CottonInfo

Defoliation

OPTIMISING YOUR END OF SEASON MANAGEMENT

Best Practice

Defoliation

Optimising your end of season management

Defoliation is one of the most miraculous but least thought about management actions that we undertake in a cotton crop.

Although cotton's primary harvest aids (Thidiazuron and ethephon) have been in use for over 40 years, how they work and interact with the crop is often not well understood. Ensuring the efficacy of harvest aid products will help maximise harvested yield and reduce leaf trash contamination in modules.

Preparing a cotton crop for harvest involves two distinct but related physiological processes: defoliation (leaf removal) and dehiscence (boll opening).

This harvest preparation and defoliation guide will help you to better understand:

- How defoliation and boll opening works.
- Important steps for harvest preparation before you defoliate.
- The impact of environment and crop factors on harvest aid performance.
- The mode of action for defoliants, boll openers and desiccants.
- Crop maturity for timely harvest aid application.
- How to improve defoliant application efficacy.

Taking a Look Inside the Plant During Defoliation & Boll Opening

Whether or not a cotton crop is in the mood to undress is a question of hormones.

Plant growth and development is controlled by naturally produced internal hormones:

- Growth promoters (juvenile hormones – auxins, gibberellins and cytokinins); or,
- Growth inhibitors (maturing hormones – abscisic acid and ethylene).

The plant's hormonal balance, which is influenced by the environment, determines growth responses. Growth-promoting hormones are ascendant during crop growth before receding as maturity is reached. At this stage growth inhibitors (particularly abscisic acid) increase, encouraging ripening and senescence.

Ethylene (normally a precursor for initiating abscission) is produced both by growing AND senescing plant tissues. While the crop is healthy and actively growing, the presence of auxin balances the impact of ethylene and the shedding of structures is not normally observed (this partly explains why crop stress that temporarily arrests growth can result in fruit shedding). It is only when the juvenile hormones decline with plant ageing that ethylene becomes a trigger for abscission and senescence.

Why Does this Matter?

Our primary harvest preparation tools (thidiazuron and ethephon) promote and increase the level of ethylene in the plant which in turn hastens leaf defoliation and boll dehiscence. If the plant is still trying to actively grow, the growth-promoting hormones counteract the ethylene. Therefore, crops that are not senescing or experiencing regrowth are more difficult to defoliate.

Preparing the Crop for Harvest

Ideally cotton crops should be mature and naturally senescing when harvest aids are applied, and the environment warm enough to not impede the hormonal processes that underpin abscission. Crop management including sowing date, the setting of last effective flowers or scheduling of final irrigation should aim to achieve this objective.

Influence of Temperature

Defoliation and boll opening is a living biological, day degree driven process.

Successful defoliation requires sufficient warmth to enable the plant's internal hormone mechanisms to complete this process. If conditions are too cold (average minimums below 12°C), both the rate of response and efficacy of applied harvest aids will be markedly reduced.

When determining last effective flower dates ensure you factor in enough season length to enable leaf drop and boll opening before conditions become cold. Just as early season crop growth and development is delayed by cold, so too are responses to hormonal defoliants and boll openers. Temperatures across all regions except CQ fall dramatically from April onwards and enter nightly cold shock zone from May (Table 1). Manage crop cut-out and setting of last effective flowers to ensure boll maturation occurs in time to start defoliation before the end of April – See ACPG. Commencing defoliation in May will still work, but the process will take longer and likely require additional applications, increasing both the cost and toxic load of defoliant into the immediate environment.

Table 1. Mean monthly maximum and minimum temperatures for a selection of regions. Conditions during May in all regions except Emerald will greatly impact defoliation performance and duration. The second smaller value depicts the drop in temperature from the previous month.

	MARCH		APRIL				MAY				JUNE			
	↑ Max	↓ Min	↑ Max		↓ Min		↑ Max		↓ Min		↑ Max		↓ Min	
Emerald	32.8	20.5	30.0	-2.8	17.0	-3.5	26.4	-3.6	13.1	-3.9	23.4	-3.0	10.3	-2.8
Dalby	30.3	16.6	27.3	-3.0	12.5	-4.1	23.3	-4.0	8.2	-4.3	20.1	-3.2	5.5	-2.7
Goondiwindi	31.9	17.7	27.8	-4.1	12.9	-4.8	23.2	-4.6	8.7	-4.2	19.5	-3.7	5.8	-2.9
Moree	31.1	17.4	27.3	-3.8	12.8	-4.6	22.5	-4.8	8.3	-4.5	19.0	-3.5	4.6	-3.7
Narrabri	30.9	16.7	26.9	-4.0	12.3	-4.4	22.4	-4.5	7.4	-4.9	18.5	-3.9	5.8	-1.6
Warren	29.4	15.8	24.6	-4.8	11.3	-4.5	19.9	-4.7	7.2	-4.1	15.5	-4.4	3.3	-3.9
Hay	29.6	14.6	24.7	-4.9	10.0	-4.6	19.7	-5.0	6.4	-3.6	15.9	-3.8	3.9	-2.5
Griffith	28.8	14.3	24.	-4.7	10.3	-4.0	19.2	-4.9	7.0	-3.3	15.5	-3.7	4.5	-2.5

