case study www.cottoninfo.com.au

December 2020

Managing silverleaf whitefly in Australian cotton

Silverleaf Whitefly (SLW), *Bemisia tabaci* Middle East Asia-Minor1 (MEAM1), is a major pest of cotton in Australia as they contaminate cotton lint with honeydew. Overseas they are also a key virus vector for diseases such as cotton leaf curl disease, which currently does not occur in Australia. SLW are a formidable pest to manage, having a large host range, rapid reproduction and the ability to quickly develop resistance to insecticides.

Rapid population increases can occur during hot conditions, particularly when natural enemies have been disrupted by insecticides. Ideally an Integrated Pest Management (IPM) approach that includes farm hygiene, agronomic management, conservation of natural enemies, crop sampling and strategic use of selective insecticides provides optimal control of this pest.

It is important that the Australian cotton industry upholds SLW management best practice to maintain its reputation for producing uncontaminated, high quality cotton.

Figure 1: Note absence of hairs on *Bemisia tabaci* nymph (top left) compared to presence on *Trialeurodes vaporariorum* (top right). Note the gap between the wings for *Bemisia tabaci* (bottom left) compared with overlaping wings for *Trialeurodes vaporariorum* (bottom right).

Identification & Characteristics

SLW adults are small in size (1.2mm), with white wings and creamy yellow bodies. When resting, the wings are folded back at a 'tent' like angle with a clear gap between them. Nymphs (juveniles) are pale yellow-green, scale-like insects that are found on the leaf underside (See Figure 1).

Whitefly Pests of Cotton in Australia

Other whiteflies including native *B. tabaci* and the greenhouse whitefly (*Trialeurodes vaporariorum)* can be present in cotton.

- *Bemisia tabaci* is a cryptic species complex, which means it's a collection of species, including Australian endemic, that look identical (morphologically indistinguishable) but with slightly different genetics and ecology (e.g. host range). Australian endemic whiteflies can be present in cotton, but SLW (MEAM1) has become the dominant whitefly found in Eastern Australian cotton crops.

– Greenhouse whitefly (*Trialeurodes vaporariorum)* are about twice the size of SLW. They holds their wings flat and slightly overlapping. This is a key visual difference between greenhouse whitefly and the *Bemisia tabaci* species complex. Nymphs are similar in size to *B. tabaci* but differ in appearance by having fine hairs around the margin (see Figure 1).

Exotic *Bemisia tabaci* NOT in Australia

Various other members of the *Bemisia tabaci* species complex that would be pests of cotton are present in other countries. These strains have different insecticide resistance profiles and may carry cotton leaf curl virus. As the different species cannot be distinguished without molecular testing, an unexpected control failure would be a significant cause for the concern that an exotic species may be present in that crop. If an un-expected control failure occurs, it is recommended to discuss this with industry researchers so that testing can be undertaken to rule out the presence of an exotic incursion. If you are concerned you can also call the

EXOTIC PLANT PEST HOTLINE
1800 084 881

SLW Lifecycle and Ecology

During summer the SLW life cycle from egg to adult on cotton can occur in as little as 15-18 days. This insect does not have a winter resting stage and instead survives on alternate hosts with lifecycle times taking much longer in cooler conditions e.g. , the longest winter generation time (egg to egg) may take up to 77 days in Emerald (CQ) versus 122 days in Narrabri (Nth NSW).

