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)

<table>
<thead>
<tr>
<th>Stage of growth</th>
<th>Days</th>
<th>Accum. Days</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting to emergence</td>
<td>5-20</td>
<td>.</td>
</tr>
<tr>
<td>Emergence to 1st square</td>
<td>27-38</td>
<td>45</td>
</tr>
<tr>
<td>Square to 1st bloom</td>
<td>20-27</td>
<td>68</td>
</tr>
<tr>
<td>1st bloom to open boll</td>
<td>45-55</td>
<td>118</td>
</tr>
<tr>
<td>Late bloom to open boll</td>
<td>55-70</td>
<td>128</td>
</tr>
<tr>
<td>Growing season</td>
<td>120-170</td>
<td>.</td>
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</table>
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:

\[
\frac{T_{\text{max}} + T_{\text{min}}}{2} - T_{\text{base}}
\]

- \(T_{\text{max}}\) = daily maximum temperature (°F)
- \(T_{\text{min}}\) = daily minimum temperature (°F)
- \(T_{\text{base}}\) = base temperature of 60 °F
# Cotton Growth (Heat Units)

<table>
<thead>
<tr>
<th>Stage of growth</th>
<th>DD60s</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting to emergence</td>
<td>45-130</td>
</tr>
<tr>
<td>Emergence to 1&lt;sup&gt;st&lt;/sup&gt; square</td>
<td>480-530</td>
</tr>
<tr>
<td>Emergence to peak bloom</td>
<td>850-1625</td>
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<tr>
<td>Emergence to 1&lt;sup&gt;st&lt;/sup&gt; open boll</td>
<td>1690-2050</td>
</tr>
<tr>
<td>Emergence to 60% open boll</td>
<td>2550-4600</td>
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</table>
## Heat Units (DD60's)

**College Station**

<table>
<thead>
<tr>
<th>ACCUMULATED DD60's</th>
<th>1997</th>
<th>1998</th>
<th>1999</th>
<th>2000</th>
<th>Average</th>
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<tbody>
<tr>
<td>Planting to Harvest</td>
<td>2830</td>
<td>2812</td>
<td>2963</td>
<td>2998</td>
<td><strong>2901</strong></td>
</tr>
<tr>
<td>EB to Defoliation</td>
<td>1526</td>
<td>1404</td>
<td>1566</td>
<td>1432</td>
<td><strong>1482</strong></td>
</tr>
<tr>
<td>Defoliation to Harvest</td>
<td>343</td>
<td>328</td>
<td>373</td>
<td>360</td>
<td><strong>351</strong></td>
</tr>
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</table>
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)
• 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

Auxin

Ethylene

Hormone Production Slows
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
• 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

P680* → PQ → cyt b → PC → paraquat

P700* → Fd → NADPH → NADP
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

Reactive oxygen species
\( (O_2^-, H_2O_2, OH^-, O^+) \)

Ozone, Drought, Pathogens

Senescence

Harvest Aids / Herbicides

Wounding

Intense Light

Excessive Heat or Cold

Heavy metals

Root nodulation

Oxidative stress
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 < 60°F and daytime temp < 75°F 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

<table>
<thead>
<tr>
<th>Defoliant</th>
<th>% Defoliation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tribufos</td>
<td>b</td>
</tr>
<tr>
<td>1.12</td>
<td></td>
</tr>
<tr>
<td>Thidiazuron</td>
<td>b</td>
</tr>
<tr>
<td>0.12</td>
<td></td>
</tr>
<tr>
<td>Tribufos+Thidiazuron</td>
<td>a</td>
</tr>
<tr>
<td>0.56 + 0.06</td>
<td></td>
</tr>
</tbody>
</table>

(Snipes and Cathey, 1992)
Cascade Effect

Harvest Aid

Signal transducers
- Ethylene

Result
- Formation of abscission zone and leaf drop

Response
- Programmed Cell Death
- Cell Wall Degradation

Altered cellular metabolism
- Cellulase and Pectinase
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
Problems: 650 & 750 HU
Open Bolls – DOT

Witten and Cothren, 2000

Pr>f 0.0001
Open Bolls – 14 DAT

Witten and Cothren, 2000

Pr>f 0.0001
Yield

Lint (lbs. / A)

Pr > f 0.0001

Witten and Cothren, 2000
Establish Your Defoliation Needs

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