Considering Other Plant Factors

Defoliation is a living process that very much depends on the mood of the cotton plant.

Crops that have naturally begun to senesce respond much better to applied defoliant and boll openers. You can enhance your crop's response by :

- Setting a high boll load. This prevents spare assimilate (the plant's internal energy supply) from being redirected to regrowth that unhelpfully increases internal growth hormones. Servicing a high boll load also depletes the canopy of stored leaf nutrients which also promotes senescence. Crops that excessively shed fruit due to stress factors at cut-out and fail to achieve a high boll load are more likely to regrow as lower bolls open, stifling natural senescence.
- Managing soil moisture leading up to crop maturity. Aim to reach the irrigation refill point when defoliation is due to commence. Too much plant stress due to dry soil conditions may hinder chemical uptake whilst excess soil moisture will encourage regrowth and create picking-related soil compaction challenges. The refill point balances these factors.
- Avoiding crops that are still 'navy green' at defoliation. Access to and uptake of excess nitrogen encourages the plant to grow rather than senesce. When combined with untimely rainfall, crops with excess nitrogen can be very tenacious about holding onto their leaves.

Preparing for Harvest

Harvest preparation entails management of two physiological processes: Defoliation and dehiscence.

Defoliation (leaf drop) is a natural physiological process that we induce through crop management and application of defoliant to promote rapid leaf abscission (separation) layer development and leaf drop. Defoliation differs from desiccation in that the leaf does not dehydrate and the water conducting tissue remains active until the leaf separates and drops. The weight of the green leaf should assist taking it to the ground reducing the likelihood of leaf trash contamination of cotton during picking. Desiccation occurs when the leaf suffers rapid trauma (frost or herbicides), killing the leaf blade before the formation of the abscission layer at the base of the leaf petiole, meaning the dead leaf may remain attached to the plant.

Boll dehiscence and carpel flaring is a largely mechanical process requiring dehydration of the entire boll. Just prior to opening, the vascular elements form a corky layer at the base of the pedicel that attaches the boll to the plant which impedes water movement into the boll. Simultaneously, inner layers of the vascular elements become tangentially arranged to the carpel, with subsequent dehydration causing the boll to dehisce instead of merely shrinking. Just like wet clothes on the line, bolls will take longer to dry out and open when conditions are cool with increased dew.

Harvest Aid Modes of Action

Despite the advent of mechanical picking since the 1950s requiring augmented defoliation, the choices of harvest aids available in Australia are narrow.

Harvest aid chemicals can be classified into three main categories by their action on the plant:

1. **Defoliants** (e.g. thidiazuron) impact plant hormonal balances to enhance natural plant senescence and cause the leaves to fall off. Defoliant activity is highly temperature dependent.
2. **Desiccants** (e.g. sodium chlorate, paraquat) normally dehydrate and kill the leaf within one to several days. Desiccants are often applied after defoliants to remove the remaining leaves and/or kill juvenile growth from the mainstem and lateral branches.
3. **Boll openers/conditioners** (e.g. ethephon) are often applied in tandem with defoliants to enhance boll opening and improve defoliation efficiency. These products release ethylene, increasing ethylene synthesis within the plant to promote abscission.

Timing Your Harvest Aid Application

Aim for the Goldilocks period of 'just right': too soon and lint yield and quality are put at risk, too late and your crop is exposed to the weather unnecessarily.