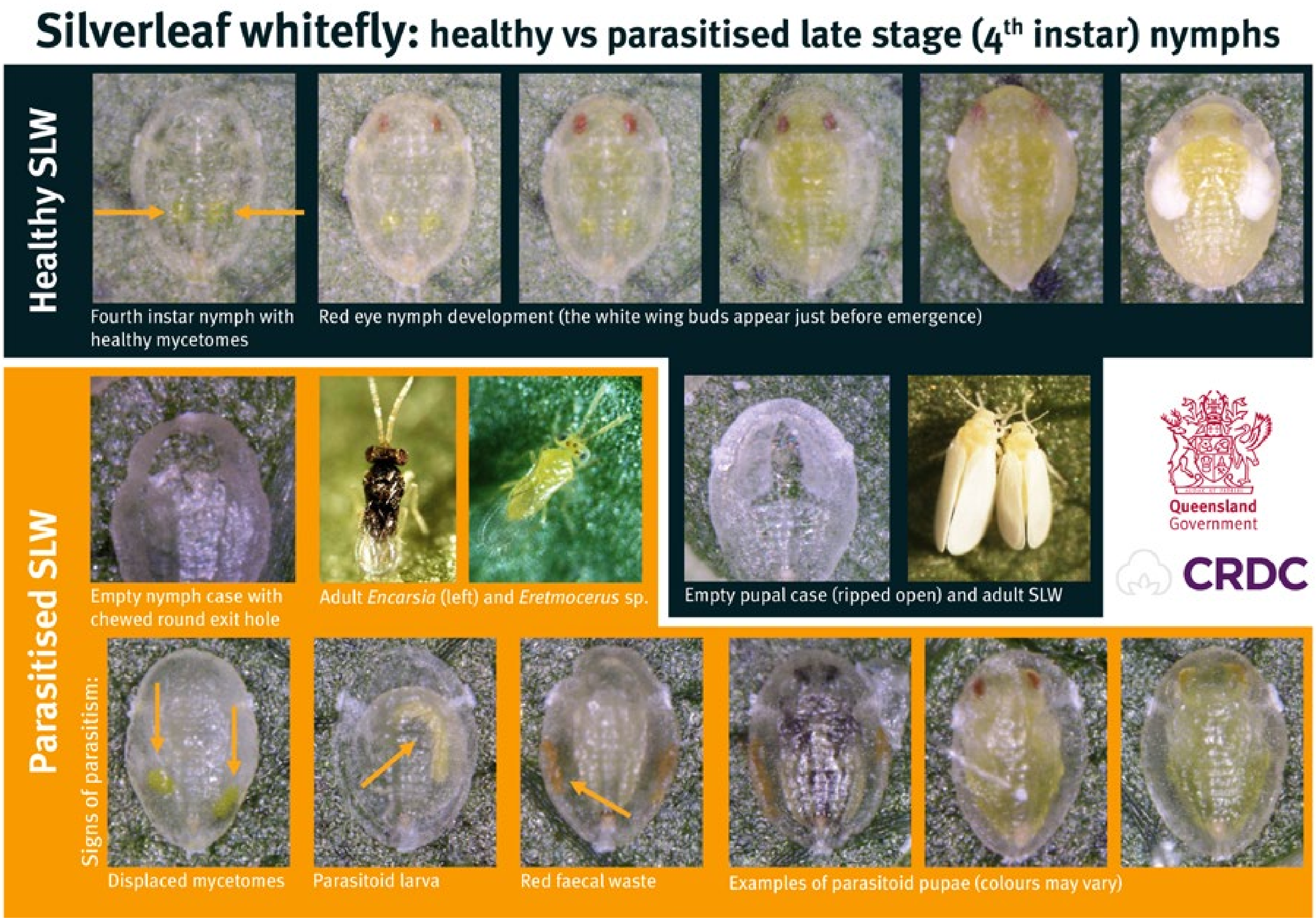

Figure 2: SLW healthy vs parasitised late stage nymphs.

Eggs

Spindle shaped eggs, approximately 0.2 mm long, are laid on the underside of leaves. Eggs are yellowish white when first laid and gradually turn brown, hatching within 6 days.

Nymphs

Upon hatching, 1st instar nymphs (crawlers) will move a small distances on the leaf to locate a suitable feeding site on which to settle. Subsequent instars (2-4) will remain in position without further movement. The late 4th instar stops feeding becoming what is termed a 'red eye nymph' (pupae) from which the adult emerges. Refer to Figure 2.

Adults

Adult mating can take place within hours of emergence with females going on to lay an average 80 - 120 eggs during an approximate 2 week lifetime. Adults are mobile, flying between plants and adjoining fields. With the aid of wind, adults can move significant distances within regions.

Honeydew production

SLW feed on the phloem vessels that transport the sugar-rich products of photosynthesis around the plant. Honeydew excretions are a by-product of this feeding. Honeydew production varies with the different life stages and status of the host plant. In general, the late instar nymphs and adult female will produce the most honeydew. Nymphs and adults feeding on a poor quality or stressed plant will produce more honeydew as they need to consume more phloem sap to maintain their nutrition levels.

Compared with aphid honeydew, that presents as a thick, wet, sticky coating on leaves and bolls that are adjacent to the aphid colony, SLW honeydew excretions are more likely to be spread throughout the plant, becoming more concentrated in the lower canopy. At first, SLW honeydew will present as "reflective speckling" on the lower canopy leaves, increasing over time (if the population is unmanaged) to a matte sheen over affected leaves and bolls, being 'dry to the touch' prior to harvest. Contaminated cotton may pass through ginning undetected, however during spinning, machinery friction can melt sugars (trehalulose) within SLW honeydew increasing costs or rendering lint un-processable. This issue is regarded as so serious by cotton processors that if a region develops a reputation for honeydew contamination, there is a risk of discounts and loss of market access. Sooty moulds, that can aid in the breakdown of honeydew (favoured by dew or high humidity), are associated with lint colour downgrade penalties.

