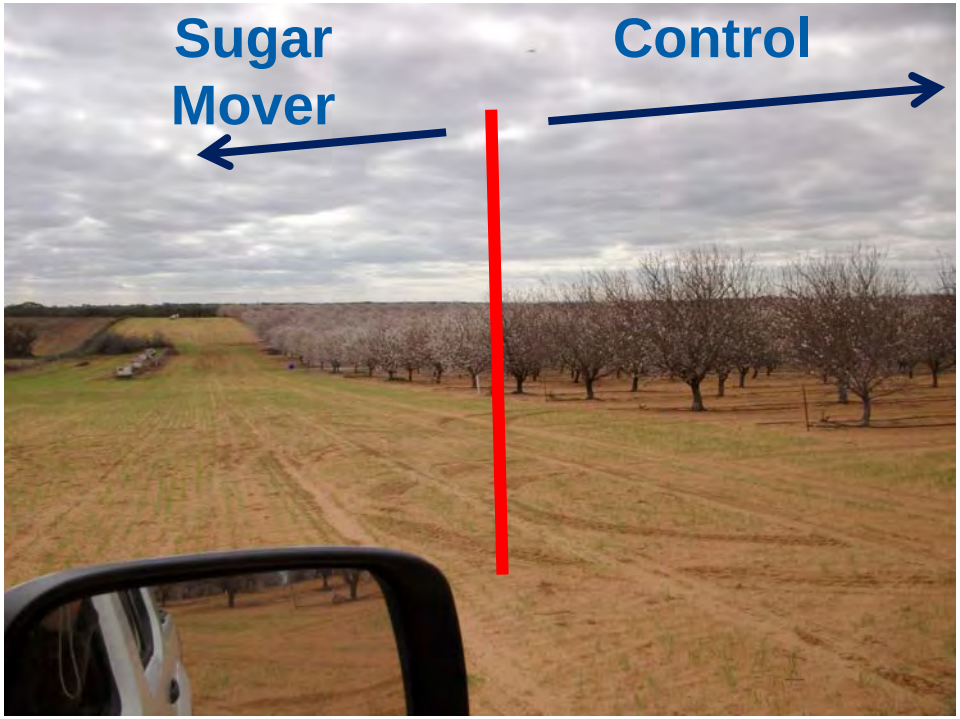
Trees without Sugar Mover

- Reduced flower buds

Trees with Sugar Mover

- Flower buds on new wood

Grower View – Sugar Mover



Stoller's Sugar Mover trial

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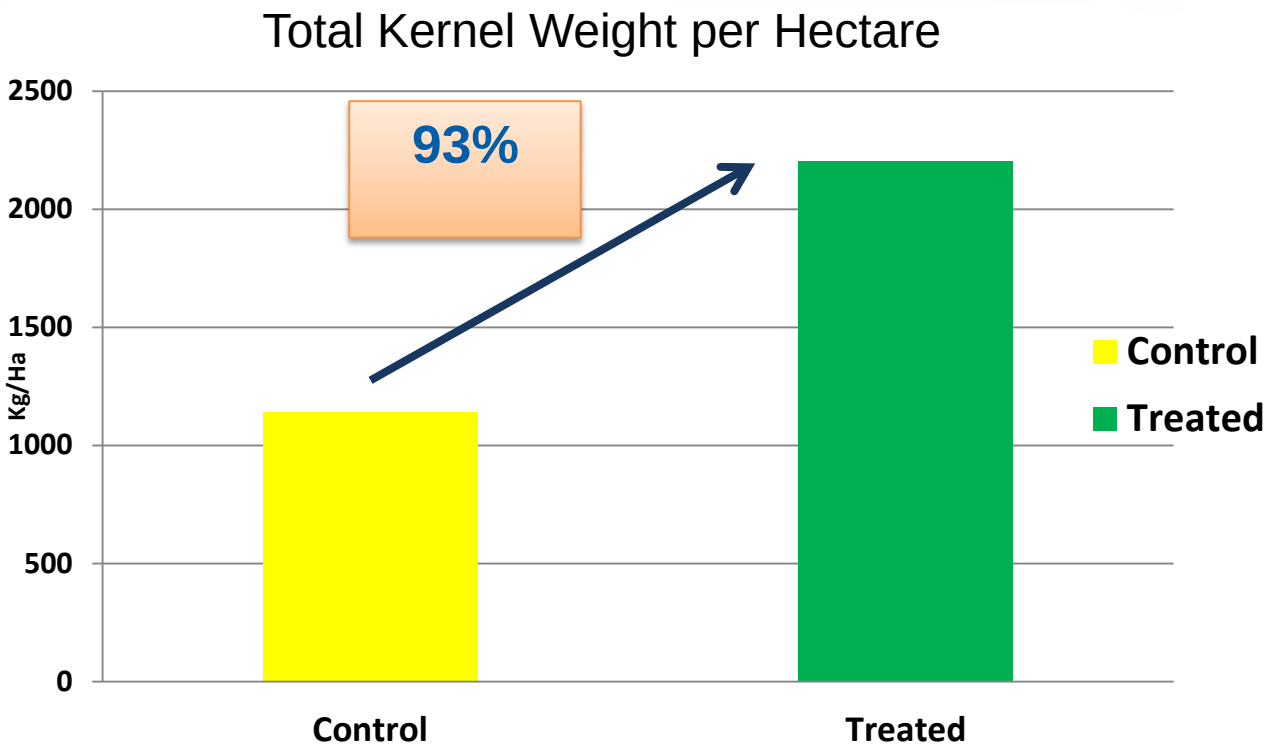

Cost-Benefit of Sugar Mover

- Sugar Mover application cost $ 60 per Ha (product only)

Actual yield increase of = 1046 Kg

Price per kg = $3.50

Total return per Ha = $3661.00

Return on Investment = 61 to 1

Final results after 2011 - 2012 harvest

Stoller’s Sugar Mover Trials
Virginia, South Australia

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Sugar Mover demonstration

- Results summary

Rootstock/Block	Treated Untreated	Average Fruit set	Improvement (treated>control)
Almond - Robert Rd	Treated	27.78	**17.5%**
Almond - Robert Rd	Control	23.64	
Hybrid – 99 Planting	Treated	33.93	**43.6%**
Hybrid – 99 Planting	Control	24.24	
Nemaguard – Homeblock 1	Treated	23.91	**134.2%**
Nemaguard – Homeblock 1	Control	10.21	

Sugar Mover demonstration

Observations

- The 2006 season was excellent for flowering and pollination. There were a high number of bud chilling hours.

- The trees treated in the trial all showed an improvement in fruit retention over the control and this benchmark.

  - The average percent fruit set on all treated almond trees was 28.54%
  - The average percent fruit set on all control almond trees was 19.36%

- The most impressive increase in fruit retention was in the older nemaguard root stock trees where the control had poor fruit retention and retention was increased from approximately 10% to 24%

