How Harvest Aids Work ?

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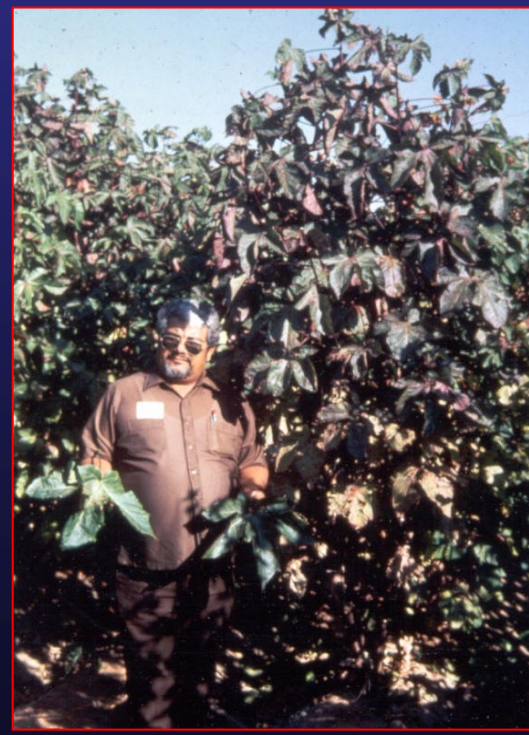
Growth Habit

- Cotton is grown as an annual crop
- Inherently it is a deciduous perennial
- Plant possesses a natural mechanism for shedding its mature leaves
- Natural shedding is not necessarily synchronized with most appropriate time for harvesting lint



Cotton Growth (Days)

Stage of growth	Days	Accum. Days
Planting to emergence	5-20	.
Emergence to 1st square	27-38	45
Square to 1st bloom	20-27	68
1st bloom to open boll	45-55	118
Late bloom to open boll	55-70	128
Growing season	120-170	.

Plant Growth and Development

- During first 14 days, leaves expand and nitrogen moves into them producing proteins
- Hormones and enzymes are very active; photosynthesis increases
- Carbohydrate production peaks 16 to 18 days after leaves unfold
- Leaves during this stage are very resistant to defoliation

Leaf Duration

- Active life very short
- A 20 day old leaf shows highest photosynthetic activity (Bondada and Oosterhuis, 1998)
- Leaf stops functioning after about 40 to 60 days
- As leaves age, the plant is naturally conditioned for senescence (i.e. leaf abscission)

Growing Degree Day Units = (DD60s) = Heat Units

- Plant growth and development is related to heat unit accumulation
- Derived by following formula:

$$\left[\frac{T_{max} + T_{min}}{2}\right] - T_{base}$$

T_{max} = daily maximum temperature (^{o}F)
T_{min} = daily minimum temperature (^{o}F)
T_{base} = base temperature of 60 ^{o}F

Cotton Growth (Heat Units)

Stage of growth	DD60s
Planting to emergence	45-130
Emergence to 1st square	480-530
Emergence to peak bloom	850-1625
Emergence to 1st open boll	1690-2050
Emergence to 60% open boll	2550-4600

Heat Units (DD60's) College Station

ACCUMULATED DD60's	1997	1998	1999	2000	*Average*
Planting to Harvest	2830	2812	2963	2998	*2901*
EB to Defoliation	1526	1404	1566	1432	*1482*
Defoliation to Harvest	343	328	373	360	*351*

Why Use Harvest Aids?

- Improve harvesting and ginning
- Minimize trash and staining of lint
- Preserve yield and quality
- Timely harvest

How Harvest Aids Work?

- **Mimic 'Mother Nature'**
  - Senescence and abscission
  - Abscission zone formation
  - Types of Harvest Aids and Modes of Action
    - Defoliants – (Hormonal and Herbicidal)
    - Desiccants – (Herbicidal)
    - Boll openers / Conditioners – (Hormonal)
    - Regrowth Inhibitors

Senescence

- Programmed genetic event
- Proceeds from juvenile to mature plant
- Latter part leads to ultimate loss of function
- Hormonally controlled ratios of promoters : inhibitors
- Environmental interactions

Three Phases of Senescence

Phase 1 – Initiation phase

Phase 2 – Degeneration phase

Phase 3 – Final or Culminating phase

Three Phases of Senescence

- Phase 1 – Initiation
  - Results in potential shutdown of cell maintenance function
  - Paralleled with increase in key degradative enzymes
  - Several senescence-associated genes (SAGs) involved in this phase have been identified
  - SAGs are similar to cysteine proteases which are required for programmed cell death (PCD)
  - PCD is the process by which individual cells activate an intrinsic senescence program

Phases of Senescence

- Phase 2 - Degeneration
  - Key metabolic processes are disassembled
- Phase 3 - Final
  - Loss of homeostasis and cell membrane integrity
  - An oxidative process that involves a general deterioration of cellular metabolism
  - Increased activation of cell-wall degrading enzymes, such as cellulase and pectinase, at the abscission layer
  - Eventually leads to cell death

Senescence Leads to Abscission

- Abscission is usually preceded by:
  - Loss of chlorophyll
  - Temporary buildup of anthocyanin
  - Breakdown of proteins and carbohydrates to amino acids and sugar… resulting in a remobilization of these constituents`

Abscission

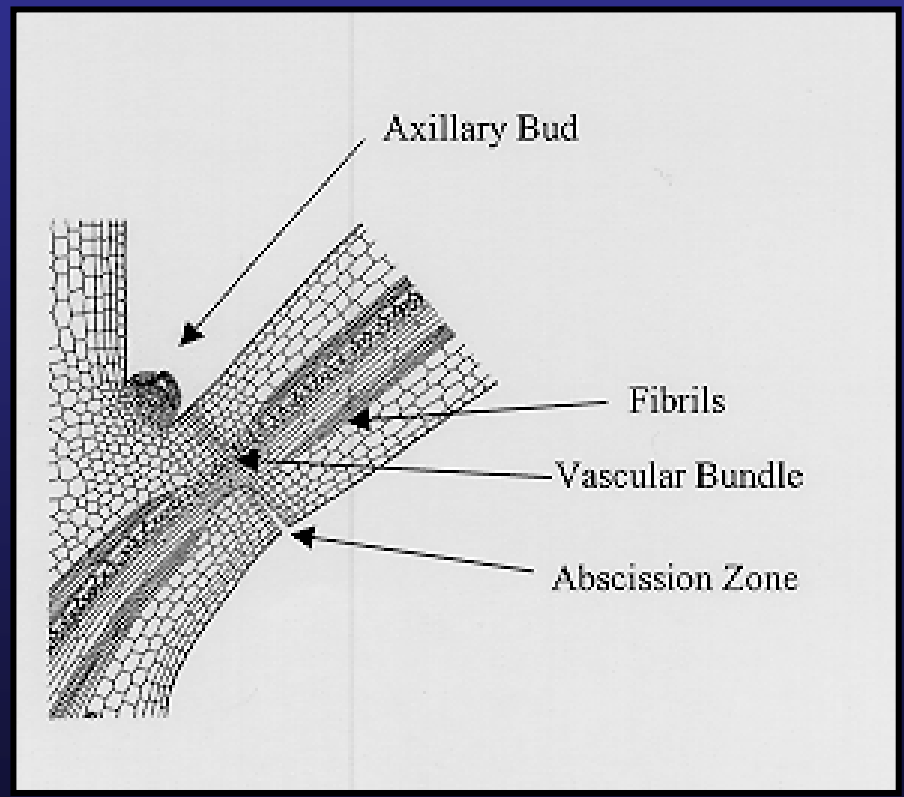
- Derived from the Latin word 'abscindere' "to tear"
- Usually occurs as a result of maturity, senescence, or injury
- A physiological process that involves an active separation of living tissue from the plant
- Separation of the leaf from the plant occurs at the base of the leaf petiole in an area called the abscission zone

Abscission Zone

- Structurally distinguishable; characterized by a structural line of weakness where abscission occurs
- Consists of one or more layers of thin-walled parenchyma cells
- Cell wall breakdown usually confined to a 'separation layer' one to three cells wide in a zone that is 5 to 50 cells wide
- Toward the end of senescence, metabolic activity increases in the abscission layers as a result of alterations in hormone levels in the leaf blade

Abscission Zone

- Located at the base of the petiole of a leaf where the petiole joins the stem
- Cells of the abscission zone are smaller and more densely filled with cytoplasm than cells in adjacent regions



Role of Hormones in Abscission

- Auxins, such as IAA, are strong inhibitors of abscission
- Abscisic acid and ethylene are promotive
- Gibberellic acids and cytokinins have variable effects
- Hormonal influence (overall)
  - Concentration dependent
  - Site of application
  - Type of tissue involved

