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Cotton aphid predators on alfalfa and their impact on cotton aphid abundance

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Abstract
In 2000 and 2001, studies were carried out to evaluate the influence of predators on the cotton aphid, *Aphis gossypii* Glover (Homoptera: Aphididae), in Xinjiang Uygur Autonomous Region, China, where alfalfa was mainly planted as an intercrop with cotton. There were 25 species of predators observed from June to August; 16 species of predators were caught in both cotton and alfalfa. Predators were classified into five groups: predatory beetles, lacewings, predatory bugs, syrphid flies and spiders. The total number of predators in alfalfa was 2.45 times and 20% more than that in cotton in 2000 and 2001, respectively. In an alfalfa-cutting experiment, it was found that predators increased significantly faster in cotton bordering the alfalfa-cutting treatment than in the non-cut control, and the growth of the cotton aphid population was delayed in a cotton field adjacent to the treatment compared to that adjacent to the control. This indicates that alfalfa-cutting induces predator immigration into adjacent cotton fields and helps control cotton aphids. The impact of alfalfa cutting on predators and cotton aphids was evident for about 14 days.

Key words: Cotton aphid; *Aphis gossypii* Glover; predators; alfalfa; cotton

INTRODUCTION

The cotton aphid, *Aphis gossypii* Glover, is one of the most serious sucking pests of cotton. Estimated annual losses caused by the cotton aphid amount to 10–15% of the attainable yield in China (Xia, 1997). Worldwide, the management of the cotton aphid depends heavily on frequent applications of synthetic insecticides which often lead to resistance development in the aphid and the depletion of natural enemies (Slosser et al., 1989; Chen et al., 1991; Sun et al., 1994). Increasing vegetation diversity may be a useful tool for managing pesticide resistance and enhancing biological control (Tahvanainen and Root, 1972; Smith and McSorley, 2000). Intercropping is commonly used in agriculture systems to increase biological diversity (Zhang et al., 1990; Parajulee and Slosser, 1999). Alfalfa, *Medicago sativa* L., is among the most prized of forage and is grown worldwide (Geng, 1995; Summers, 1998). Large numbers of arthropods accumulate in alfalfa fields, including many predatory insects (Lin et al., 2003). It was reported by Zhang et al. (2000a) that alfalfa bordering on cotton fields could improve biological control of the cotton aphid.

In Xinjiang Uygur Autonomous Region of China, the agricultural system is relatively simple. Because of plentiful food and a scarcity of natural enemies, cotton aphid outbreaks are frequent (Wang et al., 1997). In recent years, the area under cotton cultivation increased (cotton planting acreage increased over 10% annually from the 1990 to 1996), with corresponding reduction in habitats serving as a refuge, for example, the wheat planting acreage, for natural enemies of the cotton aphid (Zhang et al., 2000b). Fortunately, the marginal alfalfa zone surrounding cotton can obviously decrease the number of cotton aphids in growing seasons because of plentiful natural enemies in it (Zhang et al., 2000a). This cotton/alfalfa intercropping system has been used widely in south Xinjiang cotton areas. In order to use this system, more effectively, we should determine how to pre-

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serve the specific natural enemies in alfalfa in advance and how to enhance their move to cotton at the best time. The general method used is simply to cut the surrounding alfalfa to push the natural enemies to cotton at the period of aphid immigrating to cotton field. The objectives of this 2-year research were to clarify how alfalfa cutting affects predators of aphid in alfalfa and how that subsequently affects cotton aphids in cotton field.

MATERIALS AND METHODS

Study location. Experiments were carried out at Tashilike Village of Xinhe County, Xinjiang Uygur Autonomous Region of China (41°52′N, 82°61′E), where the fields were divided into rectangular regions surrounded with shelter-belts of poplar and willow. In the 5 ha experimental region, the area of experimental cotton was planted at density of 150,000 to 160,000 plants. Alfalfa was seeded in rows 500 m long and 10 m wide bordering the cotton field in the spring of 1997.

Surveying predators in cotton and alfalfa fields. From June to August in both 2000 and 2001, predators were sampled every four days (20 times totally each year) with a sweep net (38 cm diameter). On each sample date, 30 sweeps were taken along cotton and alfalfa. After each collection, the contents of the sweep net were transferred to a plastic bag, killed with ether, and taken to the laboratory for counting and identification. All stages except eggs of predators were counted. The investigation for diversity and abundance of predators was carried at through the alfalfa zone surrounding the cotton field, which was mainly used to propagate natural enemies for cotton aphid control.

