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Natural pest control in citrus as an ecosystem service: Integrating ecology, economics and management at the farm scale

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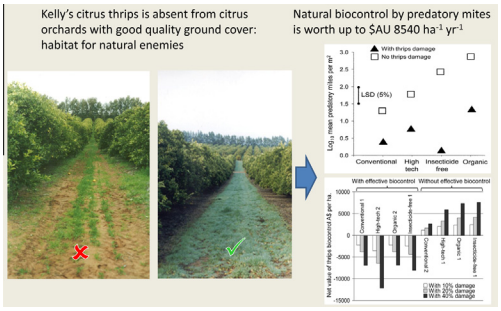
HIGHLIGHTS

- Citrus orchards with good ground cover had large predatory mite populations.
- Orchards with large mite populations had no damage from Kelly's citrus thrips.
- Growers were benefitting from natural pest control as an ecosystem service.
- The mean value of this service to growers was A$ 2600–8500 per hectare per year.
- Growers changed their production practices to benefit from natural pest control.

GRAPHICAL ABSTRACT



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ABSTRACT

While we were completing a year-long survey of soil invertebrates in eight citrus orchards in South Australia, there was an outbreak of Kelly's citrus thrips (*Pezothrips kellyanus*). Four growers in our survey reported their orchards were free of thrips, while the others reported suffering serious economic damage. A retrospective analysis, using data from the invertebrate survey, showed that orchards without thrips damage all had dense ground cover (perennial grasses, diverse forbs and with a deep litter layer), whereas orchards with thrips damage all had patchy ground cover (bare mineral soil with scattered annual weeds or a sparse monoculture of lucerne or oats and no litter layer). Orchards with dense ground cover and no thrips damage had far denser populations of predatory mesostigmatid mites (mean 6471 ± 692 m^{-2} 1 SE) compared with orchards with patchy ground cover and thrips damage (1097 ± 126 m^{-2}). Most Mesostigmata (total 17 spp.) were generalist predators, capable of feeding on thrips larvae when they move from the fruit to the soil to pupate. We suggest the absence of thrips damage is causally related to the presence of a diverse, abundant fauna of natural enemies, enhanced by good quality ground cover habitat and that growers with no thrips damage are benefitting from the ecosystem service of natural pest control. Using three scenarios of increasing severity of thrips damage (10%, 20% and 40%), we estimated the mean value of natural pest control of thrips as an ecosystem service was A$ 2640, A$ 4610 and A$ 8540 per hectare for those orchards that benefited from the service, whereas those orchards that received no such benefit potentially lost A$ 1970, A$ 3260 and A$ 5850 respectively. Our findings led to the planting of improved ground cover as habitat for predators by three growers, and the development of a commercial predator biocontrol agent for thrips by a fourth, based on mites harvested from his orchard. Growers who had effective natural pest control of thrips are more likely to have greater economic resilience in relation to price volatility shocks than those growers who do not benefit from this ecosystem service.

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1. Introduction

This paper is about how natural pest control, an example of an ecosystem service to agriculture, can be costed and implemented at the farm-scale, resulting in changes to ways in which farmers manage their land. Farmers have considerable capacity to influence what the agricultural landscape looks like and how it functions, so incentives for the use of ecosystem services at a scale relevant to farmers represent an important component for planning and implementation of ecosystem services approaches to management of landscapes (Goldman et al., 2007; Kroeger and Casey, 2007).

Natural pest control of crops (also known as conservation biocontrol) represents an important ecosystem service delivered by biodiversity (Costanza et al., 1997; Naylor and Erlich, 1997; Zhang et al., 2007). Complexity of agricultural landscapes represents an important integrator for natural pest control and conservation management, and there is mounting evidence of the benefits to farmers from diversified landscapes (Bianchi et al., 2006). Achieving landscape-scale change in order to increase complexity and habitat availability for natural enemies requires an understanding of practical methods that can be used at different scales (Gurr et al., 2003), as well as provision of policy and economic incentives (Pascual and Perrings, 2007; Goldman et al., 2007; Kroeger and Casey, 2007).

Most valuations of agroecosystem services such as natural pest control are at regional scale (e.g. Cleveland et al., 2006) and there are very few studies at farm-scale that address both the monetary value of pest control services and how they can be implemented (Thomas et al., 1991; Östman et al., 2003). This is partly because of the difficulty in obtaining from farmers the detailed financial information required. The present paper deals with both these issues in relation to control of a thrips pest (Insecta, Thysanoptera) in citrus orchards in South Australia.