There are three accepted methods for determining crop maturity and the appropriate timing for harvest aid application:

1. **Percentage open bolls** as the name suggests, this method relies on counting the number of open verses closed bolls with 60% open as the trigger point for action. However, this method is time consuming in high yielding crops.
2. **Nodes above cracked boll (NACB)** is a quick method that works well, particularly for relatively uniform crops, and is popular for scheduling first pass defoliation timing. It relies on the predictable relationship between the rate of boll opening and boll maturation: that the first position (P1) green bolls on the consecutive next 4 nodes above the upper-most cracked P1 bolls are physiologically mature and therefore will not be harmed by application of harvest aids. Application can therefore be timed to coincide the majority of leaf drop with the opening of the last pickable boll. This ensures a timely pick without compromising lint yield or quality.
3. **Boll cutting** is useful as a secondary confirmation of boll maturity, particularly in crops where boll setting has been disjointed due to uneven late season boll set. The maturity of cut bolls can be quickly determined by examining the seeds. In mature bolls, the seeds will have a fully formed embryo (no jelly) and a darkening of the seed coat (see picture).

The objective is to commence defoliation as soon as possible without compromising lint yield and quality. Defoliating too early can cause immature boll shedding and fibre quality disorders such as neps. Defoliating too late exposes the crop to field conditions for longer than necessary increasing the risks of rainfall impacting lint quality of the picking process. In most situations, if a crop is not quite mature, allowing an extra week until harvest-aid application is unlikely to result in a major picking delay as crops that are defoliated prematurely can often experience a longer defoliation period.

Non-plant Factors to also Consider when Pulling the Trigger

A range of other factors should also be taken into consideration before commencing harvest aid application.

Weather conditions – it may be better to commence defoliation up to a week earlier if that avoids a cold snap. Similarly, delaying defoliation to after forecast rain can also be prudent.

Avoiding a sticky situation - earlier defoliation commencement can also be a prudent strategy if facing the threat of late season honey dew contamination from silver leaf whitefly or aphids.

Picker availability – Regrowth presents an increasing risk if a crop is not picked soon after defoliation is complete. Open bolls also become more susceptible to lint falling to the ground (tagging out) after the leaves are removed. Aim to coincide harvest maturity with picker availability and capacity.

Which Harvest Aid to Use?

Because harvest aid selection depends on a range of factors there is a common perception that crop defoliation is an art rather than a science.

Key factors when selecting a harvest aid chemical include:

- **Plant status** – yield potential, level of crop senescence, canopy size, remaining need for boll opening and presence or extent of regrowth.
- **Prevailing field and weather conditions** – soil moisture, average temperatures, likelihood of rainfall and frost.

Thidiazuron and **Ethephon** (both of which cause an increase in ethylene evolution) are the two main products used for harvest preparation. Thidiazuron is also available as a commercial blend with diuron which offers increased efficacy under cool conditions. Second to these are the desiccants e.g. sodium chlorate and diquat. Thidiazuron and ethephon can be used separately or in combination, however label directions pertaining to how and when the two products should best be combined is limited. Current thidiazuron labels provide no information regarding the addition of ethephon as a tank mixture despite industry research showing clear benefits. Ethephon labels refer to the addition of thidiazuron as a tank mix being beneficial for product response but mixing rate guidance is not provided.

When considering how to use these products for harvest preparation it is useful to examine the characteristics of each product in relation to a range of defoliation challenges and factors (Table 2).

In a crop where bolls are largely open, thidiazuron alone may be sufficient for harvest preparation. Research literature suggests that the addition of ethephon significantly improves leaf defoliation in contrast to thidiazuron applied alone, so in a crop with significant regrowth following rainfall, adding ethephon with thidiazuron is likely to assist harvest preparation by both removing recent regrowth and suppressing continuing regrowth (as long as temperatures remain warm). As the process of defoliation is metabolic, temperature plays a significant role in crop response. Consecutive minimum temperatures below 12°C may slow plant metabolism to a point that these harvest aids become largely ineffective.

An extensive study on harvest aid combinations conducted in the US across multiple environments found that the largest improvement in boll opening in cotton treated with combinations containing ethephon occurred when post application temperatures were cool (mean 11.3°C min and 25.6°C max) and the addition of ethephon had little influence in warmer conditions (17.7°C min and 31.4°C max).

Both thidiazuron and ethephon are non-systemic and have no vapour action and therefore product performance is highly dependent on coverage. If there are many unopened bolls lower in the canopy, the addition of ethephon for these bolls would be better targeted during a second pass where direct contact with spray deposits is more likely.

Desiccants are contact activity products that rapidly kill the leaf. For this reason, they should generally be avoided as the dead leaves generally remain attached to the plant and therefore will increase the trash content of harvested lint. Desiccants are really a product of last resort when hormone based harvest aids have failed to work (e.g. under very cold conditions). Desiccants can play a role in 'burning off' regrowth following regular defoliation where harvesting might be delayed. Desiccants will not prevent new regrowth and are generally registered for ground based application.