Effect of alfalfa cutting on the population of cotton aphid and arthropod predators in a cotton field. In both years, the experiments were carried out in the same field. The alfalfa rows and the cotton field bordering it were divided into six equal blocks. Three blocks were selected for alfalfa cutting treatment alternating with the other three as non-cut controls. Each block of alfalfa that is adjacent to cotton both for treatment and control was in a band 20 m long and 10 m wide. They were placed with 30 m intervals separated by wheat fields. In treatment blocks, the alfalfa was cut to ground level. Cotton aphids and their predators were then surveyed in the adjacent cotton. Three plots of cotton were surveyed 5 m apart from the cotton-alfalfa border in every block. Fifteen cotton plants in every plots were selected and examined for cotton aphids and predators five times, once prior to alfalfa cutting, and 1, 3, 7 and 14 days post-cutting. In 2001, an additional survey was performed on day 21. Three control plots in each block were surveyed at the same time as the treatment block.

Statistical analyses. An analysis of variance (ANOVA) was performed on the mean number of cotton aphids and predators on every 15 plants per plot with ‘block’ and ‘time’ as factors to assess the influence of alfalfa cutting on aphid density and the effective duration. Where necessary, data used in ANOVA were transformed using log $(x+1)$ in order to meet assumptions of normality. Pearson correlation coefficients were used for the correlation of cotton aphid and its predators (SPSS, 1998).

RESULTS

Predators in cotton and alfalfa fields

More than 25 species of predators were identified in the study and are listed in Table 1. There were 23 species found in alfalfa and 18 species in cotton; 16 species were found in both crops. Seven species were found only in alfalfa (*Synharmonia conglobata contaminata* Menetries, *Microlestes plagiatus* Duftschmid, *Staphylinus* sp. 1, *Staphylinus* sp. 2, *Orius* sp. 1, *Orius* sp. 2, and *Tibellus* sp.). *Coccinella undecimpunctata* L. and *Erigone atra* (Blackwall) were sampled only in cotton. All the predators could be classified into five groups: predatory beetles, lacewings, predatory bugs, syrphid flies and spiders (Table 1).

The mean number of arthropod predators observed in alfalfa was higher than that in cotton in both years (Fig. 1). In 2000, the mean number of total predators in alfalfa was 2.45 times more than that in cotton. Among these, syrphid flies and lacewings were less abundant in alfalfa than in cotton ($n=600$, $F=22.125$, d.f.$=2$, $p<0.01$), while the mean numbers of predatory beetles, spiders and predatory bugs were higher ($n=600$, $F=9.630$, d.f.$=3$, $p<0.01$). In 2001, the mean number of predatory beetles, lacewings, spiders and syrphid flies were higher in alfalfa than in cotton ($n=600$, $F=18.668$, d.f.$=4$, $p<0.01$).

Table 1. Potential predators of cotton aphids collected in cotton and alfalfa fields

Order	Family	Species	Crop habitat
Coleoptera	Coccinellidae	*Adonia variegata* (Goeze)	Alfalfa and cotton
		Coccinella undecimpunctata L.	Cotton
		Coccinella sp. 1	Alfalfa and cotton
		Coccinella sp. 2	Alfalfa and cotton
		Oenopia conglobata L.	Alfalfa and cotton
		Synharmonia conglobata contaminata Ménétries	Alfalfa
	Carabidae	*Microlestes plagiatus* Duftschmid	Alfalfa
	Staphylinidae	*Staphylinus* sp. 1	Alfalfa
		Staphylinus sp. 2	Alfalfa
Hemiptera	Miridae	*Deraeocoris punctulatus* Fallen	Alfalfa and cotton
	Anthocoridae	*Orius* sp. 1	Alfalfa
		Orius sp. 2	Alfalfa
	Nabidae	*Nabis sinogerus* Hsiao	Alfalfa and cotton
		Nabis sp. 1	Alfalfa and cotton
		Nabis sp. 2	Alfalfa and cotton
Neuroptera	Chrysopidae	*Chrysopa formosa* Brauer	Alfalfa and cotton
		Chrysopa septempunctata Wesmael	Alfalfa and cotton
		Chrysopa sinica Tjeder	Alfalfa and cotton
Diptera	Syrphidae	*Epistrophe balteata* (DeGeer)	Alfalfa and cotton
		Paragus qudrifasciatus Meigen	Alfalfa and cotton
		Syrphus corollae Fabricius	Alfalfa and cotton
Araneae	Thomisidae	*Xysticus* sp. 1	Alfalfa and cotton
		Xysticus sp. 2	Alfalfa and cotton
		Tibellus sp.	Alfalfa
	Erigonidae	*Erigone atra* (Blackwall)	Cotton