Jasmonate

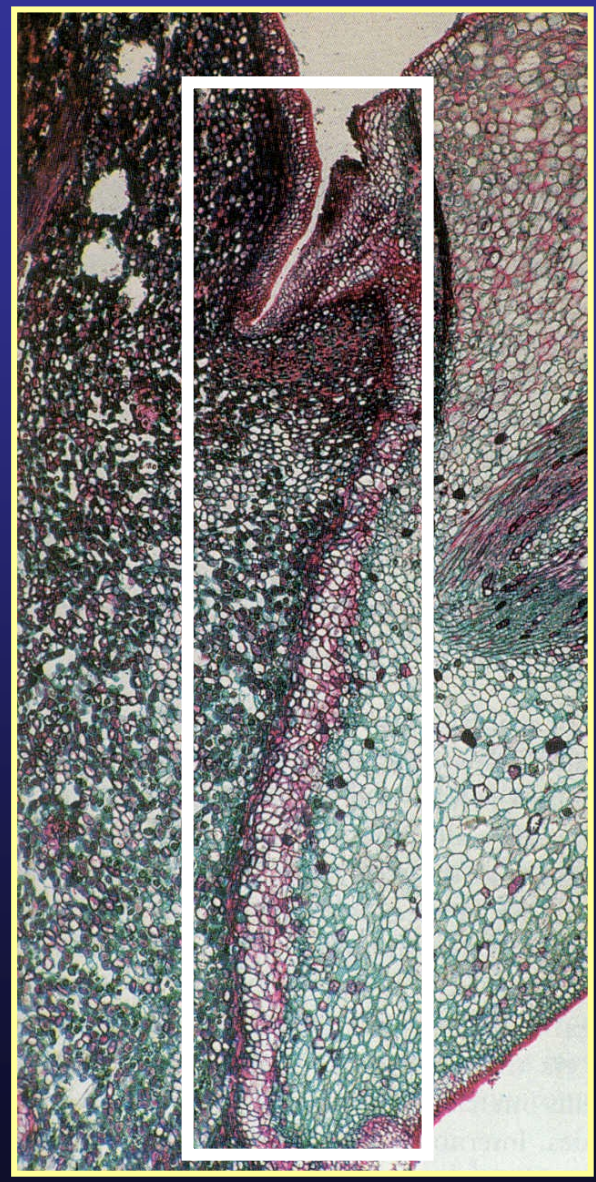
- Methyl-jasmonate (Me-Ja) is a naturally occurring ubiquitous compound in plants
- Putative hormone because of its effects on:
  - Senescence
  - Germination
  - Tuber formation
  - Signal transduction
  - Ethylene production
  - Abscission
  - Wounding (mechanical, herbivory)

Jasmonate cont.

- Little is known about the mode of action at tissue or organ levels
- Shown to inhibit IAA-induced cell elongation (auxin) by inhibiting synthesis of cell wall polysaccharides (only in monocotyledons)
- Promote abscission in bean petiole explants without enhancing ethylene production
  - Increase activities of cellulose and decrease levels of UDP-sugars
    - Important intermediates for synthesis of cell wall polysaccharides in the abscission zone

Effects of Jasmonate

- Decreases levels of cellulose
- Mechanical weakness of cell walls
- Increase abscission and defoliation



Summary

- Senescence is a programmed event
- Final stage of senescence leads to alteration of hormone levels inducing activation of enzymes associated with cell wall breakdown (e.g. pectinase and cellulase) in abscission zone
- Harvest aids mimic 'Mother Nature' in altering hormone ratios to cause abscission

Role of Harvest Aids

- Artificially stress or injure the leaves of a cotton plant
- Induce a change in the hormonal balance between the leaf petiole and stem
- Leaf abscission occurs
- Enhance boll opening

Categories of Harvest Aids

- Defoliants
- Desiccants
- Boll Openers / Conditioners

Defoliants vs. Desiccants

- Defoliants cause leaves to abscise completely from the plant
- Desiccants kill leaves rapidly, with limited abscission

Defoliation

- Achieved in two ways:
  - Application of a chemical that injures the leaf, resulting in increased concentrations of endogenous hormones…such as ethylene and abscisic acid, which promote abscission (Herbicidal)
  - Application of chemicals that act as plant growth regulators, which directly stimulate ethylene production (Hormonal)

Harvest Aid Modes of Action

- Herbicidal (Chemical shock / contact)
- Hormonal (physiological)
- Alone or combined
- Herbicidal
  - Def® / Folex®, Chlorates, Paraquat, Harvade®, Ginstar®
- Hormone-like
  - Dropp®, Ethephon products, Harvade®, Ginstar®

Def® /Folex® (tribufos)

- Often referred to as "phosphate-type" defoliants
- Most effective at removing mature leaves in cool weather and new growth in hot weather
- Does not inhibit regrowth
- Works in both warm and cool temperatures
- Can be tank-mixed with most harvest aids and boll weevil insecticides
- Mode of action:
  - Triggers quick water loss and subsequent leaf abscission

Harvade® (dimethipin)

- Contact-type characteristics
- Defoliation achieved at < 60°F; maybe reduced at > 90°F
- Compatible with all cotton harvest aids
- Must use surfactant (i.e. crop oil concentrate)

- Mode of action:
  - Rapid loss of water, not from massive cell disruption, but from gradual collapse of the leaf epidermis
  - Allows progressive water loss without rapid tissue death, which is similar to the natural aging process
  - Not readily translocated; thus, good coverage is important

Hormonal Defoliants
Three Phases of Abscission

I. Maintenance II. Shedding Induction III. Shedding

Dropp® (thidiazuron)

- A non-phosphate; true hormonal defoliant
- Generally regarded as an early-season defoliant- reduced activity under cool conditions
- Provides good removal of juvenile growth and inhibits terminal regrowth by promoting the premature formation of the abscission layers of petioles
- A cytokinin-like compound
- Depending on dose, cytokinin can inhibit or accelerate leaf growth

Dropp® (thidiazuron)

- As a harvest aid, cytokinin induces a slow but steady buildup of ethylene relative to auxin

- Thus ethylene stimulates pectinase and cellulase enzymes, inducing the breakdown of cell wall material that leads to the formation of the abscission layer and eventual leaf-fall

Ginstar® (thidiazuron & diuron)

- Removes mature leaves, juvenile growth, and regrowth
- Effective leaf penetration increases performance on thick, healthy foliage
- Activity in both hot and cool conditions activity present into the low and mid 50s
- Mode of action:
  - Both hormonal and herbicidal; combined modes of action

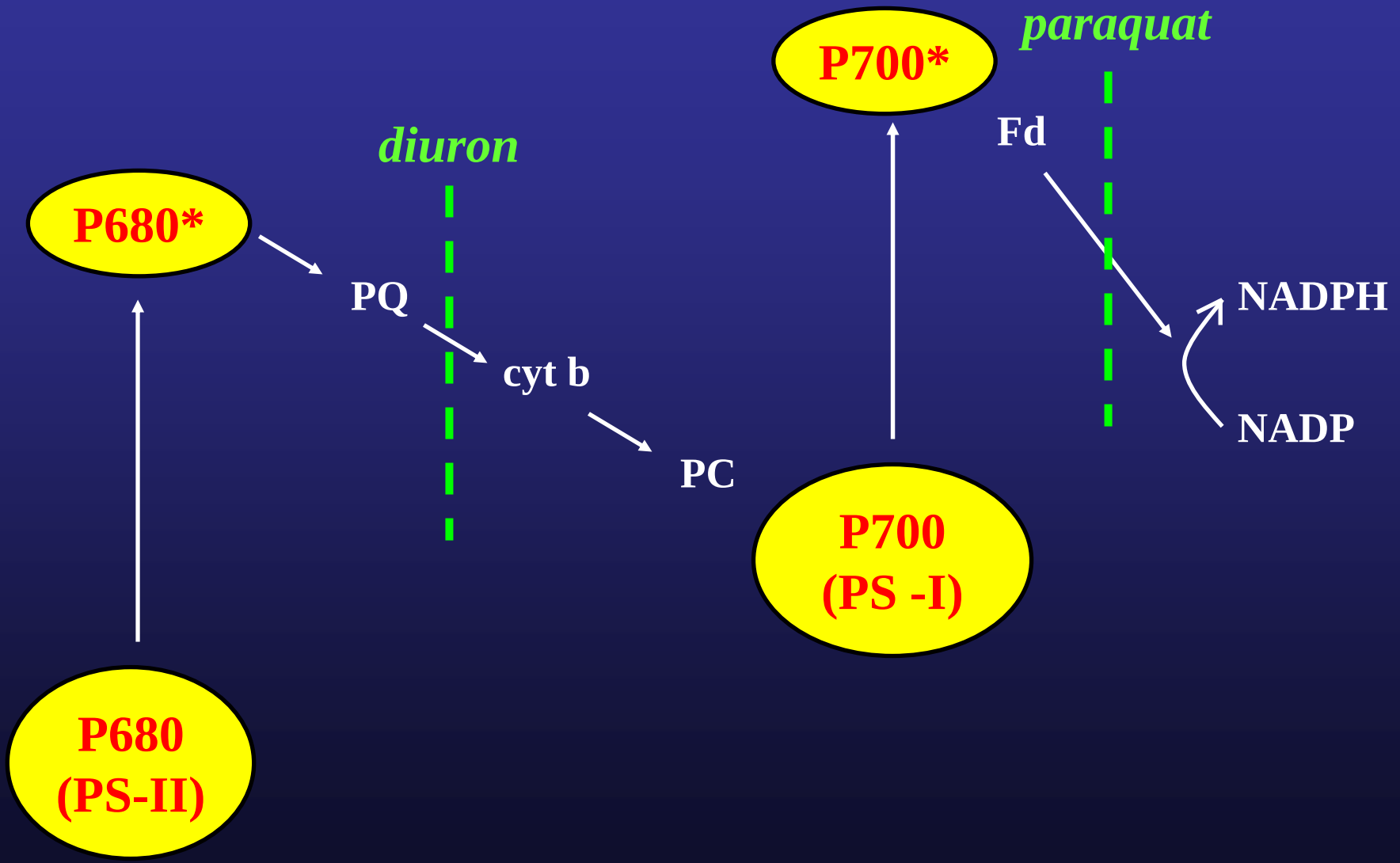
Desiccants

- Contact type herbicide which produces free oxygen radicals in the chloroplast that destroy cell membranes leading to rapid moisture loss and leaf desiccation

