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Short communication

Ecological engineering of ground cover vegetation promotes biocontrol services in peach orchards

Nian-Feng Wan[a,b,1], Xiang-Yun Ji[a,2], Xiao-Jun Gu[a,2], Jie-Xian Jiang[a,*], Ji-Hua Wu[b,3], Bo Li[b,**]

[a] Eco-environment Protection Research Institute, Shanghai Academy of Agricultural Sciences, Shanghai Key Laboratory of Protected Horticultural Technology, Shanghai 201403, China
[b] Coastal Ecosystems Research Station of the Yangtze River Estuary, Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, Institute of Biodiversity Science, Fudan University, Shanghai 200433, China

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ABSTRACT

We conducted a 2-year field experiment at two sites in eastern China, examining the effects of the ground cover by *Trifolium repens* L. on the biocontrol services in peach orchards. The results indicated that compared to those in control areas, the abundances of aphids and *Grapholitha molesta* decreased, respectively, by 31.4% and 33.3% in Shanghai and by 30.1% and 33.3% in Jiangsu, while the abundance of generalist arthropod predators increased by 116.7% in Shanghai and by 115.8% in Jiangsu in ground cover areas. Compared to that in control areas, the ratio of generalist predator abundance to aphid abundance and to *G. molesta* abundance increased, respectively, by 260.0% and 384.2% in Shanghai and by 213.3% and 253.1% in Jiangsu in ground cover areas. Our study revealed that the ecological engineering of ground cover by *T. repens* promoted biocontrol services in peach orchards.

1. Introduction

One of the goals of ecological engineering is to restore the ecosystems that have been substantially degraded by human activities (Mitsch, 2012). Ecological engineering of ground cover vegetation, as one of the most important ways for managing landscape biodiversity (Kolos and Banaszuk, 2013), has been widely adopted (Gray et al., 2012), and has the potential to enhance the abundance of natural enemies (Landis et al., 2000) and to decrease population densities of pests (Song et al., 2010). Previous studies have shown that ground cover in orchards enhances the abundance of natural enemies such as in pecan trees (Smith et al., 1996), pear trees (Song et al., 2010), apple trees (Wyss, 1996) and lemon trees (Silva et al., 2010). However, the biocontrol services involved in the populations of natural enemies have not been elaborated although there are some reports on the effects of ground cover on pests in peach orchards (Meagher and Meyer, 1990a,b). Several studies have reported that ground cover by *Trifolium repens* L. in peach orchards influences peach production (Meagher and Meyer, 1990a), the abundance of pests (Meagher and Meyer, 1990b), the temporal and spatial patterns of insects (Wan et al., 2011). However, the biocontrol services of ground cover by *T. repens*, which is a common practice in the management of peach orchards in China, have not been explored.

China is the country that has the largest area of peach planting and the largest output of peach production, with annual peach cultivation area of 45.2×10^4 hm^2 and annual peach yield of 4.6×10^9 kg. Ground cover vegetation in peach orchards was introduced into China in 1990s and then was gradually applied nationwide. Over recent years ground cover by *T. repens* has been considered as one of the most ideal approaches to enhancing soil fertility and peach quality in orchards (Wilson et al., 2010), and this

* Corresponding author at: 1000#, Jinqi Road, Fengxian District, Shanghai 201403, China. Tel.: +86 021 62205462; fax: +86 021 62201112.
** Corresponding author at: 220#, Handan Road, Shanghai 200433, China. Tel.: +86 021 65642178; fax: +86 021 65642178.
E-mail addresses: nfwan@hotmail.com (N.-F. Wan), hwfy2002@163.com (X.-Y. Ji), gxj@saas.sh.cn (X.-J. Gu), jiangjiexian@163.com (J.-X. Jiang), jihuawu@fudan.edu.cn (J.-H. Wu), bool@fudan.edu.cn (B. Li).
[1] Address 1: 1000#, Jinqi Road, Fengxian District, Shanghai 201403, China. Address 2: 220#, Handan Road, Shanghai 200433, China. Tel.: +86 021 62202767; fax: +86 021 62201112.
[2] Address: 1000#, Jinqi Road, Fengxian District, Shanghai 201403, China. Tel.: +86 021 62205462; fax: +86 021 62201112.
[3] Address: 220#, Handan Road, Shanghai 200433, China. Tel.: +86 021 65642178; fax: +86 021 65642178.

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production model is gradually accepted by a large number of farmers and has been extensively applied in orchards' management in China. However, whether the widespread adoption of ground cover by *T. repens* benefits the generalist predators and therefore potentially promotes associated ecosystem services such as the control of the most serious insect pests has not been explored.

In the Yangtze River Delta of East China, we have found that the aphids which make leaves curl and the oriental fruit moth (*Grapholitha molesta* (Busck)) which makes peach shoots wither are the most serious insect pests. Meanwhile, spiders, ladybirds and lacewings were found to be the most key generalist arthropod predators in peach orchards (Wan et al., 2011). The widespread application of ground cover by *T. repens* may have contributed to an increase in populations of generalist natural enemies and promoted their associated biocontrol services. This study was therefore conducted to investigate whether adopting ground cover by *T. repens* induced an increase in populations of three groups of key generalist predators and led to a higher control efficiency of the generalist predators over the two key insect pests.