Host range

SLW does not have an overwintering diapause stage and relies on alternative host plants to survive between seasons. When host plants are in continuous abundance throughout the year, SLW can pose more of a problem. Even a small patch of favored hosts (e.g. sow thistle) can maintain a significant pest population.

Weed hosts include; sow thistle, melons, bladder ketmia, turnip weed, native rosella, burr medic, anoda, rhynchosia, vines (cow, bell and potato), rattlepod, native jute, burr gerkin, blackberry nightshade, other Cucurbitaceae weeds, Josephine burr, young volunteer sunflowers, Euphorbia weeds, poinsettia and volunteer and ratoon cotton. Within the eastern Australian farming system between winter and spring, sowthistle is a key "green bridge" host.

In cotton growing areas, important alternative crop hosts are soybeans, sunflowers and all cucurbit crops. Post-harvest crop destruction is an effective tactic for reducing the carry-over of populations between crops.

Natural enemies

Sustainable SLW management is dependent on the conservation of natural enemies. Various studies (both Australian and overseas) have demonstrated that high levels of biological control (>70%) reliably occur in commercial cotton fields that are managed using an IPM-based approach.

Parasitoids

Several whitefly parasitoids (wasps) have been observed in Australia, including species of *Eretmocerus* and *Encarsia*. These parasitic wasps provide meaningful biological control, attacking the nymph stage of SLW. Nymph parasitism can be assessed with the aid of magnification. Tell-tale signs include the distortion of internal organs (mycetomes). These organs present within healthy, large nymphs as kidney-shaped yellow structures, symmetrically placed in the middle third of the nymph's body. As shown in Figure 2, a lack of symmetry in their alignment along the mid-line indicates parasitism, as the developing wasp larvae displaces these internal organs.

Immediately prior to wasp emergence, nymphs parasitised by *Encarsia* turn dark brown or black, whilst those parasitised by *Eretmocerus* turn yellow/ brown with red to green eyes visible. The presence of circular chewed holes on empty nymph cases is confirmation of parasite emergence. Empty cases with a 'T' shaped emergence hole signify healthy SLW adult emergence.

Parasitoids are commercially available from suppliers of biological control organisms and can be released manually or by licensed drone operators.

See table below and CottonInfo video https://www.youtube.com/watch?v=SO0cedrGIQI

Predators

Predatory insects and spiders are also very important in helping to suppress SLW populations. These predators include; big-eyed bugs, minute pirate bugs, lacewing larvae, ladybeetles, brown smudge bugs, apple dimpling bugs, red and blue beetles and lynx and yellow night stalker spiders (examples in Figure 3). The predatory bugs insert their stylet mouth parts into SLW nymphs and suck out the contents, leaving the dried, collapsed nymph "shell" attached to the leaf. Pest thrips species have also been found to feed on SLW eggs and nymphs just as they do on pest mite species.

Managing SLW

The goal of SLW management is to manage the population so as to avoid honeydew contamination of lint in the open boll stage. An effective IPM strategy for SLW should be underpinned by

- Minimising the disruption of natural enemies by avoiding unnecessary or broad-spectrum sprays, especially early in the season.
- Suppression of SLW throughout the year, including control of alternative weed hosts and coordinated crop sowing.
- Reliable information on pest abundance and distribution through good sampling.

A nymph-based sampling and spray decision support system (see below) is recommended for SLW management. This system supersedes previous guidelines based on sampling adult SLW. The nymph-based sampling method has been tested and shown to be effective from southern Queensland through to the southern-most cotton growing regions in Australia (Coleambally, Forbes, Hillston) and is expected to be relevant to most cotton growing regions in Australia.

The nymph-based sampling guidelines rely on accurate estimates of viable (healthy) and non-viable (parasitised, predated, or non-specific mortality) nymph population density over several checks in relation to accumulated crop development (day degrees, DD (base 12)). The density of large viable

Figure 3: Examples of SLW predators.

nymphs at any point in time is a direct measure of the adult population that will be present within the next 1-2 crop checks (3-7 days). The density profile for viable nymphs tracking across several checks is the key criterion for making a spray decision. The difference between viable and total SLW nymphs provides an estimate of biological control.

Sampling protocol

It is recommended that for each management unit 30 leaves are collected randomly between node 11 and node 14. Count viable and non-viable large nymphs on each (whole) leaf.

When to sample

- SLW populations naturally fluctuate. Strategic sampling should commence during early flowering (around 1000DD) and occur twice weekly.
- Nymphs are not mobile within the plant canopy so time of day does not matter for sampling, unlike adults.

