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Absence of windbreaks and replanting citrus in solid sets increase density of Asian citrus psyllid populations

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ABSTRACT

Densities of an herbivorous pest may be impacted by landscape and orchard architecture. We present two orchard experiments where the densities of the Asian citrus psyllid (*Diaphorina citri*) were compared depending on: (1) the presence or absence of a windbreak and (2) if the orchards consisted of a solid set re-planting or an orchard with a mixture of mature and reset-replacement trees. Psyllid abundance was measured on the edges of five orchards. The factor investigated was the presence or absence of a windbreak. We observed significantly fewer psyllids on the edges of orchards with windbreaks as compared to those without windbreaks. We found no significant difference in the number of natural enemies between the edges with or without windbreaks, suggesting that windbreaks do not affect densities of psyllid natural enemies. Also, during two consecutive years, we compared the densities of psyllids on young trees less than 3 years of age in a solid set re-planting versus on resets (trees planted in replacement of dead or huanglongbing-infected trees) present randomly within mature orchards. This was conducted in four orchards and among three citrus varieties. More psyllids were found in the solid set re-plantings as compared with on the resets within mature orchards. To our knowledge, this is the first report to demonstrate that the planting strategy of new trees in orchards may impact the populations of a horticultural pest. Overall our data suggest that establishment and conservation of windbreaks might be beneficial to protect orchards from *D. citri*. The data also suggest that *D. citri* populations increase more within uniform landscapes of seedling trees as compared with mature orchards with randomly interspersed young seedlings.

1. Introduction

Densities of an agricultural pest might be impacted by landscape and orchard architecture (Ricci et al., 2008). This includes the presence of non-crop habitats such as windbreaks, orchard margins, and remnant native vegetation. Current trends and economic constraints in agriculture lead to the simplification of landscapes, with the merging of small exploitations and consequently disappearance of boundaries such as field hedges between small properties (Baudry et al., 2000). Reduction of non-crop areas and the associated loss of complexity and biodiversity reduce resilience capacity of agrosystems to cope with disturbance and pest outbreaks (Altieri et al., 2011). In the present study, we examined the effect of two major Florida citrus orchard landscape features: (1) windbreaks and (2) solid set re-plantings of young citrus trees on the density of the current major citrus pest, the Asian citrus psyllid, *Diaphorina citri* Kuwayama (Hemiptera: Psyllidae).

D. citri transmits the bacterial pathogen, *Candidatus* Liberibacter asiaticus (*C*Las), which is the presumed causal agent of the citrus disease, huanglongbing (HLB) (Grafton-Cardwell et al., 2013; Hall et al., 2013). HLB is considered the most destructive disease of citrus crops worldwide. All known citrus cultivars are susceptible to HLB (Folimonova et al., 2009) and prevention of disease transmission has proven difficult (Grafton-Cardwell et al., 2013). Infected mature trees decline and may die within 5–10 years of infection, due to symptoms of HLB or because of secondary infections to the weakened trees (Bové, 2006). Before their demise, a portion of the fruit produced by infected trees is unmarketable, because these fruit are small, misshapen, with uneven color development (Bassanezi et al., 2009). Juice from infected fruit tastes bitter and unbalanced due to low soluble solids and high acid contents (Gottwald, 2010). Fruit and foliage drop are additional costly symptoms of infection (Gottwald, 2010). First discovered in

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Florida in 1998 (Halbert, 1998), *D. citri* quickly became established throughout the state, making eradication impossible.

Measures for HLB management have consisted of: (1) reduction of *D. citri* populations by intensive insecticide treatments (Qureshi et al., 2014; Boina and Bloomquist, 2015), (2) removal of infected trees to reduce *C*las inoculum (Bassanezi et al., 2013), and (3) re-planting healthy citrus plants produced in insect-proof nurseries. Among these recommended measures for HLB management, the removal of symptomatic trees is the most controversial and difficult to accomplish by citrus growers. First, it increases per-acre orchard maintenance costs by ≈$400 annually (Spreen et al., 2014); second HLB is already widespread throughout Florida with 40% of citrus trees in Florida infected with *C*las in 2012 (Spann and Schumann, 2012), and between 37.5 to 100% of *D. citri* infected with *C*Las (Coy and Stelinski, 2015); and third newly planted young trees designated to replace removed trees are more susceptible to *C*las infection than mature trees (Brlansky et al., 2014). This is likely because young trees produce more newly emerging leaves termed "flush", which is the only site of *D. citri* egg laying and nymphal development (Hall and Albrigo, 2007). Consequently, young citrus trees can be infested and infected soon after planting and die faster than mature trees (Gottwald et al., 2007) and before reaching the fruit bearing stage (Brlansky et al., 2014; Grafton-Cardwell et al., 2013). Therefore, many growers have abandoned infected tree removal and instead are attempting to prolong life and productivity of diseased trees with intense supplemental applications of micronutrients (Gottwald et al., 2012; Spreen et al., 2014; Stansly et al., 2014). This has led to widespread abandonment of systematic removal of infected trees and many growers prefer to wait until the entire orchard becomes unproductive to abandon it and replant solid set re-plantings (SSRPs). A SSRP is an orchard where all the trees have been simultaneously replanted (example of 3 year old replanting, Fig. 1A). This is in contrast with the situation where young citrus trees are intermittently re-planted to replace HLB-infected trees within an orchard of mature trees (in this situation, young citrus trees are referred as 'resets', Fig. 1B). Economical models demonstrated that the reset strategy is usually more profitable than SSRP (Muraro et al., 1999). However these models were developed before the establishment of HLB in Florida and need to be revised to be more representative of the current situation. Evaluating the susceptibility of young resets to HLB in a grove with mature trees versus solid set young trees is an important step in the development of these future economic models.

