The challenges of organic soybean production in the Riverina

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- Three years of trials at Yanco determined that the main impediment to successful organic soybean production was finding effective control options for green vegetable bug (*Nezara viridula*)
- A combination of cultural and conservation biological control with strategic bio-pesticide application can provide adequate control of species such as *Helicoverpa* sp, however more research is required to develop an integrated program to successfully control green vegetable bug
- Organic farms have a greater number and diversity of predatory insects than conventional farms but more research is needed to design agroecosystems which favour the presence and persistence of these beneficials and deter pests from the main crop

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Introduction

Market demand, price premiums and farming system rotation benefits have encouraged some Riverina organic producers to include soybeans in their farming systems. Demand is for quality, white hilum beans for domestic and export processing markets (soy milk, tofu, soy sauce and soy flour). However organic soybean production is not without its challenges. A producer workshop coordinated by NSW Agriculture, Vitasoy and RIRDC in 2002 heard that crop nutrition and insect pest management, were the key production constraints limiting expansion of the Riverina organic soybean industry (Scammel 2002).

Pest management identified as the greatest challenge at Yanco

The crop yields of organic soybeans in the Riverina range from 2.0 to 2.5 t/ha, whilst conventional crops average around 3.0 to 4.0 t/ha. Green vegetable bug (*Nezara viridula*) and *Helicoverpa* sp were identified as the biggest impediments to the Riverina organic soybean industry, with producers reporting significant yield losses, and seed graders and processors reporting considerable impact on seed quality, with grade-outs of around 10% attributed to these pests.

During 2000–03, NSW Department of Primary Industries assessed organic soybean production at Yanco Agricultural Institute's Organic Demonstration site. Agronomic management, cultural practices, trap cropping, screening of habitat species, applications of organically acceptable pesticides and release of biological control agents are some of the techniques that were investigated. It was quickly determined that the main impediment to successful organic soybean production was finding effective control options for the green vegetable bug.

Green vegetable bug is a significant pest of a range of crops including tomatoes, sweet corn, fruit and most pulses. Indications are that crop damage due to this pest is increasing in the southern irrigated cropping districts. One reason cited for this has been the transition away from broad-spectrum pesticides (such as endosulfan) to more selective pesticides (such as the nucleopolyhedrosis virus (NPV) pesticide, Gemstar®). Whilst this strategy has been effective against target species (in this case *Helicoverpa* sp.), non-target species, such as green vegetable bug, have proliferated.

Strategies to manage soybean pests organically

Crop monitoring

Regular monitoring of crops for pest and predatory species is critical in achieving optimum yield and quality. At Yanco,

crops were monitored for seasonal nutrient deficiencies using leaf petiole analysis and these compared with regular refractometer (Brix) readings (a technique frequently used by organic farmers to indicate plant stress). Foliar spray applications were made during crop growth, primarily in response to signs of plant stress and to prevent insect attack. Foliar sprays consisted of various combinations of fish emulsion, worm liquid, seaweed liquid, molasses, sugar and microbial preparations.

Methods used to monitor predator and pest species were yellow sticky traps, sentinel cards and a 'Bugvac ' (a reversed leaf blower). Soybeans were monitored using sentinel cards to determine the relationship between green vegetable bug distribution and the distance from the edge of the crop in all directions. The acceptable threshold for green vegetable bug in soybeans for human consumption (such as the organic processing market) is 0.33 bugs/m^2 at early pod-fill (NSW DPI, 2004). Results at Yanco showed that concentrations of green vegetable bug were greatest on field borders.

Conservation biological control

Conservation biological control employs habitat manipulation of non-crop (insectary) species within the agroecosystem to provide resources for natural enemies (predators and parasitoids). Insectary and trap crops have been used in a range of permanent cropping situations and also within organic gardening, however relatively little work has been done on species suitable as insectaries in Australia and less in row cropping situations.

The concept of encouraging beneficial insects with flowering (insectary) plants is based on the requirement for many adult predatory and parasitic insects to feed on nectar and/or pollen. It is the larvae of these beneficial insects that are the primary feeding stage on other insects. Flowering borders can increase the diversity of habitats and provide shelter and alternative food sources for natural enemies and can significantly increase the residency times and thus enhance the efficacy of predators and parasitoids.

Some insectary species were selected for testing at Yanco. Following monitoring for pest and predator incidence these were given ratings for their insectary potential (Table 1). French marigold, green ruffle basil and white clover showed good potential, and whilst yarrow also showed good potential, there was some question regarding its likely weed status.