2. Materials and methods

2.1. Study sites

Our study was conducted at two sites: one at Xinchang town, Pudong district, Shanghai of China (31.03°N, 121.41°E, elevation 4.3 m), and the other at Hudai town, Wuxi city, Jiangsu Province of China (31.34°N, 121.18°E, elevation 3.5 m). The two sites, at which the trees grow well and are vigorous, were both located in alluvial plain in the Yangtze River delta. Benzenehexachloride and dichlorodiphenyltrichloroethane residues were lower than detection limit (<0.004 mg kg^{-1}) and the heavy metal contents were all below the Green Food Standard in China (As, Cu, Hg, Pb, Cr and Cd were 5.7–12.4, 26.4–46.1, 0.09–0.22, 22.8–32.6, 37.4–69.4 and 0.11–0.21 mg kg^{-1} in Xinchang, and 6.8–11.8, 22.3–43.7, 0.08–0.21, 20.7–30.3, 35.7–65.5 and 0.10–0.21 mg kg^{-1} in Hudai). Peach varieties grown in the orchards were "Xinfeng" honey peach in Xinchang and "Hujing" honey peach in Hudai, both of which are mid-season maturing varieties with 8–10 year-old trees, and arranged in a 4 × 4 m grid spacing.

2.2. Treatment and management

The experiment was carried out in a randomized block design, and all treatments and controls were all replicated three times at both sites. Thirty peach trees (2–2.5 m high) at each replicate were sampled to calculate the abundance of insect pests and predators. Each experimental plot was 100 m wide and 52 m long, separated from adjacent plots by a 100 m long buffer belts. Treatment areas were covered with perennial plant *Trifolium repens* L., which was mowed twice a year to a height of about 10 cm. Control areas were bare ground, and every effort was made to keep them weed-free during the experimental period. Other managerial measures including pest management were the same for both the treatment and control plots in each orchard. Pest management in peach orchards mainly relies on physical and manual ways. To trap insect pests, we used plastic traps (Δ-shaped section, 40 cm × 30 cm × 20 cm) for suspending sex pheromones. One *Lyonetia prunifoliella* Hubn and one *Dichocrocis punctiferalis* Guenee sex pheromone were installed with equidistance (10 m apart) in a line in the treated and control orchards. Traps were hung from tree branches at a height of 1.5 m above ground and lures were replaced every month. From the early April to late September, the pheromone traps were set in orchards. The statistics of pests killed by attractants were surveyed and recorded every ten days. As lime sulfur are typical alternative to synthetic insecticides for the control of scale pests in orchards, 4–5 Baume lime sulfur were sprayed in dormant period in treated and control orchards. To prevent pathogens and pests from infesting peach, we trimmed the diseased and pest-infested peach branches with scissors in winter. Additionally, fruit bagging with yellow paper bags in June was adopted to avoid pest damage.

2.3. Sampling methods

Within each replicate plot, 30 adjacent peach trees with checkerboard type distribution, similar to each other in height and vigor, were selected as permanent sampling points to monitor the population dynamics of peach aphids, *G. molesta* and the generalist arthropod predators (spiders, ladybirds and lacewings). On each sampling date, each tree was sampled from four directions (east, south, west, and north) at three levels each (upper, middle, and lower), i.e., each tree canopy was split into 12 resource units (Song et al., 2010). At each canopy level, we spent 3–5 min to collect arthropods and count the number of individuals of each species of the arthropods.

The branch beating method was adopted to collect insect pests and predators from the peach tree canopy according to Simon et al. (2007). Insect pests and predators falling from the branches were collected, identified and counted immediately. Additionally, we took another few minutes to strip off the damaged young shoots in each twig to see if there were any *G. molesta* larvae. Sampling was done at appropriately 10-day intervals from late March to early October both in 2010 and 2011.

2.4. Data analysis

Statistical analyses were performed with SPSS 16.0. Normal distribution and homocedasticity of all data were checked by the Kolmogorov–Smirnov test and Levene test, respectively. Three-way analysis of variance with general linear model in SPSS 16.0 was performed to analyze the above indices, so as to compare the interactive effects of sites, years and orchard types on the biocontrol service indices. If the values of the biocontrol service indices were not significantly affected by the years, we considered the two years' data as a whole to compare the differences among means of treatments and controls with Tukey's Honestly Significant Difference (HSD) test at 0.05 level.

3. Results

The abundances of aphids, *G. molesta* and generalist arthropod predators were significantly affected by orchard type, but not by site and time. The interactive effects of two factors (site × time, site × orchard type, and time × orchard type) and three factors (site × time × orchard type) on the above abundances were not significant. The ratio of generalist arthropod predator to aphid abundance and the ratio of generalist arthropod predator to *G. molesta* abundance were significantly affected by the factor of orchard type but not by the factors site and time. Meanwhile, the interactive effects of two factors (site × time, site ×orchard type, and time × orchard type) and three factors also had no significant effect on the above ratios.

The abundances of aphids and *G. molesta* were significantly lower but those of generalist arthropod predators were significantly higher in ground cover areas than in control areas at the two sites (Table 1). At both sites, irrespective of ground cover, the abundances of aphids, *G. molesta* and generalist arthropod predators increased during spring but were stabilized thereafter. Meanwhile,