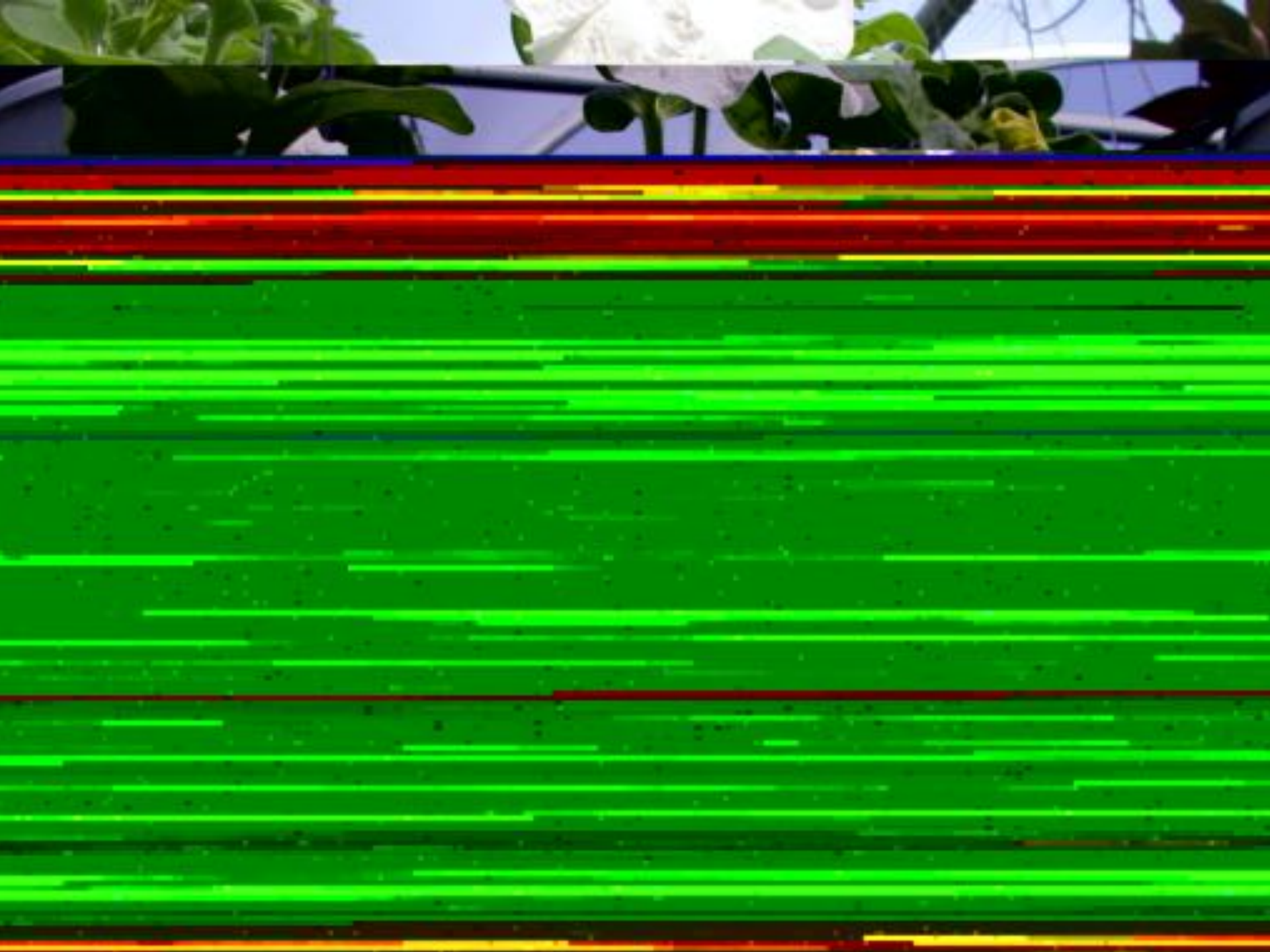
How Plant Growth Regulators Enhance Your Bottom Line

Brian E. Whipker

Floriculture Extension and Research

NC STATE UNIVERSITY



Outline

- How PGRs work
- Additional benefits
- How PGRs make you money

How Plant Growth Regulators Work

PGRs

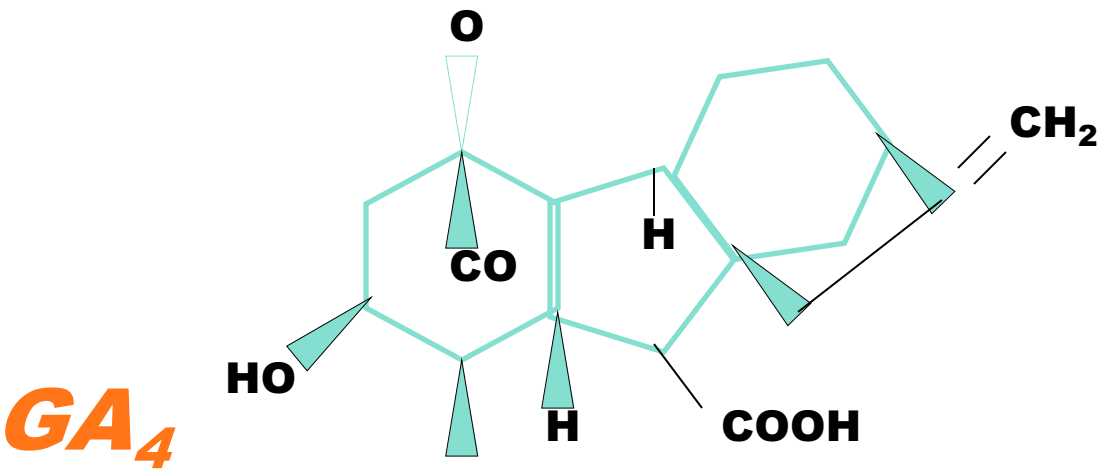
- A tool to make growing easier

Useful to understand how they work to control excessive plant stretch

Gibberellin (GA) Metabolic Pathway

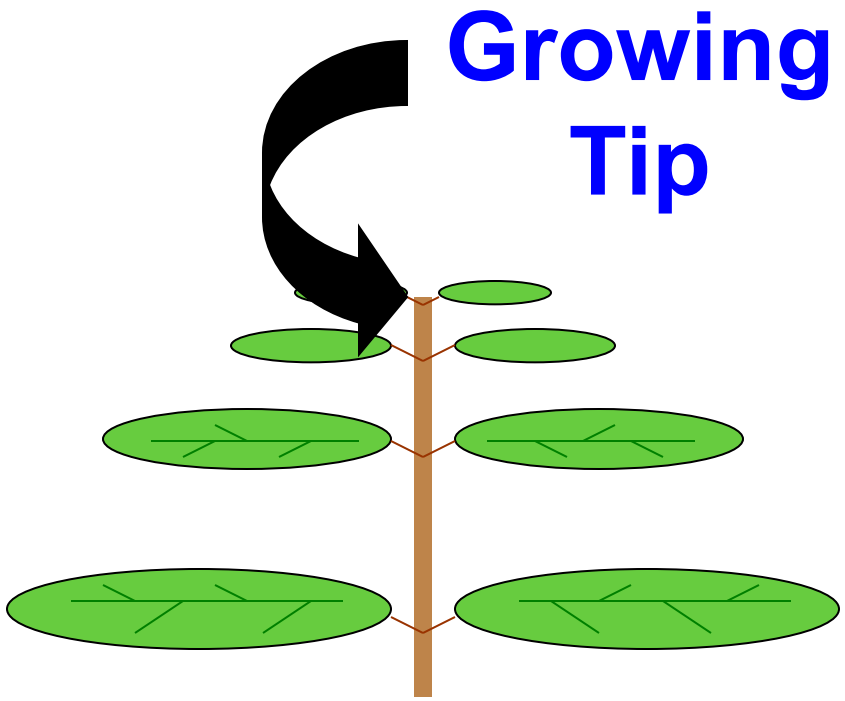
- Chemical chain of events, which leads to the production of the hormone gibberellin (GA).

- The hormone gibberellin stimulates cell elongation in plants.
  - Thus controlling GA, controls excessive stretching