Where to sample in field

- The core objective is to reliably estimate the population of SLW on a given day, but also to be able to meaningfully compare this with estimates from previous samples.
- Sample at least 30 leaves within each management unit.
- Sampling a larger number of leaves will provide more accurate data.
- Ensure that your sampling data reflects within-field variability.
- Avoid sampling edges by walking in 20-30 metres before commencing sampling.
- To help ensure sampling is representative, take the lower main stem leaf on each plant from plants spaced at least 3-5 metres apart while following a diagonal, zigzag (M-shaped) or U-shaped path through the crop. Where walking through is impractical, an alternative approach involves 4 entry points per 100 ha field, taking 15 leaves in the vicinity of each entry point.
- Early in an infestation, SLW will be present at very low densities. Sample size could initially be increased (up to 60 leaves) if more accurate estimates of nymph populations are needed.

Where to sample in the crop canopy

- From each plant, take 1 main stem leaf from the lower canopy sampling zone (i.e. 11–14 nodes down from the mainstem terminal shoot). To identify this region, use a top-down numbering system: the 1st unfurling terminal leaf (20 cent piece size) = leaf node 1. When viewed from above, leaf nodes 1 and 5 face away from each other, and nodes 11 and 14 are found directly beneath node 5 (see Figure 4).

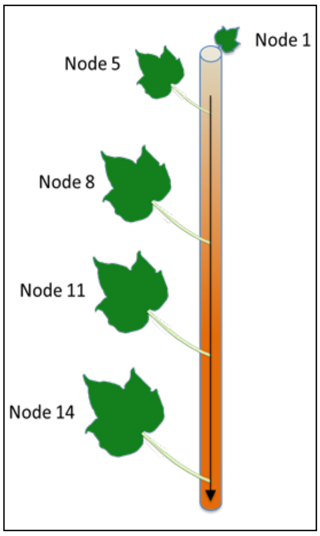

Figure 4: Cotton main-stem leaf nodes 1 and 5 face away from each other, and nodes 5, 8, 11 and 14 are generally vertically aligned.

- Accuracy can be improved by consistently collecting 15 leaves from node 11 and 15 leaves from node 14. Abundance estimates collected from a single location within the canopy (e.g. 30 leaves at node 11) can be slightly more variable than those based on multiple locations within the sampling zone.
- Tip – leaves can be collected and assessed in the comfort of a vehicle or office, however, to ensure accuracy it is recommended counts occur before leaves wilt.

What to sample

- Count viable and non-viable large nymphs on each (whole) leaf.

- Only count large nymphs (3rd & 4th instar) and pupae (that present with red eye spots) when sampling. Note that late 3rd instar nymphs are similar in size to 4th instars but lack the prominent red spots (see Figure 5).
- Use a hand lens or other magnification device to distinguish viable and non-viable nymphs.
- Ignore empty pupal cases (= to predation, natural causes & emerged parasitoids).

Making a decision

The Decision Support Tool (DST) (See figure 6) aims to provide guidance for control decisions and is based on comprehensive studies of the population dynamic profiles for SLW collected from numerous cotton fields throughout the industry over 5 seasons. The red, amber and green "pathways" depicted on the DST show typical population response scenarios with which routine infield sample data can be compared and management decisions made.

Supporting resources:

- The industry has developed a DST spread sheet to support decision making. Download the Excel-based DST file from the CottonInfo website www.cottoninfo.com.au/silverleaf-whitefly-decision-support-tool. The blue "Instructions" tab worksheet details how to input sample data and generate the graphic population dynamic visualisation on the red "Decision Support" tab. The DST generates two population density profiles, showing viable nymphs (red symbols) and total nymphs (black symbols) against potential green, amber or red population growth pathways (Fig. 5).

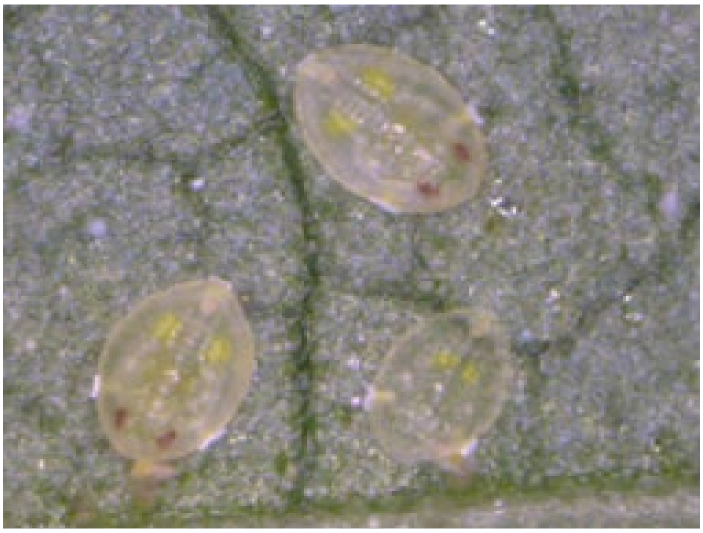

Figure 5: Large nymphs (3rd and 4th instars/pupae) are the target stage for sampling. As nymphs progress through the 4th instar and pupate, red eyespots become prominent and emergence occurs within 48hours.