Desert King & Arysta Life Sciences Plant Extract Anti-Oxidants

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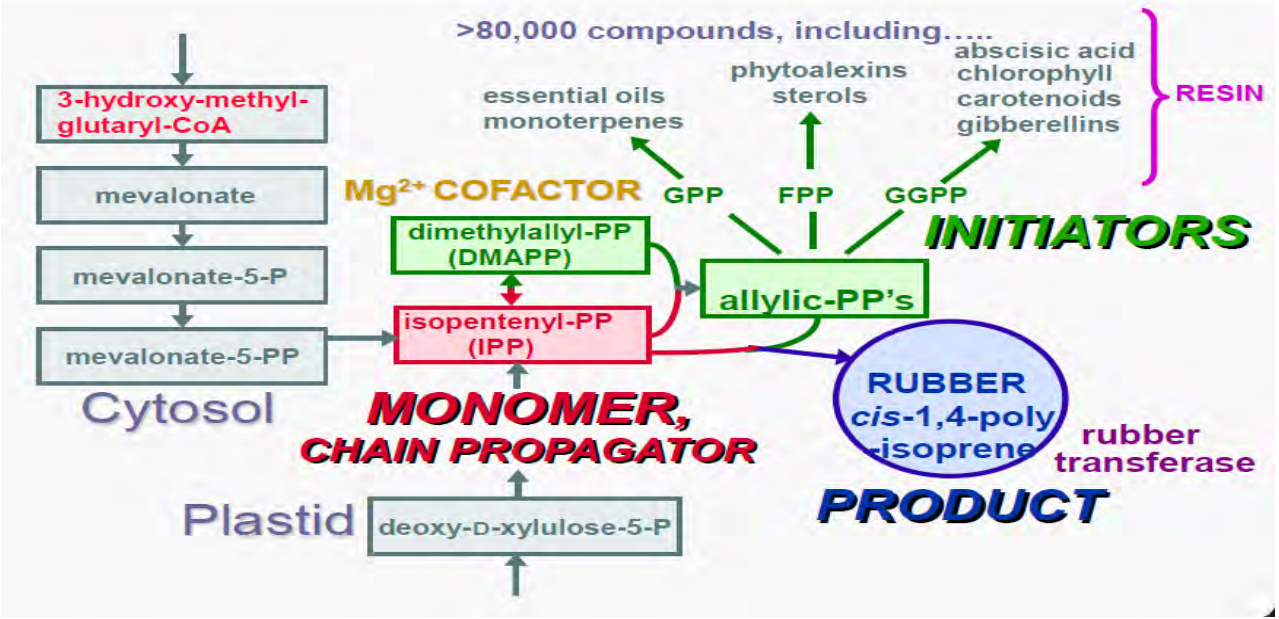
Desert Plant Extracts Almond Trials

Natural
Quillaja saponaria, Yucca shidigera

Saponins are natural transporter of Auxins in Phloem and Cytokinins in the Xylem. They are found widespread in Desert Plants. Natural Plant Hormones and Natural Antioxidants. Thus Nature's own Plant Growth Regulators. Like Ocean Sea Plants rich in Isoprenes very usually in Agriulature.

Desert Plant Extracts Almond Trials

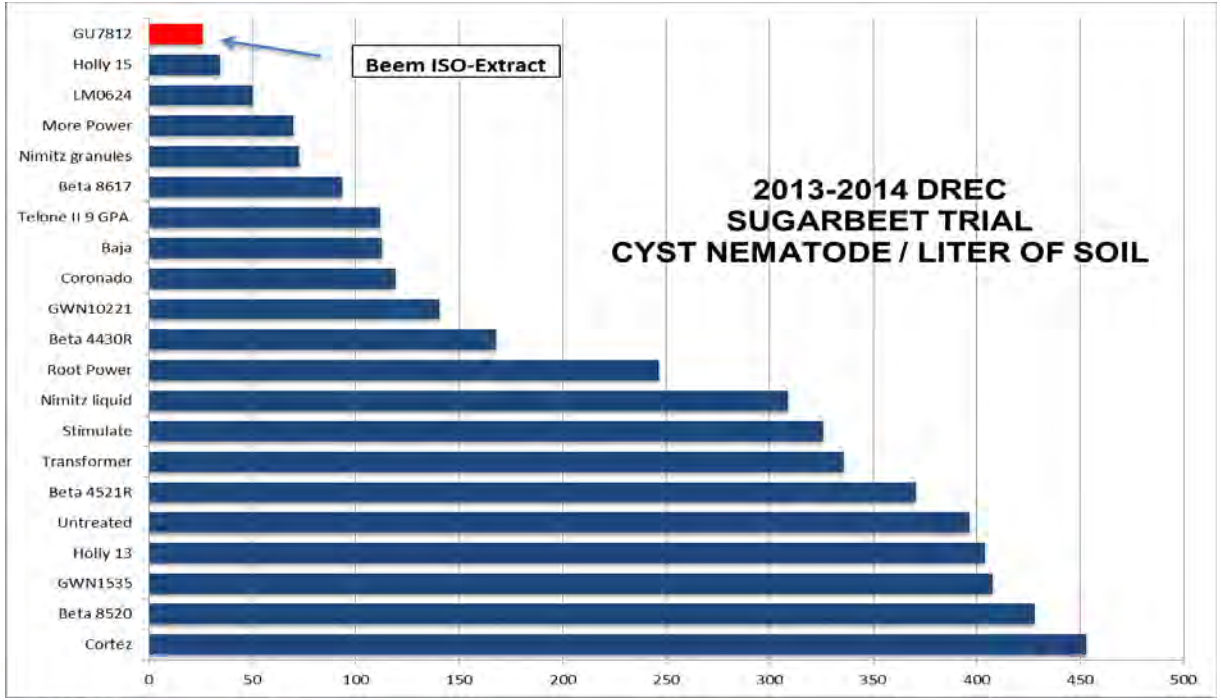
Desert Plant Extracts (Yucca, Quillaja & Guayule = ISO Extract)



