POTENTIAL IMPACT OF SILVERLEAF WHITEFLY (*Bemisia tabaci* type B) ON THE AUSTRALIAN SOYBEAN INDUSTRY AND POSSIBLE MANAGEMENT STRATEGIES

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Abstract:

Silverleaf whitefly (SLW) is the B-biotype (or B-type) of the whitefly *Bemisia tabaci* and is highly resistant to many common pesticides. Other *B. tabaci* types (strains) and whitefly species in Australia are susceptible to most current pesticides. Silverleaf whitefly is a major global pest of horticultural and agricultural crops and was first reported in Australia in 1994. Silverleaf whitefly is a much greater threat to soybeans than other whiteflies in Australia because it has a wider host range, develops pesticide resistance very rapidly, and is adapted to high temperatures. Under the right conditions, these factors can give rise to uncontrollable plagues with billions of individuals per hectare. Soybean growing areas in Australia at greatest risk are tropical areas such as Emerald and the Burdekin, and subtropical coastal regions as far south as the Northern Rivers of NSW. Soybeans are unfortunately a very attractive and susceptible SLW host and a concerted effort will be required to minimise the impact of this pest in tropical and sub-tropical Australia. The impact of SLW will only be reduced by the adoption of IPM and Area Wide Management strategies, as this pest cannot be managed with pesticides alone.

Plates 1-3: Silverleaf whitefly adult (greatly magnified), nymphs (on bladder ketmia) and damage to soybeans respectively. Note the darkened leaves, a symptom of sooty mould attack. Photographs courtesy of Paul DeBarro, Neil Forrester and Natalie Moore.

Silverleaf whitefly biology:

What do SLW look like? Silverleaf whiteflies are small fragile sap sucking insects in the same sub-order of bugs as aphids and scale insects. Adults have powdery white wings and are only 1.5 mm long (Fig. 1). SLW are similar to, but smaller than, the greenhouse whitefly (*Trialeurodes vaporariorum*) and have a distinct gap between their forewings. SLW can only be distinguished from native *B. tabaci* strains by biochemical testing (Dr Robin Gunning, NSW Ag, Tamworth).

SLW lifecycle: Eggs are laid on the underside of leaves, are very small, oval shaped, and sit on a pedicle or stalk that enables moisture to be drawn from the leaf, preventing dehydration of the eggs. Freshly laid eggs are yellow but darken as they near hatching. When laid *en masse*, SLW eggs look like brown velvet on the underside of the leaves. The first instar 'crawler stage' is the only mobile nymph stage. After hatching, crawlers travel a few centimeters to find a suitable place under the leaf to start feeding. They then insert their mouthparts into the leaf to suck up plant sap. Instars 2 to early 4 are pale yellow-green and flat and oval in shape and continue feeding without moving from the position selected by the crawler. On hairy-leaved plants, nymphs have more obvious hairs and are more rounded than flat in profile. The late 4th instar is a 'resting phase' during which the nymph stops feeding and metamorphoses into the winged adult. During this phase, whitefly nymphs become a pupa or 'red eye'.

Distribution of SLW: SLW has been identified in most soybean growing areas in NE Australia, on a range of crops and nursery plants. The first large-scale outbreak occurred in the Emerald irrigation area during 2001/02. More localised but severe outbreaks have occurred in coastal regions from the Burdekin to the Northern Rivers of NSW. The two critical factors in the occurrence of major SLW outbreaks are climate and the continuous availability of suitable hosts. Unless both factors are favourable, outbreaks are unlikely. Severe outbreaks are also more likely where the widespread use of disruptive pesticides adversely affects SLW parasites and predators.

Climate: SLW does not have an overwintering diapause stage, so its distribution is limited to those areas with milder winters. In areas with cold winters, populations can persist in glasshouses and be a recurrent problem. SLW's growth rate decreases and its generation time increases in cooler weather. SLW is more likely to be a pest in areas where the winter generation time is 80 days or less (as in areas from Biloela north). This is because the warmer winter conditions in these regions allow more generations per year, and increase the opportunity or higher numbers surviving through winter facilitating a faster build-up in spring. Moving further south (e.g. Macintyre, Gwydir, Lower Namoi), the winter generation time is around 120 days (102 days in St George). The cooler conditions in these regions mean slower generation times, reduced chances of survival and hence opportunity for a significant population build-up in late spring/ early summer. For this reason, subtropical coastal regions are at greater SLW risk then inland growing areas at the same latitude.

