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Potential of mungbean, *Vigna radiatus* as a trap crop for managing *Apolygus lucorum* (Hemiptera: Miridae) on Bt cotton

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ABSTRACT

In recent years, the mirid *Apolygus lucorum* has become the key insect pest of Bt cotton in China. Currently, insecticide use is the sole pest management option available for most Chinese cotton farmers. As irrational pesticide use may have several undesirable effects, environmentally sound and sustainable management alternatives are urgently needed. In this paper, we evaluate the potential of mungbean, *Vigna radiatus* as a trap crop for *A. lucorum* in Bt cotton. Plant suitability trials showed that *A. lucorum* population densities on mungbean were significantly higher than those on cotton. Large-scale field experiments were conducted during 2006 and 2007 to determine the effectiveness of mungbean strips for managing *A. lucorum* in Bt cotton fields. In this experiment, 0.1 ha Bt cotton fields were established, and mungbean strips covered approximately 10% of the total area. With periodical insecticide applications in mungbean strips, average mirid population densities in cotton fields were 18.1 ± 2.1 individuals per 100 plants, versus 36.0 ± 3.4 in the fields without mungbean strips in 2006. However, *A. lucorum* population still surpassed economic threshold (i.e., 5, 10, and 20 individuals per 100 cotton plants at the seeding stage, the squaring and flowering stages, and the belling stage, respectively). In 2007, aside from the insecticide sprays within the mungbean strips, 2–3 insecticide applications were done in the cotton field. As a result, *A. lucorum* populations were kept below economic threshold, and the total amount of insecticides reduced about 70% of those used in the common chemical-controlled fields. Our work shows that mungbean has considerable potential as a trap crop in Bt cotton fields, and its adoption by Chinese farmers very likely will reduce current levels of pesticide use in this crop.

1. Introduction

Plant bugs (Heteroptera: Miridae) are important pests of cotton worldwide (Wheeler, 2001). In the major Chinese cotton-growing regions, *Apolygus lucorum* Meyer-Dür and various *Adelphocoris* species have historically been considered important herbivores (Cao and Wan, 1983; Lu et al., 2008). Adults and nymphs feed on both vegetative and reproductive cotton plant tissues and attain high population densities during critical cotton squaring, flowering, and belling stages (Lu et al., 2008). Since the massive adoption of Bt cotton in China during the late 1990s, mirids have steadily become the principal insects pests of this crop (Wu et al., 2002; Wu, 2007; Lu et al., 2008), and are currently inflicting cotton yield losses up to 20–30% (Lu et al., 2007a). One of the dominant mirid species is *A. lucorum* in Bt cotton fields in Chinese Changjiang River and Yellow River cotton-planting regions (Lu et al., 2008). At present, Chinese farmers almost exclusively rely on chemical control, which may create problems of resistance development, pest resurgence and environmental pollution (Lu et al., 2007a). Given the many drawbacks of a sole reliance on chemical pesticides, environmentally friendly pest management options urgently need to be defined.

A promising, environmentally sound approach to manage insect pests in agricultural and forest systems is trap cropping (Hokkanen, 1991; Foster and Harris, 1997; Shelton and Badenes-Perez, 2006; Cook et al., 2007). The practice of trap cropping is based upon the exploitation of insect preferences for certain host plants, based upon visual, tactile or olfactory cues (Yan, 2003; Schoonhoven et al., 2005; Hokkanen, 1991; Shelton and Badenes-Perez, 2006). By interplanting highly attractive plant species with susceptible crops, pest insects can be attracted and diverted from the target crop. Additionally, the effectiveness of trap crops can be increased by targeted use of other control methods, such as insecticide sprays (Hokkanen, 1991; Shelton and Badenes-Perez, 2006). For example, Castle (2006) applied insecticides to control *Bemisia tabaci* on

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a cantaloupe trap crop, thereby preventing adult dispersal into a main cotton crop. The combination of insecticide sprays and trap crop was also used to manage *Zonosemata electa* in bell peppers (Boucher et al., 2003). Rational use of insecticides within the trap crop can lower overall pesticide use and associated environmental impacts (Hokkanen, 1991; Shelton and Badenes-Perez, 2006).

Trap cropping has been successfully used for management of mirid pests worldwide. In USA, alfalfa strips are inter-planted with cotton and managed distinctively to control *Lygus hesperus* (Stern et al., 1964, 1969; Godfrey and Leigh, 1994). Presently, cotton–alfalfa inter-planting is used at a commercial level in California (Shelton and Badenes-Perez, 2006). In Australia, alfalfa strips are established within commercial cotton fields to lower *Creontiades dilutus* infestation levels (Mensah and Khan, 1997). Recently, two other studies showed that *Matricaria recutita* could serve as a potential trap crop of *Lygus rugulipennis* on strawberry (Easterbrook and Tooley, 1999), and multiple plant species (e.g., *Trifolium pretense*, *Artemisia vulgaris*) could be used for trapping *Lygus* spp. in lettuce fields (Rämert et al., 2001). However, trap cropping waits to be explored as a management option for mirids, such as *A. lucorum*, in Bt cotton in China.

In this paper, we examine the potential of mungbean, *Vigna radiatus* L. as a trap crop for *A. lucorum* in Bt cotton in China. Two-year plant suitability trials were conducted to compare *A. lucorum* population levels in separate cotton and mungbean plots. Then, the effects of mungbean strips on *A. lucorum* infestation levels in cotton were determined in large-scale field experiments.