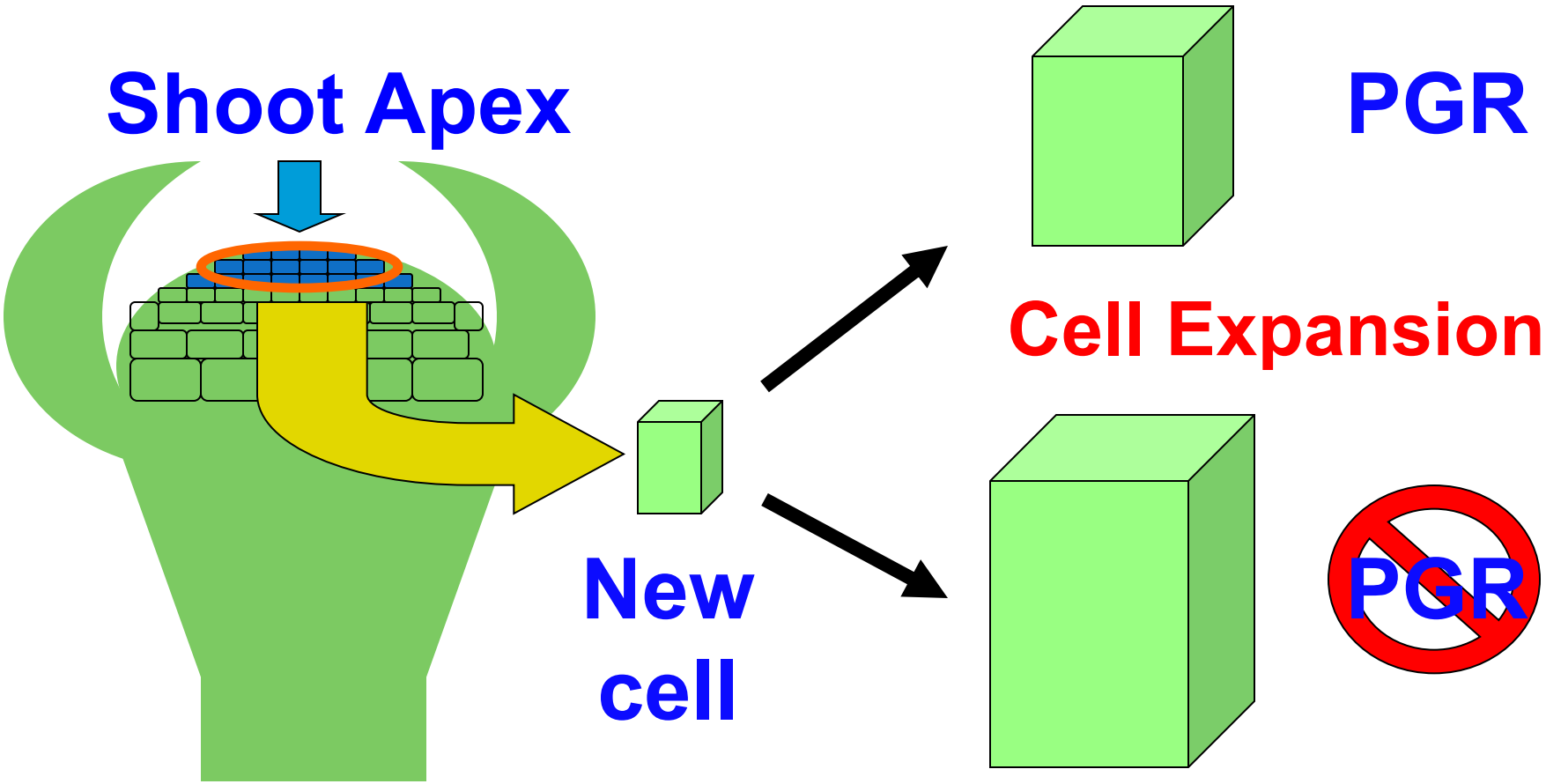
PGR Classifications

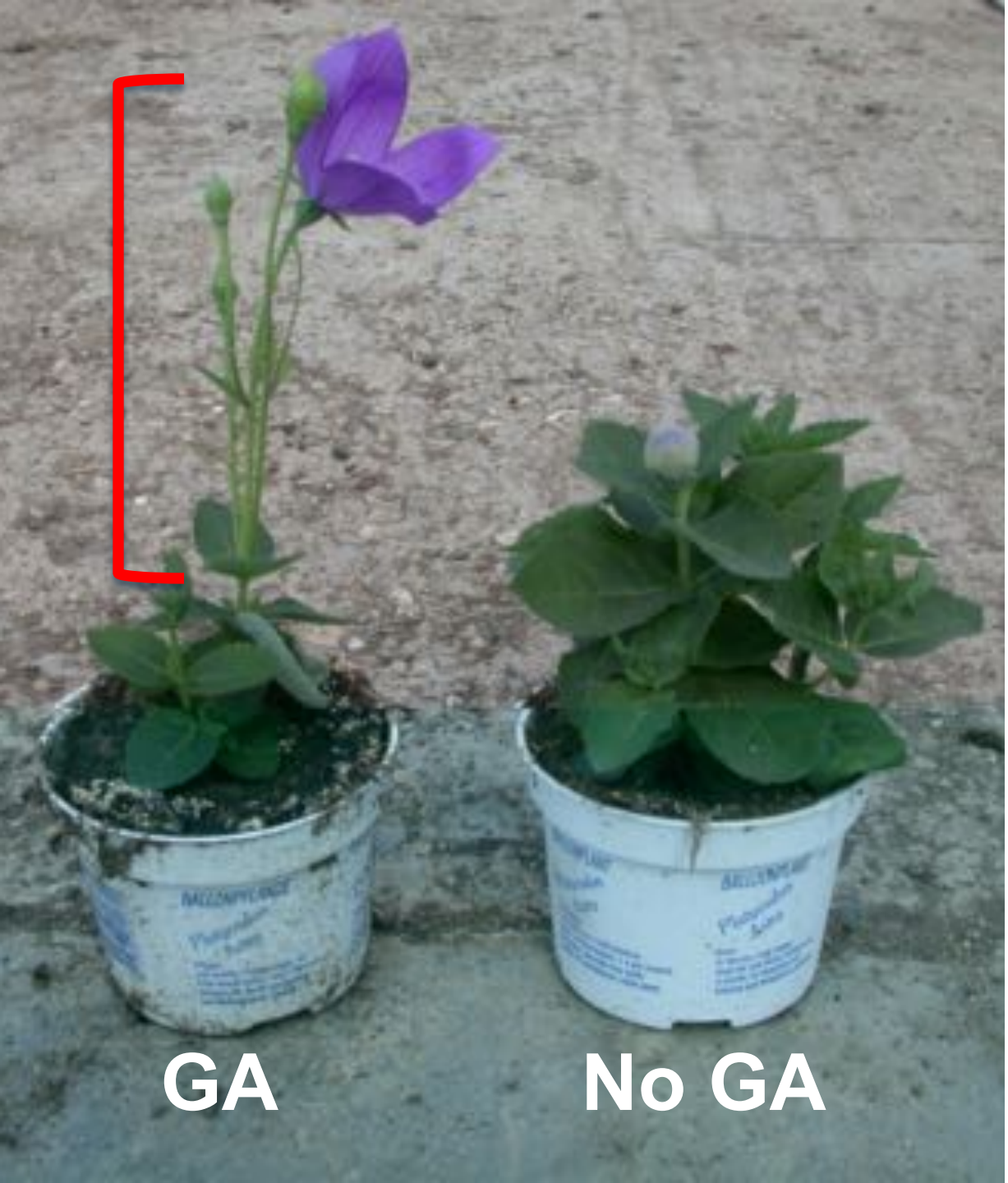
- Type II - Cell Elongation Inhibitors
  - Retard growth by inhibiting the production of the hormone gibberellin
    - Therefore plants are shorter



Cell Elongation Inhibitors

- Influence cell expansion



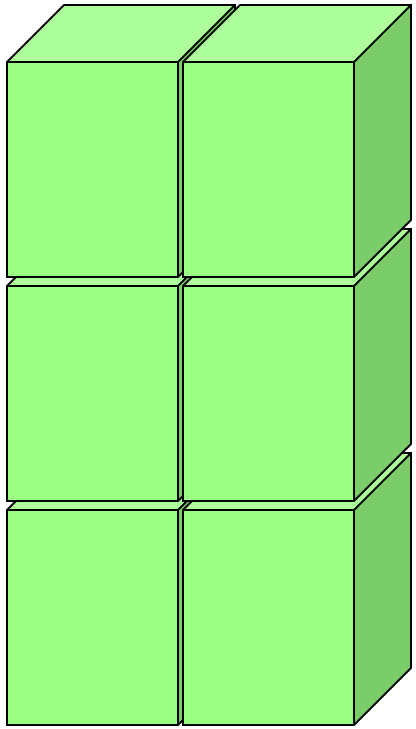


Applying GA increases cell elongation

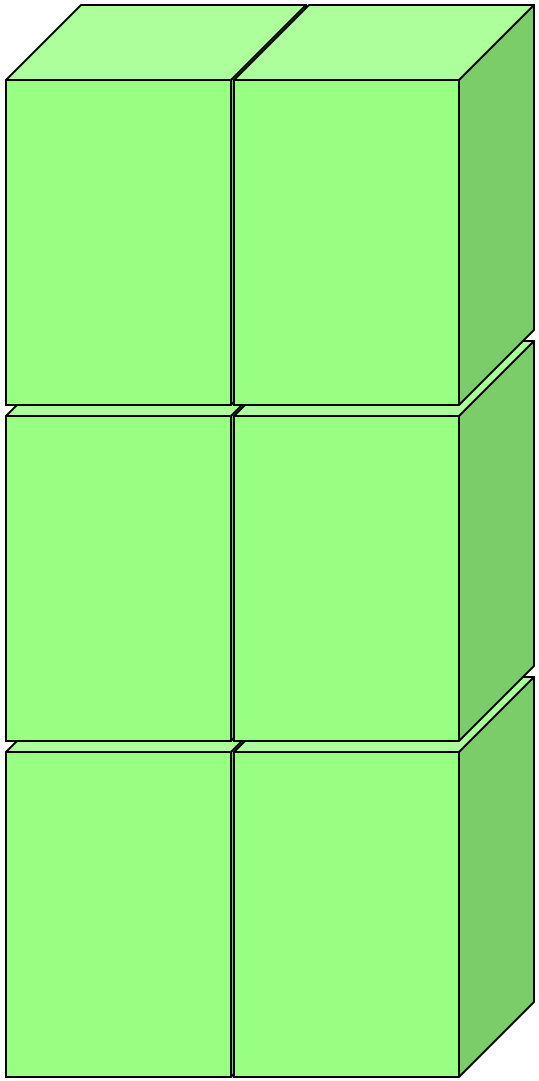
Balloon Flower with stalled growth (left)

Cellular Action (Type II)

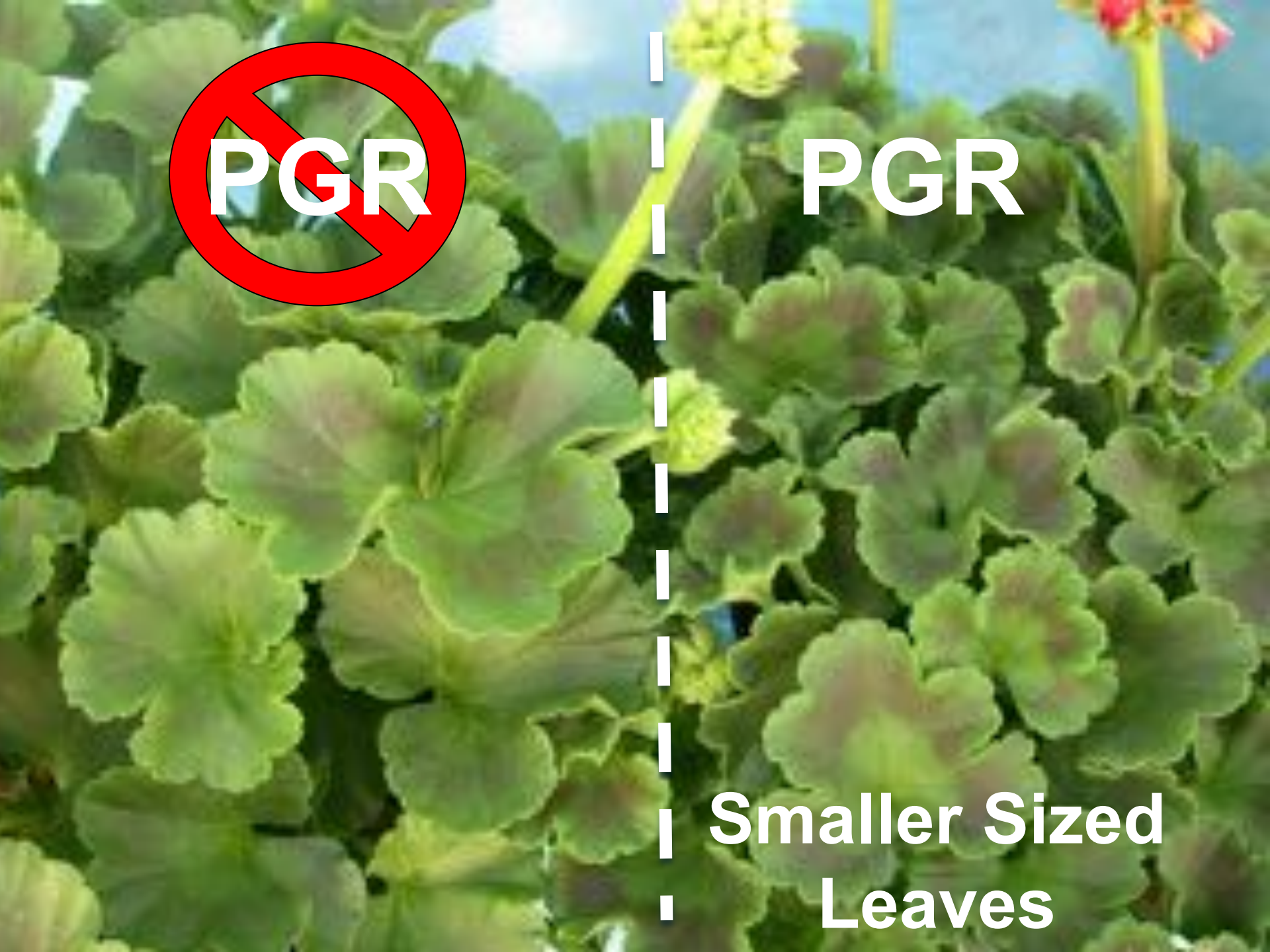
- Expansion (size) varies
- *Not cell number!*