Australia has about 2000 citrus growers on 29,000 hectares of land. National production in 2009–10 was 595,000 tonnes, of which almost half was exported, worth A$ 187 million (ABARES, 2010). The long-term economic outlook for the Australian citrus industry has been of sufficient concern to warrant a national enquiry (Productivity Commission, 2002). The conclusion was that the outlook was generally favorable, but that growers needed to adopt production methods that reduce input costs and to improve fruit quality in order to secure higher prices. An option for growers to achieve these aims is to make wider use of ecosystem goods and services, for example by reducing their reliance on insecticides by adopting strategies for natural pest control.

Kelly's citrus thrips, *Pezothrips kellyanus* (Bagnall), has been an economically important pest in New Zealand (Froud et al., 2001) and the Mediterranean (Vassiliou, 2007), for some time. It was first recorded in Southern Australia in 1935, but major damage has occurred only since the 1990s (Webster et al., 2006). Adult females lay their eggs in citrus flowers. Adults and larvae feed upon the skin the around the calyx (Mound and Jackman, 1998) causing scarring and down-grading of fruit quality because of unsightliness (though fruit quality is unaffected). The thrips pupates entirely in the soil or litter layer (Jamieson and Stevens, 2006; Baker et al., 2011) and it is during this phase that it is vulnerable to soil-dwelling predatory mites. Growers tend to use repeated sprayings to try and maintain fruit quality during an outbreak. Income lost is compounded by the high cost of chemical control, and there may be no net financial benefit or an overall loss. There is a large price differential between premium fruit and that used only for juicing. Thus quality rather than quantity is an important economic driver for citrus production. Economic survival of many growers depends on their production of fresh fruit for export markets, with strict quality control regulations. Anecdotal reports by growers suggest thrips damage may affect as much as 40% of the navel orange crop in an outbreak year (Baker et al., 2011).

An integrated pest management program for *P. kellyanus* in South Australia has been under development (Baker et al., 2002; Crisp et al., 2011), but the only control method available at the time of our research was use of the organophosphate insecticide, chlorpyrifos. Vassiliou (2007) found chlorpyrifos was highly effective against *P. kellyanus*, but resistance has been reported anecdotally. Regardless, chemical control remains the only viable option for most growers. More recently combined use of chlorpyrifos and biocontrol has been trialled (Navarro-Campos et al., 2012).

Our aims in this study were (1) to test whether the presence or absence of natural enemies on citrus orchards in South Australia was associated with the presence or absence of damage to citrus due to *P. kellyanus*; (2) to determine whether the presence or absence of natural enemies was associated with particular citrus production methods, availability of suitable ground cover habitat or seasonal factors; (3) to undertake an economic assessment of the value of natural pest control as an ecosystem service to citrus growers.

2. Methods

2.1. Study system

In January 1998 we began collaboration with 34 South Australian citrus growers to provide the scientific basis for an environmental management system, focussing on soil nutrient cycling (Colloff et al., 2003). In August 1998, we began a year-long survey of soil chemistry and invertebrate biodiversity in eight orchards that were representative of four major production management categories in the region. Eight growers self-selected from the broader group of 34, based on management category and the capacity to provide data on their nutrient, energy, water and chemical inputs and outputs and production costs against revenue. Orchards were not visited by researchers prior to selection. In August 1999, at the beginning of a severe thrips outbreak, we were asked to investigate the potential for control of *P. kellyanus* using natural enemies. At that time, growers had a choice between using chlorpyrifos and doing nothing.

During discussions in August 1999 with growers who had participated in the soil biodiversity survey it emerged that, by chance, four properties had serious thrips damage (one in each management category) and the other four were mainly unaffected, possibly indicating the presence of natural pest control of thrips. The location of orchards with thrips damage and those without showed no geographical clustering within the Riverland region (Supplementary data Fig. S1). The chance parity of thrips 'positive' and thrips 'negative' groups provided an important starting point for our investigations.

2.2. Study sites

Eight properties were chosen for the initial study on soil biodiversity in the Riverland of South Australia in August 1998. Properties were located between Waikerie (34°11′S, 140°00′E), Paringa (34°11′S, 140°47′E) and Loxton (34°28′S, 140°34′E) (Supplementary data Fig. S1). Properties were coded in order to protect privacy and commercial confidentiality. The reason for this was that the identity of growers could be inferred from the combination of type of production, location and orchard characteristics. Financial data was provided to us with the proviso that it would not be associated with individual growers. The main purpose in selecting properties for studies was to obtain a spectrum of different production methods representative of citrus growing in the Riverland. The management categories were as follows: