Agriculture, Ecosystems and Environment 215 (2016) 20–29

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

The impact of landscape composition on the occurrence of a canopy dwelling spider depends on orchard management

Manon Lefebvre[a,b], Pierre Franck[a], Jean-François Toubon[a], Jean-Charles Bouvier[a], Claire Lavigne[a,*]

[a] INRA, UR1115 Plantes et Systèmes de culture Horticoles, F-84000 Avignon, France
[b] Centre Technique Interprofessionnel des Fruits et Légumes, Centre de Balandran, BP 32, F-30127 Bellegarde, France

ARTICLE INFO

Article history:
Received 13 February 2015
Received in revised form 11 August 2015
Accepted 8 September 2015
Available online 25 September 2015

Keywords:
Cheiracanthium mildei
Perennial crops
Exclusion nets
Organic
Semi-natural habitat

ABSTRACT

Enhancing naturally occurring generalist predators can improve pest control. In orchards, canopy-dwelling species are major actors of pest control because pests attack fruits and growing shoots within the canopy. *Cheiracanthium mildei,* an arboreal spider, is a predator of several important insect pests. We assessed its autumnal occurrence in a set of 61 commercial apple orchards over three consecutive years (2010–2012). We determined the impact of agronomic and land-cover characteristics on *C. mildei* occurrence at both the local and landscape levels using a random forest analysis and regression trees. This approach highlighted the differential effect of landscape variables according to local orchard pest management. First, the presence of exclusion nets against the codling moth *(Cydia pomonella)* increased *C. mildei* occurrence by 59%. Second, landscape variables only influenced *C. mildei* occurrence in orchards that were not covered by nets. In particular, abandoned orchards increased *C. mildei* occurrence in orchards not covered by nets and not surrounded by organic orchards. Third, overall, habitats containing trees increased *C. mildei* abundance in orchards with and without nets, which is consistent with the arboreal habitat of this species. Lastly, the occurrences of *C. mildei* and of *C. pomonella* were not related, indicating that the enhancement of *C. mildei* does not preclude a control of this major pest.

1. Introduction

Among the species that contribute to pest control, generalist predators are of particular interest. Their ability to feed on a range of prey allows them to persist in crops when pest numbers are low (Symondson et al., 2002) and thus prevent pest outbreaks early in the season before specialist natural enemies are abundant (Landis et al., 2000). In orchard systems, major insect pests, such as aphids or Lepidoptera larvae, are present in tree canopies, where they affect tree growth and/or fruit marketability. While numerous studies have been performed on landscape factors affecting ground-dwelling generalist predators (Gardiner et al., 2010; Rusch et al., 2014; Schmidt et al., 2008), less attention has been paid to generalist predators that dwell throughout the canopy (but see Stutz and Entling, 2011). Among these, arboreal spiders are particularly abundant (Wyss, 1995; Pekár, 1999a).

Pest control by natural enemies may be influenced by farming practices at both the local and landscape scales and by landscape complexity (Landis et al., 2000; Médiène et al., 2011). Among the local practices that affect spiders, pesticide pressure has a large impact (Bogya et al., 2000; Bogya et al., 2000; Pekár, 1999b). Many insecticides are toxic to spiders, although responses differ among spider species and populations (Mansour et al., 1983; Pekár, 2012). In addition insecticides reduce the amount of prey that is available for generalist predators, which may decrease predator abundance (Pekár, 1999b). As an alternative to insecticides, nets are used in apple orchards as a physical barrier to prevent codling moth damage. These nets allow a large reduction in insecticide use and modify the tree microclimate, thus potentially affecting canopy spiders (Romet et al., 2010; Sauphanor et al., 2012).

Overall, landscape complexity has a positive impact on generalist natural enemies (Chaplin-Kramer et al., 2011). Furthermore, the response to landscape complexity is expected to be higher in intensively managed fields than in extensively managed fields because spill-over from semi-natural habitats contributes

* Corresponding author at: INRA-Unité PSH, 228 route de l'Aérodrome Domaine Saint Paul – Site Agroparc, CS 40509 84914 Avignon cedex 9, France. Fax: +33 4 3272 2432.
E-mail address: claire.lavigne@avignon.inra.fr (C. Lavigne).

http://dx.doi.org/10.1016/j.agee.2015.09.003
0167-8809/

more to natural enemy abundance in the former (Roschewitz et al., 2005; Tscharntke et al., 2012, 2005a; Tuck et al., 2014). Most studies, however, have been conducted in arable crops. The landscape may have less impact on natural enemies in orchards, because of both the higher stability of the vegetation and the higher within-field structural and compositional complexity (D'Alberto et al., 2012; Shackelford et al., 2013).

Semi natural habitats were found to increase spider species richness in annual crops (Drapela et al., 2008; Lüscher et al., 2014; Schmidt et al., 2008; Shackelford et al., 2013), in grasslands (Miyashita et al., 2012) and in vineyards (Hogg and Daane, 2010). Because they are arboreal, spiders that are found in tree canopies in orchards may particularly benefit from the presence of woods or hedgerows where they find shelter and alternative food resources (Entling et al., 2007; Herrmann et al., 2010; Taylor and Bradley, 2009; Tscharntke et al., 2005). Semi-natural habitats may also impact the distribution of arthropods within the orchard. Because of short-distance migration from an adjacent woody habitat or because the surrounding habitat provided resources, canopy spiders were more abundant in the less central part of apple orchards, vineyards and olive groves (Hogg and Daane, 2010; Paredes et al., 2013; Sackett et al., 2009). The opposite trend occurred when bird predation on spiders was higher near woods (Herrmann et al., 2010).