Continuity of suitable hosts: The continuous availability of suitable hosts is essential for whitefly outbreaks. Hosts may be susceptible weeds or cultivated crops. The discontinuity of host availability in some Australian soybean producing areas in inland northern NSW and the Darling Downs is a major factor in reducing the likelihood of outbreaks. In these regions, the predominant cotton/ cereal or cotton/ legume rotation does not particularly favor whitefly, as neither the cereals nor the winter legumes grown (particularly chickpeas and vetch) are particularly good hosts. Furthermore, in early spring, there is often a 'gap' period with very few attractive, suitable cultivated hosts. The availability of weed hosts varies seasonally with rainfall but in general, the lack of weed hosts through winter and the lower temperatures means that populations do not build up quickly. In some of the 'more inland' coastal soybean valleys, lucerne will be an attractive and continuous host for SLW.

SLW damage

How susceptible are soybeans to SLW? Soybeans are very susceptible and attractive to SLW. Other highly susceptible crops include cucurbits, cotton, lucerne, peanuts, sunflowers and tomatoes. Less attractive host crops include chickpeas and mungbeans. Grasses such as maize and sorghum are not hosts. Proximity of crops to other sources of SLW is a major risk factor. Soybeans at greatest risk are either close to earlier maturing susceptible crops, eg maturing cotton or cucurbits, or are close to susceptible weed hosts such as sow thistles, bell vine, bladder ketmia, native rosella, wild cucurbits and *Rhynchosia* spp. (prostrate native legumes). Stressed soybean crops may also be also more attractive to SLW than well-watered crops. In extreme plague conditions, SLW will settle on any crop, even on crops not normally attractive to the pest.

Susceptibility of soybean varieties: Observations to date suggest clear differences in attractiveness of different soybean varieties to SLW. However, these have mostly been noted in small plot trials. Evidence suggests that SLW are not 'fussy' in larger commercial crops and will rapidly infest less preferred soybean varieties where they (SLW) have no other choice. Some more varieties may be more susceptible to SLW damage, and may suffer greater damage (particularly reduced podfill) in response to a given SLW population than other varieties. However, this is difficult to quantify without detailed field evaluation. Andrew James (soybean plant breeder with CSIRO) is of the view it is currently unlikely that there are viable sources of resistance in the Australian soybean-breeding program.

SLW damage and symptoms:

Damage description: SLW can be devastating in soybeans. By sheer weight of numbers, SLW remove plant assimilates, thus affecting plant growth and pod fill and ultimately reducing yield. SLW may also inject toxins while feeding and these can interfere with the plant's physiology and reduce or even prevent podfill. Lack of podfill has been reported in many SLW-infested soybean crops in the Bundaberg region this season. A worrying observation is that severely damaged crops sometimes exhibit no outward symptoms, the crop appearing to be normal and healthy from a distance. However, closer inspection reveals these crops have significant (readily visible) SLW adult and nymphal populations under the leaves, and have pale pods that are not filled.

Like aphids, whiteflies secrete copious amounts of 'honey dew', a food source for sooty mould (a fungus). This covers leaves with a black sooty growth, which reduces photosynthesis. Nymphs will produce more honeydew on poorer quality hosts (eg stressed plants), as they need to feed and excrete more to meet their food requirements. Once SLW populations explode in a region, soybean crops can be damaged severely within in a short time if conditions are favourable (eg. during hot, dry weather). During the summer of 2001/02, SLW severely damaged many soybean crops in Central Queensland to the extent that these crops were ploughed in.