Influence of alfalfa cutting on cotton aphid predators

After the cutting of alfalfa, the predators in alfalfa migrated to the adjacent cotton. In 2000, these were primarily spiders, lacewings, predatory bugs and predatory beetles (Table 2). Within the alfalfa-cutting plots, the population of spiders increased greatly to day 14 ($n=45$, $F=4.495$, d.f.$=4$, $p<0.01$), while there were no significant differences within the control plots ($n=45$, $F=2.473$, d.f.$=3$, $p=0.058$) within 7 days. On the 14th day of post cut alfalfa, spiders increased significantly compared to the 1st day, but remained far lower than in treatment plots. The mean number of lacewings increased significantly in both alfalfa-cutting plots ($n=45$, $F=21.72$, d.f.$=4$, $p<0.01$) and control plots ($n=45$, $F=5.794$, d.f.$=4$, $p<0.01$), but the number was higher in treatment plots than that in control plots during the same time ($n=45$, $F=4.213$, d.f.$=4$, $p<0.05$). There were no significant differences in numbers of either predatory bugs or predatory beetles between treatment and control plots (for predatory bug: $n=45$, $F=3.458$, d.f.$=4$, $p>0.05$; for predatory beetle: $n=45$, $F=4.291$, d.f.$=4$, $p>0.05$). Compared to the precut survey, the number of total predators in the treatment plots was significantly greater on the day 7 after cutting ($n=45$, $p<0.01$), while that in the control plots did not increased significantly until day 14 after cutting ($n=45$, $p<0.01$).

Syrphid flies appeared late in the experiment in 2000 that were not observed in 2001 (Table 3). In the treatment plots, the mean number of lacewings increased significantly from the day 1 after cutting ($n=45$, $F=6.205$, d.f.$=4$, $p>0.05$) and remained higher in number on day 7 while that in control plots did not increase significantly until day 14 after cutting ($n=45$, $F=5.315$, d.f.$=4$, $p<0.05$). Predatory beetles were first found on day 7 after cutting in treatment plots and on day 21 after cutting in control plots. Predatory bugs and syrphid flies were low in number through out the experiment. As in 2000, the number of total predators in alfalfa-cutting treatment increased significantly on day 7 after cutting, while that in the control did not increase significantly until day 14. However, from

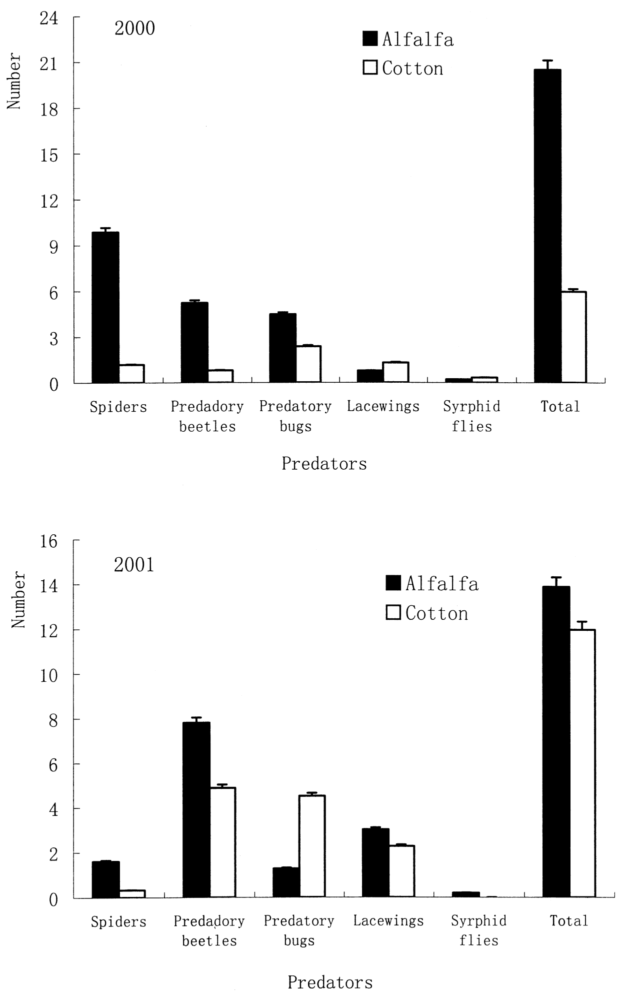

Fig. 1. Mean number (±SE) of predators collected (n=21) per 4 days per 30 sweep-net samples from cotton and alfalfa.

day 14 to day 21, the increase rate of population of predators was higher in control than in treatment plots.