The Isoprenoid Pathway –
a plant based chemical factory

Desert Plant Extract on Row Crops

UC Desert Research Center 2013
Holtville, California
Dr. Becky Westerdahl, UC Davis Plant Nematologist



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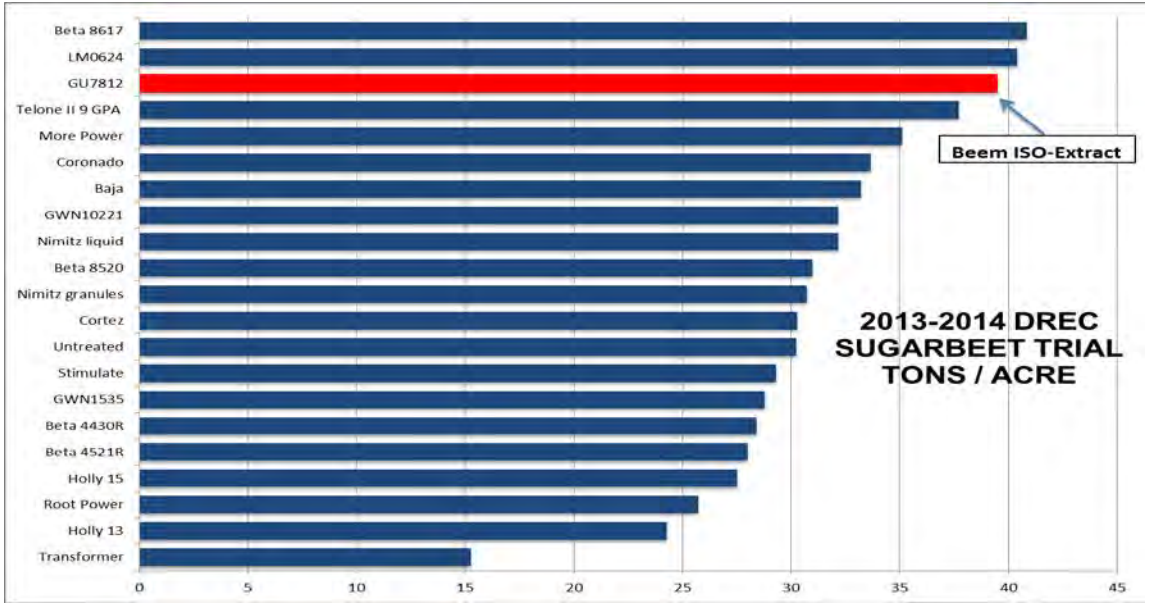


