Fall armyworm and cluster caterpillar in cotton – What do we know?

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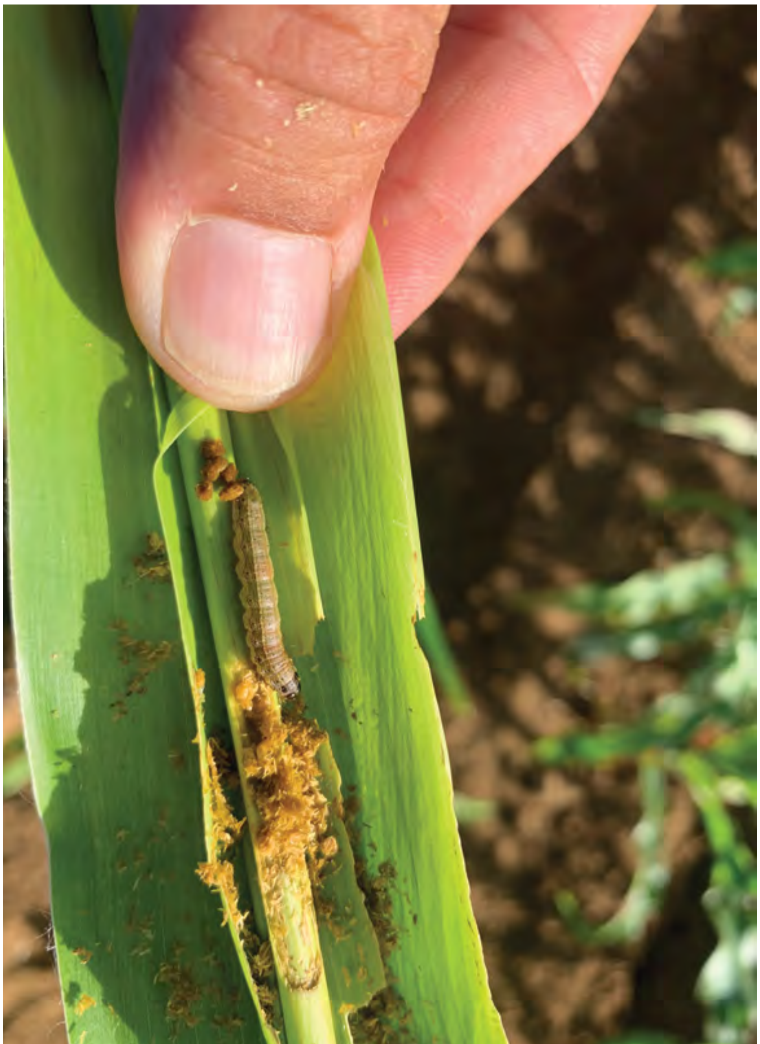
THE recent incursion of fall armyworm (*Spodoptera frugiperda*) in northern Queensland has caught the attention of many people within the cotton industry, and generated questions about the potential impact of this new pest. What many would be unaware of is that our own endemic species the cluster caterpillar (*Spodoptera litura*) has been a pest wherever cotton has been grown in our tropical regions. In considering the potential impact that fall armyworm might have on the cotton industry, we can perhaps take some clues from the experience with *S. litura* including the more recent plantings of cotton in the north using Bollgard 3 varieties. First of all, let's recap what we know about fall armyworm as it pertains to the current incursion in northern Australia.



Fall armyworm recently found on a corn crop at Mareeba, north Queensland. (PHOTO: Paul Grundy)

What is in a name?

Spodoptera frugiperda is commonly called the fall armyworm (FAW) due to its behaviour and ecology in the Americas. This species naturally occurs year round in tropical regions of central America including the southern reaches of Texas and Florida in the US. It commonly builds up in numbers during the summer months and consequently spills out into temperate regions during the end of summer and early autumn (America's 'fall'), sometimes reaching as far north as Canada. In the US FAW does not diapause or persist in these temperate regions and hence this pest only occurs in these regions when it disperses from the south each season.

FAW was reported in Africa in 2016 and has also been detected across the northern hemisphere in India and China during the past three years. The method of spread is not precisely known but it is suspected that movement has been greatly assisted by the transportation of produce and that multiple introductions may have taken place. In 2019, FAW was detected in Timor, and given the ability of moths to travel long distances, it was only a matter of time before it would immigrate into Australia's tropical top end. To date detections have been confirmed as far south as the Burdekin and west to Croydon. It is expected that this pest will establish throughout northern Australia as it can make use of a range of host species including tropical pastures.