Paraquat / Sodium Chlorate

- Performs as defoliant and desiccant
- Used for effective defoliation and desiccation of stripper cotton
- Economic defoliation of mature leaves in cool weather
- Apply under cool to moderate temps, high rates and high temps may cause desiccated leaves to 'stick'
- Mode of action:
  - Acts as a non-selective leaf desiccant

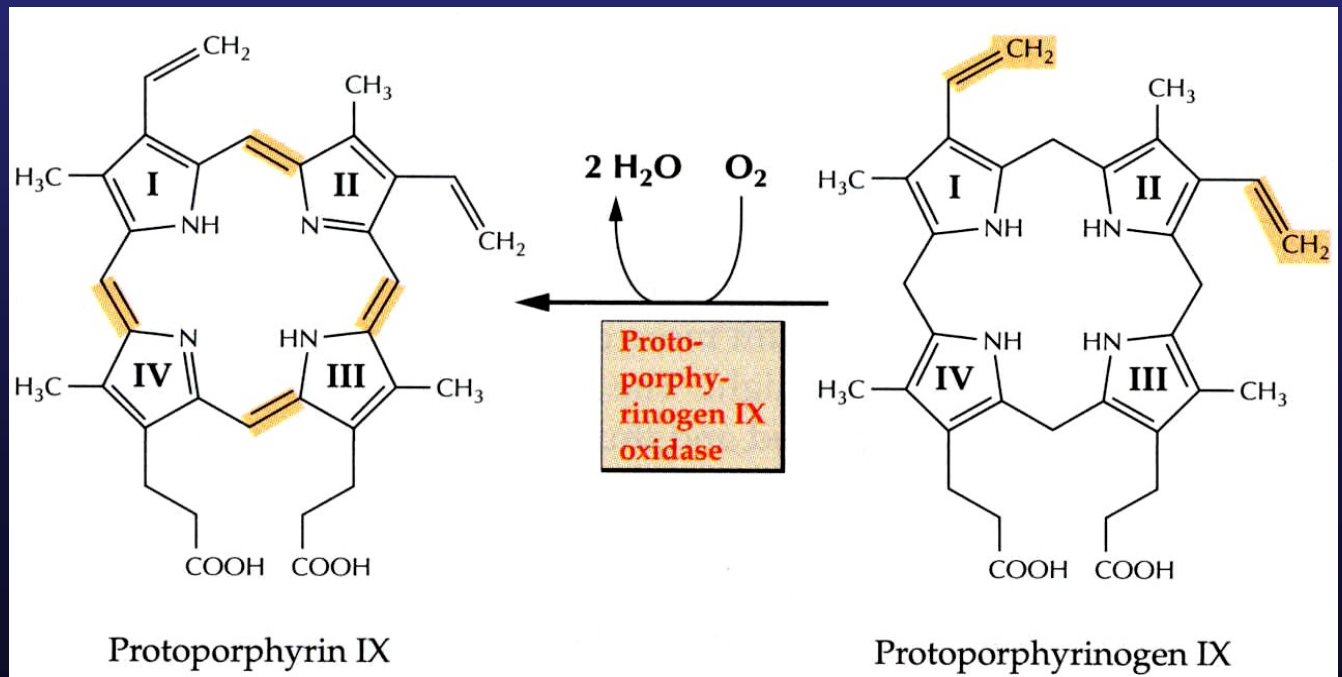
Desiccants


P700*
paraquat
Fd
diuron
P680*
PQ
cyt b
PC
NADPH
NADP
P700
(PS -I)
P680
(PS-II)

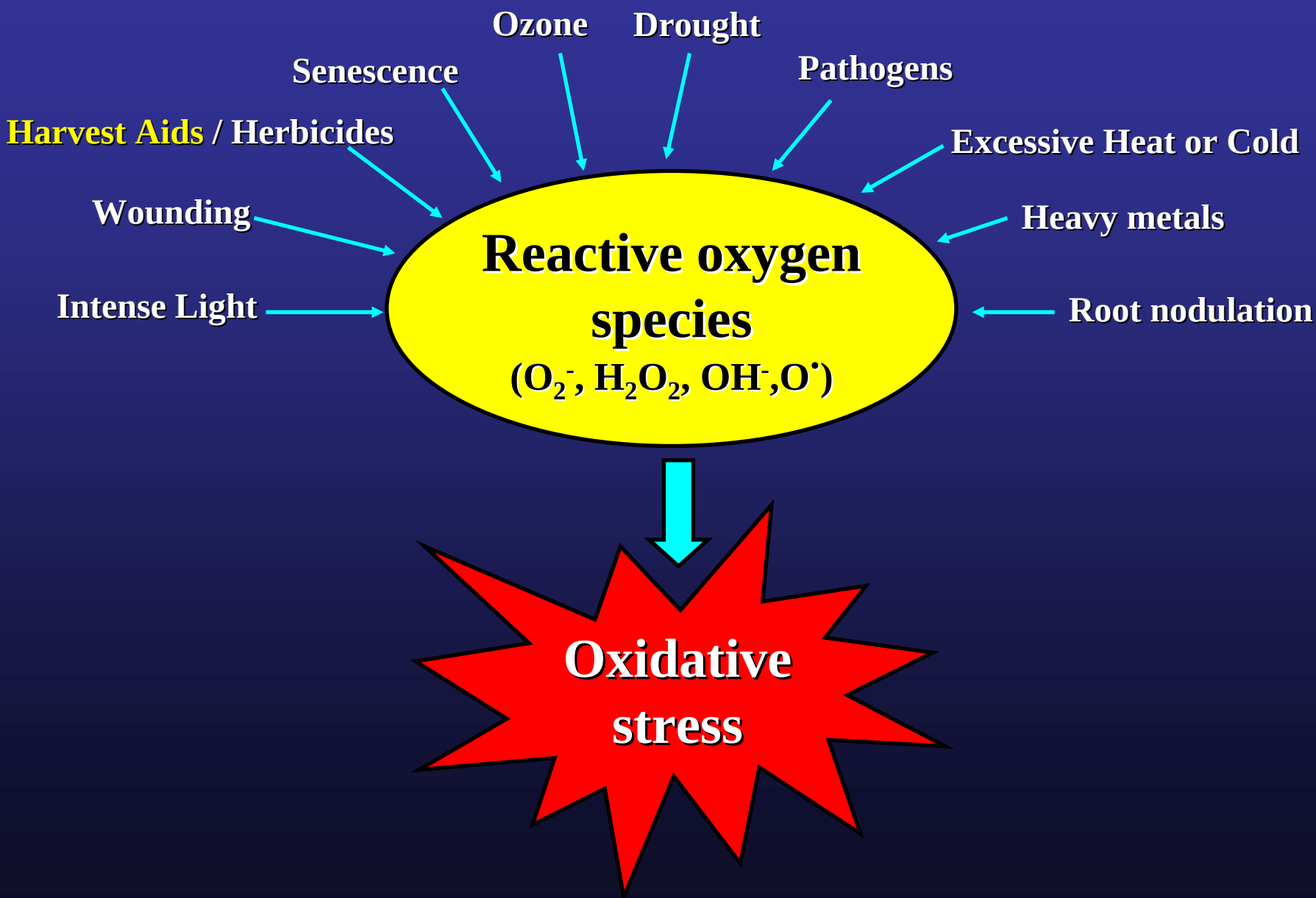
PPO Inhibitors

Cell Membrane Disruptors

- **Mode of Action**
  - **Inhibition of protoporphyrinogen oxidase (also called Protox)**
- **Inhibiting Protox results in accumulation of singlet oxygen in the presence of light**