PGR



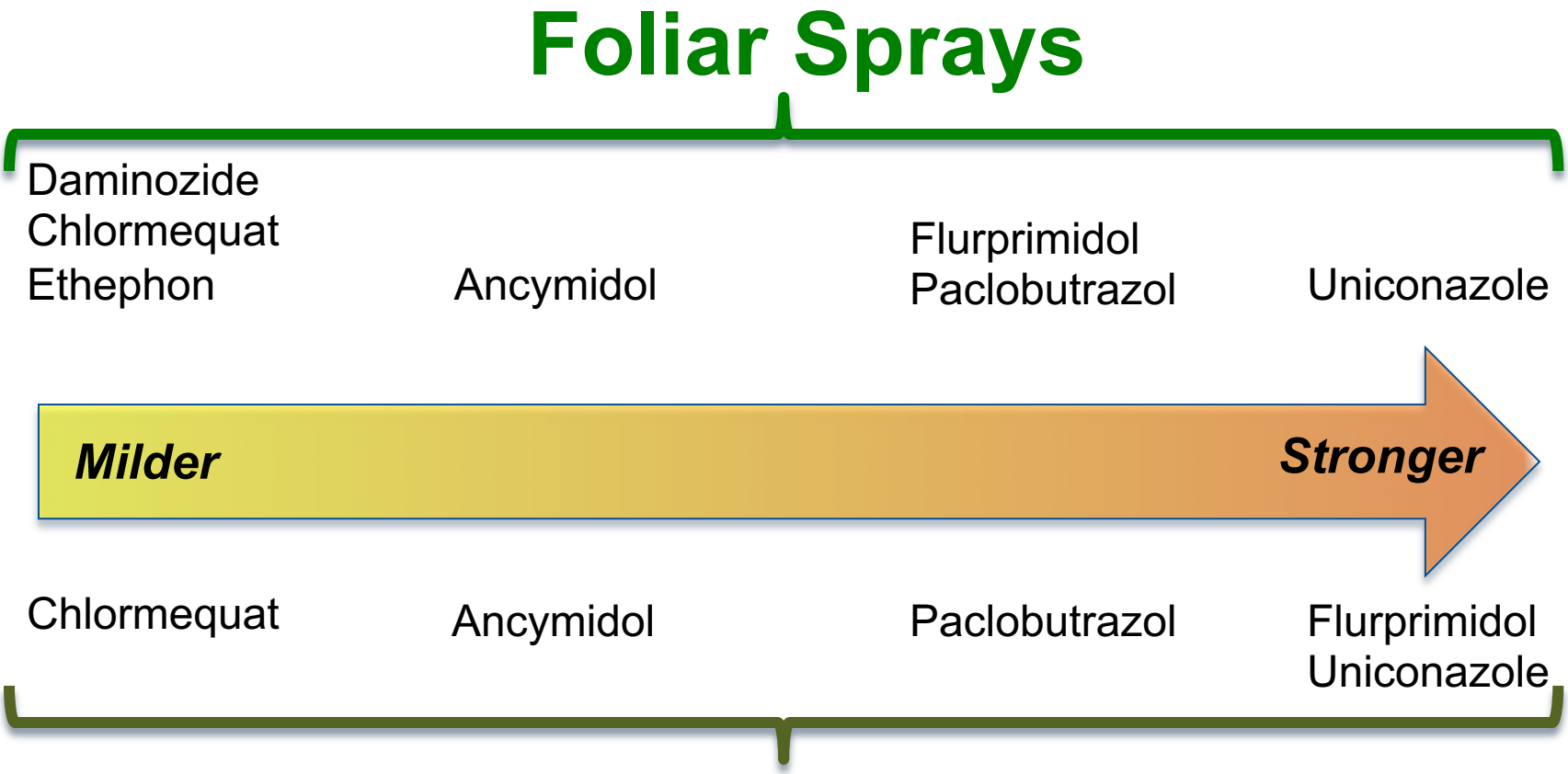
PGR Results:
Smaller Plants


PGR
PGR
Smaller Sized
Leaves

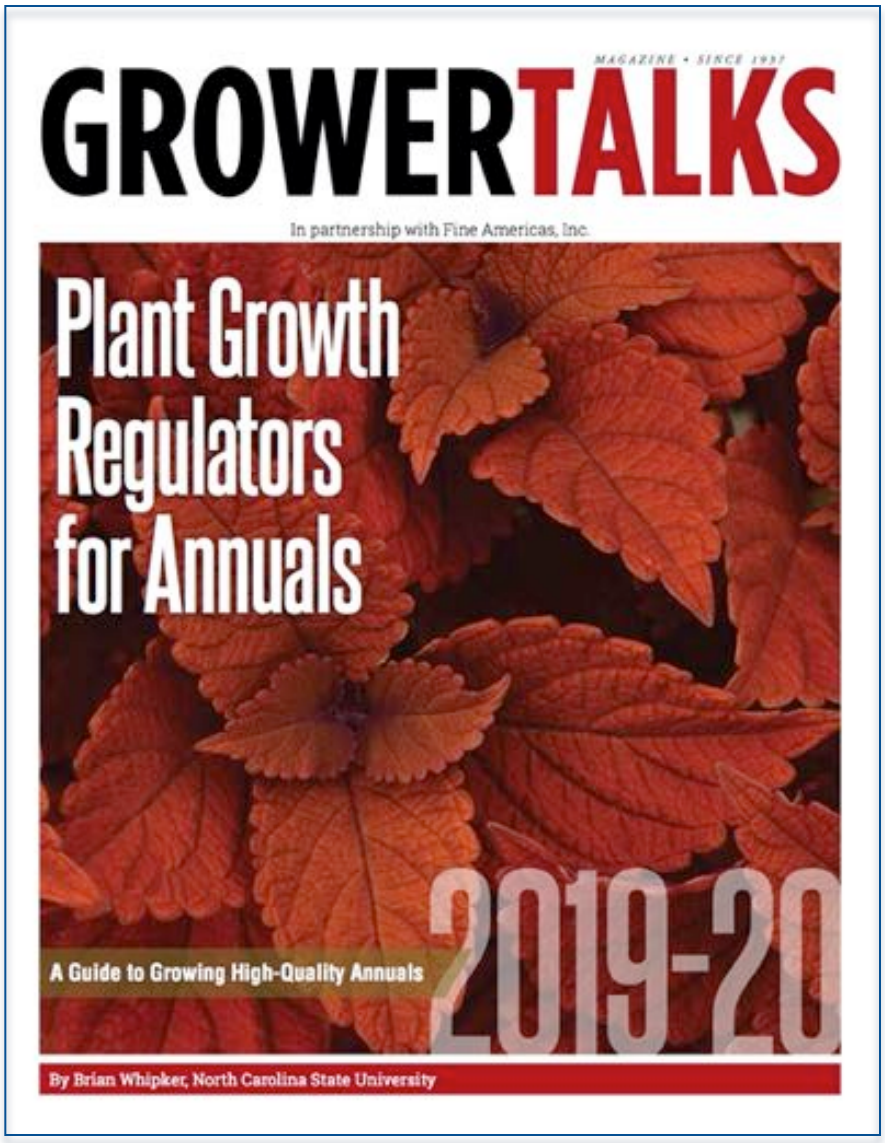
PGRs Which Control the GA Pathway

Chemical	Trade Names
Ancymidol	Abide, A-Rest
Chlormequat chloride	Citadel, Chlormequat E-Pro, Cycocel
Daminozide	B-Nine, Dazide
Fluprimidol	Topflor
Paclobutrazol	Bonzi, Paczol, Piccolo, Piccolo 10XC, Downsize (*drenches only*)
Uniconazole	Concise, Sumagic

Relative Strength of PGRs



PGR Guide: Fine/GrowerTalks



- **2020-2021**
  - Perennial PGR Guide by Joyce Latimer of Virginia Tech
- **2019-2020**
  - Greenhouse PGR Guide by Brian Whipker of NC State University

PGR Rates

Growth Regulators for Floricultural Crops in Greenhouses

Brian E. Whipker, Department of Horticultural Science, North Carolina University

This table lists labeled rates of plant growth regulators (PGRs) for greenhouse crops, as well as recommendations based on research at North Carolina State University and recommendations by suppliers. Read the label for a complete listing of precautions. The degree of control can vary depending on a number of factors, including plant type, cultivar, stage of development, fertilization program, growing temperatures and crop spacing. When using a PGR for the first time, it's good to test the rate on a few plants prior to treating the entire crop. Keep accurate records and adjust rates for your location. Also keep in mind as a general rule, sunbelt growers should consider the upper half of the rate range, while northern growers—especially under lower light conditions—should begin trials at the lower end of the rate range. Additional information about plant growth regulators is available at www.pgrinfo.com.

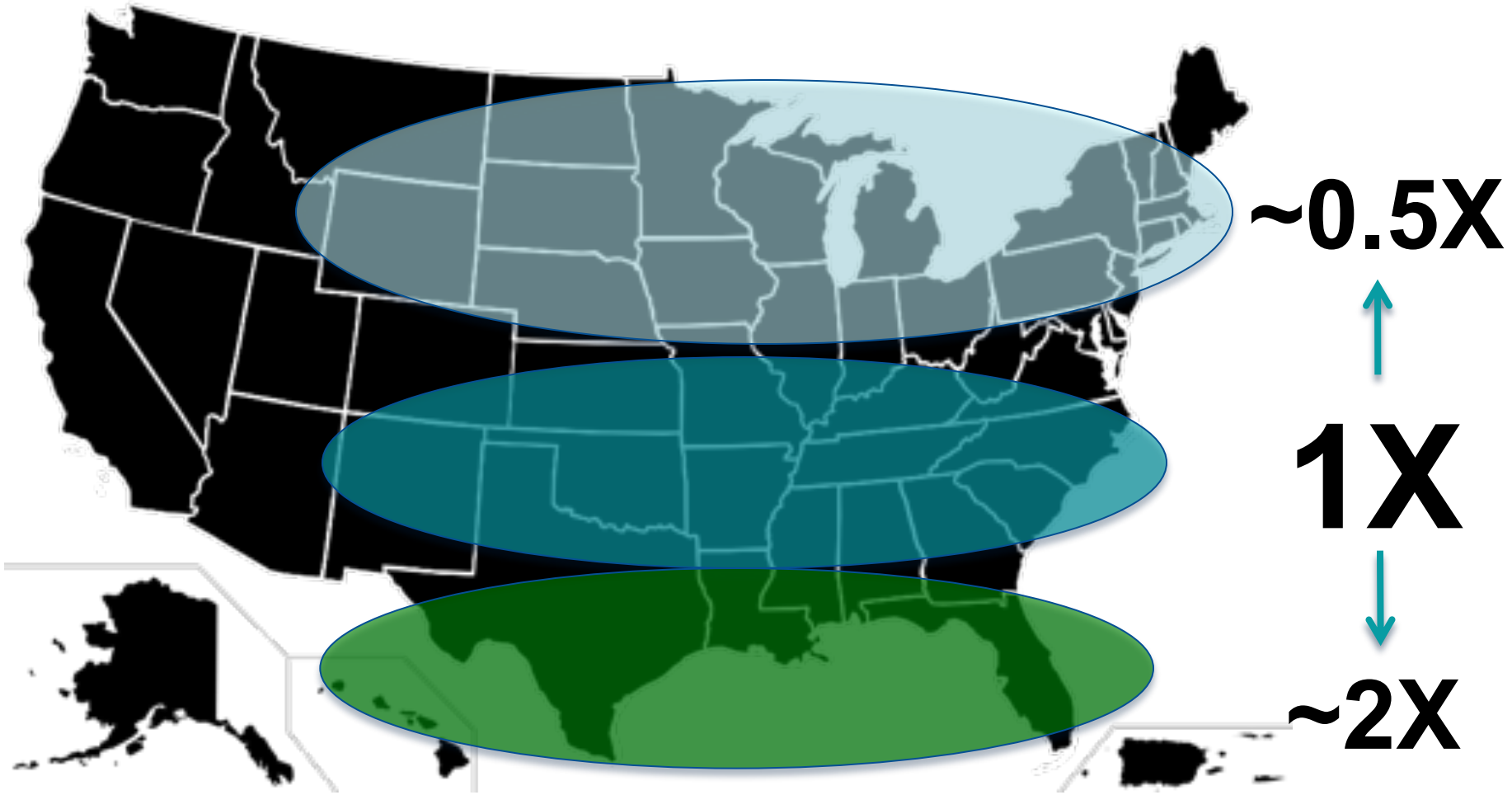
General recommendations: Plug culture and flat culture have different recommended rates. The rates in this table include recommendations for both plug (lower rates) and flat culture (higher rates). Apply ALL foliar sprays of plant growth regulators using 0.5 gal. per 100 sq. ft. of bench area.

Growth Regulators for Floricultural Crops in Greenhouses

CROP	PURPOSE	CHEMICAL	RATE*	PRECAUTIONS AND REMARKS
ABUTILON	To control plant growth	**Citadel**/Cycocel	750 to 1,500 ppm spray	
		Dazide/B-Nine	2,500 ppm spray	Rate for use on plugs.
		Piccolo/**Piccolo 10 XC**/ Bonzi/Paczol	5 ppm spray	Can be applied once plant fills the pot, 2 to 3 weeks after transplanting.
	To increase branching	Florel/**Collate**	250 to 500 ppm spray	Applied 2 weeks after transplanting. Follow with a pinch if needed.
ACHILLEA	To control plant growth	**Dazide**/B-Nine	2,500 ppm spray	One or 2 sprays may be needed to keep plants more compact.
		Piccolo/**Piccolo 10 XC**/ Bonzi/Paczol/Downsize	0.5 to 1 ppm drench	Apply to moderately moist substrate.
ACHMELLA OLERACEA	To control plant growth	**Piccolo**/**Piccolo 10 XC**/ Bonzi/Paczol	15 ppm spray	Apply 2 weeks after transplant. Repeat a week later or a week after pinch if needed.
AGASTACHE	To control plant growth	**Citadel**–**Dazide**/Cycocel–B-Nine	3,000 ppm + 1,500 ppm spray	Rates for compact genetics needing slight growth control.
AGERATUM	To control plant growth	**Abide**/A-Rest	7 to 26 ppm spray	
		Dazide/B-Nine	2,500 to 5,000 ppm spray	One or 2 sprays may be needed to keep plants more compact.
		Piccolo/**Piccolo 10 XC**/ Bonzi/Paczol	15 to 45 ppm spray	High rates of Piccolo 10 XC may delay flowering. Late applications and overdosing may cause slow growth on transplantation. This can be avoided by using multiple applications of 25% to 50% of the specified rate and monitoring plant growth.
		Citadel/Chlormequat E-Pro/ Cycocel	800 to 1,500 ppm spray	
		Concise/Sumagic	2 to 30 ppm spray	Cultivar response rates vary. Use lower rates to hold plants.
		Topflor	20 to 60 ppm spray	Based on NC State University trials. Adjust rates for other locations.
[illegible]	To control plant growth	[illegible] Bonzi/Paczol	5 to 10 ppm spray	[illegible] leaf stage.