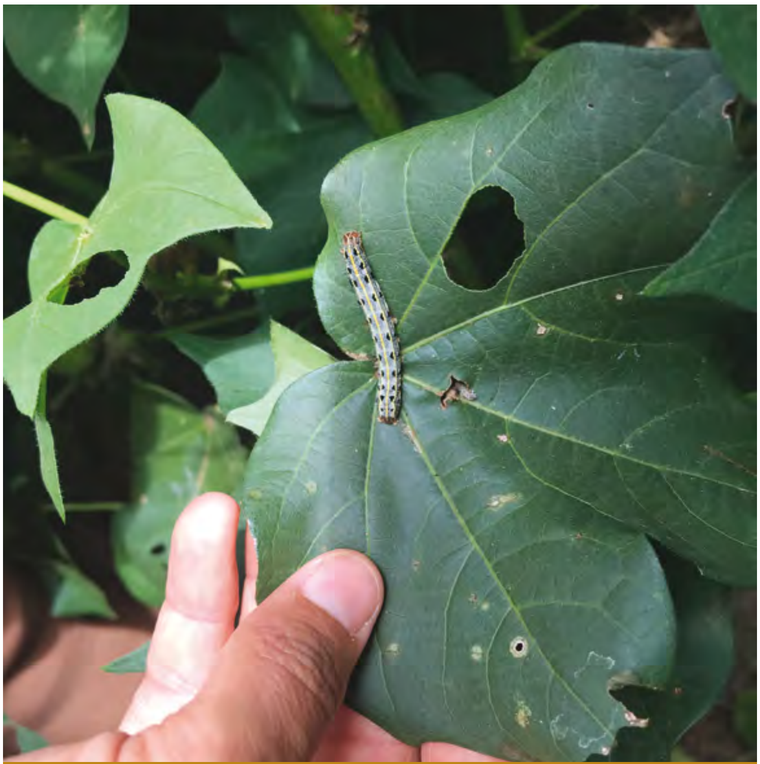
While FAW has a reported host range of up to 350 species, it is likely to exhibit preferences for certain hosts, particularly those belonging to the Poaceae family (grasses and cereals). FAW is unlikely to be a major pest for every crop species listed as a potential host. For example, *Helicoverpa armigera* also has a very wide host range, yet is only a major pest of several crops and is best characterised as a sporadic or minor pest in broad range of others.

From the detections so far, it would appear that FAW will be a likely pest of grain crops such as maize and potentially sorghum. Overseas literature suggest that there are strains that have preferences for different crop types, but how this pest will affect Australian crops will very much depend on our climate, cropping calendar and competition from our existing pests and natural enemies. Ultimately, it will take time to know which crops are most likely to be affected and how severely.

FAW in cotton

For cotton, the literature is relatively vague. Cotton is recorded as a host and references are made in USDA literature to FAW potentially damaging cotton squares, flowers and fruit. Bt traits in cotton are reported to provide reasonable control for FAW with Cry2ab and Vip3a being touted as the most effective proteins. At this early stage, it would be reasonable to conclude that FAW are unlikely to pose an immediate threat to cotton production in Australia given the nearly ubiquitous adoption of Bollgard 3 varieties. But Bollgard 3 is not currently registered for control of FAW and field studies may be required to enable an APVMA

Cluster caterpillar (*S. litura*) egg mass.



***S. litura* on BG3 cotton.**

registration for this new use. There are several unknowns that will take time for researchers to examine and understand.

Potential resistance factors are currently unknown for the population in northern Australia. Recent studies published from Brazil and China have shown that FAW can carry resistance alleles to Bt proteins Vip3Aa2 and Cry2Ab2 expressed in corn leaves. Resistance frequencies in Brazil were reported to be at very low levels (Bernardi *et al*. 2015) (population frequency 0.0009) which is much lower than the frequency found by CSIRO for *H. armigera* prior to the Australian deployment of Vip3a in Bollgard 3.

These forms of resistance were found to be recessive similar to the mechanisms identified by CSIRO for *Helicoverpa spp*. in Australia and therefore should be able to be managed by the 'high dose + refuge' strategy that underpins a large part of Australia's Bollgard 3 Resistance Management Plan (RMP). It is possible that the RMP for Bollgard 3 will require modification as part of a submission to the APVMA to add a new target pest to the current registration, should FAW establish as a routine pest, particularly for cotton in Australia's northern regions. Any changes will depend on both the presence of pre-existing resistance alleles as well as ensuring that refuge options are suitable for FAW. The use of pigeon pea might come into question if this refuge is not a preferred host for FAW and unable to generate the populations of moths needed to dilute resistant alleles. To date pigeon pea refuges grown in the Ord region of *North West* Australia have not been a host to the related *Spodoptera litura*, which is frequently observed in conventional cotton refuges.