Oxidative Stress



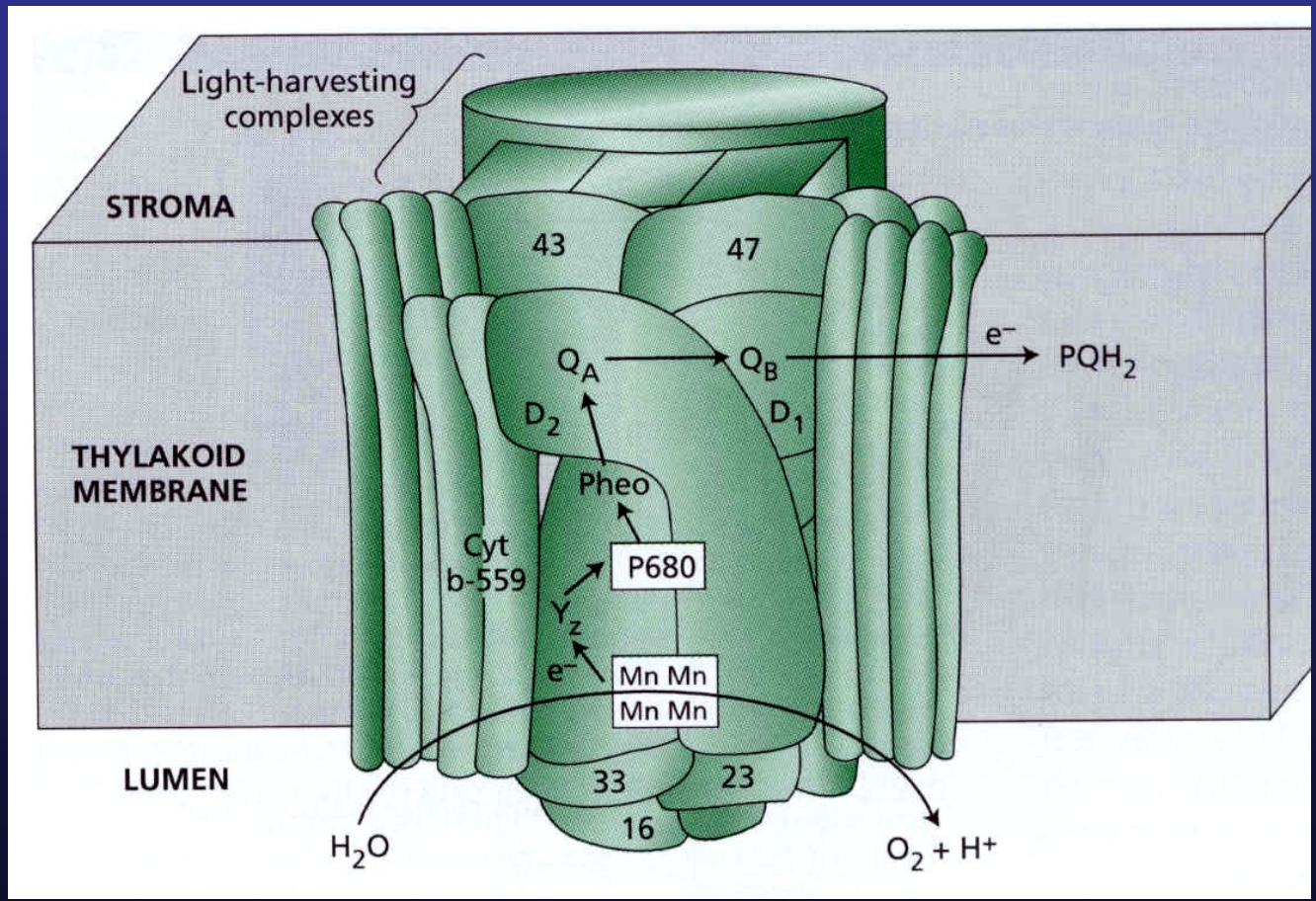
Light

- Can cause extensive damage to the photosynthetic apparatus, especially PSII
- Can lead to inactivation of electron transport and promote oxidative damage to the reaction center, particularly D1 and D2
- Photoinhibition occurs when damage to PSII outpaces the plant's ability to repair itself

Photodamage to PSII

- D1 and D2 constitute the core polypeptides of the photosynthetic reaction center of PSII
- D1 damaged during the photochemical reactions of PSII is targeted for degradation by proteolysis
- Oxidative damage to D1 alter its conformation, rendering the damaged protein venerable to proteases

Photosystem II (P680)



PPO Inhibiting Compounds

- Absorbed mostly by leaves
  - Some limited root absorption
- Mainly contact-type herbicide
- Translocated mainly in xylem
  - Movement within plant from leaf absorption is limited
- Degradation in the plant is through conjugation with glutathione and/or glucose

PPO Inhibitors

Cell Membrane Disruptors

- Subsequently leads to a light-induced breakdown of cell components
- Cell membranes are destroyed by this light peroxidation reaction which results in:
  - Cell leakage
  - Inhibited photosynthesis
  - Bleaching of chloroplast pigments
- Primary site of action
  - Cellular membranes

Boll Openers / Conditioners

Dehiscence

Boll Openers / Conditioners

- Ethephon (Prep™, Boll'd®, Ethephon® 6)
  - An ethylene precursor
- Ethephon + cyclanilide (Finish®)
  - An ethylene precursor plus an ethylene synergist
- Ethephon + AMADS (Cotton Quik®)
- Used in conjunction with defoliants

Prep™ (ethephon)

- Trade name for 2-chloroethyl phosphonic acid
- Affects hormonal activity (ethylene) to enhance boll opening
- Possesses some hormonal defoliation properties but is not classified as a defoliant
- Helps synchronize optimum harvest timing
- Best response at night temps > 60°F and day temps between 85 and 95°F
- Mode of action:
  - Application to green tissue results in its being absorbed into the plant where it breaks down to ethylene; enhances cellulase and pectinase activity; promotes maturity

Cotton Quik™ (ethephon & AMADS)

- Combination of ethephon and 1-aminomethanamide dihydrogen tetra oxo sulfate
- Promotes hormonal activity (ethylene)
- Works best under dry, hot conditions
- Night temps < 60ºF and daytime temp < 75ºF slow plant responses
- Mode of action:
  - Same as ethephon, except AMADS act as a synergist to enhance activity

Finish™ (ethephon & cyclanilide)

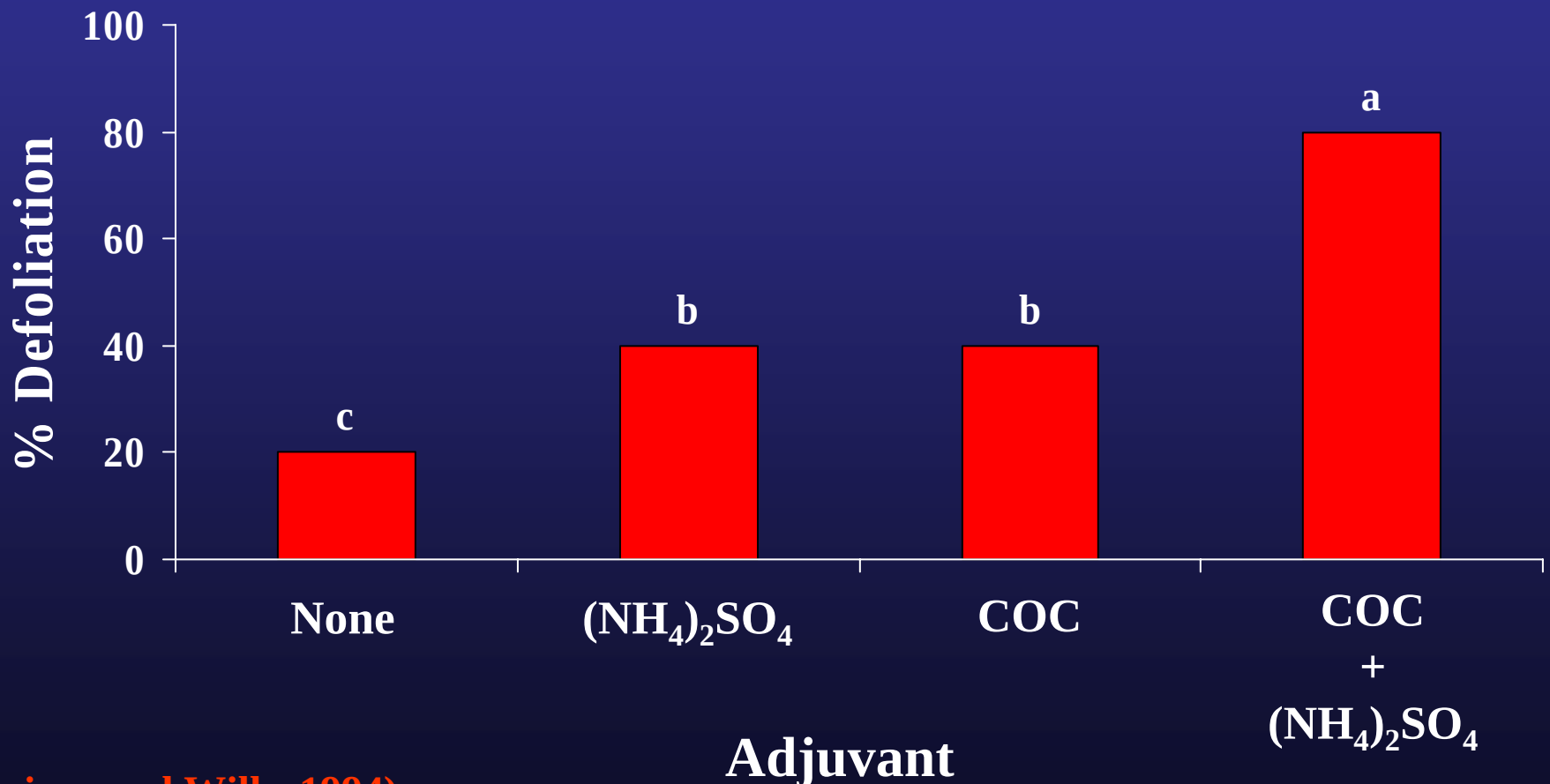
- Ethephon products stimulate ethylene production
- Cyclanilide is a synergist that promotes defoliation and inhibits terminal regrowth
- Thorough spray coverage essential to good performance
- Cyclanilide inhibits auxin transport
- Works best under hot, dry conditions
- Night temp < 60°F and
  daytime temp < 75°F slow response