Impact of alfalfa cutting on cotton aphid abundance in a cotton field

In June, the population of the cotton aphid began to increase. In the control plots, cotton aphids increased rapidly from day 3 to 14 after alfalfa-cutting in 2000 and from day 14 to 21 in 2001 (Tables 2 and 3). However, the numbers in the treatment plots were maintained relatively stable because of adjacent alfalfa-cutting. Although the number of aphids increased from day 14 in 2001 in treatment plots, the increase was slow compared with CK.

The correlation coefficients of cotton aphids and predators are shown in Table 4. In 2000, there were significant correlations between total predators and cotton aphids (Treatment: r=0.817, p<0.05, CK: r=0.968, p<0.01). Lacewings and predatory bugs were significantly correlated to cotton aphid density in control plots (lacewings: r=0.961, p<0.01; predatory bugs: r=0.987, p<0.01). In 2001, predators again showed significant correlation with cotton aphid populations (Treatment: r=0.896, p<0.05, CK: r=0.993, p<0.01). Lacewings, predatory bugs and syrphid flies were significantly correlated with cotton aphids in both treatment and control (p<0.01). The correlation between predatory bugs and cotton aphids was significant in control plots (r=0.965, p<0.01).

Table 2. Mean number (±SE) of cotton aphid predators in cotton field before/after alfalfa-cutting in 2000

Predators	Item	Precut	1st d post-cut	3rd d post-cut	7th d post-cut	14th d post-cut
Spiders	Treatment	1.2±0.02 a[a]	0.9±0.01 a	1.0±0.02 a	2.9±0.11 b	3.1±0.15 b
	CK[b]	0.8±0.01 ab	0.1±0.01 a	0.4±0.01 ab	0.3±0.01 ab	1.3±0.02 b
Lacewings	Treatment	6.1±0.28 a	9.2±0.50 a	12.1±2.12 a	19.6±2.07 b	24.3±9.28 b
	CK	3.3±0.17 a	2.4±0.20 a	2.3±0.08 a	7.9±1.20 b	15.1±3.67 b
Predatory bugs	Treatment	0 a	0 a	0 a	0.4±0.01 a	0.9±0.02 a
	CK	0 a	0 a	0.2±0.01 a	0.2±0.01 a	0.3±0.01 a
Predatory beetles	Treatment	0.1±0.01 a	0 a	0 a	0.1±0.01 a	0.1±0.01 a
	CK	0 a	0 a	0 a	0 a	0.1±0.01 a
Total predators	Treatment	7.4±2.12 a	10.1±2.50 a	13.1±3.74 a	23.0±5.01 b	28.4±5.29 b
	CK	4.1±0.08 a	2.6±0.12 a	3.0±0.20 a	8.4±2.01 ab	16.9±2.58 b
Aphids	Treatment	1.9±0.05 a	0.4±0.01 ab	0.2±0.01 b	0.1±0.01 b	2.3±0.01 a
	CK	6.7±1.06 a	10.0±2.16 a	16.4±4.12 a	78.3±9.72 b	433.3±28.10 c

[a] Means followed by the same letter within the time sequence are not significantly different (p>0.05).
[b] CK means the control plots with no alfalfa cutting.

Table 3. Mean number (±SE) of cotton aphid predators in cotton field before/after alfalfa-cutting in 2001