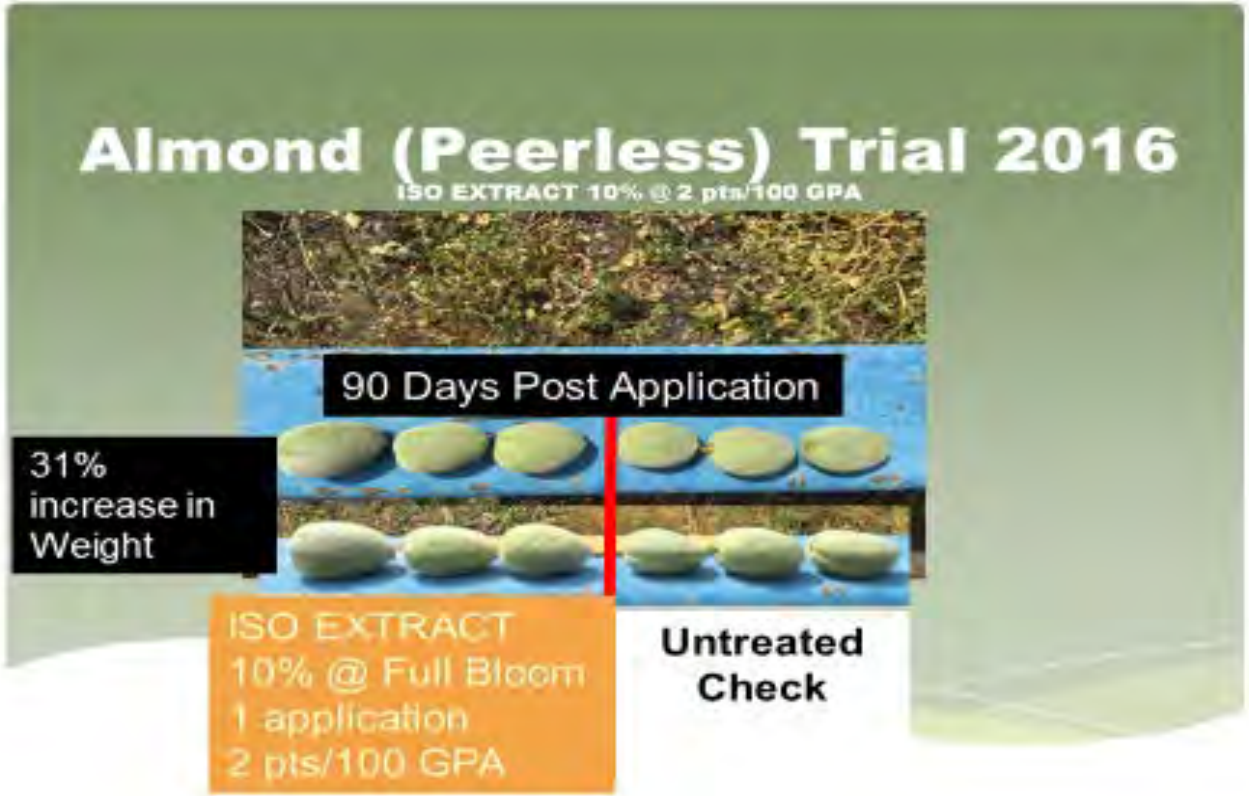
Desert Plant Extract on Row Crops

Desert Plant Extract on Fruit Crops

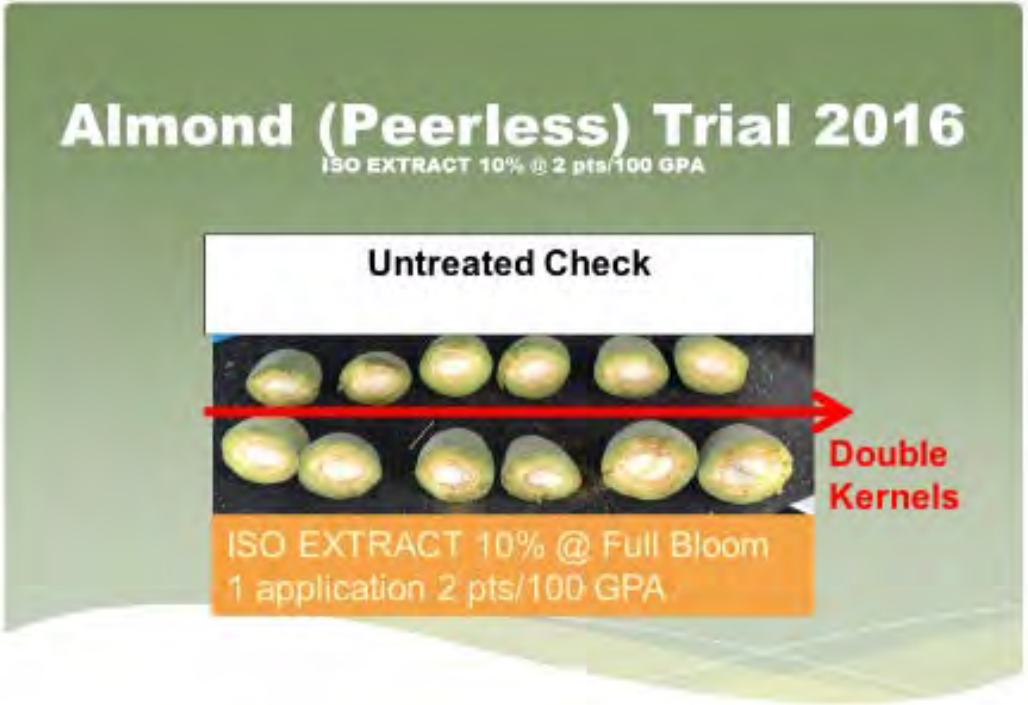
Aroura Blueberry Variety, Washington, 2016

Largest Blueberry Grower in Washington State Promoted earlier maturity and market timing. Reported 41% yield increase, Higher BRIX and Improved Berry Color. 12.3% increase in Individual berry weight at harvest time after 3 applications @ 1 pt/Acre starting at petal