Agriculture, Ecosystems and Environment 246 (2017) 117–123

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

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

A comparison of naturally growing vegetation vs. border-planted companion plants for sustaining parasitoids in pomegranate orchards

Miriam Kishinevsky[a,*], Tamar Keasar[b], Ally R. Harari[c], Elad Chiel[b]

[a] *Department of Evolutionary and Environmental Biology, University of Haifa, Haifa, Israel*
[b] *Department of Biology and Environment, University of Haifa – Oranim, Tivon, Israel*
[c] *Department of Entomology, Agricultural Research Organization, The Volcani Center, Israel*

ARTICLE INFO

Keywords:
Conservation biological control
Plant diversification
Parasitoid diversity
Parasitoid spatial distribution
Punica granatum

ABSTRACT

Diversification of vegetation within and around agricultural habitats is an effective strategy to support populations of natural enemies of crops' pests. Such diversification can be achieved by conservation of natural vegetation that develops spontaneously around the plots, as well as by active introduction of companion plants to the crop. In this study we compared these two approaches in pomegranate orchards in Mediterranean climate. First, we evaluated ten candidate companion plant species for their potential to attract parasitoids of pomegranate pests. We then planted a combination of the two leading species – celery and Syrian oregano – along the perimeter of five orchards. In five additional, paired orchards, no plants were added. Arthropods were sampled from added and naturally growing companion plants throughout the pomegranate fruit growth season. Parasitoids were the most common natural enemies in our samples, and their overall abundance was similar in both treatments. Pest levels did not differ between treatments either. However, the distribution of some parasitoids (*Neochrysocharis* and *Telenomus*) and pests (leafhoppers and dipteran leafminers) within the orchards was affected by the margin vegetation type: these insects were more abundant in the margins than in the centers of the orchards with companion plants (suggesting a role as trap plants), whereas the opposite was observed in orchards with natural vegetation. We conclude that introduction of companion plants and conservation of local natural vegetation were equally effective in sustaining parasitoid numbers and diversity, but that planting attracted some parasitoids away from the orchards towards their margins. This possibly provides these natural enemies with a refuge from agricultural disturbances, but might reduce their contribution to pest control.

1. Introduction

Conservation biological control uses habitat management interventions to enhance the abundance and activity of natural enemies in agricultural plots. This is often done by active introduction of non-crop plant species (planted companion plants), or by preserving the wild vegetation that develops spontaneously inside and around the plot (wild companion plants). Both strategies increase the number of companion plant species in the agroecosystem. This, in turn, often boosts the diversity and richness of the natural enemy community (Landis et al., 2000; Parolin et al., 2012). Companion plants provide various resources to natural enemies including pollen, nectar, alternative hosts, hibernation or aestivation sites and shelter (see Landis et al., 2000; Naranjo et al., 2015; Parolin et al., 2012; Parker et al., 2013 for reviews). Although conserving naturally-growing wild companion plants in agricultural plots is relatively easy, farmers often prefer specific planted companion plants. One reason could be that spontaneously-growing wild species are usually considered to be weed pests or reservoirs of crop viruses. Another reason is lack of research: some commercially-grown planted species have been evaluated as companion plants for several crops and habitats, while wild plants native to the tested areas are rarely evaluated (Fiedler et al., 2008).

Despite the potential benefits, the overall effects of non-crop plants on the arthropod community and the agricultural crops may vary greatly due to the complex nature of such systems, and may depend, among other factors, on the composition of plant species. For example, some companion plants may provide resources not only to natural enemies but also to pest species, which can lead to increased herbivore populations and crop damage (Landis et al., 2000; Lavandero et al., 2006). Companion species can also act as trap plants, affecting the spatial distribution of herbivores and natural enemies within the plot even if their total numbers remain unchanged (Cook et al., 2006; Hokkanen 1991). For example, plants can be used to pull pests away from the agricultural field (Khan et al., 1997), or, on the other hand,

* Corresponding author at: Department of Evolutionary and Environmental Biology, University of Haifa, Abba Khoushy Ave 199, Haifa, 3498838, Israel.
E-mail address: mashakish@gmail.com (M. Kishinevsky).

http://dx.doi.org/10.1016/j.agee.2017.05.034
Received 1 March 2017; Received in revised form 25 May 2017; Accepted 29 May 2017

plants can be planted at the borders of the field in order to attract natural enemies from the surrounding area (Parker et al., 2013). Theoretically, this method could, unintentionally, decrease the numbers of natural enemies inside the plot and lower the efficiency of biological control agents.

These considerations make it difficult to predict whether introduction of planted border- companion plants, or conservation of spontaneously-growing wild companion plants, would be the preferable method to enhance natural enemies in a given agro-ecosystem. Here, we addressed this issue in pomegranate (*Punica granatum* L. (Lythraceae)) orchards in a Mediterranean climate. The pomegranate season in Israel begins with flowering in April and ends with the harvest in October. Locally important pests of pomegranate include several lepidopteran and hemipteran species, while the composition of natural enemies in the orchards is generally unknown. We focused on parasitoids since we found them to be the most abundant group of natural enemies in the sampled areas. Based on this crop-specific information, we asked how the identity of companion plants (planted vs. wild) along the border of the orchards affects the abundance, diversity and spatial distribution of natural enemies and pests. To address this question we evaluated candidate planted companion plants for pomegranate and selected two species for further study. In the following season we conducted a planting experiment to compare the arthropod assemblages on the selected planted companion plants to those on the wild vegetation growing within and around matched orchards.