Predators	Item	Precut	1st d post-cut	3rd d post-cut	7th d post-cut	14th d post-cut	21st d post-cut
Spiders	Treatment	0.7±0.01 ab[a]	0.4±0.01 ab	1.3±0.01 a	1.1±0.02 ab	0 b	0.2±0.02 ab
	CK[b]	0 a	0.9±0.02 ab	0 a	0 a	0.9±0.01 ab	1.1±0.02 b
Lacewings	Treatment	0 a	2.2±0.02 b	1.8±0.01 ab	11.1±1.23 c	7.8±2.59 c	26.4±5.14 d
	CK	1.3±a	2.4±a	3.1±ab	3.8±ab	10.7±bc	30.0±c
Predatory bugs	Treatment	0 a	0 a	0 a	0 a	0 a	0.9±0.03 a
	CK	0 a	0 a	0 a	0 a	0 a	0.2±0.01 a
Predatory beetles	Treatment	0 a	0 a	0 a	6.7±1.06 ab	28±3.15 b	10.7±3.67 b
	CK	0 a	0 a	0 a	0 a	0 a	60.2±9.07 b
Syrphid flies	Treatment	0 a	0 a	0 a	0 a	0 a	0.4±0.01 a
	CK	0 a	0 a	0 a	0 a	0 a	0.4±0.01 a
Total predators	Treatment	0.70±0.02 a	2.7±0.21 a	3.1±0.30 a	18.9±2.01 b	35.8±5.14 bc	38.7±4.68 bc
	CK	1.3±0.04 a	3.3±0.51 ab	3.1±0.24 ab	3.8±0.50 ab	11.6±2.10 b	92.0±10.10 c
Aphids	Treatment	1.4±0.06 a	1.4±0.06 a	5.0±1.25 a	9.3±2.06 ab	16.3±4.05 ab	58.1±8.88 b
	CK	0.2±0.01 a	1.0±0.02 ab	0.6±0.04 a	9.0±1.18 bc	53.7±4.26 cd	199.9±13.30 d

[a] Means followed by the same letter within the time sequence are not significantly different ($p > 0.05$).
[b] CK is same as Table 2.

Table 4. Correlation coefficients between cotton aphids and their predators

Year	Item	Cotton aphid	Spiders	Lacewings	Predatory beetles	Predatory bugs	Syrphids	Total
2000	Treatment	1	0.844	0.805	0.739	0.631	—	0.817*
	CK[a]	1	0.832	0.961**	0.737	0.987**	—	0.968**
2001	Treatment	1	−0.467	0.958**	0.376	0.966**	0.966**	0.896*
	CK	1	0.680	0.998**	0.965**	0.965**	0.965**	0.993**

[a] CK is same as Table 2.
Significant difference, * $p < 0.05$; ** $p < 0.01$.

DISCUSSION

Habitat management can potentially enhance the effectiveness of natural enemies in biological control (Landis et al., 2000). Increased habitat diversity achieved through strip cropping is known to conserve and enhance the efficacy of natural enemies of crop pests by providing food sources of adults, alternative prey, overwintering sites, or other forms of refuge within crop systems (Mensah, 1999). The lack of ecological diversity in many crop systems may limit the natural biological control of pests (DeLoach, 1971).

In Xinjiang Autonomous Region of China, the monoculture of cotton could be a major cause of pest problems. In the recent two decades, the area of cotton production increased rapidly, and now constitutes about 40–60% of total cultivated land in some counties (Zhang et al., 1998). Wheat, the primary habitat for natural enemies of the cotton aphid, has been reduced in area. As a result, cotton aphid outbreaks have become more frequent (Wang et al., 1997).

More aphid predators were present in alfalfa than in cotton. Many studies have been done on alfalfa as an intercrop for cotton (Stern et al., 1976; Mensah and Khan, 1997; Mensah, 1999). One of the goals was to make use of natural enemies accumulating in cotton field (Zhang et al., 2000b). This was demonstrated by our survey in which many predators could be caught by alfalfa.

Alfalfa-cutting is known to induce natural enemy migration (Schaber et al., 1990; Letourneau and Altieri, 1999). Cutting could be an important cultural means of encouraging the dispersal of natural enemies among habitats (Landis et al., 2000). Alfalfa strips can be cut two or three times during the season (Harper et al., 1990), so the alfalfa-cutting policy may be used repeatedly. In the present study, the number of predators was kept increasing and the rapidly increasing period of the cotton aphid was delayed in treatment of alfalfa-cutting compared with the control. Predators in the treatment increased significantly in number until day 14 after cutting, while the cotton aphid population increase was delayed. Furthermore, the correlation between predators and the cotton aphid was significant. It was concluded that alfalfa-cutting could compel the migration of predators controlling the population of the cotton aphid and remain effective for about 14 days. This is in agreement with results obtained previously (Harper et al., 1990). Lacewings were the dominant group of predators controlling the cotton aphid (Zhang et al., 2000b).

However, the alfalfa-cotton intercropping system may have the risk of causing other increases such as lygus bug that infects both cotton and alfalfa (Goodell, 1998). Nevertheless, the alfalfa zone certainly can help us to propagate many natural enemies naturally for the control of cotton aphids. This convenient intercropping system should allow us to decrease the insecticide dosage in cotton fields gradually. More work is also needed to determine the optimum size of strips and time for alfalfa-cutting, which are important for both management of the cotton aphid and commercial income from alfalfa.

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