fall, followed by two weeks later and then two weeks prior to harvest. This is after 2 apps above.

Desert Plant Extract on Almond



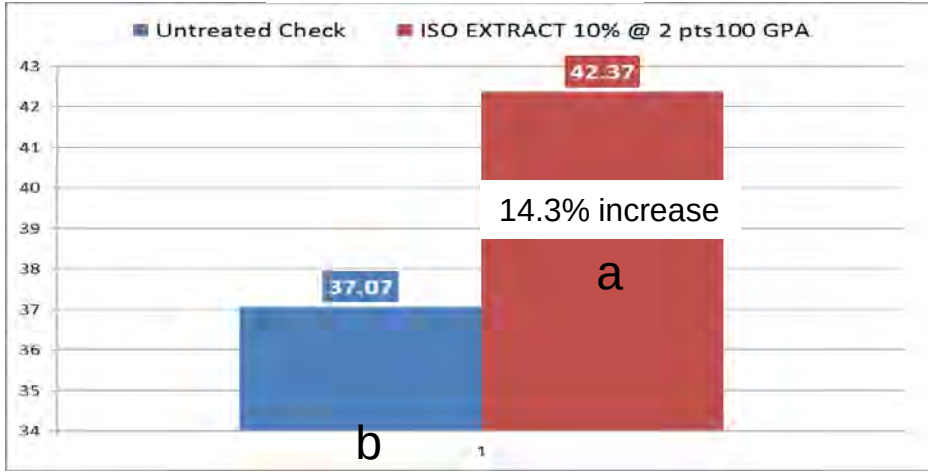
Desert Plant Extract on Almond



Almond (Peerless) Trial 2016

ISO EXTRACT 10% @ 2 pts/100 GPA

Hull Length mm



Means followed by same letter or symbol do not significantly differ (P=.05, Duncan's New MRT)
Mean comparisons performed only when AOV Treatment P(F) is significant at mean comparison OSL