Table 2. Harvest aid active ingredients and characteristics

ACTIVE INGREDIENT TRADE NAME EXAMPLES	PRODUCT TYPE	RAINFAST PERIOD	PRODUCT IMPACT ON				RISK OF LEAF FREEZING
			Mature leaves	New growth	Re-growth prevention	Boll opening	
Thidiazuron Dropp, Escalate, TDZ	Defoliant	24 hrs	✓ Excellent	✗ Poor	✓ Excellent	✗ Poor	✓ Unlikely
Do not use when night temps fall below 12°C and/or mean day/night temps fall below 18°C. Mixing with glyphosate could cause leaf freezing.							
Thidiazuron + Diuron Thi-Ultra, Dropp Ultra MAX, Escalate Ultramax	Defoliant	24 hrs.	✓ Excellent	✗ Poor	✓ Excellent	✗ Poor	😐 Possible
Can be used in all conditions as well as where thidiazuron alone is unsuitable (i.e. night temps fall below 12°C and/or mean day/ night temps fall below 18°C). Use higher rate for denser canopies. Crops with moderate to high levels of nitrogen remaining in the soil are more prone to leaf freezing than crops that have depleted soil nitrogen. Do not apply if a total of 50 mm of rain is expected within 3 days of application.							
Pyraflufen-ethyl ETee, Sledge.	Defoliant	2 hrs.	✓ Excellent	😐 Fair	😐 Fair	✗ Poor	😐 Possible
Always applied as a tank mixture with other defoliants (Ethephon & Thidiazuron) and appropriate crop oils. Refer to label for specific advice. Leaf desiccation may be observed during the defoliation process. Some desiccated leaf may be retained.							
Ethephon Ethephon 900, Prep, Promote Plus	Boll Opener	8 hrs	✗ Poor	✓ Excellent	😐 Fair	✓ Excellent	✓ Unlikely
Use higher rates on stressed plants, heavier crops and ensure uniform coverage of bolls.							
DESICCANTS FOR REGROWTH							
Diquat 200g/L Reglone, Diquat 200	Desiccant for regrowth	1 hr	😐 OK	😐 OK	✗ No activity	✗ No activity	✗ Likely
Carfentrazone-ethyl 400g/L Hammer	Desiccant for regrowth	1 hr	😐 OK	😐 OK	✗ No activity	✗ No activity	✗ Likely
Paraquat 135g/L + Diquat 115g/L Spray Seed	Desiccant for regrowth	1 hr	😐 OK	😐 OK	✗ No activity	✗ No activity	✗ Likely
Sodium chlorate Leafex	Desiccant Defoliant		😐 OK	😐 OK	✗ No activity	✗ No activity	😐 Possible

*Desiccants will effectively kill new and mature leaves but a high proportion of foliage will remain attached causing increased lint trash. Desiccant will not prevent further regrowth.

Things to Consider Before, During and After Application

1. Application method

Both aerial and ground-based application can be used. The best method for your situation will depend primarily on row configuration, canopy density and local conditions (Table 3).

Table 3. Comparison of application methods for harvest aid application.

	AERIAL	GROUND
Timeliness	Quick application enables more ground to be treated while temperatures are suitable	Limited by ground speed
Coverage (solid plant)	Unlikely to match ground-based application, particularly in dense crops	Ability to apply larger volumes
Coverage (skip configurations)	Potential product wastage	Ability to use droppers or angled nozzle bodies to better surround the plant line, particularly on wider row spacings
Crop damage	No crop disturbance	Wheel track damage likely in closed rows*
Application limitations	Sensitive adjacent environments may pose limitations regarding some harvest aids (refer to label)	Less chance of drift

*Wheel tracks can pull cotton lint to the ground and therefore wider booms are preferable (CRDC-funded research has found that lint losses associated with wheel tracks are comparable to the additional costs associated with contract aerial application).

2. Weather conditions

Temperature, humidity and rainfall can all have a large impact on harvest aid performance. Ensure you check weather forecasts well before application to optimise the effect of the applied product(s).

- Commence crop defoliation before the likely onset of frost.
- Uptake of hormonal agents such as thidiazuron will be improved when applied during the day with higher temperatures and sunlight intensity assisting penetration of the waxy leaf surface. This is particularly relevant for crops that have grown under low humidity or moisture stress environments where leaves can develop waxier protective layers. Contact activity agents such as diquat or sodium chlorate are less sensitive to application time of day.
- Avoid application if rainfall is forecast within 24 hours.
- Higher humidity during and soon after application will assist harvest-aid chemical uptake.
- Follow thidiazuron label directions for rate vs temperature considerations.