Adjuvants / Surfactants

- **Utilized to increase the activity and/or uptake of defoliants**

- **Activators**
- **Enhancers**

Use of Adjuvants
with 0.05 lbs/A Dropp



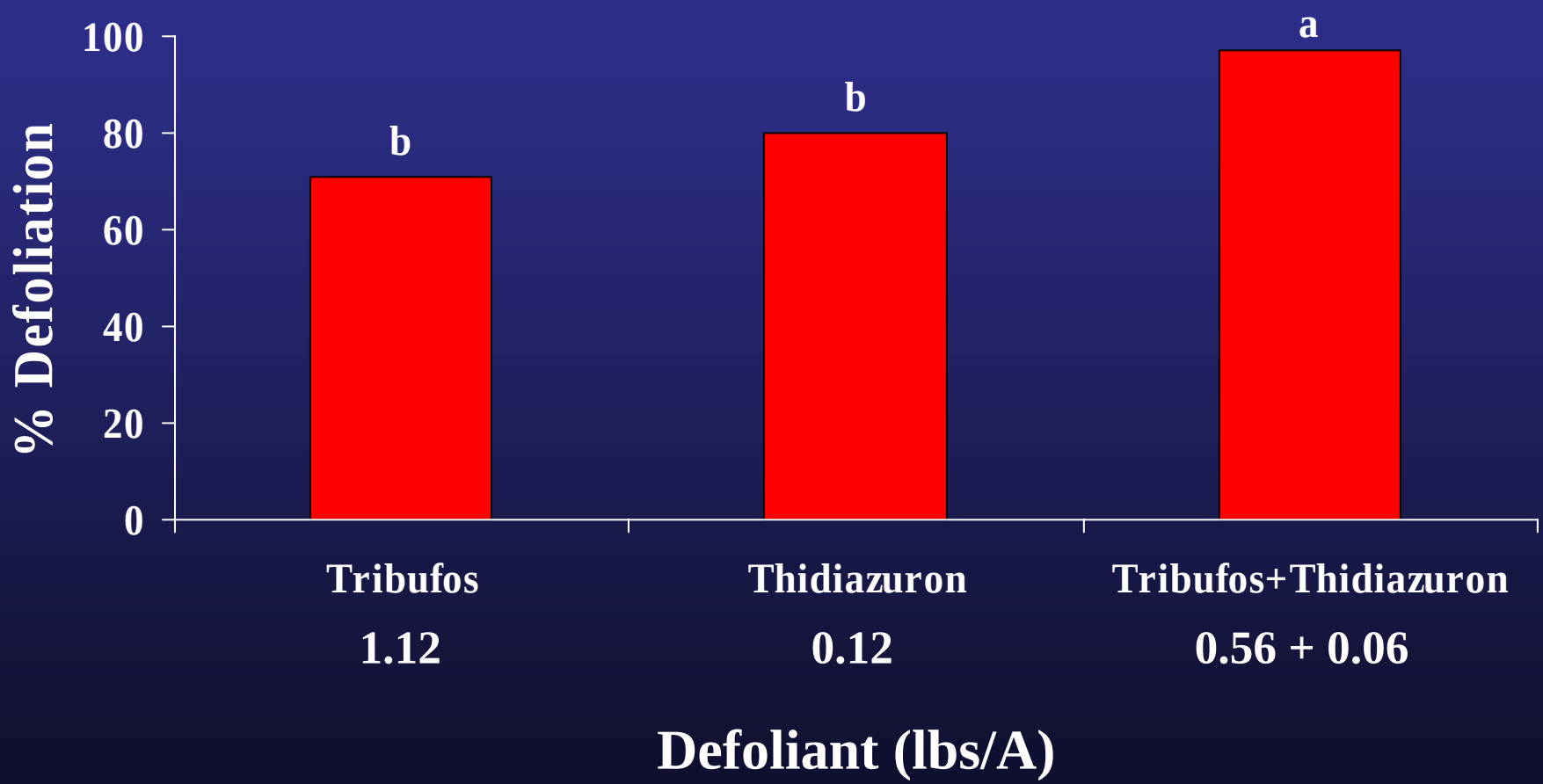
(Snipes and Wills, 1994)

Use of Diverse Chemistry

- Likened to the use of differing modes of action of herbicides to enhance weed control
- Allows for lower use rates
- May increase the probability of consistent responses