* Mixing Rate Table on page 51

Rate Adjustments



Type II PGRs

- Type II - Cell Elongation Inhibitors
  - Group A
    - **Chloromequat** (Cycocel/Citadel/Chloro-Epro)
    - **Mepiquat chloride** (Terpal)
  - Group B (N - containing heterocyclic compounds)
    - **Ancymidol** (A-Rest/Abide) [pyrimidine]
    - **Flurprimidol** (Topflor/Cutless) [pyrimidine]
    - **Paclobutrazol** (Bonzi/Piccolo/Paczol) [triazole]
    - **Uniconazole** (Sumagic/Concise) [triazole]
    - **Propiconazole** (Bumper 250 EC) [triazole]
  - Group C
    - **Daminozide** (B-Nine/Dazide)
    - **Prohexadione calcium** (Regalis)
    - **Trinexapac-ethyl** (Cutaway, Moddus/Primo Maxx II)

GA Pathway

Isopentyl pyrophosphate

↓

Farnesyl pyrophosphate

↓

Geranylgeranyl pyrophosphate

↓

ent-kaurene

X=blocked steps

↓ X

ent-kaurenol

↓ X

ent-kaurenal

↓ X

ent-kaurenoic acid

↓

GA_{12}-aldehyde

↓

Gibberellins

Ancymidol
Paclo's
Uni's
Flurprimidol

Less Growth:
Shoots
Leaves
Roots

GA Pathway

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

X = blocked steps

X X

Chlormequat

ent-kaurene

ent-kaurenol

ent-kaurenal

ent-kaurenoic acid

GA_{12}-aldehyde

Gibberellins

Less Growth:

Shoots

Leaves

Roots

GA Pathway

X=blocked steps

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

ent-kaurene

ent-kaurenol

ent-kaurenal

ent-kaurenoic acid

GA_{12}-aldehyde

X X

Gibberellins

Daminozide

Less Growth:
Shoots
Leaves
Roots

GA Pathway

X=blocked steps

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

X X

ent-kaurene

X X

ent-kaurenol

X X

ent-kaurenal

X X

ent-kaurenoic acid

GA_{12}-aldehyde

X X

Gibberellins

Chlormequat

Ancymidol
Paclobutrazol
Uniconazole
Flurprimidol

Daminozide

Tank Mix:
Synergy?

GA Pathway

- GA is a plant hormone which influences cell elongation.

- The anti-GA PGRs block the pathway and thus limit the amount of cell elongation.
  - Blockage point varies
  - Synergy possible with multiple blockage sites

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PGR Research

Additional Benefits of Plant Growth Regulators

NC STATE

PGR Toolbox

Growth Control
Ancymidol
Chlormequat Chloride
Daminozide
Ethephon
Flurprimidol
Paclobutrazol
Uniconazole

GA Blockers

Improved Branching
BA (benzyladenine)
BA + GA
Dikegulac Sodium
Ethephon

Growth Enhancement
BA + GA

Flower Enhancement
BA (benzyladenine)
Ethephon

Flower Control
Ethephon

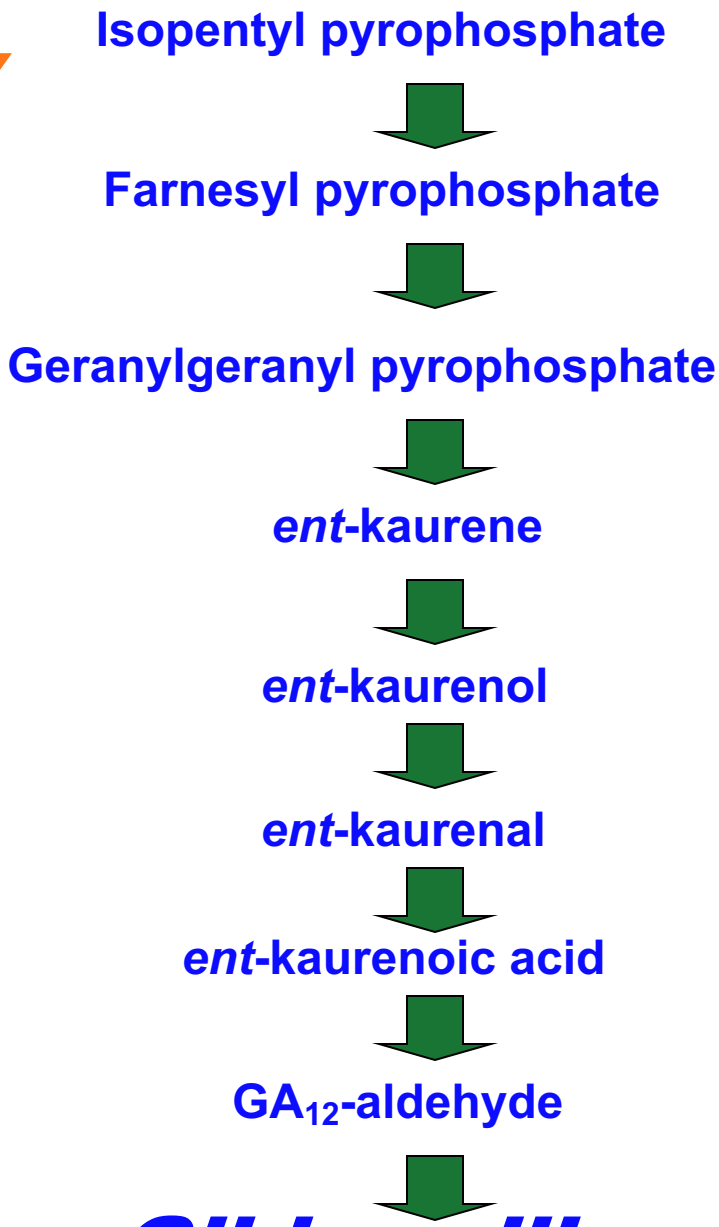
Added Benefits

- Greener leaves
- Reduced water stress
- Disease suppression

Greener Leaves

- PGR treated leaves are darker green
- Suggests a higher chlorophyll content
  - Cells smaller, so chlorophyll more concentrated
  - Increased chlorophyll production because of blocked pathway

GA Pathway


Isopentyl pyrophosphate
Farnesyl pyrophosphate
Geranylgeranyl pyrophosphate
ent-kaurene
ent-kaurenol
ent-kaurenal
ent-kaurenoic acid
GA_{12}-aldehyde
Gibberellins

GA Pathway

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

ent-kaurene

X *ent*-kaurenol X

X *ent*-kaurenal X

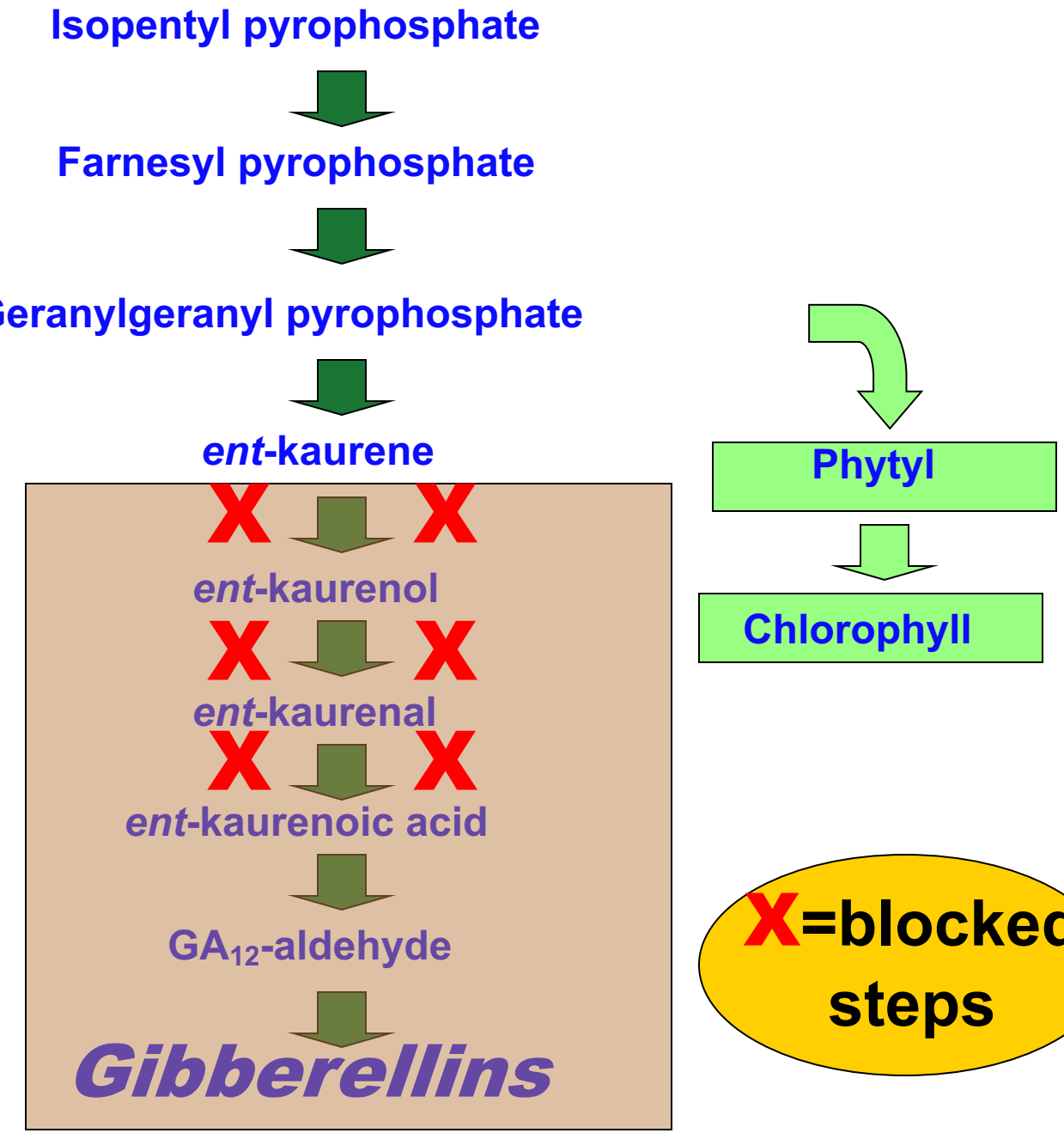
X *ent*-kaurenoic acid X

GA_{12}-aldehyde

Gibberellins

X=blocked steps

GA Pathway

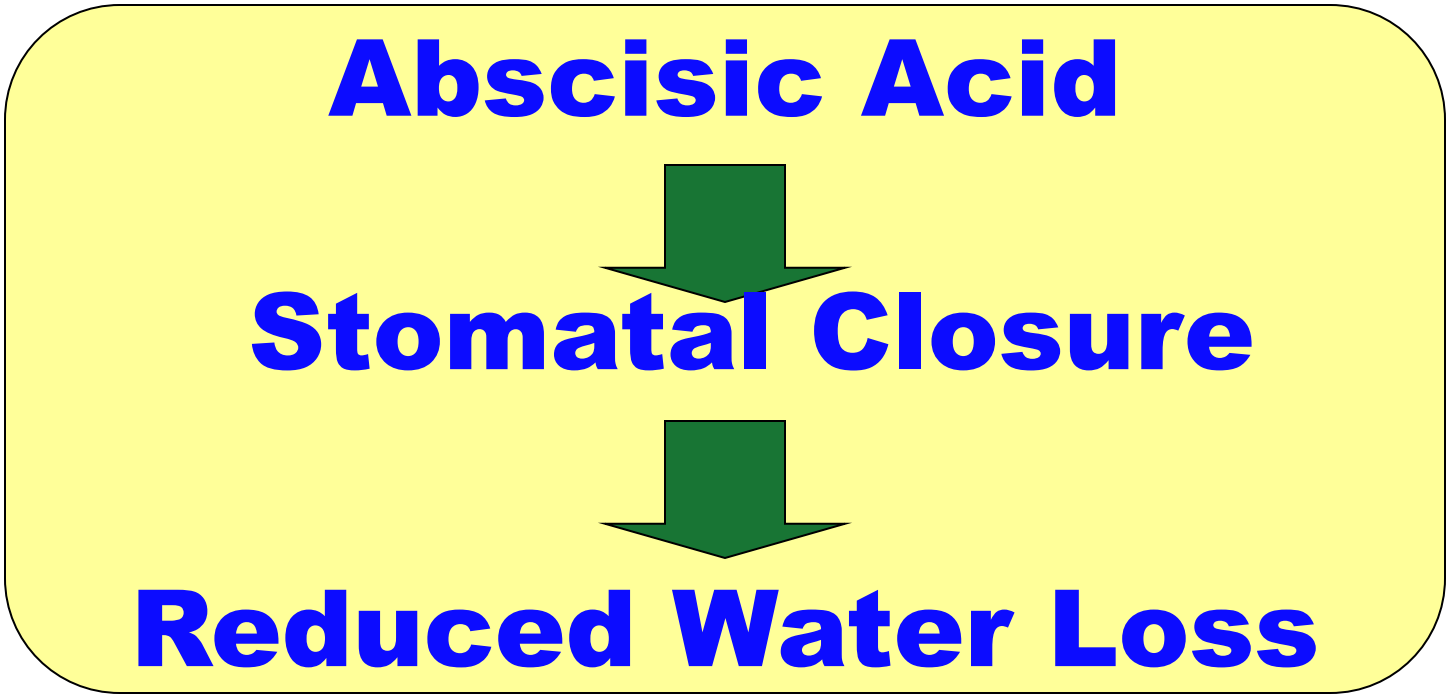


Why greener leaves?