- The industry is also developing an app to automate nymph counting. For more information contact your CottonInfo REO.
- The day degrees relies on the use of the base 12-day degree calculation. The more recent base 15 calculation has not yet been verified with nymph-based sampling guidelines. A day degree calculator is available at the CSD website's members' portal https://www.csd.net.au

DST scenarios

GREEN PATHWAY: The objective should be to ensure that the profile of viable nymphs tracks within the boundaries or not much above the boundary of the GREEN pathway.

- A viable nymph profile tracking within or close to the bounds of the green pathway represents very low SLW population density, negligible risk of cotton lint contamination with honeydew and therefore indicates a "no spray" situation.
- The green pathway is a conservative indicator of low population density. Due to inherent variability associated with sampling, one or two data points slightly above the upper boundary of the green pathway does not constitute a "breakout" and cause for concern that the population is increasing rapidly (see below for supporting information related to nymph mortality).
- A sharp increase in viable nymph density above the green pathway for two or more consecutive checks (spanning 7 days) is deemed as a breakout population.

AMBER PATHWAY: Viable nymph profiles tracking within or close to the amber pathway of the DST represent a population that poses a moderate risk for lint contamination at crop harvest.

- Populations tracking along the amber pathway typically increase rapidly during the open boll phase, thereby constituting a significant honeydew contamination risk.
- **A viable nymph profile tracking within or above the bounds of the AMBER pathway for two (spanning 7 days) or more checks represents a population that is likely to require control action.**
- The exact timing of control should take into account crop stage and the insecticide mode of action. If the crop is at 1250-1450 DD, a slower acting Insect Growth Regulator (IGR) product would be an appropriate choice. These products have a low impact on beneficial insects that can continue to exert biological control after the efficacy of the insecticide residues have degraded. If the crop is nearing or has open bolls (1600+ DD), a faster acting insecticide would be a more appropriate choice. A follow up treatment for SLW may be necessary during the late stages of boll opening if natural enemies are disrupted and SLW populations recur. The difference between viable and total SLW nymphs will provide an estimate of natural mortality of which biological control is a component.

RED PATHWAY: SLW populations tracking in the Red Pathway will exhibit rapid exponential growth well before the beginning of the open boll stage.