It also has been pointed out that the reduction of the local inoculum by HLB-infected tree removal in an orchard is not effective in cases where infected psyllids are able to migrate from nearby non-managed areas (Bassanezi et al., 2013). This issue is referred to as the "bad neighbor effect" (Spreen et al., 2014) and is caused by growers who fail to remove HLB-infected trees or to manage their *D. citri* populations. This likely contributes to infection of neighboring orchards with *C*Las-infected psyllids. However, the major problem in Florida spans beyond the "bad neighbor" effect given that there were approximately 51,386 ha of abandoned citrus in Florida in 2013 (US Department of Agriculture, 2013) that receive no insecticidal treatment and are an important source of *C*Las-infected psyllids (Tiwari et al., 2010). It is known that *D. citri* move frequently from abandoned to managed orchards (Boina et al., 2009; Lewis-Rosenblum et al., 2015). *D. citri* are also able to disperse several kilometers without wind assistance and over fallow fields, lakes, and roads (Martini et al., 2013, 2014; Lewis-Rosenblum et al., 2015). Therefore protecting an orchard from *D. citri* immigration is essential, especially for protection of young trees.

A possible tactic to protect citrus orchards from infestation by *D. citri* is the use of windbreaks. Windbreaks consist of either living trees or artificial structures and are erected to protect orchards from prevailing winds and storms, reducing abrasion and wind scars on fruit. They have been also very important tools in managing citrus canker (causal agent: *Xanthomonas axonopodis* Hasse), which is spread by wind-blown rain. This is a fungal disease that causes yield loss in commercially cultivated citrus (Gottwald and Timmer, 1995; Moschini et al., 2014).

Living windbreaks surrounding citrus orchards are known to be habitat for predators such as lady beetles and spiders (Inoue et al., 1991) and have proven to efficiently reduce some citrus pests, such as the brown soft scale, *Coccus hesperidum* L., or the Texas citrus mite, *Eutetranychus banksi* McGregor (Reed et al., 1970). In contrast, in South Africa, the thrips, *Scirtothrips aurantii* Faure, has been found in higher densities in citrus surrounded by silky oak (*Grevillea robusta*, Proteaceae) windbreaks than in the center of orchards, because silky oaks offer alternative habitats for thrips (Grout and Richards, 1990). To date, the effect of windbreaks on populations of *D. citri* has not been described. This is despite the fact that *D. citri* tend to aggregate on the edges of orchards (Gottwald, 2010) and that Shen et al. (2013) suggested that windbreaks may delay *C*las infection. The objectives of this investigation were to assess the effect of: (1) windbreaks on *D. citri* population densities and (2) reset planting versus SSRPs on *D. citri* populations infesting young citrus trees.

2. Material and methods

2.1. Insect vacuum sampling device

All samples were collected with an insect vacuum. Sanders and Entling (2011) showed that suction sampling is particularly efficient for aboveground vegetation characterized by high canopy density and Thomas (2012) proved that this method is particularly effective for *D. citri*. The vacuum insect sampler used was a D-Vac

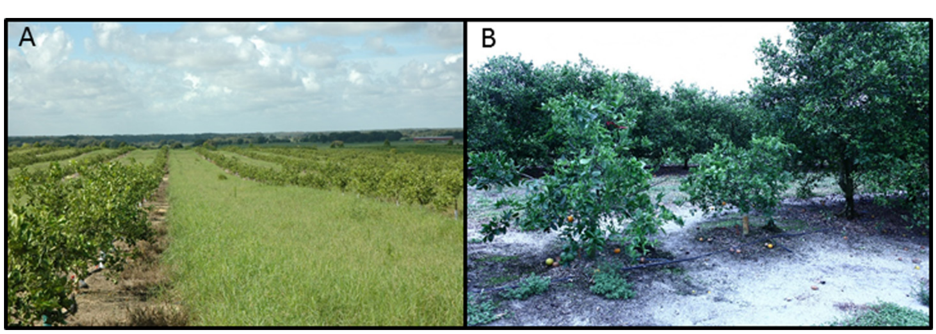

Fig. 1. Example images of: (A) solid set re-planting where all the young citrus trees have been re-planted <3 years ago following removal of dying trees, or (B) reset trees where young trees were intermittently re-planted to replace diseased trees within a mature orchard.