Greener Leaves

Reduced Water Stress

- Blocked GA pathway increases abscisic acid production … and
- Interferes with the breakdown of abscisic acid



Stomates

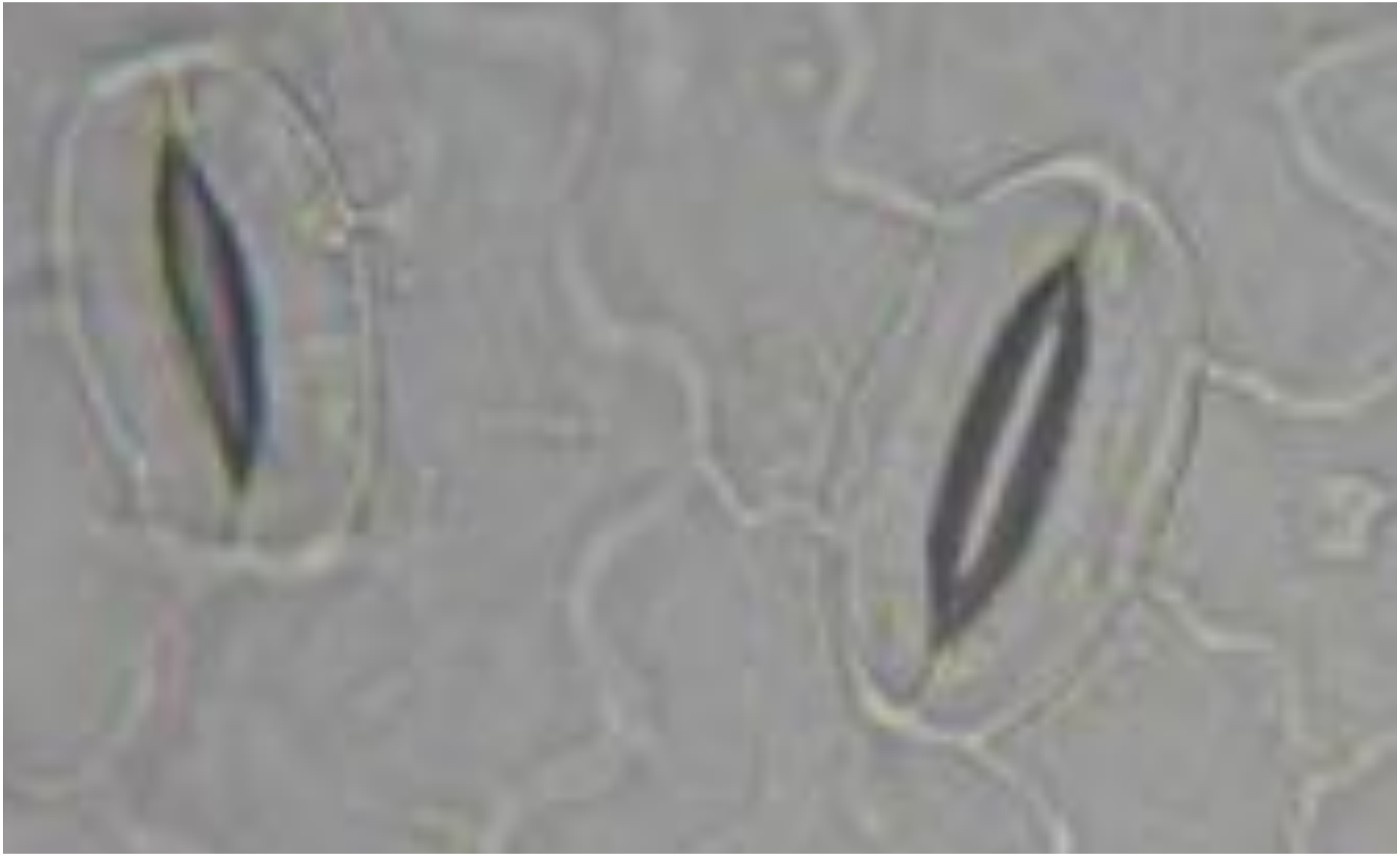
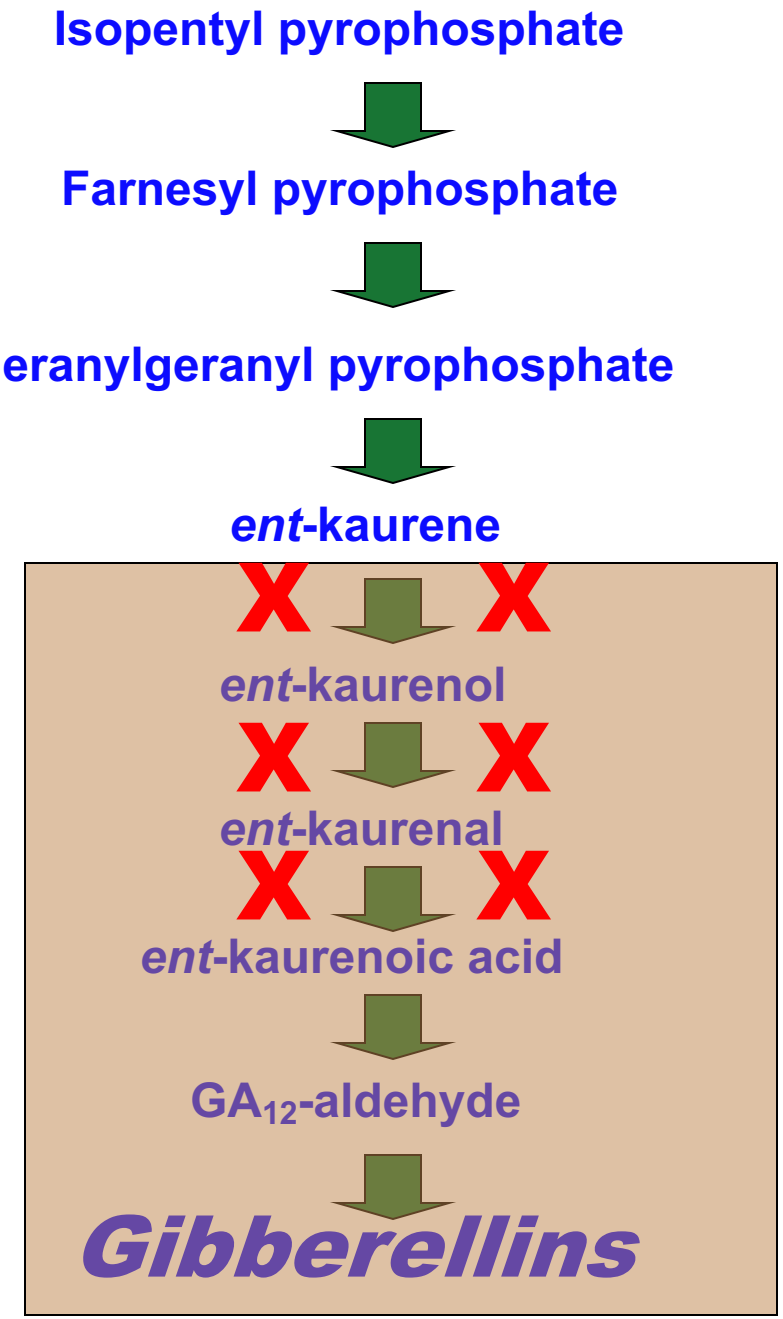


Photo: Brian Krug, UNH

GA Pathway



X=blocked steps

GA Pathway

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

ent-kaurene

ent-kaurenol

ent-kaurenal

ent-kaurenoic acid

GA_{12}-aldehyde

Gibberellins

Phaseic Acid

Abscisic Acid

Why less water stress?

X=blocked steps

GA Pathway

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

ent-kaurene

X *ent*-kaurenol X

X *ent*-kaurenal X

X *ent*-kaurenoic acid X

GA_{12}-aldehyde

Gibberellins

Phaseic Acid

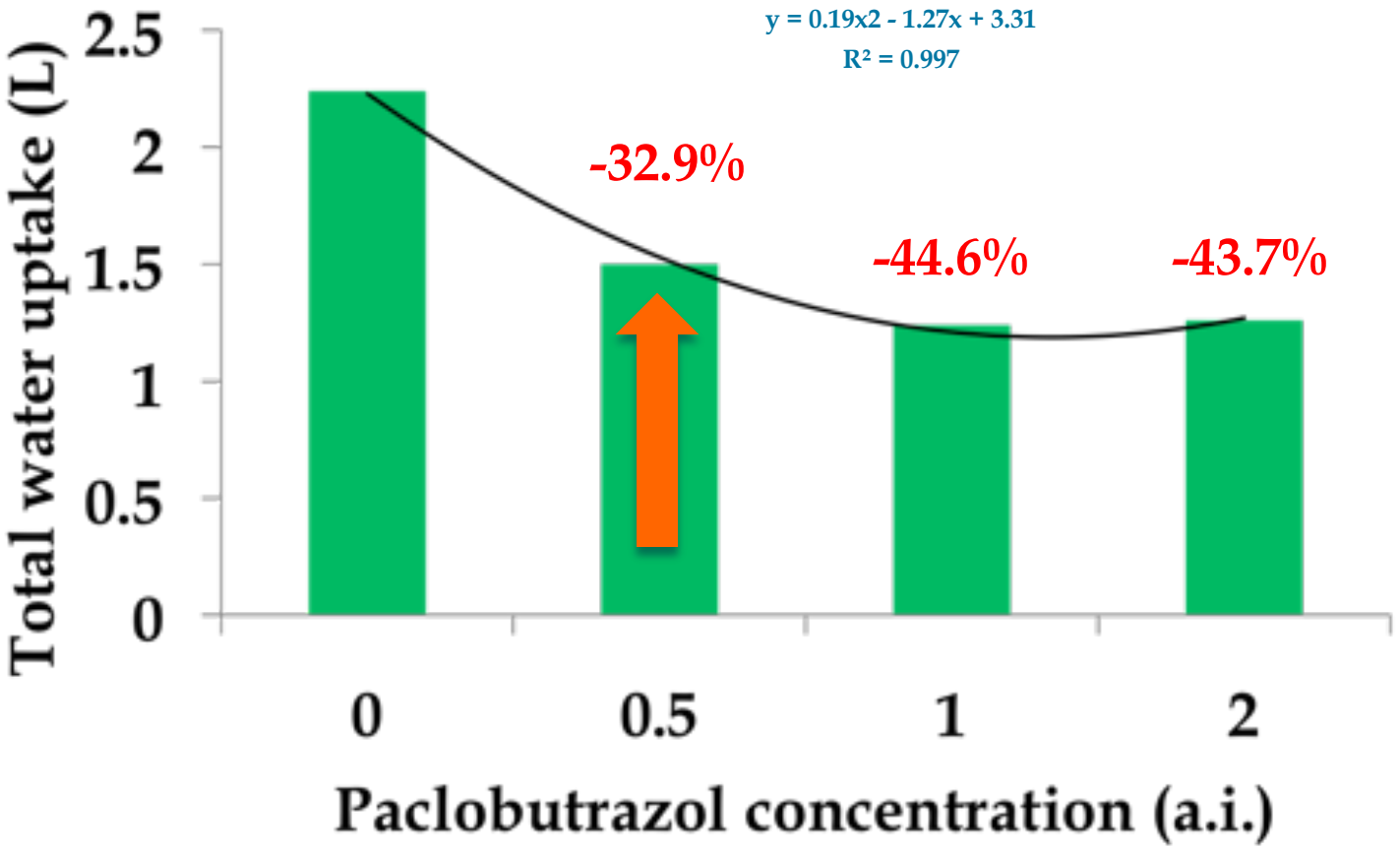
X X

Abscisic Acid

Why less water stress?

