EXECUTIVE SUMMARY

The review examines semiochemicals, substances or mixtures of substances emitted by one species that can be used to modify the behaviour of receptor organisms, and the role of these semiochemicals, particularly those derived from the inner tissues and organ surfaces of cotton plants, in the sustainable management of *Helicoverpa* spp. in cotton.

In the review, we examine the behavioural sequence leading to oviposition and how it is influenced by semiochemicals. The importance of leaf surface chemicals as cues in host plant selection will become evident in the review. For ovipositing moths such as *Helicoverpa* spp. that do not feed on the same plant, and thus do not contact the inner tissues, recognition and selection of the host plant for oviposition after landing, is determined by small quantities of many types of chemical substances. These include free amino acids, organic acids, sugars, secondary metabolites, vitamins, minerals, growth regulators etc. that come from the inner tissues of the plant onto the plant surface, as well as surface wax components. Detection of these substances on the leaf or organ surfaces of the plant provides specific information to the female moth on plant health, physiology and nutrition. Such information guides the moth to either accept or reject the plant for oviposition. The review then examines the evidence for learning in adult moths' host recognition and selection behaviour and concludes that while learning or prior experience of the moth with the plant, either during the development of the larval or adult stages, may be an important factor under laboratory or glasshouse conditions, it may not be important under large scale commercial field conditions. One weakness in the literature that we noted about insect learning and host selection was that all the information available comes from either laboratory or glasshouse studies and may not hold true in the field.

Behaviour manipulation methods for pest management are reviewed. There are three principal elements of a behavioural manipulation method: a behaviour of the pest, a means by which the behaviour is manipulated appropriately, and a method that utilises the behavioural manipulation method for the protection of the resource from the pest. Stimuli that act over a long distance such as chemical stimuli (e.g. pheromones), visual stimuli, attractants and repellents enable the insect to encounter the plant. After the insect has landed, short range stimuli such as stimulants and deterrents, which occur on the organ or leaf surfaces of the plant, guide the insect to either accept or reject the plant for oviposition or feeding. Most stimulants and deterrents are non-volatile chemicals and are perceived by the insect (particularly moths) on the leaf or organ surface of the plant. It is clear in the review that short-range stimuli (stimulants and deterrents) are considered more likely to be useful for pest management than long-range stimuli (mating disruption, moth attractants). This is because successful manipulation of the pestilential behaviour (e.g. feeding on the resource) or a behaviour related to the resource (e.g. finding the resource) (i.e. short range stimuli) will ensure the protection of the resource, but successful manipulation of behaviours unrelated to the resource (e.g. mating disruption for moths, moth attractants) may reduce the local population but still not protect the resource because of immigration of outside populations into the area being protected.

The review then examines the role of semiochemical research in *Helicoverpa* behaviour and management in Australian cotton. The pest management strategies being used in the cotton industry include beneficial insects, trap cropping, intercropping, transsgenic cotton, biological pesticides, host plant resistance and synthetic insecticides. It was clear in the review that virtually all the methods of pest management currently used in the cotton industry involve some changes in pest behaviour, whether intentional or not. Ultimately, the success of any particular strategy to manage *Helicoverpa* in cotton will depend on the feeding and oviposition behaviour of *Helicoverpa* spp. in relation to the host plant. The use of stimulants in conjunction with biological pesticides can increase contact that may be suppressed if the pest responds to the toxin by ceasing to feed to avoid a lethal dose. Trap crop strategy is being utilised to reduce the size of *Helicoverpa* populations by diverting *Helicoverpa* eggs from cotton to the trap crops. It was clear in our review that most potential trap crops are only briefly more attractive than cotton. *H. armigera* female oviposition and orientation on pigeon pea is elicited by different optimum stimulus concentrations. The same kairomone concentration that attracts *H. armigera* females is active as an oviposition deterrent, whereas a lower kairomone concentration stimulates egg laying. This selective response reveals that each plant-released stimulus concentration has to be determined on the plant surfaces to enable effective use of these crops as either a trap or refuge crop in pest management.

We then examine the role of semiochemicals on the survival of *Helicoverpa* spp. larvae on transgenic cotton plants and find that there is a significant gap in our understanding of the behavioural events that lead *Helicoverpa* larvae to feed and survive on the transgenic crops. For example, it is not clear whether any chemicals on the leaf surface of transgenic plants are different from those on non-transgenic plants and if they are whether these chemicals are detectable by the larvae by contact, serving as a cue to the insect to alter its feeding behaviour on transgenic cotton plants so as to avoid a lethal dose of the toxin similar to the feeding behaviour of *H. virescens* on cotton with gossypol.

Then we examine the research capabilities of NSW Agriculture and Queensland Department of Primary Industry's Chemical Ecology Unit in Brisbane. We conclude that the two State organisations are well placed to undertake complementary semiochemical research should CRDC decide to invest in that area to exploit plant surface chemicals to manage key pests in Australian cotton.

Finally, we make a series of recommendations based on this review or background information. These are:

Recommendation 1: that the CRDC commission research to assess and compare chemical components of the organ surfaces and inner tissues of cotton plants, other hosts and non-host plants, and also potential trap crops in relation to genotype, plant growth stage, conditions and physiology to determine how these chemicals influence acceptance or rejection of hosts, as a step towards development of better management strategies for *Helicoverpa* spp. in cotton.

Recommendation 2: that the research initiated in recommendation 1, as part of the objective identify those plant surface chemicals that can be better exploited as stimulants, deterrents, attractants and repellents in conventional spray programs, either alone or in combinations with biopesticides or synthetic insecticides to enhance the management of *Helicoverpa* spp. in cotton. The project application on semiochemicals to CRDC in 1999 entitiled "Semiochemicals of organ surfaces of cotton plants and pest management" under which this review was commissioned seek to address recommendations 1 and 2. In the light of this review and given that a new project application could not occur until the year 2000/2001, we recommend that the preliminary project as per 1999/2000 application be revised as a joint NSW Agriculture and QDPI Chemical Ecology Unit project and continue this season to allow preliminary investigations in line with recommendations 1 and 2.

Recommendation 3: that the research initiated in recommendations 1 and 2, as part of their objectives, assess the opportunities for creative management of crop insect pests through genetic modification of the host's chemical profile or in novel plant breeding programs to produce cotton plants which are a less suitable host and trap crops which are a more attractive host to *Helicoverpa* spp.

Recommendation 4: that the CRDC commission research to assess differences in leaf surface chemistry of Bt and non-Bt plants in response to stress, water-logging, cloud cover, pest damage, humidity etc., and determine whether there is a linkage between changes in organ surface chemistry of Bt plants and the expression of Bt toxins and how all these relate to the feeding behaviour and survival of *Helicoverpa* spp. larvae on Bt plants, as a step towards development of improved resistance management strategy for Bt plants. CRDC has approved NSW Agriculture research to examine the expression of Bt plants under different agronomic conditions. These experiments could be used for initial investigation into semiochemicals on Bt plants this season or for future semiochemical research on Bt plants.

Recommendation 5: that the CRDC approve joint research collaboration between NSW Agriculture and QDPI's Chemical Ecology Unit in Brisbane in the establishment of a "Semiochemical Research Unit". This unit which would develop, lead and co-ordinate research into both long and short range chemical stimuli to identify behaviour modifying compounds from organ surfaces or inner tissues of plants to manage *Helicoverpa* spp.