3. Maximising efficacy during application

Applying harvest aids requires the same attention to detail when setting up your equipment and mixing product as when pesticides are used. Always adhere to label directions. Ensure your sprayer is cleaned and calibrated, and that the appropriate water quality, adjuvants and application rates are used.

- No harvest aids are systemic and therefore application coverage is key for efficacy.
- Adjuvants play an important role in enhancing the performance of thidiazuron and ethephon. Crop petroleum spray oils (PSOs) are the most commonly used adjuvants that increase surface penetration and absorption particularly under unfavourable conditions. Refer to label for directions regarding the addition of PSOs.
- Be mindful of drift and adjacent sensitive environments. Cotton harvest aid drift onto other crops and native vegetation (particularly deciduous perennial crops) can cause leaf and fruit drop.

4. Follow up applications

A single pass may be sufficient, however if additional applications are required:

- Allow sufficient time for complete crop response between application passes. The period required for leaf drop following application will vary with conditions. Re-application prior to complete leaf drop is inefficient as a significant proportion of spray deposits will be intercepted by leaves that are in the process of defoliating, taking valuable harvest aid uselessly to the ground. Re-application intervals may vary from 7-20 days with cool conditions increasing the interval required.
- Modify the ratio of subsequent thidiazuron and ethephon applications according to crop response. If mature bolls are proving difficult to open, consider a higher rate (refer to label).
- Be mindful of withholding (WHP) periods. Ethephon has a 14 days WHP between application and when picking can be undertaken.

Bollgard II® » Bollgard 3

Bollgard® Production Changes that Impact Harvest Aid Performance

Aggregated, regional means for planting and defoliation dates from Cotton Seed Distributors' variety trial program spanning 1997-2020 provide insights about farming practice changes that are likely impacting harvest preparation.

Following the introduction of Bollgard technologies both the time of sowing and commencement of defoliation have become later across all valleys with the exception of Emerald which now plant and harvest earlier following Bollgard 3 (Figures 1 & 2). Likewise, nitrogen application and yield have also increased over time.

In particular the trend towards later defoliation – which subject crops to cooler conditions combined with increased nitrogen use and yield that point to larger canopy – offers some explanation for increased reports of difficulty with crop defoliation.

Figure 1. Mean change in sowing date (days) following the introduction of Bollgard II® (2005-2015) and Bollgard® 3 (2016-2020) for CSD cultivar trial sites across regions.

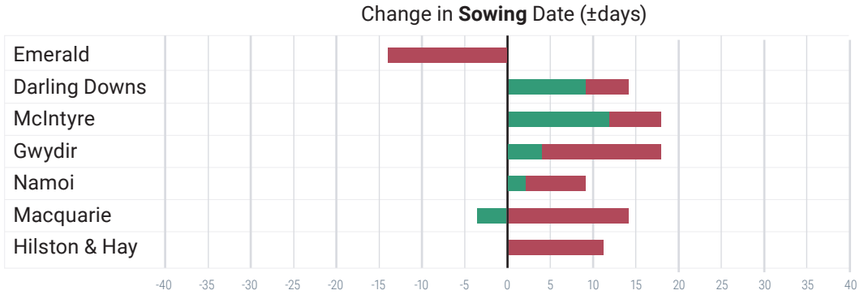
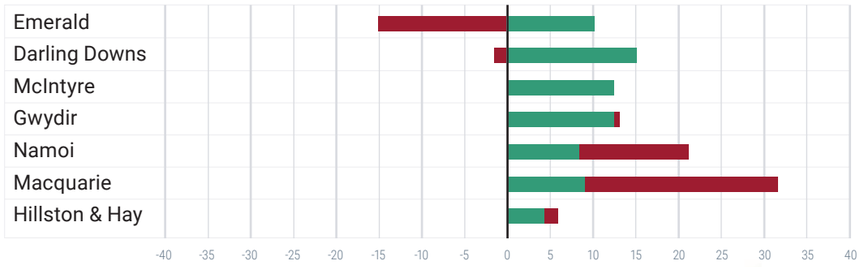


Figure 2. Mean change in defoliation commencement date (days) following the introduction of Bollgard II® (2005-2015) and Bollgard® 3 (2016-2020) for CSD cultivar trial sites across regions.



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