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Effect of pollen quality on the efficacy of two different life-style predatory mites against *Tetranychus urticae* in citrus

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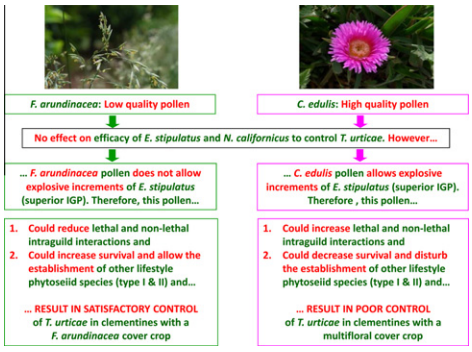
HIGHLIGHTS

- Pollen or prey is required for phytoseiid establishment in citrus seedlings.
- Pollen supply did not enhance *Tetranychus urticae* control.
- Pollen effects depend on pollen type and phytoseiid species considered.
- *Carpobrotus edulis* enhances explosive increments of omnivorous phytoseiids.
- Pollen quality may explain abundance of omnivorous phytoseiids in the field.

GRAPHICAL ABSTRACT



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ABSTRACT

Cover crops can serve as a reservoir of natural enemies by supplying alternative food sources as pollen. However, pollen quality and availability can modulate phytoseiid communities. In clementine trees associated with a cover crop of *Festuca arundinacea* Schreber, these communities were more diverse than those associated with a multifloral wild cover crop. As a consequence, the former had a better regulation of *Tetranychus urticae* Koch (Acari: Tetranychidae) populations than the latter. Longer provision of higher quality pollen in the multifloral cover relative to *F. arundinacea* is suspected to interfere with the biological control of *T. urticae* by specific phytoseiid predators (*Phytoseiulus persimilis* Athias-Henriot and *Neoseiulus californicus* (McGregor)) by enhancing the less efficient generalist pollen feeder *Euseius stipulatus* (Athias-Henriot) which is a superior intraguild predator. To determine whether pollen quality is behind these results, the effect of the provision of two different pollens (*Carpobrotus edulis* (L.) L. Bolus and *F. arundinacea*) on the efficacy of two phytoseiid species (*E. stipulatus* and *N. californicus*) to regulate *T. urticae* populations has been studied under semi-field conditions. Results suggest that pollen provision does not enhance the ability of these phytoseiids to reduce *T. urticae* populations. However, *C. edulis* pollen resulted in explosive increases of *E. stipulatus* numbers that did not occur with *F. arundinacea* pollen. Therefore, poor quality pollen may prevent pollen feeders from reaching high numbers in the field. This effect could benefit phytoseiid species suffering intraguild predation by *E. stipulatus*, the predominant phytoseiid species in Spanish citrus orchards and explain field results.

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1. Introduction

The two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) is an important pest of citrus (Jacas et al., 2010). Mite populations in clementine mandarins (*Citrus clementina* Hort. ex Tan.) can increase rapidly and cause severe economic losses mainly due to fruit scarring (Ansaloni et al., 2008). Until now, *T. urticae* control in Spain has been mainly based on pesticides and the extensive use of these acaricides has led to many management problems (Martínez-Ferrer et al., 2006; Urbaneja et al., 2008). Conservation biological control strategies through habitat management have been proposed as an efficient and sustainable alternative to pesticide use (Jonsson et al., 2008; Landis et al., 2000). Indeed, habitat management of agricultural systems using non-crop plant species as ground covers have been reported as an effective option to control mite populations in citrus (Aguilar-Fenollosa et al., 2011a,b,c; Jacas and Urbaneja, 2010).

Ground covers can affect arthropod population dynamics and serve as reservoirs of natural enemies through provision of food sources when prey food is rare or absent, by supplying a shelter for overwintering or estivation or a refuge from agricultural practices, and even for breeding (Alston, 1994; Jonsson et al., 2008; Liang and Huang, 1994; Mailloux et al., 2010). However, cover crops can harbor both beneficial and harmful arthropods and if they are not properly managed, harmful arthropods can develop as a pest (Aucejo et al., 2003). Different studies on cover crops have proposed the use of some perennial grasses (Poaceae) because they are unsuitable hosts for phytophagous mites (Alston, 1994; Barbosa, 1998; Flexner et al., 1991; Nyrop et al., 1998) and specifically for *T. urticae* in clementine mandarin orchards (Aucejo et al., 2003). Recently, a mono-specific cover of the perennial grass *Festuca arundinacea* Schreber (Poaceae) has demonstrated to improve the regulation of *T. urticae* in clementine trees when compared with a wild cover or bare soil, both by reducing the successful settlement of *T. urticae* in clementine mandarin trees (Aguilar-Fenollosa et al., 2011a) and by enhancing the populations of more efficient specialist predators relative to generalist pollen feeder predators (Aguilar-Fenollosa et al., 2011b). Furthermore, the use of *F. arundinacea* as a cover crop is economically more cost effective than wild cover or bare soil in clementine mandarins (Aguilar-Fenollosa et al., 2011c) and it is being currently promoted in Spanish citrus orchards (Jacas and Urbaneja, 2010). *Neoseiulus californicus* (McGregor) and *Euseius stipulatus* (Athias-Henriot) are two phytoseiid mites frequently found both in the canopy and in the *F. arundinacea* cover crop in mandarin clementine groves (Abad-Moyano et al., 2009a; Aguilar-Fenollosa et al., 2011b). The tetranychid specialist *N. californicus* is commercially available as a biological control agent against tetranychid mites (McMurtry and Croft, 1997), and when feeding on pollen, this predator can survive and even reproduce (Castagnoli and Simoni, 1999; Sazo et al., 2006; Ragusa et al., 2009). *E. stipulatus* is an omnivorous predator that can exclusively feed and successfully reproduce on pollen (Bouras and Papadoulis, 2005; Ferragut et al., 1987) and its role as a biological control agent is limited to some tetranychid species (Ferragut et al., 1992; González-Fernández et al., 2009; Grafton-Cardwell et al., 1997).