The worst damage occurs where seedling soybeans are inundated by SLW plagues. In general, the earlier the invasion by SLW, the greater the damage potential as (a) the ratio of SLW numbers relative to plant biomass is greater in young crops, and (b) the earlier crops are infected, the more time SLW populations have to increase. SLW have no effect on yield once pods are filled. There is anecdotal evidence that some soybean cultivars are more susceptible to SLW attack and damage than others, but further data is required. The critical questions are "Are any cultivars more attractive to SLW than others?" and "Are any cultivars more tolerant of attack, i.e. able to suffer lower yield losses in response to high SLW pressure?" Currently there is no data to determine how many SLW are required to cause significant damage to a soybean crop.

SLW and soybean diseases: SLW is a highly efficient vector of geminiviruses, which include the begomoviruses (Morales and Anderson, 2001), and closteroviruses (Wisler *et al.*, 1998). At least four geminiviruses infect soybeans, namely bean dwarf mosaic virus (present in Africa and South America), soybean crinkle leaf virus (SE Asia), bean golden mosaic virus (South America) and mungbean yellow mosaic virus (SE Asia) (Tolin 1999, Morales and Anderson, 2001). SLW could be expected to hasten the spread of these viruses if they entered Australia. Experience overseas indicates these diseases can cause severe damage to soybeans.

SLW situation as at February 2003

Emerald and ***Central Queensland**:* At the time of writing, SLW populations (in cotton) were building in the Emerald irrigation area but levels were lower than at the corresponding time last season. Reasons given are greatly increased levels of parasitism, due in part to the reduced use of non-selective OP's against mirids in cotton, and in part because of the lag effect where parasite and predator populations take time to build in response to pest pressure. Because of last season's SLW damage, very few if any soybeans were planted in the Emerald area this season.

Inland and Coastal Burnett: In the inland South Burnett, activity has been undetectable to low in soybeans, but much higher in succeptible weeds such as Anoda weed. In the Bundaberg region, SLW populations in soybeans away from horticultural susceptible crops are not yet considered a threat. However, soybeans closer to susceptible horticultural crops (particularly capsicums, tomatoes and sweet potatoes) are experiencing severe SLW damage, many crops suffering reduced podfill.

Darling Downs: On the Darling Downs and at St. George, Melina Miles (QDPI Toowoomba) reported that the percentage of whitefly populations that are SLW, and the number of sample sites with SLW were increasing. SLW were at detectable levels in some soybean and cotton crops.

Lockyer Valley: Significant whitefly outbreaks have been observed in some soybean crops in the Coominya, Lowood and Gatton districts. Whitefly adults from one heavily infested crop were identified (by Robyn Gunning) as being exclusively SLW, i.e. the B-type of *B. tabaci*. One heavily infested trial exhibited (as at late Feb) the early symptoms of reduced podfill, having small seeds and abnormally pale pods. All crops with significant SLW activity were in close proximity to other SLW-infested crops (mainly cucurbits) and weeds, particularly star burr and rattle pods.

Northern NSW: While SLW has been recorded in a variety of horticultural crops in coastal northern NSW, only one severe outbreak of the B-Biotype was confirmed in soybeans in northern NSW in the 2001/2002 season; namely at Newrybar, north of Ballina. As at January 2003, whitefly adults were again reported in soybeans in this area but only in low numbers. They were confirmed by testing to be SLW (*B. tabaci* type B). Postscript: moderate to severe infestations were reported in many crops in March.

SLW Management

Why is SLW so difficult to manage? SLW is difficult to manage because of its wide host range and because its population can increase extremely rapidly. Once SLW populations explode in a cropping region, SLW cannot satisfactorily be managed with pesticides alone, even where effective products are registered. This is because of sheer weight of numbers (billions/ha) and because SLW can rapidly become resistant to new pesticides (within a single season). Hard pesticides used against other pests are likely to flare SLW as they kill SLW parasites and predators. Area wide management strategies that include planting gaps between susceptible hosts, the conservation of beneficial insects, and the use of pesticides only as prescribed in resistance management strategies, hold the most promise for SLW. There are no silver bullets and 'pesticide-alone' strategies are doomed to failure! For soybeans, the problem is compounded by the attractiveness of the crop, and the fact that soybeans mature later in the season than other susceptible crops such as cotton.