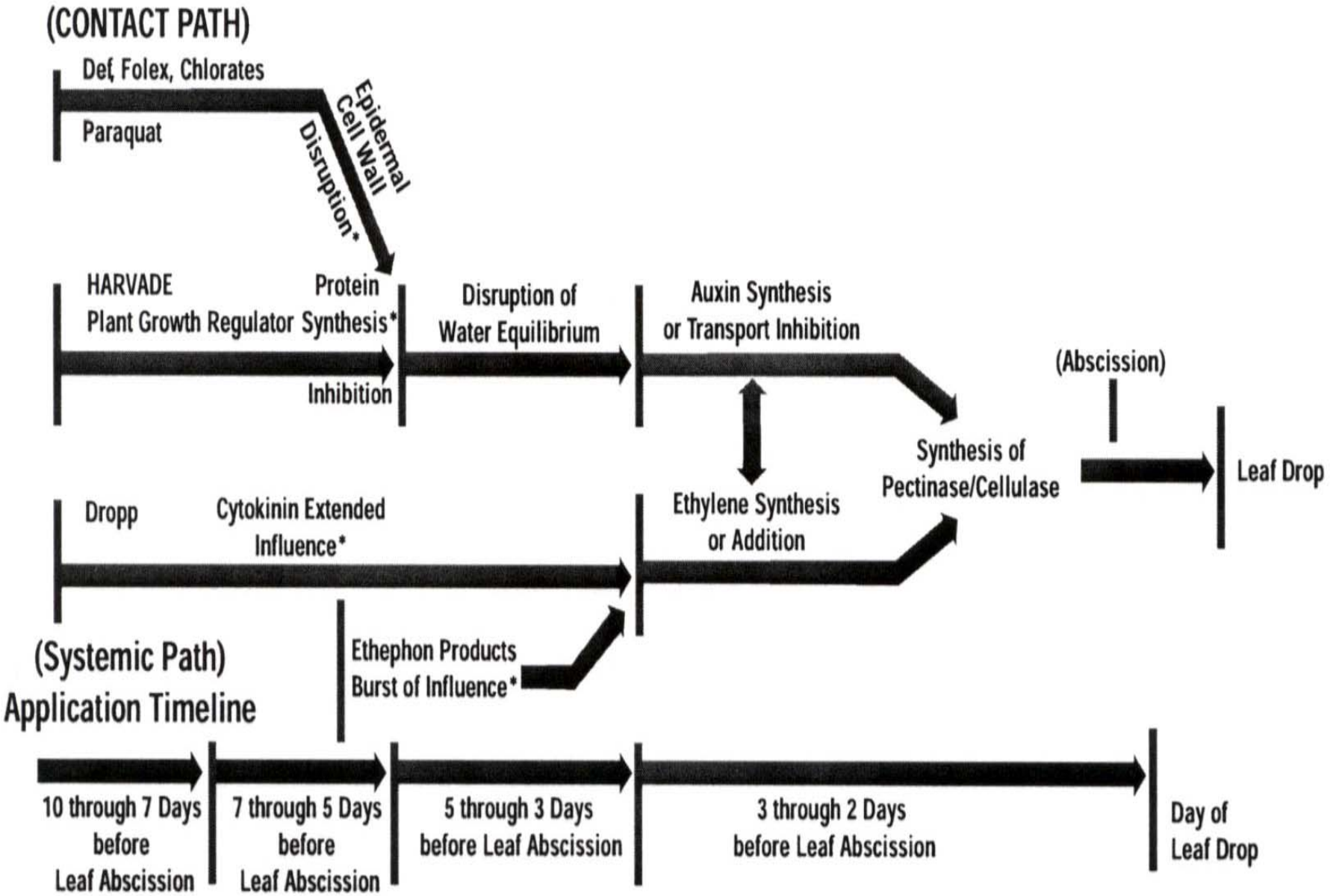
Mixtures of Chemistry

Lower Use Rates

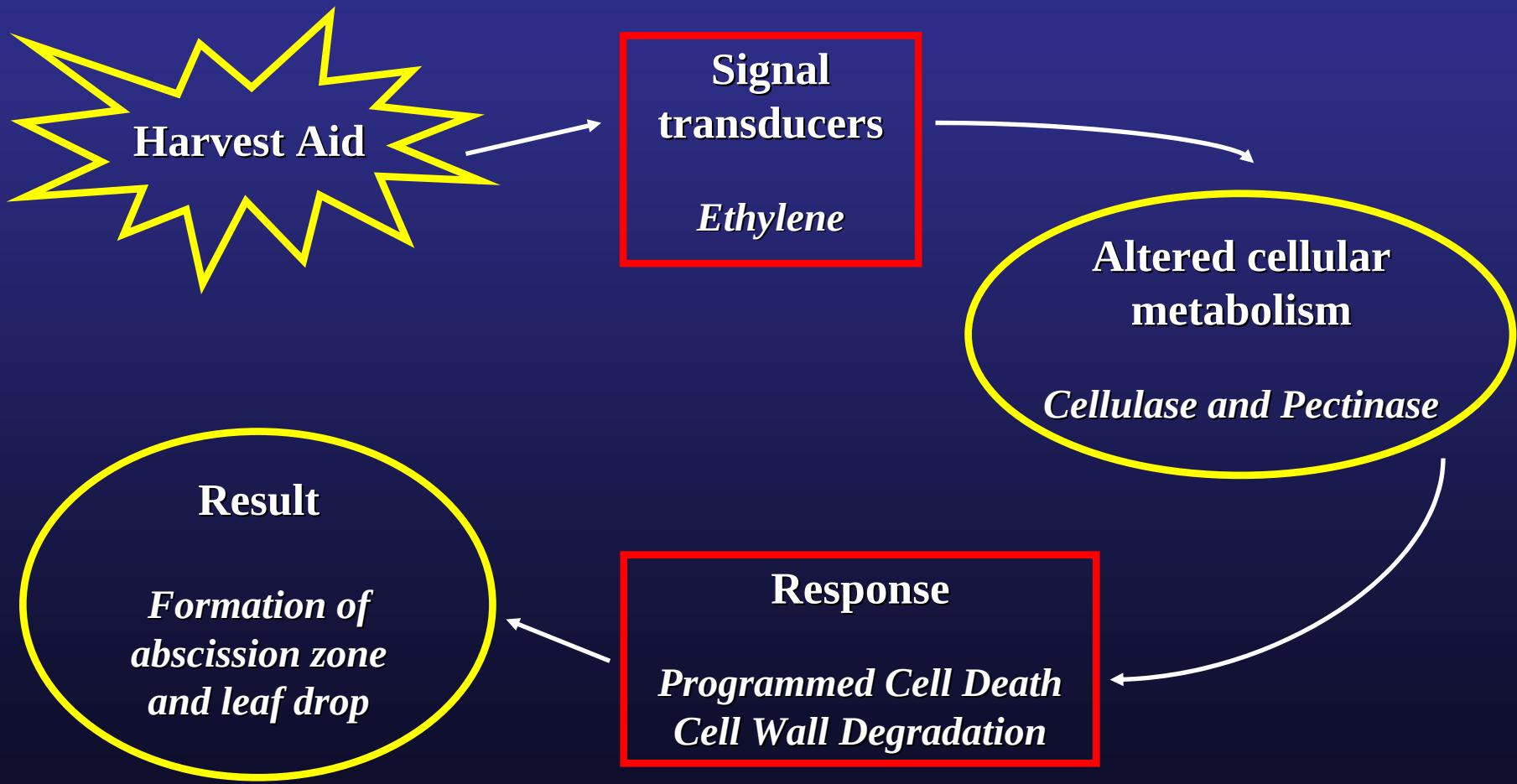


(Snipes and Cathey, 1992)

HARVEST AID ACTION



Cascade Effect



How to Prepare a Crop for Harvest

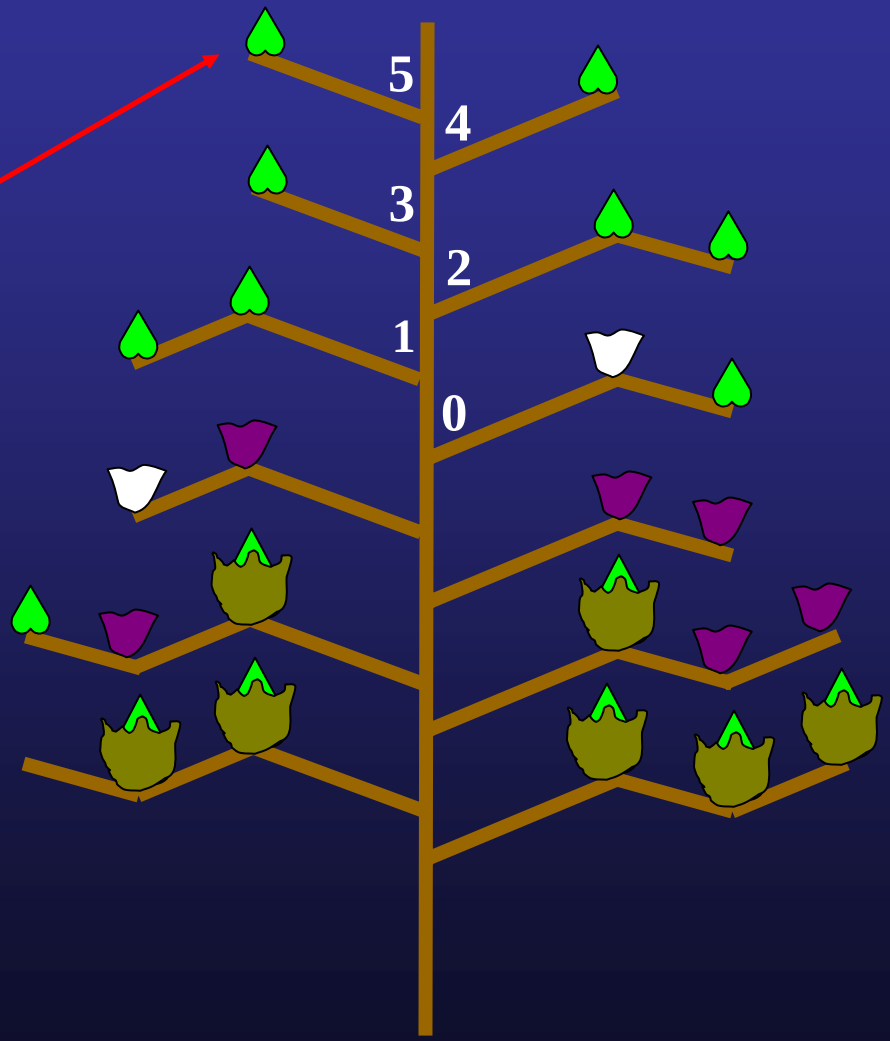
- Preparation is a season-long process
- Begin with timely uniform stand establishment
- Include adequate but not excessive nitrogen fertilization
- Development of adequate plant structure
- High retention of early set fruit
- Avoidance of late season irrigation
- Use other management practices that contribute to crop earliness
- Uniform Cutout

Support of Cotton 'Cutout'
Physiological Maturity

- Defined as NAWF = 5
  (Bourland, Phillips, and Tugwell, 1986)
- Crop maturity can be defined as the flowering date of the last 'effective' boll population
  (Bourland et al., 1991)
- Once NAWF = 5…the number of flowers needed to produce 1 lb. of seedcotton increases dramatically (Oosterhuis et al., 1993)
- At NAWF = 5…95% of all 1st pos. harvestable fruit are established
  (Kerby and Hake, 1996)

Cotton Cutout
NAWF = 5

Last effective boll contribution to yield



When to apply Harvest Aids?