What insights might *Spodoptera litura* provide for FAW and cotton?

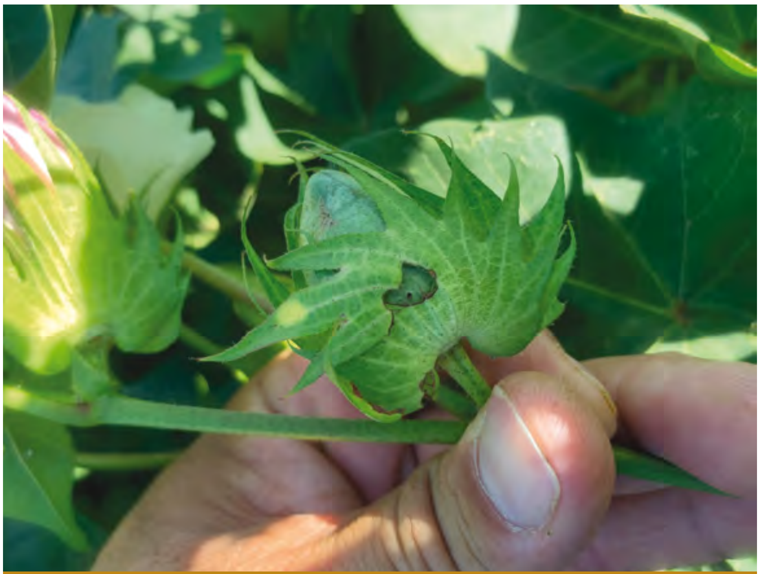
Cluster caterpillar (*Spodoptera litura*) has been a frequent pest of cotton in northern Australia. This species was a primary pest of concern during a pre-commercial phase of crop testing where a large range of crop types were being assessed at the Kununurra Research Station during the 1950s for suitability to be grown locally in preparation for the Lake Argyle and Ord River Irrigation scheme. During this pre-commercial testing period, *S. litura* were noted in the local Agricultural Department records as being a particularly difficult-to-control pest of cotton.

The advent of the organochlorine product 'Endrin' (which provided effective control of cluster caterpillar) into the marketplace paved the way for broader scale test farming to commence in 1964. During the decade that followed, pioneering cotton farmers in the region battled a complex of caterpillar species including *Helicoverpa punctigera* and rough bollworms (*Earias huegeliana*) with *S. litura* being particularly problematic in 1965 and 1968.

The combined spraying for these pests led to the emergence of *H. armigera* as the primary pest species from 1971 onwards due to fast-emerging resistance that precipitated the industry's collapse in 1974 with a 40 per cent reduction in yield and over 40 insecticide applications made in what was the final season. What is notable, is that this industry failure occurred within 10 years of commercial test farming across an area of land averaging 1000 hectares in an environment with no previous chemical use or agricultural production.

The collapse of the northern cotton industry served as an early warning of the potential for resistance to overcome our ability to control insects. This enabled southern districts that were also developing resistance at the time to change tactics in time to better manage resistance that was a constant challenge for various products right up until Bollgard II entered the market in the mid 2000s.

Since the advent of Bollgard II, cotton has been grown in various locations in northern Australia. In the Burdekin region, commercial scale cotton production with Bollgard II varieties occurred between 2007 and 2012. During this period *S. litura* were observed to survive in crops on a number of occasions, feeding primarily on leaves. On occasion larvae were also observed to feed on fruiting structures and in particular on open flowers. The damage caused by these populations often appeared to be superficial with larvae rarely penetrating bolls in the way that Helicoverpa do. The threshold for both FAW and *S. litura* in Bollgard 3 cotton is an unknown and will require research to understand both the feeding behaviour of larvae and potential damage impacts.



Superficial damage by cluster caterpillar to square and boll bracts (not very fair dinkum compared to heliothis).

The advent of Bollgard 3 has reduced the frequency with which *S. litura* have been observed in cotton during the past three or four seasons with the addition of the Vip3A endotoxin providing good incidental control. Basic bioassay comparisons of *S. litura* survival on Bollgard 3 vs Bollgard II foliage conducted in the Ord during 2018 found that control efficacy was significantly improved for Bollgard 3.