2. Materials and methods

2.1. Comparative plant suitability trials

Plant suitability trials were conducted at the Langfang Experimental Station of Chinese Academy of Agricultural Sciences (Hebei Province, China) during 2006 and 2007. We established multiple 4 m × 4 m plots in a 15m-wide parcel positioned within a Bt cotton field. Within these plots, we planted 43 different plant species of 13 families in 2006, and 130 species of 21 families in 2007 (Lu, Y.H., unpublished data). Each plot contained only one plant species and each plant species was grown in a total of three plots as separate replicates. Individual plots were spaced at 1 m intervals. Among the different plant species was a transgenic cotton variety (SGK321) and a mungbean variety (JILVDOU2). SGK321 expresses the Cry1Ac and CpTI toxic proteins, and was provided by the Biotechnology Research Institute (Chinese Academy of Agricultural Sciences, CAAS). JILVDOU2 was supplied by the Baoding Institute of Agricultural Sciences, Hebei Province, China. In early May, all different plant species were sown and plots were subsequently managed using identical agronomic practices and without insecticide use.

In each plot, we surveyed *A. lucorum* population numbers from mid-June to mid-September during both years. This sampling period coincides with the time during which *A. lucorum* is present in cotton fields in China (Lu et al., 2008). Sampling consisted of a visual inspection of plants for presence of *A. lucorum* adults, followed by knock-down techniques to determine abundance of nymphs and adults (Rämert et al., 2001). Visual inspections mainly surveyed the upper part of plants. Knock-down techniques basically consisted of pulling parts of the plants over a rectangular 40 cm × 26 cm × 11 cm white-colored pan, after which plant material was struck four times and the number of dislodged individuals was counted. During each sampling event, total number of adults and nymphs were recorded for both the visual inspection and knock-down method. Plots were sampled every 5 days, and sampling was conducted in four 1 m^2 subplots within each plot.

2.2. Large-scale field experiment

In 2006, we established a total of six 700 m^2 (35 m long, 20 m wide) cotton fields at the Langfang Experimental Station. In 2007, research was conducted in six 800 m^2 (40 m long, 20 m wide) cotton fields in both Langfang and Xiajin (Shandong Province). During both years, cotton (var. SGK321) was planted between May 1 and 5 and subsequently managed using standard agronomic practices.

In 2006, we planted one (20 m long, 1.5 m wide) strip of mungbean in the middle of three cotton fields, and left the same-sized strip bare in the remaining three fields. Mungbean was planted on June 27, when cotton was at the squaring stage. Subsequent cotton fields were separated by >10 m intervals, which were kept free of vegetation. In 2007, we planted a (20 m long, 1 m wide) strip of mungbean on May 3–5, at both the northern and southern border of three cotton fields in each site. In the same fields, we planted a second mungbean strip (40 m long, 1 m wide) from south to north in the center of each field on July 5. During both years, fields with and without mungbean strips were managed in the same fashion and mungbean strips received identical fertilizer and irrigation treatment as cotton fields.

During both years, we monitored *A. lucorum* population density in mungbean every 5 days using the knock-down technique. At each sampling event, we monitored *A. lucorum* population levels in 10 different locations per mungbean strip. Mirid population densities in cotton were determined by visually inspecting a total of 20 plants at five random sites within each field, at 5–7 day intervals (Wu et al., 2002; Lu et al., 2008). In 2006, mirid population surveys were done from July 25 to September 8 at Langfang, while in 2007 surveys were conducted from June 21 to September 9 at Langfang, and from June 20 to September 3 at Xiajin. For both mungbean strips and cotton fields, we recorded the numbers of *A. lucorum* adults and nymphs at each sampling event.

From the first appearance of *A. lucorum* on mungbean, endosulfan (0.210 kg A.I. ha^{-1}) was applied at 10-day intervals in the mungbean strips. In 2006, no measures were taken to control *A. lucorum* in cotton fields. In 2007, we also applied insecticides in cotton, depending on *A. lucorum* densities within each field. When *A. lucorum* population density within a given field exceeded economic threshold (i.e., five *A. lucorum* per 100 cotton plants at the seeding stage, 10 individuals per 100 plants at the squaring and flowering stages, and 20 individuals per 100 plants at the belling stage) (Zhang et al., 1986), acetamiprid (0.018 kg A.I. ha^{-1}) was applied uniformly within the respective field.

2.3. Data analysis

Statistical differences in *A. lucorum* population density in mungbean strips vs. cotton fields, and in cotton fields with vs. without mungbean were determined using paired *t*-tests (SAS Institute, 1988). Prior to analysis, data were log-transformed ($\lg n+1$) to meet assumptions of normality and homogeneity of variance.

3. Results

3.1. Comparative plant suitability trials

In 2006, the number of *A. lucorum* nymphs and total individuals on mungbean were significantly greater than those on cotton from June 14 to August 28 (paired *t*-tests, $P < 0.05$) (Fig. 1a and c). However, adult densities on mungbean were only significantly greater than those on cotton from June 14 to July 29, and from August 13 to 28 (paired *t*-tests, $P < 0.05$) (Fig. 1b). In 2007, adult and total *A. lucorum* densities were significantly greater in mungbean