Cultural and agronomic practices: The best long-term solution is to slow the build-up of populations throughout the summer. In Central Queensland last summer, all major outbreaks could be traced back to an initial nearby source, either weeds or earlier susceptible crops. Cultural and agronomic practices to reduce the build up of SLW include good weed and volunteer crop hygiene, avoiding successive plantings of susceptible crops, planting breaks between susceptible crops, reducing the planting window for a given crop, avoiding moisture stress (in irrigated crops) and selecting more rapidly maturing cultivars/crops. In 'high-risk' areas such as Emerald with a continuum of other SLW susceptible crops, the growing of soybeans may be impractical or at least very risky, particularly when planted so as to mature at the end of summer.

Biological Control: The next best strategy is to manage the cropping system in a way that maximises the build-up of beneficial insects attacking SLW. Avoid the use of broad-spectrum pesticides against other pests, particularly during the earlier stages of crop development (pre-podfill). This will help conserve the many species of predators and parasites attacking SLW. At least 14 wasp parasites of SLW have been recorded in Australia. Parasitism levels in the Emerald area are markedly higher than last season (currently up to 80%), and are due to lower pesticide use to date this season. Paul DeBarro (CSIRO) has imported another three SLW parasites (*Eretmocerus* spp.) from the USA (but of Middle Eastern origin). These parasites will not be ready for release for another 12-18 months (depending on the results from specificity tests) and won't impact on SLWF for at least another 2 years, but should boost SLW parasitism levels even higher. The very high incidence of parasitism at Emerald this season illustrates the importance of adopting IPM strategies.

Big-eyed bugs, pirate bugs, lacewing larvae and ladybirds also prey upon whitefly nymphs. Very high ladybird populations were observed in many SLW-infested crops in Central Queensland last summer. Experience in the US suggests populations of ladybirds and other predators build in response to SLW, and significantly reduce SLW activity.

Pesticide options for SLW in soybeans: Currently there are no effective pesticides registered for SLW control in soybeans in Australia. The cotton industry and Pulse Australia are jointly seeking permits for a range of pesticides for cotton and pulses. Potential options that have been investigated include oils and soaps, and Pegasus (diafenthiuron). Registrations (or permits) for oils and soaps will be easier to obtain for soybeans, as residues are unlikely to be an issue with these products. As well, SLW is unlikely to develop resistance to oils and soaps because they work by suffocating SLW. However to be successful, oils and soaps must be applied with a high water volume (at least 250L/ha) and must be deposited on the underside of the leaves where SLW feed. As a result, oils and soaps are only likely to be effective in younger crops with smaller canopies where effective spray penetration and coverage are more likely. As the oils and soaps have little residual activity, repeated applications would be necessary where there is continuous SLW invasion pressure.

The registration of SLW pesticides in soybeans will depend on the availability or generation of residue and efficacy data, pesticide company support for new products in a relatively small market, as well as the economics of using expensive products ($70-$170/ha) in a moderate value crop. Also, proposed use patterns in soybeans would have to 'fit in' with resistance management strategies for other SLW susceptible crops such as cotton. In cotton, the basic strategy is to use 'soft' options early in the crops life and to only use 'hard' options late in the life of the crop to prevent adults from emigrating to surrounding crops. For this reason, using hard options against SLW in early soybeans would be damaging, as it would flare other pests and in the long run worsen the SLW problem. The same comments apply to the management of pests other than SLW, as spraying with non-selective products for these pests could also flare SLW. The advent of SLW will therefore force the development of multi-pest management strategies in soybeans and other crops. No matter how tempting it may be, and no matter what the SLW pressure, soybean growers are cautioned not to use unregistered pesticides. Unfortunately, the softest new generation pesticides are also the most expensive and are most likely too expensive for soybeans.