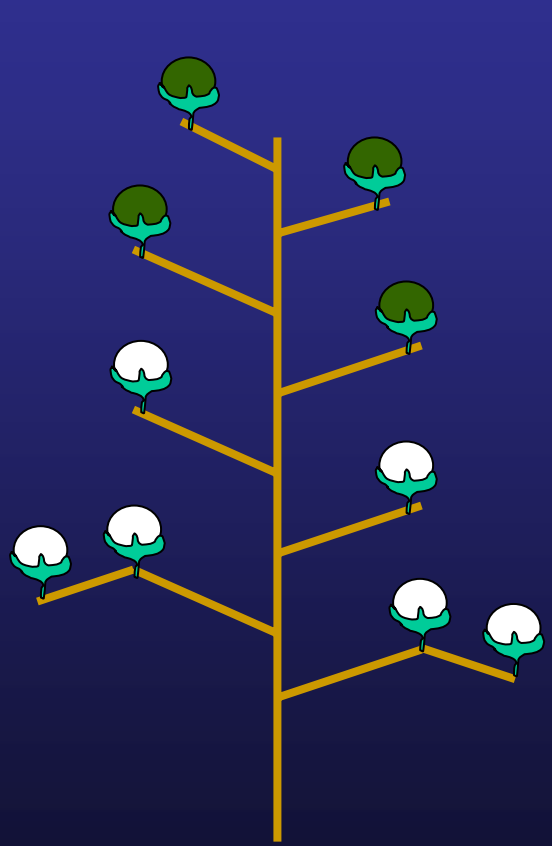
Sharp Knife Test

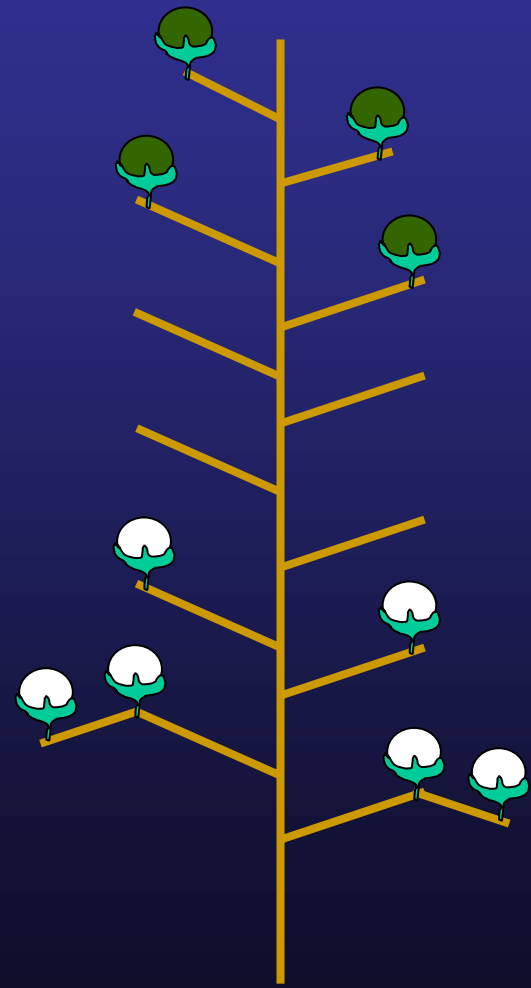
- Position dependent
  - Proximal
  - Distal
- Observance of ‘Black Layer’
- Variable results

Percent Open Bolls

- Percent open bolls
  - 60% open bolls
- Accurate counts of all fields and areas

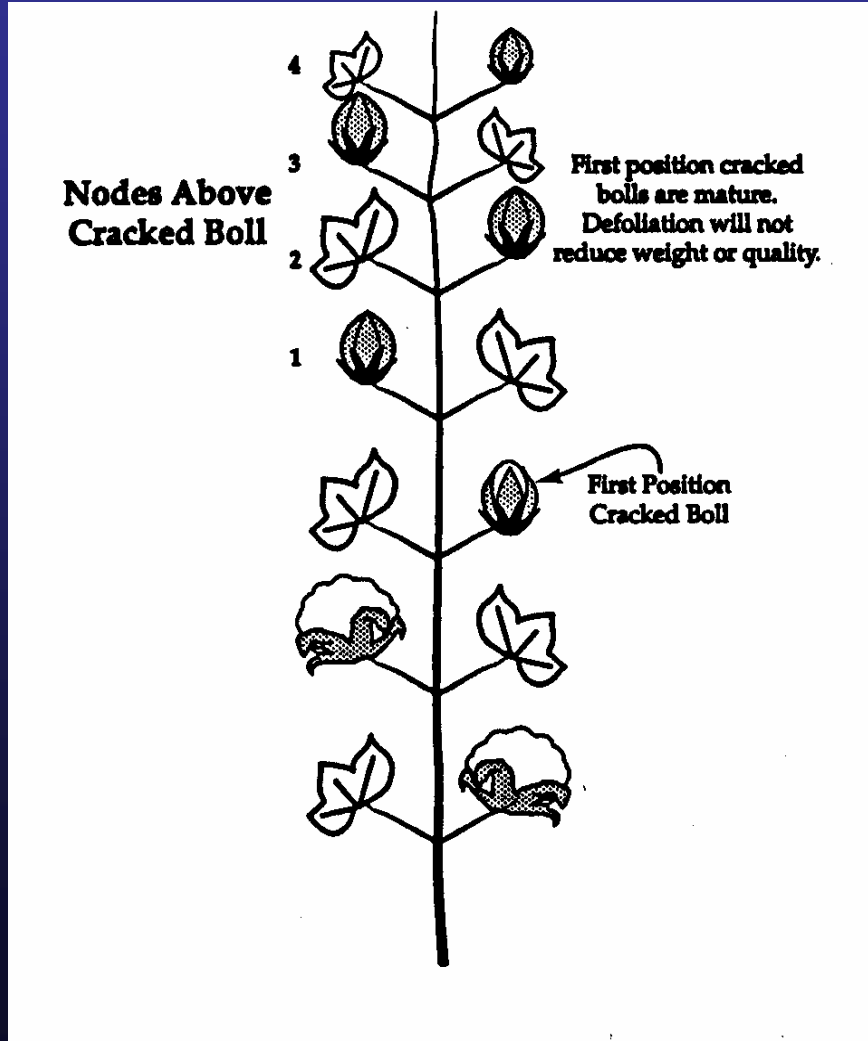
Percent Open Boll - Problems





Nodes Above Cracked Boll

- Nodes Above Cracked Boll (NACB)
  - NACB = 4
- Accurate counts of all fields and areas



Accumulated Heat Units

- Determine physiological maturity
  - Accumulation of Growing Degree Days (DD60s) or Heat Units
  - Cessation of Insecticide applications (350 HU)
    (Bagwell and Tugwell, 1992; Karner and Goodson, 1998)
  - Defoliation of cotton
    (850 HU)
    (Arkansas group / Cotman)
- Less time consuming
- Reduced scouting