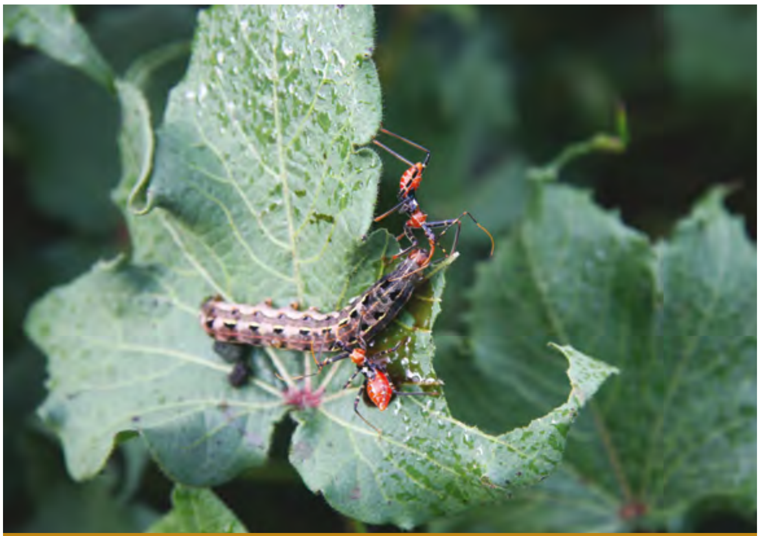
But it was notable during these bioassays that control was incomplete with small percentages of larvae (over 10 per cent) able to persist for several weeks, albeit with grossly delayed growth and development. In a field environment, the survival of these individuals would be unlikely compared to laboratory conditions. This does suggest that the level of endotoxin expression in Bollgard 3 varieties is only just sufficient to provide control and therefore may be inconsistent with the 'high dose' assumption upon which the Bt RMP strategy is based.

Limitations of control

The limitations for Bollgard 3 for suppression of *S. litura* became apparent during the 2019 season at Kununurra. A cotton crop that was sown mid-January was subject to several weeks of extreme heat coupled with cloudy weather. The result was a crop that suffered extensive fruit shedding by the time of early flowering (16 nodes). By mid-March, the crop was compensating as weather conditions had improved, but the lower canopy foliage that had been subjected to environmental stress was subsequently shaded by the overlying compensatory canopy growth. The expression in the lower canopy was poor, enabling a significant population of *S. litura* to survive. As these larvae developed, they migrated from the lower canopy to the top of the crop where they were able to damage developing squares and flowers.

A simple experiment conducted at the time demonstrated that altering the light environment was important for the expression of Bt endotoxins and subsequent *S. litura* control in the lower canopy. In bioassays, the mortality of *S. litura* fed leaves collected from the lower canopy in plots where adjacent rows were removed (enabling increased light penetration) was 84 per cent. In comparison, *S. litura* larvae fed leaves that remained shaded only had 60 per cent mortality.

While this exercise was very simplistic, it highlighted that a key aspect to achieving control of less susceptible caterpillar pests such as *S. litura* in tropical environments is to grow the crop at a time, and in a way, that will maximise plant health and subsequently Bt endotoxin expression. Difficulties are likely to arise when the crop is exposed to extended periods of stress due to hot temperatures, moisture stress or cloudy weather. Canopy management in relation to improving the light environment and by default the management of *S. litura* will also be an important consideration for cotton production in Australia's north going forward and is now reinforced by the presence of FAW.



Assassin bugs predating a *S. litura* in the Burdekin.

It is important to highlight that the current registration for Bollgard 3 only pertains to *Helicoverpa spp*. in Australia with no claims made for the control of alternate caterpillar species such as *S. litura* or *S. frugiperda*, and a successful application to the APVMA to add a new pest species to the Bollgard 3 label would be required before it could be definitively stated that this product controls FAW.

Potential impact

But as experience with *S. litura* in the Ord during the 1960s demonstrates, ignoring the potential impact of these species would be folly. While Bollgard 3 by and large will prevent economic damage by these pests, it is important to recognise that these species are just as capable of developing resistance to Bt endotoxins as *Helicoverpa spp*. This knowledge should also be front of mind when it comes to understanding and identifying resistance mechanisms and the efficacy of the RMP. For example, pigeon pea may be an unsuitable refuge for northern Australia as it is not a preferred host for *S. litura* and the preference of FAW is unknown. The recessive nature of known resistance alleles in FAW overseas does confirm the importance of having suitable refuges as part of any RMP.

In terms of natural enemies, a broad range of predators and parasites has been recorded for *S. litura* with many generalists being likely to take advantage of and also feed on FAW. Similar to the management of other pest species, the preservation and encouragement of natural enemies will also be important for the management of both Spodoptera species, particularly in northern Australia.

