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Short communication

Ecological engineering of trap cropping promotes biocontrol services in peach orchard ecosystems

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ABSTRACT

We conducted a 2-year field experiment in eastern China examining the effects of two trap crops (sunflower, *Helianthus annuus* and corn, *Zea mays*) on the biocontrol services in peach orchard ecosystems. We found that compared to levels in control areas without any trap crops, the abundance of *Conogethes punctiferalis* population in tree canopies in peach orchards with trap crop sunflowers and with trap crop corns decreased by 39.4 and 47.3% in 2010 and by 48.1 and 57.5% in 2011, respectively. Substantial number of *C. punctiferalis* population was found in the trap crop samples. In sunflowers we found 23.3 ± 4.4 per flower head in 2010 and 21.3 ± 4.0 in 2011. In the corn trap crop, counts of *C. punctiferalis* population were made per ear and per stalk, there were 96.0 ± 25.9 individuals per 20 ears in 2010 and 88.9 ± 23.2 in 2011, and there were 44.2 ± 7.1 individuals per 20 stalks in 2010 and 40.3 ± 6.3 in 2011. We conclude that the trap crops can be used to promote biocontrol services in peach orchard ecosystems.

1. Introduction

Promotion of biocontrol services is one of the goals of ecological engineering (Wan et al., 2014b), and trap crops, one of the most important tools for such management of pest insects, have been widely used by farmers (Trdan et al., 2005; Nibouche et al., 2012). Trap cropping is the planting of a trap crop to protect the main cash crop from a certain pest or several pests. There are two types of planting the trap crops, in which perimeter trap cropping (border trap cropping) is the planting of trap crop completely surrounding the main cash crop and row intercropping is the planting of the trap crop in alternating rows within the main crop. Trap crops can reduce damage from some insect pests in vegetable (Ludwig and Kokt, 1998; Moreau and Isman, 2012), canola (Carcamo et al., 2007), and cotton fields (Castle, 2006; Lu et al., 2009). However, trap cropping has not been studied in peach orchards, although there have been some studies on the effects of ground covers on pest management in peach orchards (Meagher and Meyer, 1990a,b; Wan et al., 2014b,c).

China has the largest area planted peaches in the world (45.2×10^4 hm^2) and the greatest production (4.6×10^9 kg per year). In recent years, trap cropping has been widely adopted in China for integrated pest management (IPM), especially in orchards. However, whether the widespread use of trap cropping promotes the control of insect pests has not been carefully examined.

The yellow peach moth, *Conogethes punctiferalis* (Guenée) (Lepidoptera: Crambidae), one of the most serious fruit borers, often causes damage to many orchard, spice, and vegetable crops (Xiao et al., 2012). In the Yangtze River delta of eastern China, we have found that two trap crops (*Helianthus annuus* and *Zea mays*) provide a significant level of controlling this pest in peach orchards (Wan et al., 2011). Thus, this study was conducted to investigate whether using *H. annuus* and *Z. mays* as trap crops decreased the abundance of *C. punctiferalis* population in peach orchards and if so, to what degree.

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2. Materials and methods

2.1. Study sites

The study was conducted in Hudai town, Wuxi city, Jiangsu Province of China (31.34°N, 121.18°E, elevation 3.5 m), a region where fruit trees grow well. The site was located in an alluvial plain of the Yangtze River delta. The study orchard consisted of "Hujing" honey peach, a mid-season maturing variety. Trees were 8–10 years old and arranged in a $4 \times 4\,m^2$ grid spacing.

2.2. Treatment and management

The experiment was used a randomized block design, and all treatments and the control were replicated three times. Trap crops were planted in early April, using either *H. annuus* (conventional varieties from local farmers) or *Z. mays* (SHENTIAN #3 from the Crop Institute of the Shanghai Academy of Agricultural Sciences). Sunflowers or corns were planted surrounding the peach trees in a row about 0.4 m apart from each other, respectively. Control areas had no trap crops, and every effort was made to keep treatment and control areas weed-free during the experimental period. Management of treatment and control areas as well as the pest management was described by Wan et al. (2014b). After the peach was harvested, we pulled the trap crops out of the peach orchards in early October so as to prevent them from becoming a source of new infections.