X=blocked steps

Paclobutrazol Effect on Total Water Use by Zinnia



Data source: Ahmad, Whipker and Dole, NCSU

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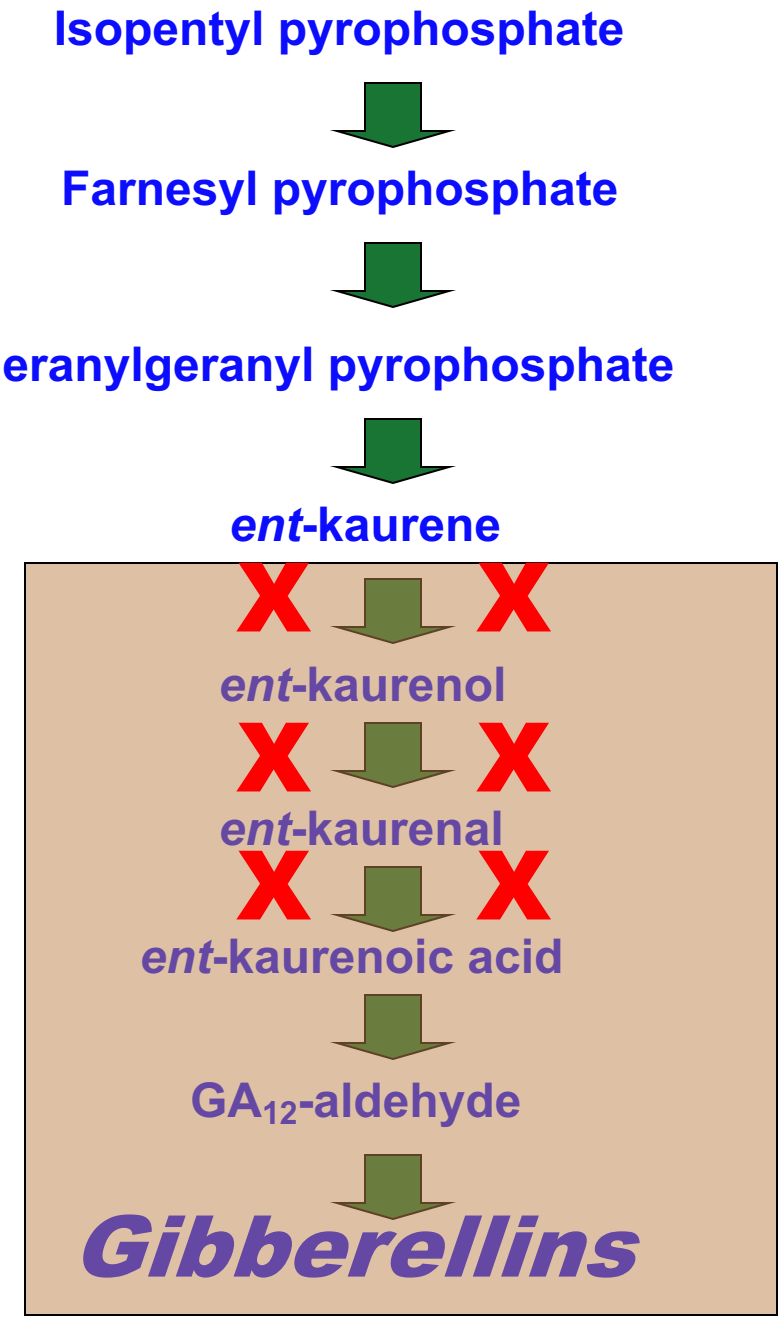
Disease Suppression

- Applying paclobutrazol (Bonzi) to trees reduced the incidence of fungal diseases.

- Thought to due to the inhibition of sterol production in fungi.
  - Sterols essential constituents of membranes.
  - Same mode of action as sterol biosynthesis inhibitor class of fungicides (SBIs).

GA Pathway



X =

Paclobutrazol blocked steps

GA Pathway

Isopentyl pyrophosphate

Farnesyl pyrophosphate

Geranylgeranyl pyrophosphate

ent-kaurene

X *ent*-kaurenol X

X *ent*-kaurenal X

X *ent*-kaurenoic acid X

GA_{12}-aldehyde

Gibberellins

Squalene

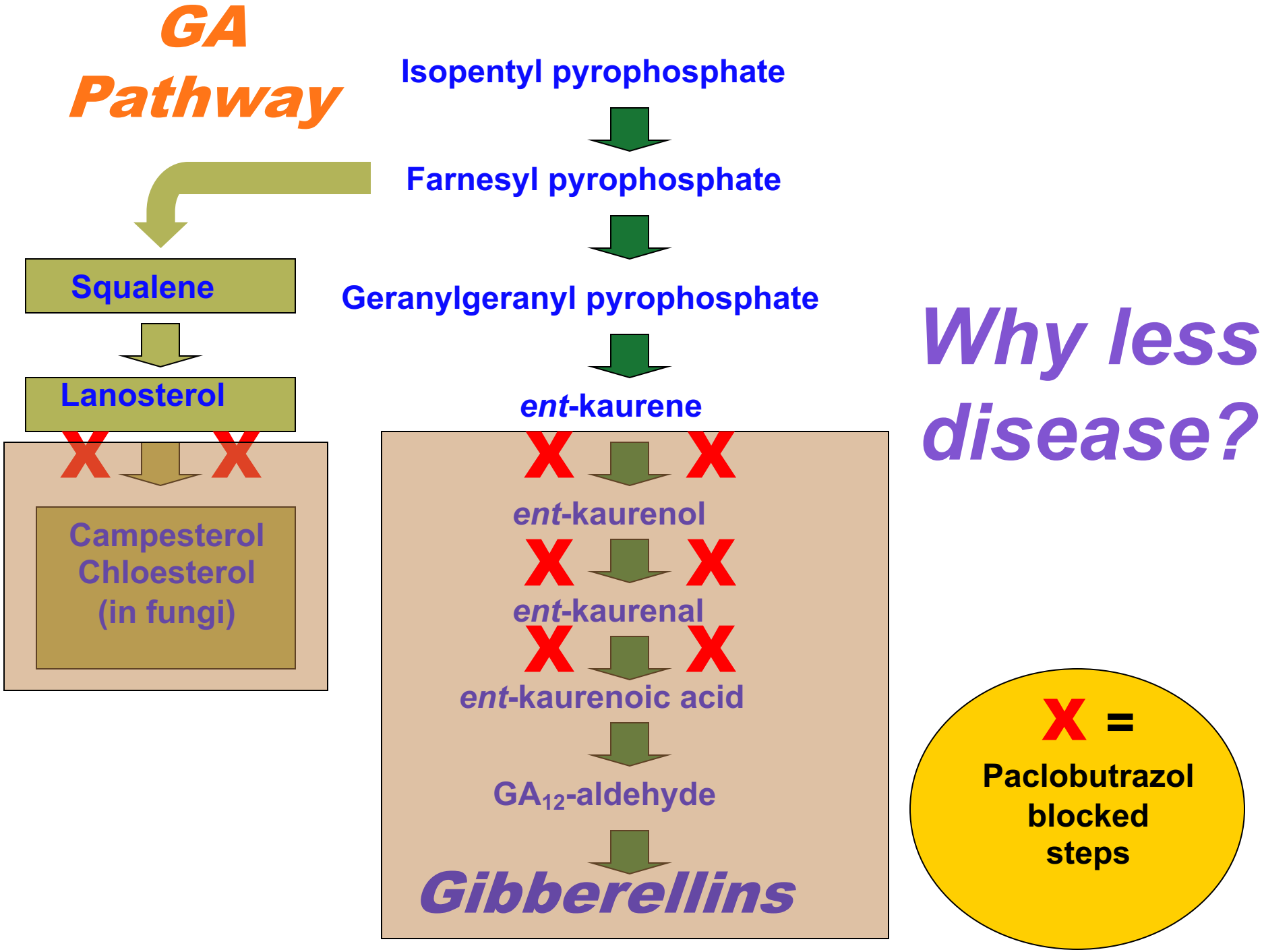
Lanosterol

Campesterol
Chloesterol
(in fungi)

Why less disease ?

X =

Paclobutrazol blocked steps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ent-kaurenal
ent-kaurenoic acid
GA12-aldehyde
Gibberellins
Squalene
Lanosterol
Campesterol
Chloesterol
(in fungi)
X
Why less disease?
X =
Paclobutrazol blocked steps