In instances where control of FAW might be required in cotton, emergency use permits have been obtained enabling the use of Spinetoram and Chlorantraniliprole. Other products are currently being considered so refer to the APVMA (*https://portal.apvma.*

gov.au/permits) for the most up to date list. These products were chosen because of their likely efficacy and ability to be used within an IPM program that seeks to preserve natural enemies of both FAW and other key pest species. As the pest status of FAW becomes clearer over time, consideration for how insecticides are used across different industries will require a strategic approach to limit the chance of resistance developing in FAW as well as other key pests such as *H. armigera*. Any decision to control FAW should also consider risk of flaring other pests, such as mealybug.

To sum up

The extent to which FAW becomes a pest within cotton farming systems will take time to unfold. Its initial spread and abundance may be uncharacteristic of longer term patterns, because as a new species it will need to compete with a range of endemic caterpillar species for the same host resource and the large range of existing natural enemies that could provide suppression may take time to respond to a new species. The pest potential of FAW will ultimately depend on its prevalence in the environment, its regional and seasonal distribution, inherent resistance factors and capacity for crop damage. At the very least it is likely that this species and *S. litura* will require consideration from a resistance management perspective, particularly for northern Australia but potentially also further south in regions such as central Queensland.

1 DAF, 2 CRDC and 3 CottonInfo.

References: Bernardi, O; Bernardi, D, Ribeiro, RS; Okuma, DM; Salmeron, E; Fatoretto, J; Medeiros, FCL, Burd, T; Omoto. C (2015) Frequency of resistance to Vip3Aa20 toxin from *Bacillus thuringiensis* in *Spodoptera frugiperda* (*Lepidoptera: Noctuidae*) populations in Brazil. Crop Protection 76, 7-14.

IT'S AMAZING THE THINGS YOU FIND IN A COTTON FIELD

CSD's Bob Ford reports the following find:

"Just found when plant mapping at Auscott. Looks like the rain created issue with bird nests in the trees. The bird took advantage of cotton and its large leaves and collected open bolls from the bottom of the plant and created a nest. Don't know what bird it was."

Well, Greg Ford (no relation), Director and Principal Ecologist with Balance! Environmental and co-author of the excellent book, Birds on Cotton Farms is confident he has the answer.

"I'm pretty sure that nest and eggs belong to a native grassland bird called the Golden Headed Cisticola, also known as Barleybird and Tailorbird. The latter name comes from the way it makes its nest by stitching together broad leaves with spiderweb and plant fibre to make its nest.

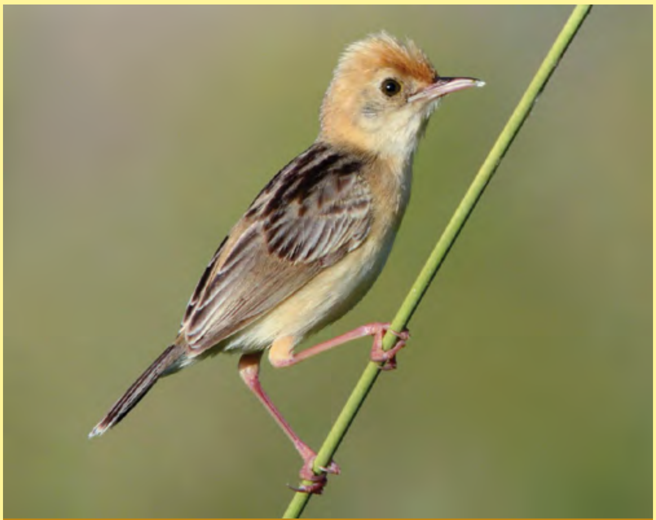
They love wetter areas with tall, rank grass and are common along watercourse country. But also love grassy verges and crops along irrigation ditches, around storages, etc.

"Many of your farmers would be familiar with them as the males sit on tall grass stalks or fences and sing their hearts out during spring. They're a bit wren-like in shape with long cocked up tail but bigger than your average bluewren. They're a light brown colour with darker streaks and in the right light they have a really golden hue in their head feathers, which the males erect as a little crest when they're singing.

"They're insectivores and will be doing a great job helping with the pest management program around that crop."

An interesting find nestled into a cotton plant.

On closer inspection, they were definitely not insect eggs.



Golden Headed Cisticola – tiny, sandy-colored bird with short tail and dark-streaked back. Breeding adult males have orange-gold crown. Song a thin, high-pitched, drawn-out buzzing. Inhabits grasslands of northern and eastern Australia, where perches prominently.