2.3. Sampling methods

Within each replicated subplot, thirty peach trees (2–2.5 m high) with a checkerboard distribution were selected as permanent sampling points to monitor the population dynamics of *C. punctiferalis*. On each sampling date, each tree was sampled from the four cardinal directions at three levels (upper, middle, and lower), thus splitting the canopy into 12 resource units (Song et al., 2010). The number of *C. punctiferalis* population was counted in each of these 12 units. Sampling was done at approximately 10-day intervals from early May to late September in both 2010 and 2011. Sampling in the sunflower trap crop was done during the flowering period (from late June to Mid-to-late July). During this period, we sampled the sunflower heads four times at approximately 7-day intervals. Ten sunflower heads were randomly chosen and examined in each replicate to count the number of *C. punctiferalis* population. Sampling of the corn trap crop was done by examining corn plants late June (late whorl stage) to late September (the maturation stage). Twenty corn plants were randomly selected and examined at approximately 10-day intervals, counting the number of *C. punctiferalis* population in the stalks and ears.

2.4. Data analysis

Statistical analyses were performed with SPSS 16.0. Normal distribution and homocedasticity of all data were checked by the Kolmogorow–Smirnov test and Levene test, respectively. Independent sample *t*-tests were conducted to compare the number of *C. punctiferalis* population collected between 2010 and 2011 in the flower head of *H. annuus*, in the ears of *Z. mays* or in the stalks of *Z. mays* intercropped around peach orchards. An HSD test at the 0.05 level was used to compare the differences among means of the number of *C. punctiferalis* population in tree canopies in different peach treatment plots.

3. Results

3.1. C. punctiferalis population densities in trap crops

Numbers of *C. punctiferalis* population collected within sample units within trap crops were not significantly different between the two study years (Table 1). Compared to that in the flower heads of *H. annuus*, in the ears of *Z. mays* and in the stalks of *Z. mays* in 2010, the number of trapped *C. punctiferalis* decreased by 8.58%, 7.40% and 8.82%, respectively, in 2011.

3.2. Timing of population activity

During the flowering period of sunflowers, the greatest density was in mid-July in both 2010 and 2011 (32.2 ± 1.1 and 29.8 ± 1.1 individuals per flower head, respectively). Meanwhile, the highest number of *C. punctiferalis* population found in corn stalks occurred in mid-September in both 2010 and 2011 (83.7 ± 4.8 and 80.0 ± 3.3 individuals per 20 stalks, respectively), while that in the corn ears was in mid-September in 2010 and in mid-July in 2011(236.7 ± 9.9 and 210.0 ± 8.4 individuals per 20 ears, respectively) (Fig. 1). In both years, irrespective of trap cropping, the abundance of *C. punctiferalis* population in tree canopies peaked in late June.

3.3. Effects of trap crops on population density in peach tree canopies

Trap cropping had a significant effect on the number of *C. punctiferalis* population found in peach tree canopies in both 2010 and 2011 (Table 2). Compared to the control plots, the number of *C. punctiferalis* population in peach tree canopies in plots with adjacent sunflower or corn trap crops was lower by 39.4% and 47.3% in 2010 and 48.1% and 57.5% in 2011, respectively (Table 2) Overall, *C. punctiferalis* population density was consistently lower in plots surrounded by either of the two trap crops than in control plots of pure peach, providing evidence for the direct control effect of these trap crops on the *C. punctiferalis* population in peach orchards (Fig. 2).

4. Discussion

Studies on the species diversity in agro-ecosystems is the focus of ecological engineering (Tropek et al., 2013; Wan et al., 2014a, 2015), and some studies have suggested that plant diversity in agro-ecosystems might promote biocontrol services, as evidenced by the fact that insect pest abundance decreases in these settings (Andow, 1991; Wan et al., 2014b). According to preliminary estimates, when peach orchards were intercropped with sunflowers and corns, the abundance of *C. punctiferalis* population in tree canopies decreased by more than 30% and the boring rate of peach

Table 1
Abundance of *Conogethes punctiferalis* population in two trap crops in peach orchards.

Year	Flower disks of *Helianthus annuus* (individuals per flower head)	Ears of *Zea mays* (individuals per 20 ears)	Stalks of *Z. mays* (individuals per 20 stalks)
2010	23.3 ± 4.4a	96.0 ± 25.9a	44.2 ± 7.1a
2011	21.3 ± 4.0a	88.9 ± 23.2a	40.3 ± 6.3a

Notes: During the flowering period of sunflowers, the flower heads of *H. annuus* were sampled four times at appropriately 7-day intervals from late June to Mid-to-late July in 2010 and 2011; the stalks and ears of corn were sampled ten times at appropriately 10-day intervals from late June to late September in 2010 and 2011, respectively; different letters in the same column indicate that means are significantly different at $P < 0.05$ (independent samples *t*-test) between 2010 and 2011 in Xinchang of Jiangsu Province of China (four sample dates for sunflowers and 10 sample dates for corns were considered as four and 10 replicates, respectively).