There are many examples of the use of biological control for green vegetable bug throughout the world and a comprehensive coverage of these is given in Waterhouse (1998). Research undertaken by Rahat *et al* at Yanco during the summer of 2001–02 investigated the scope for improving the impact of the an egg-parasitoid wasp *Trissolcus basalis* (Wollaston), on green vegetable bug by use of conservation biological control. Though levels of control are good in some crop systems, the impact of *T. basalis* in Australia is not always adequate (Clarke 1990) especially in

Table 1
Species screened as potential insectary plants at NSW DPI's Organic Demonstration Farm, Yanco. Source: S. McDougall, 2000 NSW DPI.

Insectary Plant	Scientific name	Flowering	Potential
Azerbijan basil	*Ocimum basilicum*	summer	Moderate
borage	*Borago officinalis*	spring-summer long flowering	Moderate
calendula	*Calendula arvensis*	spring-summer long flowering	Moderate
cosmos*	*Cosmos bipinnatus*	summer - long flowering	Moderate
cow pea*	*Vigna unguiculata*	late summer -short flowering	Moderate
fennel	*Foeniculum vulgare*	autumn	Moderate *(weed potential)*
feverfew	*Chrysanthemum parthenium*	autumn	Moderate
French marigold	*Tagetes patula*	summer - long flowering	Good
grain amaranth*	*Amaranthus spp.*	summer	Moderate *(weed potential)*
green ruffle basil	*Ocimum basilicum*	summer - long flowering	Good
leaf amaranth*	*Amaranthus spp.*	late summer	Moderate *(weed potential)*
Mexican sunflower*	*Tithonia rotundifolia*	summer	Moderate
parsley	*Petroselinum crispum*		Moderate
pigweed	*Portulaca oleracea*		Poor
Pineapple sage	*Salvia officinalis*	autumn	Poor - frost sensitive
sorghum*	*Sorghum bicolour*	autumn	Poor
strawberry clover	*Trifolium fragifernum*	autumn	Moderate
Thai basil	*Ocimum basilicum*	summer - long flowering	Moderate
white clover	*Trifolium repens*	autumn	Good
wormwood	*Artemisia absinthium*	late summer	Moderate
yarrow*	*Achillea millefolium*	summer	Good (weed potential)

* species also intercropped with mixture of clovers and buckwheat, intercropped plants tended to have higher bugsucker pred/prey ratios and lower sticky trap pest numbers.

areas where soybeans are planted extensively (Waterhouse 1998). The Yanco study focused on adult *T. basalis* longevity and aimed to determine whether nectar from a range of plant species befitted this parasitoid, and if their use in field margins or within-crop strips offers scope to increase longevity of *T. basalis*, and hence improve parasitism of green vegetable bug.

Plants of alyssum (*Lobularia maritima* L.), canola (*Brassica napus* L.), French marigold (*Tagetes patula* L.), basil (*Ocimum basilicum* L.), buckwheat (*Fagopyrum esculentum* Moench), cosmos (*Cosmos bipennatus* Cav.), calendula (*Calendula arvensis* L.), coriander (*Coriandrum sativum* L.), nasturtium (*Tropaeolum majus* L.) and phacelia (*Phacelia tanacetifolia* Bantham) were grown in a glasshouse and as they began to flower were used in bioassays to determine if their flowering increased *T. basalis* longevity.

Results showed that longevity of *T. basalis* on flowering French marigold, basil, buckwheat and cosmos was greater than other species, whilst longevity on inflorescence-free shoots of French marigold, phacelia, cosmos and basil was significantly ($P < 0.001$) greater than on equivalent non-flowering shoots of other species. Further research is required to determine if these findings can be transposed into the field.

Trap cropping

Another method of pest management is the planting of 'trap' or 'catch' crops in strips adjacent to the main crop. Trap crops, due to their 'preferred host' status, attract the pest away from the main crop, where the pest is then allowed to develop to their peak and is then destroyed. In a demonstration at Yanco, pigeon peas were found to be an excellent trap crop for *Helicoverpa* sp. whilst sunflowers were particularly attractive to green vegetable bug.

Parasitoid/predator augmentation

Commercially reared, *Trichogramma* (a predatory wasp) parasitised *Helicoverpa* eggs, were released at Yanco to control *Helicoverpa* sp and loopers. This is an expensive operation ($100/ha) and so is generally only used on highly productive irrigated soybeans where yields are expected to reach 3.0–4.0 t/ha.

Figure 1 *Insectary crops of Green ruffle basil and French marigold adjacent to organic soybeans at NSW DPI Organic Demonstration Site at Yanco*

Organically acceptable pesticides

Products permitted for use in organic farming are assessed against criteria which are set out in national organic standards. Organically acceptable bio-pesticides include pesticides derived from natural materials such as microorganisms (bacteria, viruses, fungi and protozoa), nematodes and certain minerals. Some are derived from plants, including *Tanacetum cinerariaefolium* (the source of pythrethrum), *Derris elliptica* (the source of rotenone), and *Azadirachta indica* (the source of neem). Products developed using recombinant DNA technology (GMO) or through exposure to ionising radiation are not permitted for use in organic systems.