Disease Suppression

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Disease Suppression

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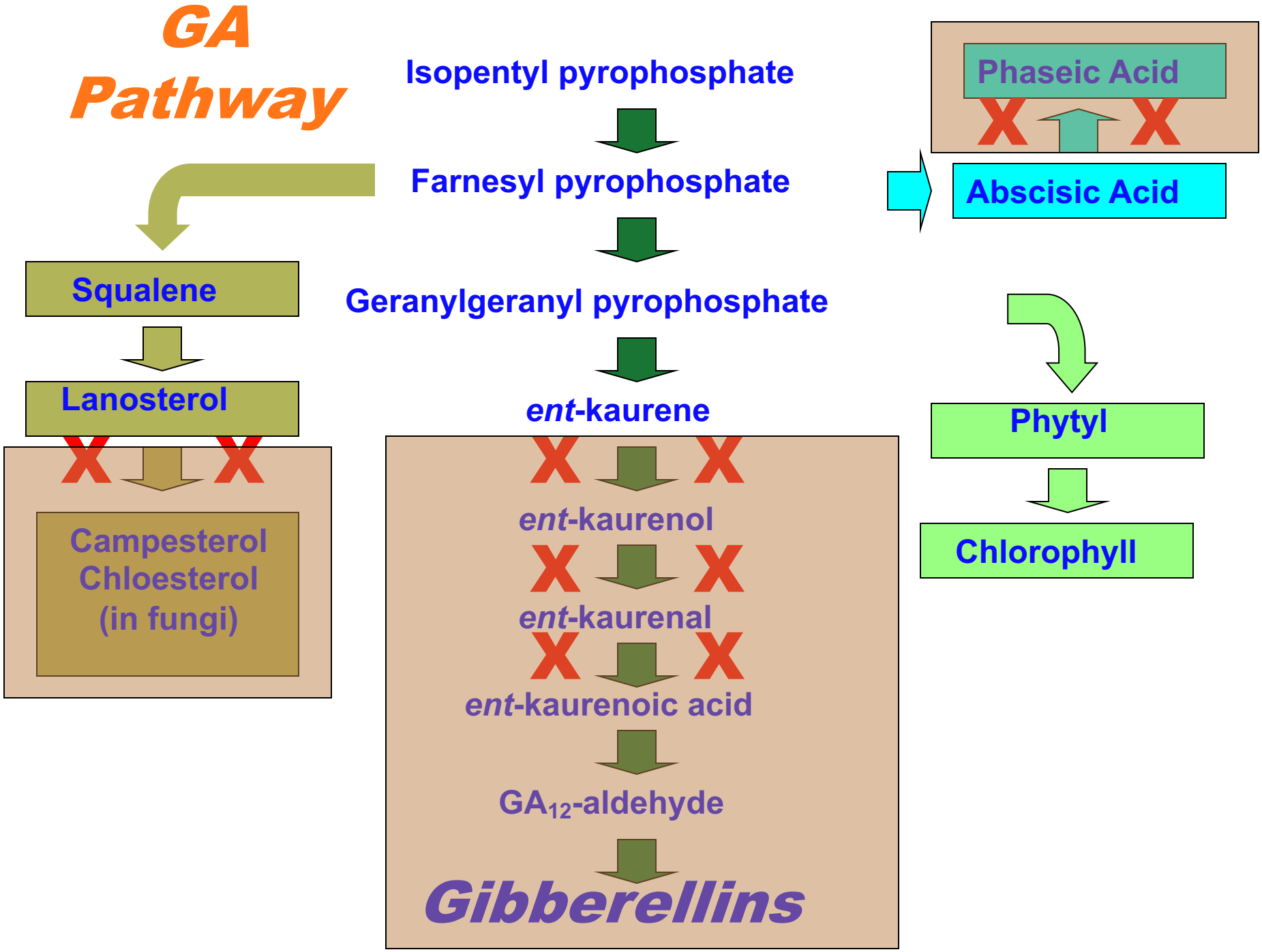
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Gibberellins
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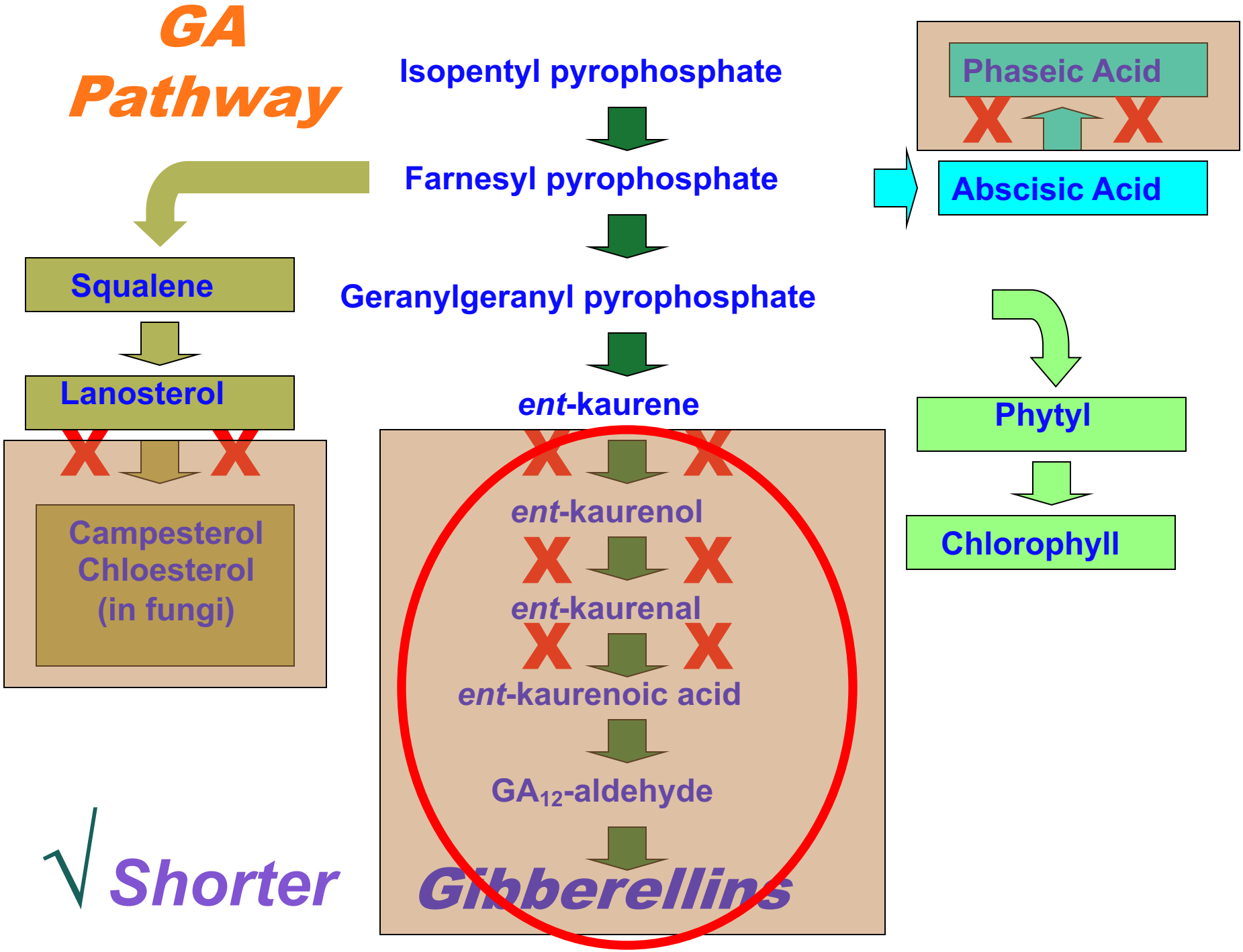
Abscisic Acid
Squalene
Lanosterol
Campesterol
Chloesterol
(in fungi)
Phytyl
Chlorophyll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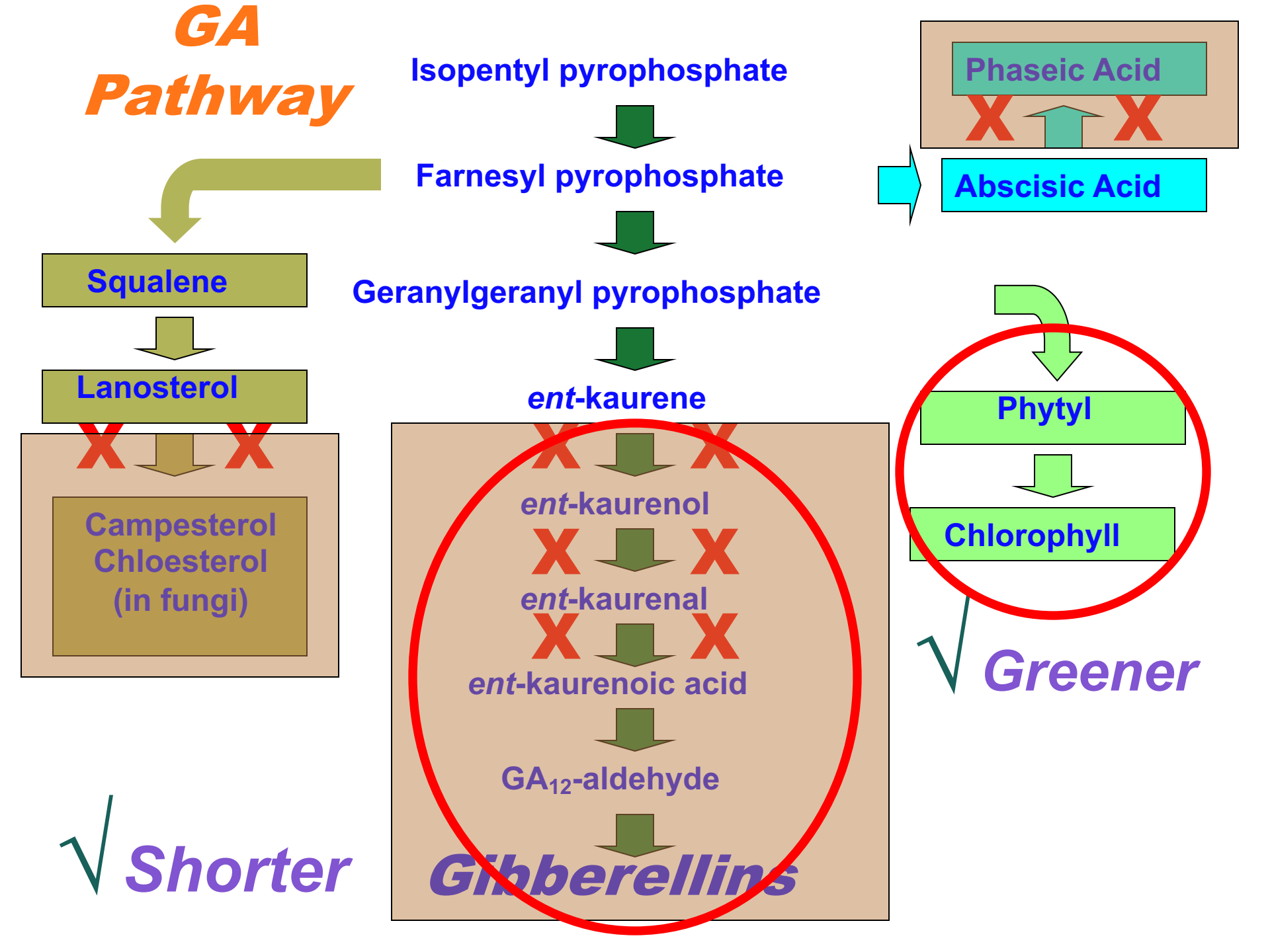
Chloesterol
(in fungi)
Phytyl
Chlorophyll
√ Shorter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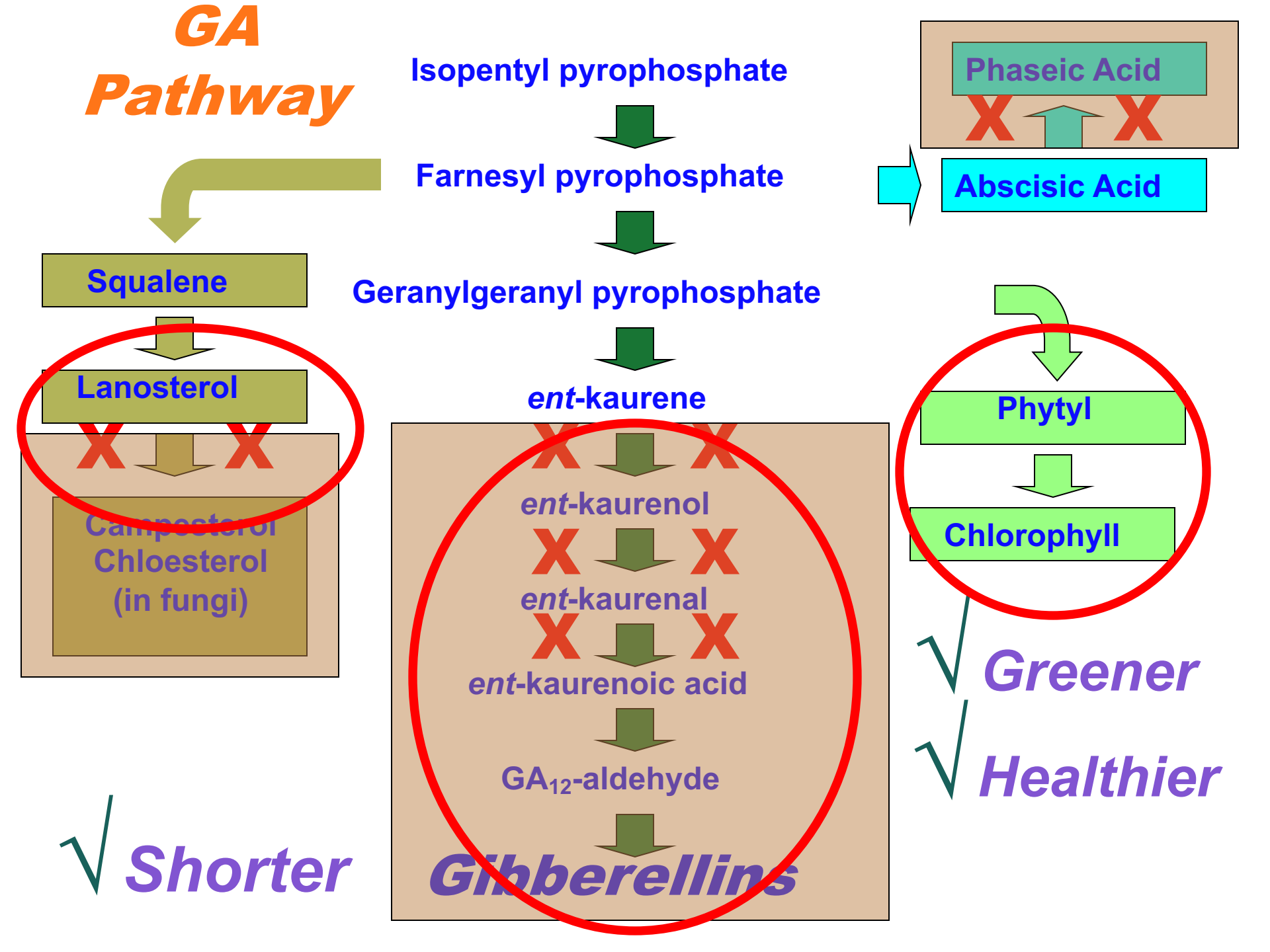
Gibberellins
Phaseic Acid
Abscisic Acid
Squalene
Lanosterol
Campesterol
Chloesterol
(in fungi)
√ Shorter
Phytyl
Chlorophyll
√ Greener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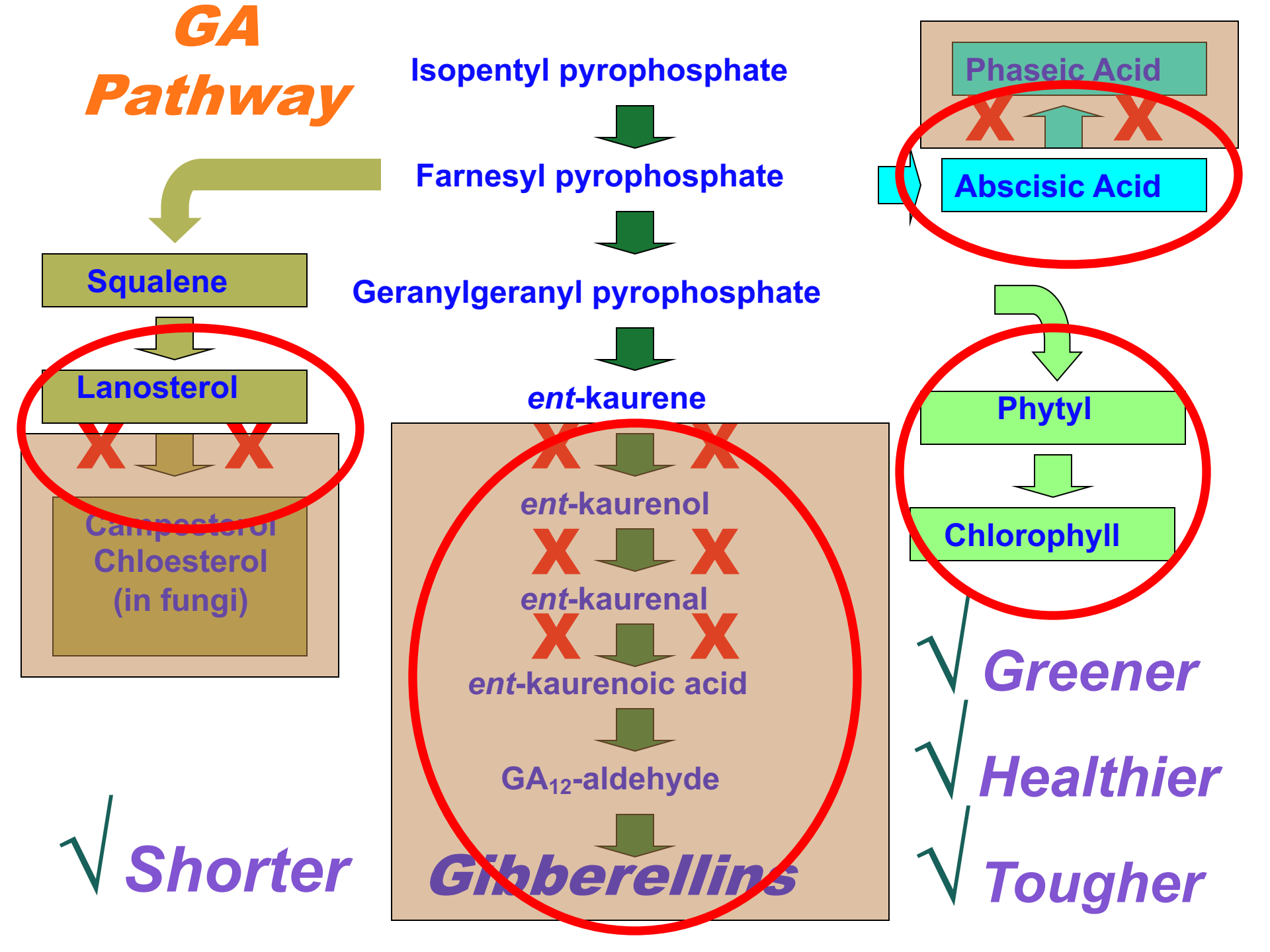
Phaseic Acid
Abscisic Acid
Squalene
Lanosterol
Campesterol
Chloesterol
(in fungi)
Phytyl
Chlorophyll
√ Greener
√ Healthier
√ Shorter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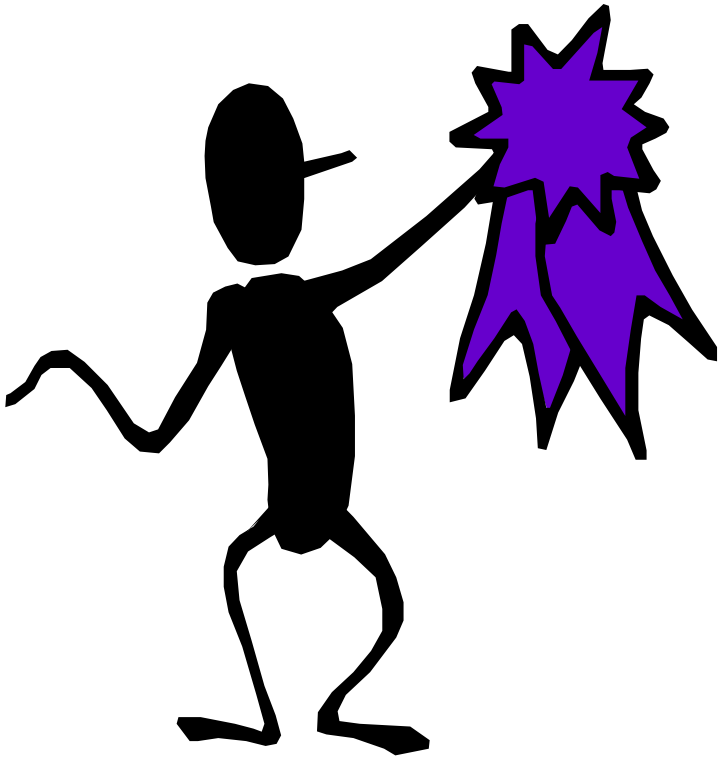
Lanosterol
Campesterol
Chloesterol
(in fungi)
Phaseic Acid
Abscisic Acid
Phytyl
Chlorophyll
√ Shorter
√ Greener
√ Healthier
√ Tougher