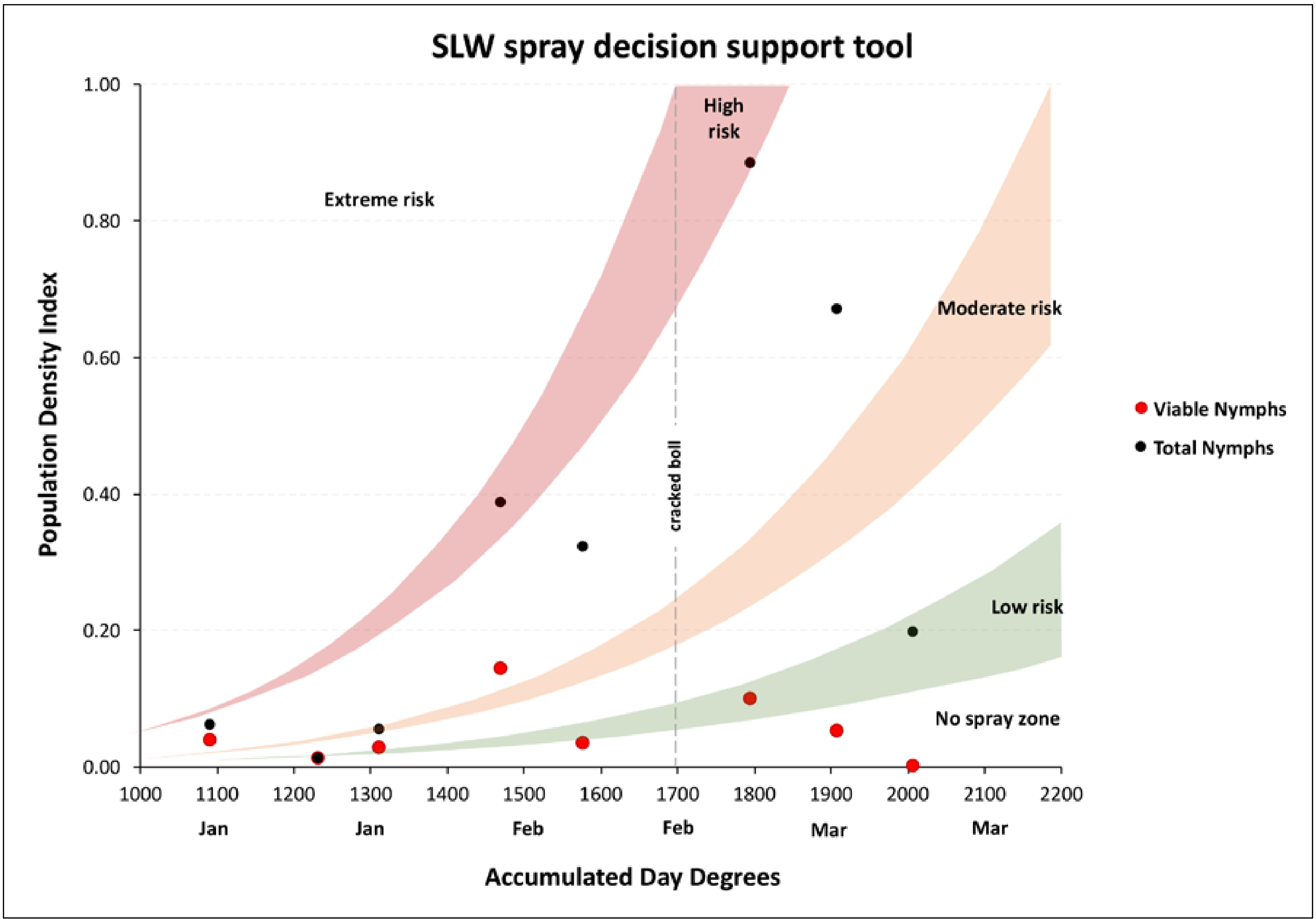

Figure 6: DST visualisation of viable (red dots) and total (viable + nonviable; black dots) large SLW nymph (large and red eyed nymphs) profiles over several checks from a commercial crop in New South Wales. The difference in height between red and black dots at any point in time is a direct measure of SLW mortality in the system.

- **A viable nymph profile tracking within or close to the boundaries of the RED pathway for two checks (spanning 7 days) represent an unambiguous control situation.**
- Red pathway populations represent the highest risk of lint contamination, but they are the simplest to define and manage since:
  - ◊ High SLW numbers occurring well before boll opening allow time for the implementation of a control strategy without the immediate risk of lint contamination.
  - ◊ Insecticides such as IGRs, that have a slower mode of action and reduce population recruitment, can be used to best effect prior to canopy closure thereby improving spray penetration.
  - ◊ The efficacy provided by early IGR usage can then be reinforced by natural enemies that are largely un-disrupted by these products, suppressing populations for much longer.

In southern Queensland and central/northern New South Wales, the obvious presence of SLW adults in the crop in the second half of January or earlier, accompanied by above average temperatures and low rainfall, are typical harbingers of populations tracking along the red growth pathway.

Viable Nymphs vs Total Nymphs

The population density profile for viable (red dots) and total (viable + non-viable) nymphs (black dots) generated by the DST indicates the average number of non-viable large nymphs in the leaf sample for that check. The magnitude of difference between the red and black dots at each check represent expected natural nymph mortality due to beneficial insects, and provides supplemental information that can assist in decision making. For example, if the viable nymph profile breaks out of the green pathway but the divergence between red and black dots has increased, mortality is increasing. A valid option would be to delay a control decision until consecutive checks were made to see whether the improved biological control can suppress viable nymph densities back into the green pathway.

> *"SLW numbers can rapidly increase if natural enemies are reduced by insecticides, especially during hot conditions".*

Other considerations

Temperature is a major driver of SLW populations. Cool conditions slow population increase. Heavy rainfall may temporarily reduce adult SLW numbers but does not have a lasting impact on population growth, as nymph populations are unlikely to be affected. Make sure sampling continues after rainfall even if overall abundance of SLW in the field appears to have fallen.

Chemical use strategy in "spray" situations

Insecticides should be used as directed according to their label specifications and optimal performance recommendations from the manufacturer, including timing of use.

Each management option will reflect the compromise between wanting to delay treatment, reducing the risk of re-infestation and need for retreatment whilst targeting populations that are small enough for products to provide effective control, and aiming to ensure control is in place before there is risk to open cotton.

Knowledge of the mode of action and natural enemy impacts should guide product selection. There are a range of products registered for SLW control, that vary from non-residual quick knockdown of adults through to slower acting IGRs that disrupt specific life-stages, breaking the lifecycle and consequently taking up to 3 weeks to provide control. See Table 1 for insecticides registered for the control of SLW.

Pest control can be compromised by insecticide resistance. Annual insecticide resistance monitoring is conducted for all major pests of cotton including

SLW. Based on the results of these testing programs, some products are subject to industry usage recommendations by the Transgenic & Insecticide Management Strategy (TIMS) committee for resistance management purposes.