Laboratory assays conducted at Yanco evaluated the effectiveness of Natural Pyrethrum Concentrate (Pestech Australia Pty Ltd) on the mortality of green vegetable bug. At the recommended rate of 1 mL/L this product gave inadequate control (41% mortality) under laboratory conditions. Doubling the rate (to 2 mL/L) produced 81% mortality after 24 hours. The relative ineffectiveness of these laboratory results suggests that further field evaluation is unjustified.

In another demonstration, the neem product AzaMax (Organic Crop Protectants (OCP)) was applied by two different methods. Applied as a crop foliar spray (at 2.5 L/ha) AzaMax had little visual impact on green vegetable bug mortality. OCP suggested that the product may lose its efficacy within a number of months following manufacture, suggesting that a repeat evaluation of the effectiveness of fresh AzaMax is required. On another occasion AzaMax was applied as a soil drench via drip irrigation. Following application, a mass migration of green vegetable bug from the crop was observed. It was inconclusive whether this was an antifeedant response, or purely a coincidental migratory response, however, it was an interesting phenomenon that is worthwhile revisiting.

Observations on the effectiveness of bio-pesticides made at Yanco are consistent with those made in trials conducted on green vegetable bug (in sweet corn) at New Zealand's Lincoln University organic site, the trial results confirming that there are few (if any) pesticides (including 'conventional' pesticides) that provide effective control against green vegetable bug (Dr. Steven Wratten, pers. comm. 2002).

Future research

Due to increasing biodiversity and reduced chemical usage, organic farms have a greater number and diversity of predatory insects. Beneficial insects (predators and some parasitoids) which commonly occur in soybean crops include *Braconid* wasps, predatory shield bugs (*Cermatulus nasalis*), spined predatory shield bugs (*Oechalia schellenbergii*), damsel bugs (*Nabis kinbergii*), orange caterpillar parasite (*Netelia producta*), ladybird beetles, soldier beetles (*Chauliognathus lugubris*) and pollen beetles (*Dicranolaius bellulus*). More research is needed to design agroecosystems which favour the presence and persistence of these beneficials and which deter pests from the main crop.

Work at Yanco showed that by integrating a combination of cultural practices such as pupae busting and trap cropping, augmentative releases of parasitoids, the planting of insectary borders to enhance and conserve natural predators, combined with strategic applications of bio-pesticides (such as nucleopolyhedrosis virus (NPV) and *Bacillus thuringiensis* (Bt)), *Helicoverpa* sp. populations in soybeans can be reduced to an economically acceptable threshold.

Whilst work at Yanco failed to identify a satisfactory integrated management program for the control of green vegetable bug, it has highlighted a number of areas where future research efforts should be targeted. Results at Yanco suggests that green vegetable bug prefers feeding on crop edges and that certain plant species, if planted on borders, could act as a nectar source thus enhancing the parasitism of beneficials such as *Trissolcus basalis*. Furthermore, planting a strip of a preferred host plant (eg early maturing soybean, sunflowers) immediately adjacent to nectar sources would expose a high proportion of the pest population to well-nourished natural enemies causing potentially higher rates of mortality. Further field experiments to test these hypotheses are warranted.

Organisms known to cause stink bug mortality include the entomopathogenic fungi, *Beauveria bassiana* (Bals.), *Metarhizium anisopliae* (Metsch.) and *Paecilomyces lilacinus* (Thom.). Commercial bio-pesticide formulations of *B. bassiana* are currently registered in the United States as Mycotrol ES® (Mycotech, Butte) and Naturalis L® (Troy Biosciences). Researchers at Queensland DPI's Biopesticides Unit at Indooroopilly have been comparing the effectiveness of these products and a collection of native isolates taken from green vegetable bug. Initial bioassays with one isolate achieved an 80% mortality of 1st instar green vegetable bug within 3 days and 100% mortality within 7 days. (Knight *et al* 2003). Further field evaluation of these products, particularly in southern soybean cropping districts is required to ascertain their efficacy.

Conclusion

Demonstration plantings of organic soybeans at NSW DPI's Organic Site at Yanco from 2000–03 confirmed that the greatest challenge for organic soybean production is pest management. Yanco trials showed that a combination of cultural and conservation biological control and with strategic bio-pesticide application can provide adequate control of species such as *Helicoverpa* sp, however more research is required to develop an integrated program to successfully control green vegetable bug. There are few effective organically acceptable pesticides available to control this pest and limited research has been undertaken into increasing the effectiveness of its natural predators and other cultural methods of pest management, particularly in southern cropping districts.

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Further information

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