In addition to semi-natural habitats, the crop mosaic may impact spider communities. Some specific agrobiont spiders can inhabit annual crops (Samu et al., 2011). In contrast, other spider taxa are frequently found in different arboreal perennial crops (Bucher et al., 2010; Isaia et al., 2010; Ozturk et al., 2013) but, to date, have not been described in annual crops. These species could benefit from the diversity of orchards over the landscape, providing different phenologies, amount of prey and pesticide calendar use. A particular case is that of abandoned orchards, which are biodiversity rich areas (Pekár, 1999b) but possibly not sources of arthropods to their environment (Altieri and Schmidt, 1986).

Lastly, the impact of the landscape-level pesticide pressure on the abundance of spiders has never been tested, although a model indicates that it is of primary importance (Topping et al., 2014). Consistently, abundances of arthropod pests and parasitism rates in apple orchards in the study area were lower when the area of conventional orchards in the landscape was larger (Maalouly et al., 2013; Ricci et al., 2009).

Cheiracanthium mildei L. Koch 1864 (Eutichuridae), a wandering yellow sac spider, is a generalist predator. This species is a large (body size of adult females is approx. 15 mm) nocturnal arboreal spider that searches actively for prey at night and hides in silken retreats during the day (Peck, 1970). It is native to Mediterranean regions (Pryant, 1951) and has invaded north-eastern Europe (Muster et al., 2008) and northern America (Corrigan and Bennett, 1987; Hogg et al., 2010) in recent decades. Adults have a late-spring and summer reproduction, while subadults overwinter in penultimate stage (Mansour et al., 1980a). The species is present in tree canopies in orchards of south-eastern France during the whole growing season and overwinters in a silken retreat hidden under tree bark (Lefebvre, pers. obs.). The species may be directly sensitive to insecticides (Mansour et al., 1981a) and was more abundant in orchards under integrated pest management (IPM) than in conventional orchards (Bogya et al., 2000).

C. mildei has been frequently recorded in perennial crops, such as vineyards (Hogg et al., 2010), citrus groves (Mansour and Whitecomb, 1986), cotton fields (Mansour et al., 1980b) and apple orchards (Corrigan and Bennett 1987; Mansour et al., 1983; Miliczky and Calkins, 2002). In these crops, *C. mildei* exhibits high rates of predation on a diversity of Lepidoptera at larval and egg stages (Mansour et al., 1980b; Miliczky and Calkins, 2002) but also on a leafhopper and a scale pest (Hogg and Daane, 2014; Mansour and Whitecomb, 1986). It has been also suggested to predate on aphids, particularly *Dysaphis plantagineae*, a major pest in apple orchards (Boreau de Roincé, 2012; Dib, 2010). *C. mildei* is particularly voracious compared to other spider species (Hogg and Daane, 2014; Mansour et al., 1983; Miliczky and Calkins, 2002). In addition, it is prone to cannibalism and may exert intra-guild predation, but this did not hamper pest control in experimental systems (Hogg and Daane, 2011, 2014; Hogg et al., 2013). Because of its high voracity and high abundance in orchards, *C. mildei* may contribute substantially to pest suppression (Wise, 1993). Understanding local and landscape factors that affect its abundance is a pre-requisite for conservation biological control programs that focus on this species.

In Californian vineyards, where it is an invasive species, *C. mildei* is less abundant in vineyards that are surrounded by woody landscapes. This is consistent with the fact that few *C. mildei* were captured inside oak woods, in contrast to native spiders (Hogg and Daane, 2013). Semi-natural habitats may play a different role in regions where *C. mildei* is native. In the study area, *C. mildei* was indeed observed in woods and hedgerows (Lefebvre pers. obs.). *C. mildei* may benefit not only from alternative prey but also from the nectar of the spontaneous flora in such habitats (Taylor and Bradley, 2009).

In the present study, we investigated factors affecting the autumnal occurrence of *C. mildei* in apple orchards of southeastern France. Individuals were sampled over three consecutive years using corrugated cardboard band traps that were wrapped around tree trunks to assess the occurrence of the overwintering populations (Horton et al., 2001; Pekár, 1999b). We simultaneously recorded the presence of diapausing larvae of the codling moth (*Cydia pomonella*, Tortricid), the main insect pest of the apple orchards, in these band traps. Using random forest and regression tree approaches, we determined the effects of orchard management and landscape characteristics on these occurrences.

2. Material and methods

2.1. Study area

This study was carried out from 2010 to 2012 in an intensive apple production area of approximately 80 km^2 in the lower Durance valley in southeastern France under a Mediterranean climate (coordinates in the WGS84 system from 43°47′11″N to 43°51′10″N and from 4°51′29″E to 4°59′25″E) (Fig. 1). The landscape was further characterized by the presence of a dense network of windbreak hedgerows (mainly monospecific hedgerows of Cupressaceae or *Populus* trees, approximately 10 m high and 3 m wide) that protect orchards against the prevailing northern winds and of spontaneous hedgerows (based on *Prunus* and *Cornus* species) that displayed a very diversified flora. The area was mainly agricultural, with 12% of the area being covered by villages and approximately 6% being woody. The crops were mainly perennial fruit orchards, most of them (72%) being pome fruit (apple and pear). Perennial fruit crops covered 33% of the area. Annual crops (cereals and vegetables) covered 20% of the area. Permanent and temporary grasslands (mainly harvested for hay) represented 13% of the area. The rest was mainly covered by hedgerows (approx. 5%) and interstitial spaces.

Monthly meteorological data were registered in the meteorological station of Avignon (INRA-84007004): the minimal, maximal and mean temperatures were similar during the three studied years, but the accumulated precipitations differed from an annual value of 738 mm in 2010 to 521 mm in 2012. In 2011, the accumulated precipitations were particularly high in the summer