For example, the application of pyriproxyfen is restricted to 1 application per season, timed to occur within a window spanning 200 DD, and typically targeted for crops that have accumulated 1350 to 1550 DD. Specific dates for recommended pyriproxyfen usage in each region are set each year in consultation with local industry representatives. This is done to minimise multi-generation exposure of SLW to this compound within each region. Likewise, restricted usage recommendations are also in place for spirotetramat (1 SLW application per season) to prevent the development of resistance.

In Australia, SLW have developed resistance to several insecticide groups including organophosphates, carbamates, pyrethroids, some neonicotinoids, pymetrozine, pyriproxyfen and spirotetramat. The risk of resistance selection to additional insecticides is very high. The Insecticide Resistance Management Strategy (IRMS) in the Cotton Pest Management Guide has been developed to manage the risk of resistance development, providing guidance as to when and how often certain insecticides can be used.

PHOTOS CSIRO

Light honeydew contamination.

Heavy honeydew contamination.

Moderate honeydew contamination.

Heavy honeydew contamination.

Figure 7: SLW honeydew contaminated leaves and lint.

Management of SLW in late planted and developmentally delayed crops

SLW management involving situations of late season mass-immigration of adults into crops with open bolls should be based on (a) expected time to defoliated leaf drop, (b) lint contamination level, and (c) prior chemical use from a resistance management perspective. During defoliation, adult SLW will leave the crop while falling leaves will take the nymphs with them to the ground. Displaced adult SLW will relocate to nearby host crops and weeds. The nymph-based DST method will be of limited value for crops facing a mass immigration situation.

When considering late season SLW management at or prior to the first pass of defoliant, product choice should consider potential efficacy and any control delay, residual impact and withholding periods (WHPs). When the risk of honeydew contamination is high, earlier commencement of defoliation should be considered. The presence of honeydew on leaves is a good indicator of potential lint contamination (see Figure 7).

If defoliation is not due for 10-14 days and honeydew is collecting on the leaves, managing SLW numbers with a knockdown product maybe a prudent intervention.

Situations in which defoliation is 15-21 days away may be managed by a knockdown spray in the first 7 days, followed by continued monitoring. Commencing defoliation earlier (50% open bolls) may be warranted if significant population resurgence is evident 7 days following treatment.

If defoliation is ≥ 21 days, the use of a systemic mode of action product with residual activity would be a prudent choice being effective on both nymphs and adults within the canopy.

When it is too late – cotton lint is contaminated

When open cotton has been severely contaminated with honeydew, intentionally delayed harvest may increase the odds of crop exposure to rainfall that may remove most of the honeydew. Rainfall of 15-20 mm (either single or multiple falls) is sufficient to wash-off the majority (>80%) of honeydew. The breakdown of honeydew can also occur through the action of sooty moulds that are favoured by dew or high humidity. The breakdown of honeydew sugars by moulds is relatively slow, with the process also presenting significant risks for lint colour downgrade penalties.

If conditions during the delayed harvest remain dry, the high risk for honeydew contaminated lint will remain. If you are concerned cotton is contaminated, it is important to talk to your ginning company/marketer to discuss processing options that may alleviate downstream market discount risks.

Further information

Visit www.cottoninfo.net.au

Cotton Pest Management Guide (contains Insecticide Resistance Management Strategy (IRMS)) www.cottoninfo.com.au/publications/cotton-pest-management-guide

INTEGRATED PEST MANAGEMENT FOR SLW

Take a year-round approach – Major regional outbreaks of SLW have occurred when climatic conditions (especially mild winters) and a sequence of hosts (winter weeds or alternative crops) enable prolonged population buildup. Reducing available weed hosts and avoiding early season management decisions that disrupt natural enemies, (e.g. the use of broad-spectrum insecticides against other pests) can help reduce the severity of SLW outbreaks.

Area Wide Management (AWM) – SLW numbers can build rapidly and adults can move between fields and farms to find suitable hosts. Consider all potential hosts in cropping and non-cropping areas. Area wide management (AWM) involves sharing and coordinating tactics with neighbours and has been found to be effective in management of SLW. Strategies may include coordinated sowing windows, weed management, consensus about delaying the use of disruptive insecticides to conserve natural enemies, shared adherence to IRMS and drone release of natural enemies.

Coordinated planting – Late maturing cotton can have a higher risk for lint contamination due to influxes of SLW adults displaced from crops defoliated earlier.

Natural enemies – Natural enemies (predators and parasitoids) play a vital role in suppressing SLW population growth. Minimising the disruption of natural enemies by avoiding unnecessary sprays can help to prevent the rapid build-up of SLW numbers. Native vegetation, both on farms and in the region, can also be an important source of natural enemies.