June 3rd Evaluation (25% increase in Nut Retention)
June 3rd Evaluation (31% increase in Hull/Nut Weight)
Aug 28th Harvest (22% increase in Total Yield)

Non-Pareil Nut Retention & Yield

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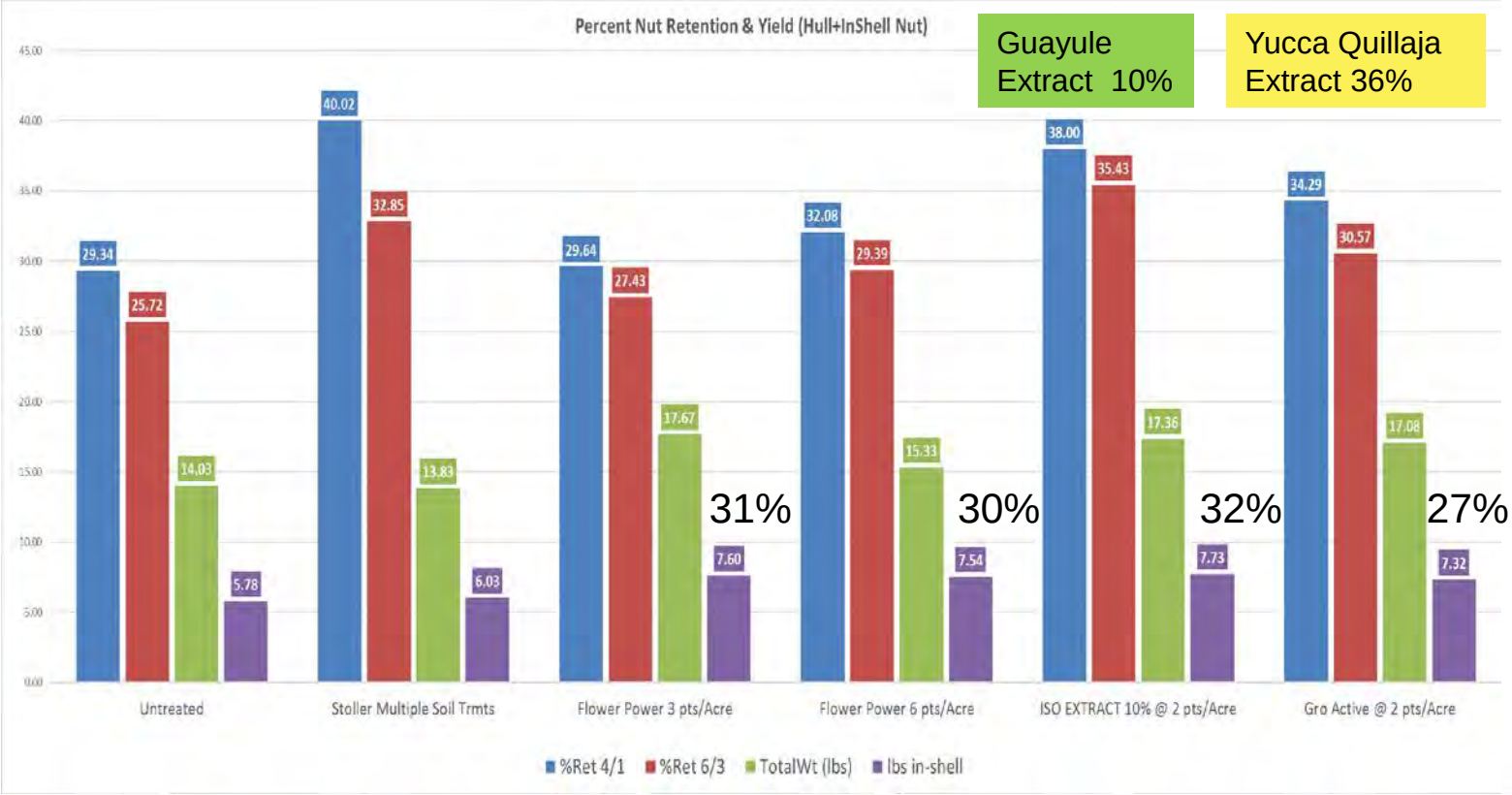
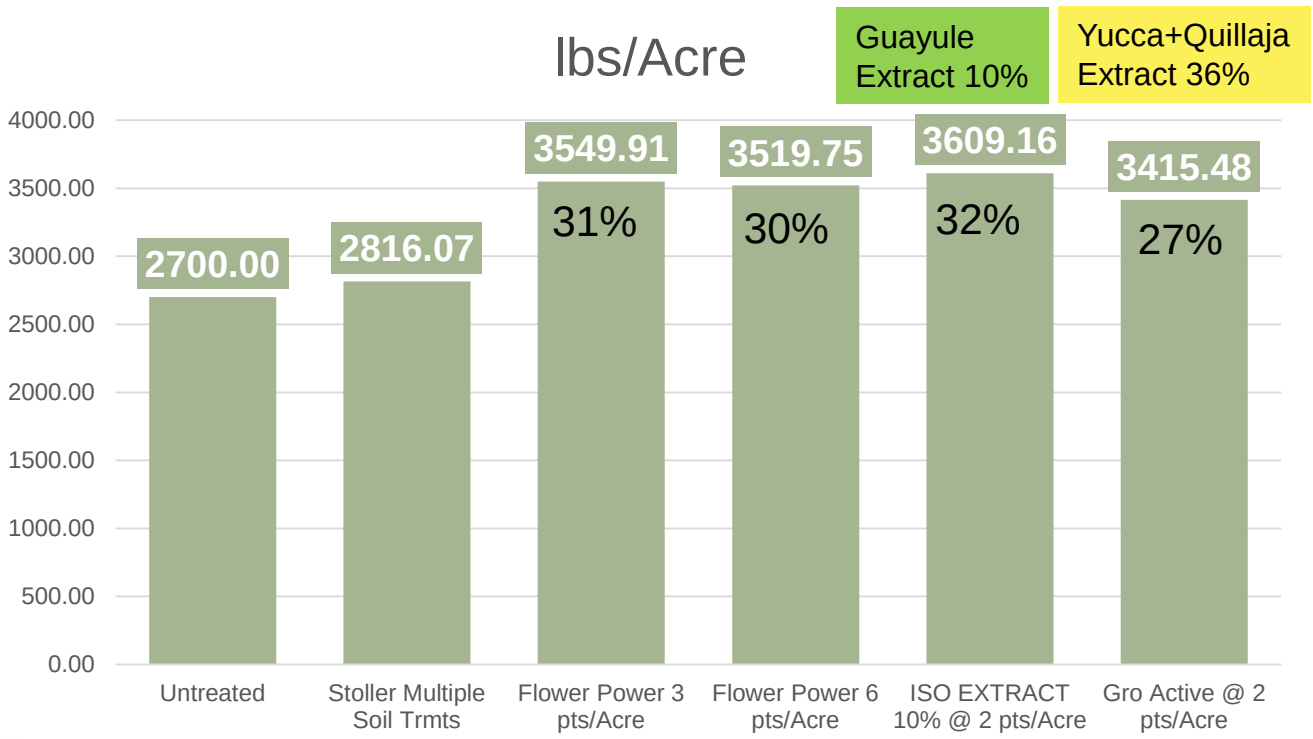
Non-Pareil Almonds



Non-Pareil Nut Yield In-Shell

Non-Pareil Almonds



- **Summary for Almond Production**

  Plant Hormones Are Powerful
  By Plant Hormone Mimics
  By Plant Growth Transporters
  By Anti-Oxidants and Plant Extracts
  By Selected Blends of Nutrients
  Yield Increases Range from 7-30%

Thanks and Good Day