Super Plants!!!



How PGRs Make You Money

Economic Benefits

- Chemical costs are a concern to growers.
  - A variable cost
- The growth controlled with PGRs allows for tighter plant spacing.
  - Thus there is less square foot week costs.
    - Therefore lower fixed costs assigned to a pot.
- So we need to evaluate if the fixed cost savings is greater than the variable costs of applying a spray.

Geraniums in 4 inch pots

Economics: 4-inch Geraniums

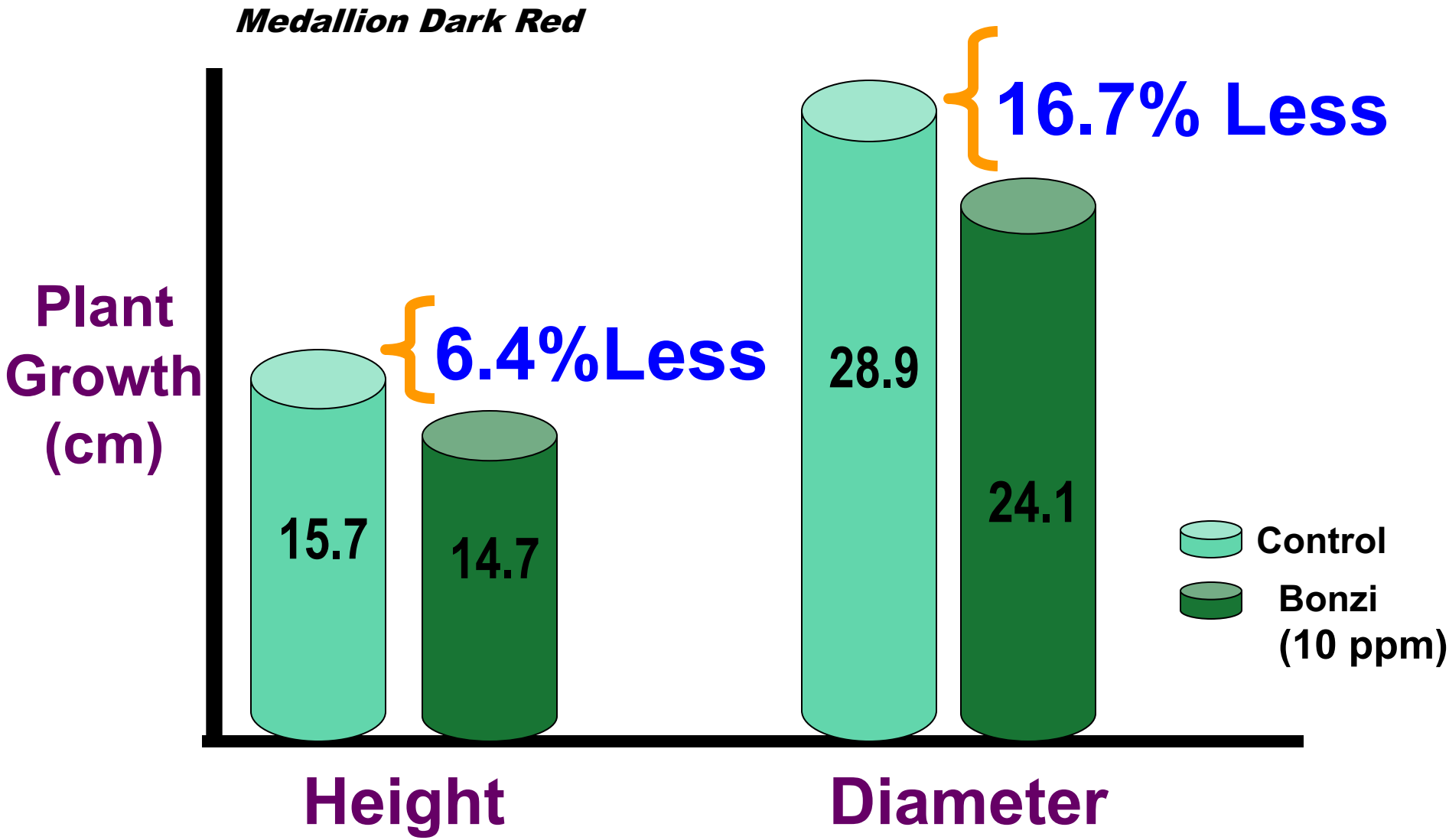
- Geranium spacing (4 inch pot)
  - 4 weeks at 4”x4” spacing (pot tight)
  - 6 weeks at 6”x 6” spacing

Spaced Used

Spacing		Sq Ft	Wks		Sq Ft Wks
4”x 4”	[0.33 x 0.33]	0.1089	x 4	=	0.436
6”x 6”	[0.50 x 0.50]	0.25	x 6	=	1.5

Total Square Foot Weeks **1.936**

Bonzi on Geraniums



Economics: 4-inch Geraniums

Spaced Used

Spacing		Sq Ft		Wks		Sq Ft Wks
4”x 4”	[0.33 x 0.33]	0.1089	x	4	=	0.436
6”x 6”	[0.50 x 0.50]	0.25	x	6	=	1.5

Total Square Foot Weeks **1.936**

Bonzi at 10 ppm **(x 0.834)**

Total Square Foot Weeks **1.687**

Economics: 4-inch Geraniums

Fixed Cost per Pot

	Square Foot per Week Cost		
Sq Ft Wks	$0.15	$0.20	$0.25
1.936 (no PGR)	$0.290	$0.378	$0.489
1.687 (PGR)	$0.253	$0.337	$0.422
Savings	$0.037	$0.048	$0.062

Bonzi @ 10 ppm ($100.00/qt)

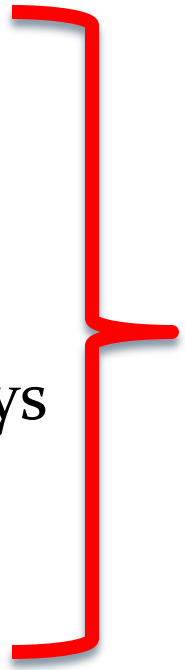
Cost for 1,000 sq ft (9,000 pots)	$5.00
Cost per pot	$0.0008

Economics of PGRs

- Allows for tighter spacing
- Improves per pot profit

Summary

- How PGRs work
- Additional benefits
- How PGRs move in the plant
- Improving the efficacy of PGR sprays
- How PGRs make you money



Increase efficiency

Increase space utilization

Provide added benefits

Improves your profitability

Additional Ideas

NC STATE

Hortus K-IBA

Coleus (Day 16)

0 100 200

K-IBA Concentration (ppm)

NC STATE

Hortus K-IBA

New Guinea Impatiens (Day 18)

0 100 200

K-IBA Concentration (ppm)

NC STATE

Hortus K-IBA

Lantana (Day 2)

NC STATE

Hortus K-IBA

Lantana (Day 18)

0 100 200

K-IBA Concentration (ppm)

NC STATE

Paclo Liner Soak

Coleus (Day 18)

0 2.5 5 10 20

Piccolo Concentration (ppm)
[Paclobutrazol]

NC STATE

Begonia
'Super Olympia Rose'

0 1 3 6

Fresco (ppm)

Fresco foliar sprays increased plant growth

NC STATE

Fresco for Overcoming PGR Overdose

Plants initially treated with a Paclo drench of 8 ppm which stopped growth.

Growth enhanced with a Fresco foliar spray from 2.5 to 10 ppm.

NC STATE

+5 Weeks

No plant growth regulator applied

2 ppm Piccolo 10XC drench

2 ppm Piccolo 10XC drench, **2X**

4 ppm Piccolo 10XC drench

4 ppm Piccolo 10XC drench. **2X**

'Bubblegum'

Branch Enhancement

- Benzyladine (BA)

configure™

Questions