650 HU


750 HU

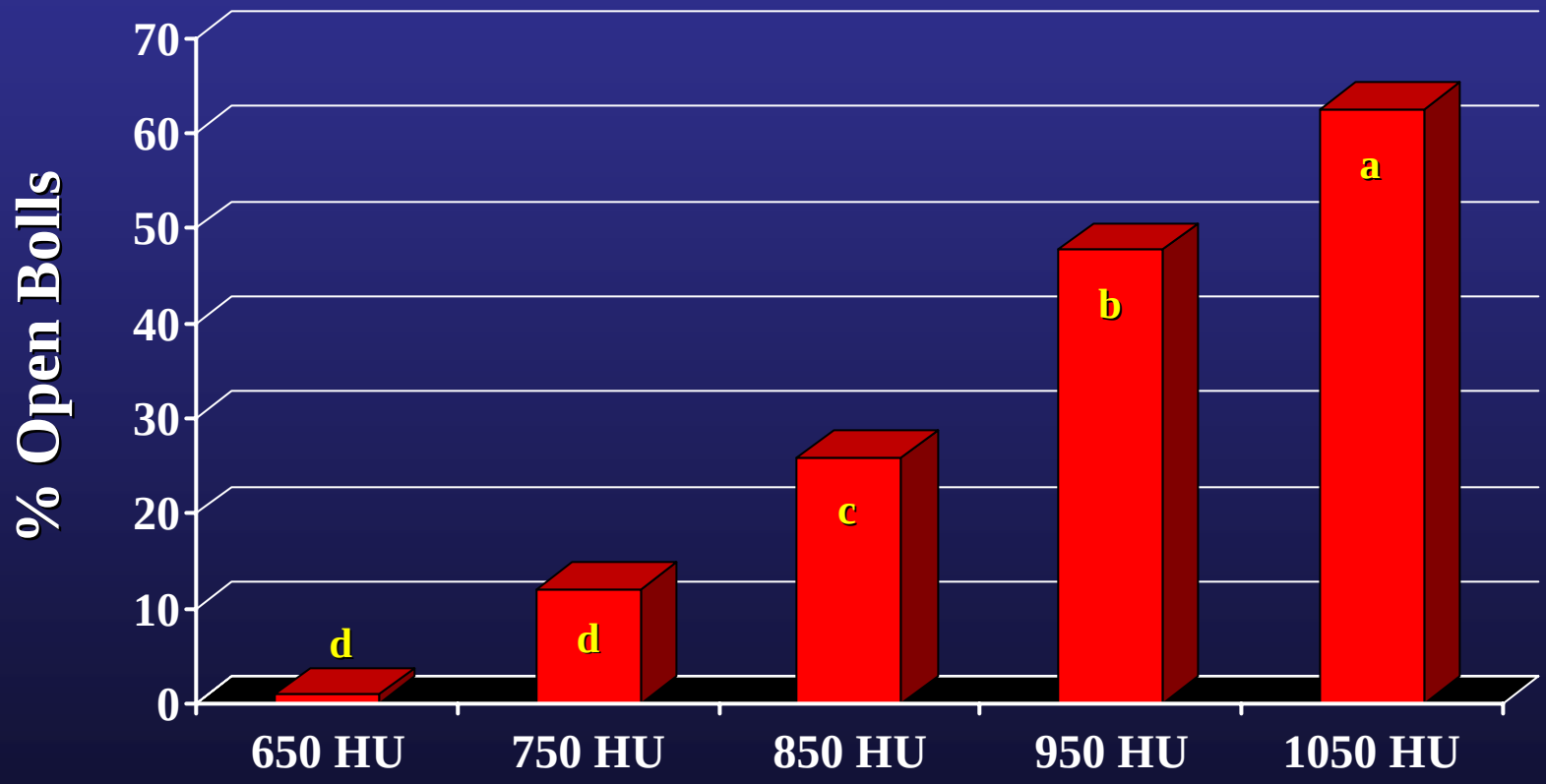

Problems: 650 & 750 HU


850 HU


950 HU


1050 HU

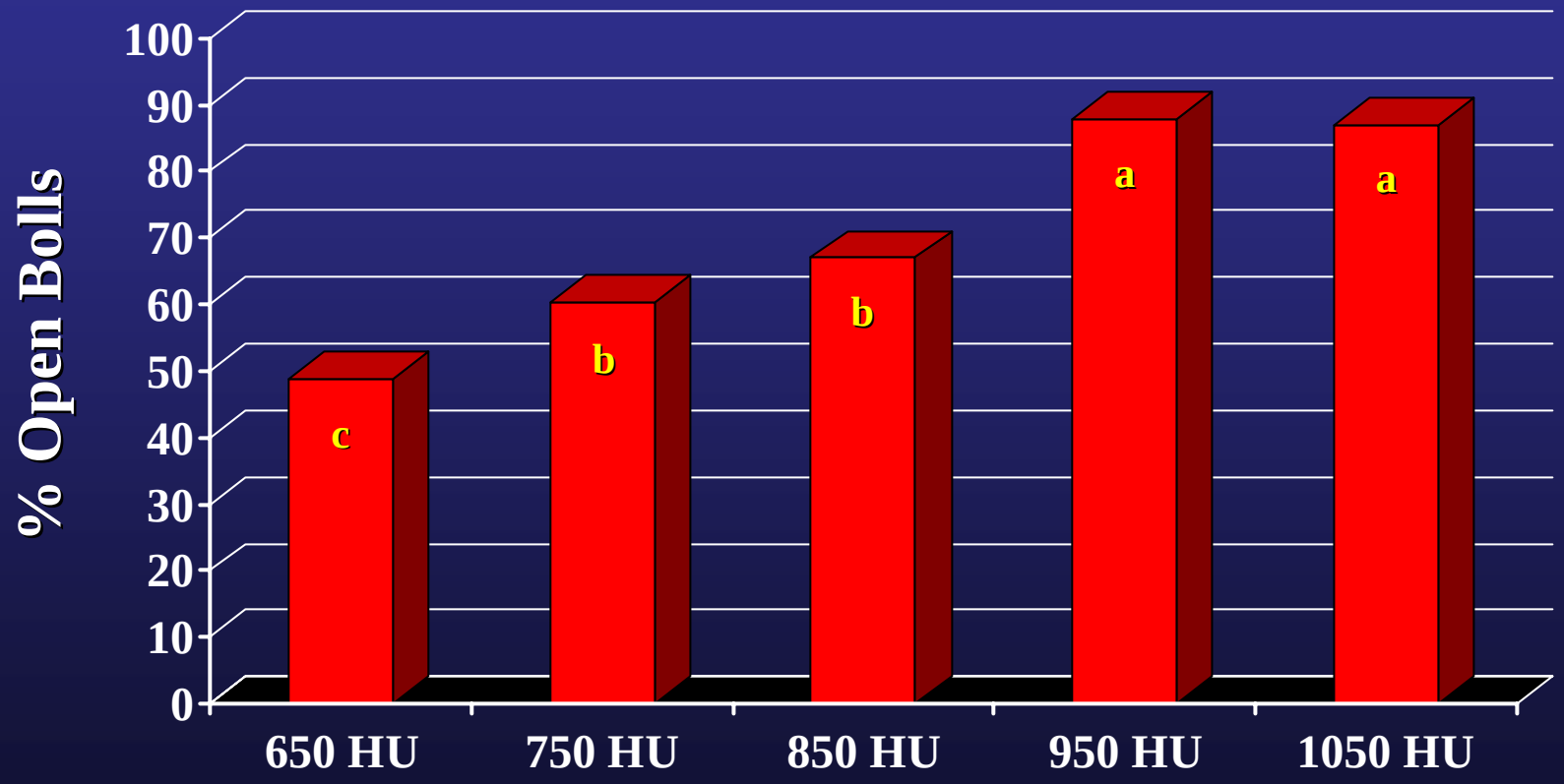
Open Bolls – DOT



Witten and Cothren, 2000

Pr>f 0.0001

Open Bolls – 14 DAT



Witten and Cothren, 2000

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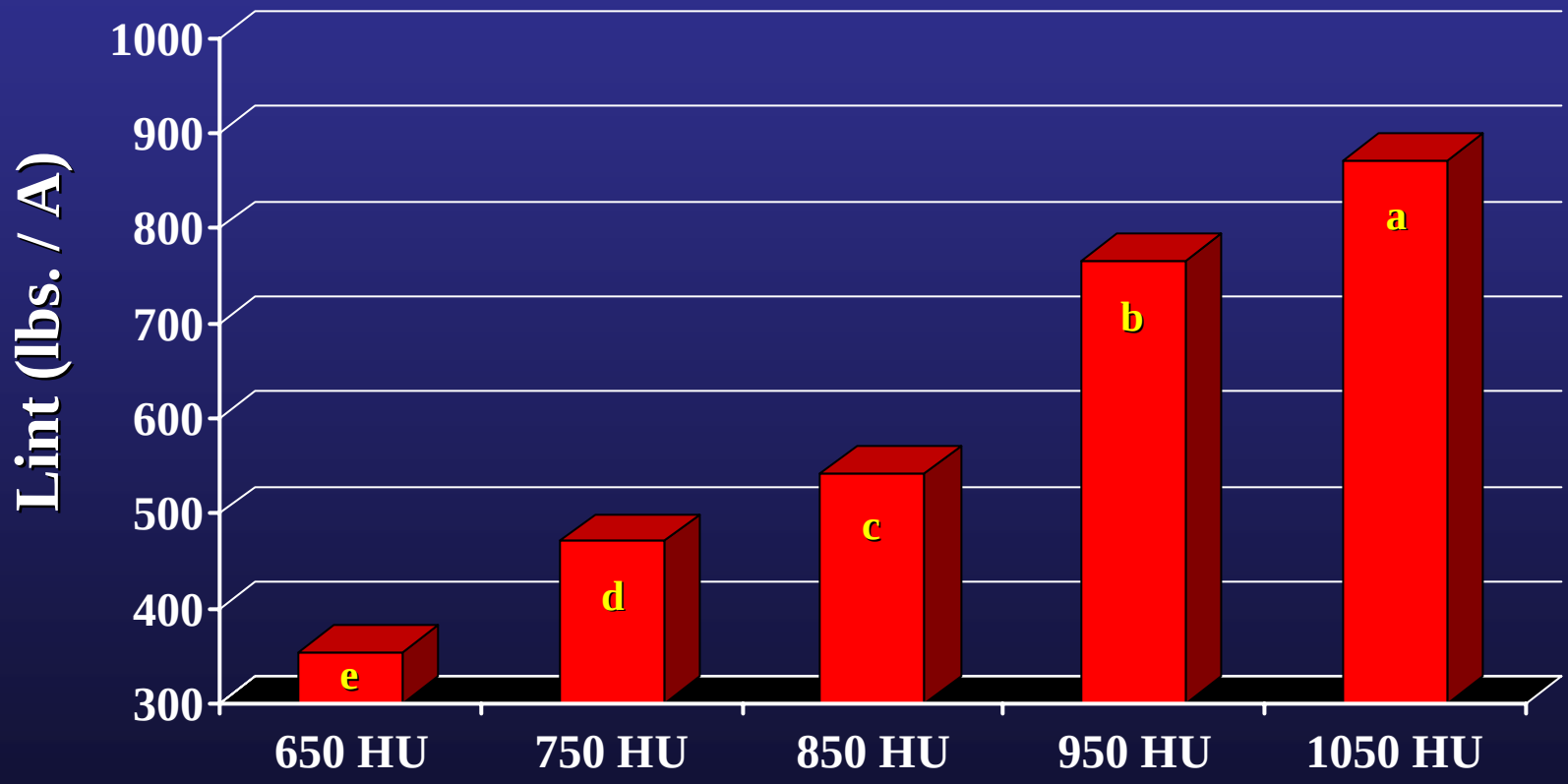
Yield



Witten and Cothren, 2000

Pr>f 0.0001

Establish Your Defoliation Needs

- Removal of mature leaves
- Removal of juvenile foliage
- Regrowth inhibition
- Boll opening
- Weed and vine desiccation
- Harvest scheduling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