SLW and pesticide resistance: The SLW inadvertently introduced to Australia came with resistance to most organophosphates (OP's, eg chlorpyrifos), carbamates (eg methomyl) and synthetic pyrethroids.(SP's, eg deltamethrin). Since then, resistance has developed in some Australia regions to imidacloprid (Confidor), endosulfan, bifenthrin (Talstar), insect growth regulators (IGR's) and amitraz. SLW can develop pesticide resistance extremely rapidly, due to its short generation time: egg to adult in as little as 12 days in summer, and due to huge populations in heavily infested crops (billions/ha). It develops resistance to pesticides much faster than heliothis (*Helicoverpa armigera*). If pesticides were misused (eg. repeated applications of the same product), SLW could develop resistance within a single season. Spraying SLW in soybeans with the same products sprayed earlier in the season on cotton (or other susceptible crops) would greatly hasten the development of resistance. Non-adherence to resistance strategies would also jeopardise the granting of NRA permits/registrations for new SLW pesticides in soybeans.

Biopesticides: QDPI's Biopesticides Unit are field-testing *Beauveria* and *Paecilomyces* products registered in the USA and are also developing their own products and formulations based on fungal pathogens. The targets are whitefly nymphs. Biopesticides would suit IPM programs in soybeans as they are selective, leave no residues and are extremely unlikely to suffer resistance problems. However, they suffer the same constraints as oil sprays in that coverage is a key efficacy issue.

Area wide management: SLW can only be satisfactorily managed on an area-wide basis. Chemical control alone will not give effective long-term control, and all industries must collaborate if there is any chance of containing the problem. Overseas experience suggests cultural practices, the conservation of beneficial insects, and the judicious and responsible use of selective pesticides (or biopesticides) are the three strategies most likely to stabilise SLW populations. The indiscriminate and undisciplined use of pesticides will only hasten the development of pesticide resistance in SLW, and will greatly worsen the SLW problem. The use of unregistered pesticides may also create market-threatening residue problems for the Australian soybean industry. Exactly what strategies are developed will depend on the climate and cropping practices for each particular region. Any strategies will require underpinning with base data regarding the temporal and spatial incidence of SLW. This will require monitoring of susceptible crops and weeds in a region on a regular basis.

Evaluation of SLW control strategies in soybean: Products for SLW control, and other methods of control, are difficult to evaluate. This is because SLW are very mobile and can occur in such large numbers. Where SLW populations are very high in host crops adjacent to SLW trials, re-invasion of these trials is a major problem. This will make the evaluation of soybean-specific management strategies more difficult and expensive.

Monitoring whiteflies: Monitoring protocols have to be standardised to allow comparison of data between regions and samplers. Protocols will be adapted from those currently used in cotton. Current cotton guidelines are to sample from a minimum of 2 sample sites per 20-35 ha and to sample 15 leaves from each site, taking each leaf from a separate plant. In cotton, the recommendation is to sample from the 5th leaf below the 1st unfolded leaf below the terminal. However, this may be impractical in younger soybean crops, or in large crops where the leaves are intertwined. More appropriate protocols are currently being investigated for soybeans. In cotton, the recommendation is to carefully turn over the recommended leaf and rate the leaf for adults as infested (≥ 3) or uninfested (< 3). Nymphs are sampled using a 10-cent-sized sampling ring (≈ 23 mm diameter), which is placed between the main veins on the underside of the leaf. Nymphs can be either counted or the presence or absence system used. As soybeans have trifoliolate leaves, sampling may be simplified by only assessing whiteflies on the central trifoliolate.

We need to identify your whiteflies! It is important that whiteflies sampled are correctly identified to determine what proportion of the population is SLW. Please contact your local Qld or NSW Agriculture District agronomists or entomologists, to coordinate the sending of specimens to Dr

Robin Gunning, Centre for Crop Improvement, NSW Agriculture, Calala Lane, Tamworth, NSW 2340. Adult whiteflies are preferred for analysis. Late-stage nymphs are also acceptable, but not eggs. Please send specimens so that they arrive as quickly as possible and in good condition for analysis. Keep specimens cool and send alive. Do not kill or place in alcohol. (See also information at: www.cotton.crc.org.au).

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