2. Materials and methods

2.1. Plant evaluation experiment (2013): selecting planted companion plants

2.1.1. Selection of candidate plants

Ten plant species were selected for screening as potential planted companion plants: basil *Ocimum basilicum* L. (Lamiaceae), celery *Apium graveolens* L. (Apiaceae), common yarrow *Achillea millefolium* L. (Asteraceae), false yellowhead *Dittrichia viscosa* L. (Asteraceae), french marigold *Tagetes patula* L. (Asteraceae), gaura *Oenothera lindheimeri* (Engelmann et A. Gray) (Onagraceae), rosemary *Rosmarinus officinalis* L. (Lamiaceae), Syrian oregano *Origanum syriacum* L. (Lamiaceae), vitex *Vitex agnus-castus* L. (Lamiaceae) and white petunia *Petunia x hybrida* (Vilm) (Solanaceae). In accordance with criteria outlined by Fiedler et al. (2008), the evaluated species are of different life-forms (see Table 1), and their flowers produce pollen and/or nectar as potential resources for natural enemies. These species were expected to thrive and flower during the hot and dry pomegranate season, and are readily available in local nurseries.

2.1.2. Study area and experimental design

The experiment was conducted in a 4-ha, 6-year-old pomegranate orchard (cv 'Wonderful') in the Hefer Valley in central Israel (32°22'48N, 34°55'58E). The climate in the sampled area during the pomegranate fruit growth season (May-October) is characterized by high temperatures (average ± SD: 24.9 ± 4.3°C, max: 38.3°C, min: 7.7°C) and RH (70.4 ± 15.5%), with no rainfall. Ninety plants (9 each of the ten candidate species) were planted individually in a randomized block design: 60 plants were placed at the ends of the orchard's 30 tree rows (one plant at each end of each row), and 30 additional plants were planted along a dirt path that ran perpendicular to the rows in the center of the orchard. The distance between adjacent plant individuals was 6 m. The test plants were introduced into the orchard in May 2013, and were fertilized and drip-irrigated throughout the season along with the pomegranate trees.

2.1.3. Arthropod sampling

Arthropods were sampled using a Vortis Insect Suction Sampler (Burkard Manufacturing Co. Ltd., Rickmansworth, UK). Each plant was suction-sampled individually for 15 s, and samples were preserved in 75% ethanol until sorted. Sampling was conducted monthly from May through September 2013.

2.1.4. Arthropod classification

We identified the collected arthropods to a minimum level of order. Hemiptera and Diptera were identified to suborder or family levels. Parasitic Hymenoptera, the most abundant group of natural enemies collected (see below), were identified to genus and morphospecies based on Goulet and Huber, 1993; Grissell et al., 1997, (Superfamily Chalcidoidea key); Hayat, 1983; Huber et al., 2009; Masner, 1976, 1980; Noyes, 2003; Pinto, 1997, 2006; Pricop, 2013; Schauff et al., 1997; Shaw and Huddleston, 1991; Ulrich, 2006; Woolley, 1997. These sources also provided information on host range.

2.1.5. Analysis of arthropod abundance

The abundance of parasitic Hymenoptera and potential pomegranate pests (Aleyrodidae, Aphididae, Auchenorrhyncha, Lepidoptera and Pseudococcidae) on the test plants was calculated by averaging the numbers collected from the individual plants of each species on each sampling date. This generated one data point per plant species for each sampling date. The effects of plant species on pest and parasitoid richness was analyzed using Kruskal Wallis tests, since the data did not conform to the assumptions of ANOVA even after transformations. All analyses were performed using SPSS 12.0 (IBM SPSS statistics, Chicago, IL, USA).

2.1.6. Selection of suitable companion plants for pomegranate orchards

The suitability of plants for use in margin planting in pomegranate orchards was estimated according to the abundance of potential pests and natural enemies found on them throughout the season, as detailed in the Results section. Two plant species, celery and Syrian oregano, were eventually selected for the planting experiment, which was conducted in the following season.

Table 1
Plant species evaluated in the first year of the study.

Family	Species name	Common name	Life-form	Native?
Asteraceae	*Achillea millefolium* L.	Common yarrow	Perennial Forb	No
	Dittrichia viscosa L.	False Yellowhead	Perennial shrub	Yes
	Tagetes patula L.	French marigold	Annual Forb	No
Apiaceae	*Apium graveolens* L.	Celery	Biennial Forb	Yes
Lamiaceae	*Ocimum basilicum* L.	Basil ('Magic Mountain')	Perennial shrub	No
	Origanum syriacum L.	Origanum	Perennial shrub	Yes
	Rosemarinus officinalis L.	Rosemary	Perennial shrub	No
Onagraceae	*Oenothera lindheimeri* Engelmann et A. Gray	Gaura	Perennial Forb	No
Solanaceae	*Petunia x hybrida* Vilm	White petunia	Perennial Forb	No
Verbenaceae	*Vitex agnus-castus* L.	Vitex	Perennial shrub	Yes