Grow a healthy crop – Growing a healthy crop not only optimises yield potential but also minimizes moisture stress. SLW tend to produce more honeydew on stressed crops. Optimising nutrition and water inputs avoids maturity delays and the risk of SLW resurgence or immigration from surrounding crops.

Field selection – Cotton sown in close proximity to other host crops, such as melons or soybeans, are at greater risk of mass immigration mid-season. Aim to separate susceptible crops that have alternate maturity timeframes to reduce between crop population exchange.

Host free period & farm hygiene – Winter weeds such as sow thistle and volunteer cotton are a favored overwintering host for SLW. Removing hosts within fields and adjacent farm areas will reduce the "green bridge" not only for SLW but other pests such as aphids and mealybugs between seasons. Destroy crop residues immediately after harvest to prevent these areas acting as reservoirs for SLW and other pests.

Table 1. Registered insecticides for the control of silverleaf whitefly.

Information on insecticides is a guide only. All pesticide applications must accord with the currently registered label for that particular pesticide, crop, pest and region. Always follow label and manufacturers advice.

Insecticide (MOA Group)	Formulation	Rate	Impact on natural enemies	Control Interval[1]	Comments
Paraffinic oil	778 g/L EC & 792 g/L SC	2% V/V (min 2L per sprayed ha)	very low		Most effective when targeting low, early season populations. Apply in a minimum of 100 L/ha for ground applications. Multiple applications are more effective.
Pyriproxyfen (7C)	100 g/L SC & EC	0.5 L/ha	very low	14-30	Ensure thorough coverage, Max 1 application within 30 day regional window. An IGR with translaminar movement[2]. It disrupts egg hatch, and moulting from 4th instar nymph to adult. Adult female fertility is reduced by contact with pyriproxyfen.
Clitoria ternatea extract	400 g/L EC	2L/ha	Low		Apply as indicated by field checks and pest presence. Ensure good coverage. Maximum 5 applications per season. Treatment effects may not be seen for 3 or more days. A repeat application may be required at 14-20 days if conditions favour pest development.
Buprofezin (16)	440 g/L SC	1L/ha	Low	14-30	Maximum of 1 application per season targeting whitefly. An IGR that disrupts moulting of nymphs has contact and vapour activity. Reduces adult female fertility.
Diafenthiuron (12A)	500 g/L SC	0.6 or 0.8 L/ha	Low	7-14	Suppression of whitefly. Target early developing populations, may not give satisfactory control on established whitefly populations, Maximum of 2 applications per season. Has translaminar movement, contact and vapour activity. Activated by UV light and insect metabolic processes.
Afidopyropen (9D)	100 g/L DC	0.35 L/ha + 0.2% v/v Hasten Spray Adjuvant	Low	14-21	Provides suppression of whitefly adult and nymphs, best targeted at nymph stage. Maximum 2 applications per season targeting SLW, ground application only. Has translaminar movement and acropetal mobility[3].
Cyantraniliprole (28)	100 g/L SE	0.6 L/ha + oil	Moderate	14-30	Target early developing populations. Two consecutive applications of cyantraniliprole 10-15 days apart may be required. Maximum 2 applications per season.
Spirotetramat (23)	240 g/L SC	0.3-0.4 L/ha + Hasten Spray Adjuvant 1.0 L/ha	Moderate	14-30	Use higher rate when targeting high pest populations and when crop is well advanced. Do not reapply within 14 days. Has translaminar and systemic mobility in both phloem and xylem. Controls nymphs and reduces fertility in female whitefly. Maximum of 1 application when targeting whitefly.
Emamectin benzoate/ acetamiprid, (6/4A)	32.5g/L/218g /L DC	0.3-0.35 L/ha	Moderate	7-14	Target developing populations, Maximum of 2 applications per season and use an insecticide from another MOA between applications. Acetamiprid has translaminar movement and acropetal mobility. Emamectin benzoate has translaminar movement.
Dinotefuran (4A)	200 g/kg WG	250-375g/ha	Moderate	7-14	Target developing populations, use higher rate if targeting high pest populations, maximum of 2 application per season and use an insecticide from another MOA between applications Has translaminar movement and systemic mobility.
Bifenthrin (3A)	100 g/L EC 250 g/L EC 240 g/L SC	0.8 L/ha 0.32 L/ha 0.33 L/ha	Very High	7-14	The adult stage should be targeted. Do not spray crops with a high population of the juvenile stages. Thorough coverage of the crop canopy is essential. Maximum of 1 application per season[#].

[#] see label for instructions to minimise impact on bees

[1] control interval – dependent on rate, timing, immigration and pressure, activity of natural enemies

[2] translaminar – movement through leaf from upper to lower surface

[3] acropetal – base to apex movement within plant