The relationship between pollen availability and satisfactory pest control has been studied in different systems. In San Joaquin Valley citrus groves (California, US), increases of *Euseius* (=*Amblyseius*) *hibisci* (Chant) populations were associated with peaks of wind-borne pollen, which allowed this species to satisfactorily control the citrus red mite *Panonychus citri* (McGregor) (Kennett et al., 1979). Citrus growers in China used pollen of the Asteraceae *Agerantum conyzoides* L., as an alternative food mainly for *Amblyseius* spp., to benefit *P. citri* control (Liang and Huang, 1994). *E. stipulatus* and *N. californicus* increased their numbers and reduced the populations of the herbivore *Oligonychus perseae* Tuttle, Baker and Abbatiello in avocado groves supplied with corn pollen in Spain (González-Fernández et al., 2009). However, ample pollen supply in Spanish clementine mandarin orchards is suspected to enhance *E. stipulatus* populations to an extent that could impair the control exerted on *T. urticae* by other phytoseiids specialized in tetranychid species (Aguilar-Fenollosa et al., 2011b). In a semi-field assay, Abad-Moyano et al. (2010a,b) found negative effects of *E. stipulatus* on the efficacy in spider mite suppression by *N. californicus* and on population development of *Phytoseiulus persimilis* Athias-Henriot. These experiments suggested that lethal and non-lethal intraguild interactions between *E. stipulatus* and *P. persimilis* and *N. californicus*, respectively, could contribute to the deficient natural control of *T. urticae* often observed in Spanish commercial clementine orchards (usually grown on bare soil or in association with a wild cover).

Furthermore, Aguilar-Fenollosa et al. (2011b) described a higher abundance of *E. stipulatus* in clementine trees when a multifloral cover was used compared with a *F. arundinacea* cover crop. These authors suggested that an extended pollination period could promote an increase in numbers of this superior intraguild predator when compared with *F. arundinacea* that blooms in spring only. However, increases in numbers of pollen feeder predators could be attributed not only to an extended blooming period but also to the nutritional quality of the pollen, its grain structure, or even the cheliceral morphology of the predatory mites (Flechtmann and McMurtry, 1992a; Lundgren, 2009).

In fact, not all pollens are equally suitable for development and reproduction of polyphagous predacious mites. In the case of Poaceae grasses, the quality of pollen as food source is controversial. Ouyang et al. (1992) described a poor performance of *E. tularensis* (Congdon) when offered *Festuca rubra* L. (Poaceae) or *Hordeum vulgare* L. (Poaceae) pollen, among others, as food. However, Rhodes grass (*Chloris gayana* Kunth) (Poaceae) pollen benefited control of *O. perseae* and *Phyllocoptruta oleivora* (Asmead) by *E. scutalis* (Athias Henriot) in avocados and citrus, respectively, in Israel (Maoz et al., 2008, 2011; Palevsky et al., 2010) and resulted in larger populations of *E. victoriensis* (Womersley) that controlled populations of eriophyid mites in Australian citrus (Smith and Papacek, 1991). In Italian vineyards, Poaceae pollen retained on plant foliage was very important for enhancing phytoseiid populations in natural hedgerows (Duso et al., 2004).

For the above mentioned reasons, the objective of this study was to compare, under semi-field conditions, the effect of two pollen sources, suspected of being qualitatively different, on the efficacy of specialist *N. californicus* and generalist *E. stipulatus* on the regulation of *T. urticae* populations.

2. Material and methods

2.1. Stock colonies

T. urticae colonies were maintained on 2-year-old clementine mandarin plants (*C. clementina* cv. Clementina de Nules (INIASEL 22)) grafted on Citrange Carrizo rootstock (*Poncirus trifoliata* (L.) Rafinesque-Schmaltz × *Citrus sinensis* (L.) Osbeck). Plants were not sprayed with insecticides or acaricides. Mite colonies were kept in a glasshouse located at Instituto Valenciano of Investigaciones Agrarias (IVIA) (Montcada, Valencia, Spain) at 25 ± 1 °C, 60 ± 10% RH and natural photoperiod. Colonies were initiated with mites collected in clementine mandarin orchards in the region of La Plana (Castelló de la Plana, Spain).

Individuals of *E. stipulatus* were collected from clementine mandarin orchards infested with *T. urticae* and *P. citri* in Montcada. *N.*