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Mowing Versus Insecticide for Control of Alfalfa Aphids and their Differential Impacts on Natural Enemies

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ABSTRACT

A study was conducted in a alfalfa fields on the loess plateau in northwest China to determine the impact of mowing and spraying imidacloprid on alfalfa crops on the population dynamics of aphids and their natural enemies. The results showed that mowing was very effective in controlling spotted alfalfa aphid, *Therioaphis trifolii* (Monell), and pea aphid, *Acyrthosiphon pisum* (Harris). Mowing in early June significantly reduced the average number of both aphid species in different seasons and kept them at low density. To a lesser degree, populations of their predators were also reduced under mowing. Consequently, the ratio of predators to aphids increased tremendously. A lower predator-aphid ratio occurred after spraying with imidacloprid, which led to an increase in the seasonal average number of both aphid species and a decrease in number of predators, including coccinellids, green lacewings and syrphid flies. The majority of these predators were killed by the insecticide, resulting in rapid recovery of the pests and severe damage to the crop. Based on the findings, it is recommended that the alfalfa crop should be harvested as early as possible if aphids are the only targeted pests, especially when the aphid populations peak near the harvest season. In seed fields, necessary chemical pest control should utilize highly selective insecticides. Sustainable pest control practices are important for agricultural stability. Our findings show that properly timed mowing of alfalfa fields is more effective at controlling pest aphids and maintaining their natural enemy diversity than the spraying of imidacloprid. This Insecticide had negative impacts on natural enemy composition and was only temporarily effective against aphids, leading to rapid rebounds in their populations. We suggest that toxic pesticides be avoided when possible to sustainably control pests.

Key words: biological control; *Medicago sativa*; aphids; natural enemy; mowing; insecticides.

INTRODUCTION

Mowing (Liu and Zhou, 2004; Liu et al., 2007) and spraying insecticides (Fenton, 1959; Radcliffe et al., 1976; Tao et al., 2005) are two important agricultural practices for managing pests in alfalfa fields. The timing and frequency of mowing, type of insecticides used, and the schedule of application can all have significant impact on species composition and the population dynamics of insects and their predators (Summers, 1976; Harper et al., 1990; Kang et al., 2005). The key aphid species on alfalfa include the spotted alfalfa aphids, *Therioaphis trifolii* (Monell), pea aphids, *Acyrthosiphon pisum* (Harris), and bean aphid, *Aphis medicaginis* Koch (Radcliffe et al., 1976; Cuperus et al., 1982; Bommarco and Ekbom, 1996). In Northwest China, most alfalfa fields are infested primarily by the first two species (He and Zhang, 2006; Lan and Liu, 2007; Liu et al., 2008; Du et al., 2012; Liu et al., 2012), that often cause severe damage to the crop. For example, in 1968, 60% yield of alfalfa crop was lost to aphids in the Yimeng Melin of Inner-Mongolia. The overwintered crop appeared chlorotic in large patches, and did not recover the next spring. The whole field had to be plowed and planted with other grass species instead (Bai et al., 1990).

An understanding of the impacts of mowing and insecticide treatments on alfalfa aphids and their predators is critical for developing an integrated pest management strategy. So far, several studies have been undertaken to investigate insect community structure and species dynamics in alfalfa fields (Stern et al., 1959; Pimentel and Wheeler, 1973; Wheeler, 1974, 1977; Liu and Zhou, 2004; Wang and Liu, 2014). These studies have focused on the variation in numbers of aphids and their predators after mowing and insecticide treatments (Radcliffe et al., 1976; Summers, 1976; Harpe et al., 1990). However, there exists little information about management impact on aphid population dynamics (Liu et al., 2008). This paper reports a systematic investigation of the population dynamics of aphids and their predators after the alfalfa crop was cut or sprayed with insecticide. The results from this study have important implications for designing strategies to control aphids on alfalfa crops.

MATERIALS AND METHODS

Experimental design

The experiment was conducted in a 3-year old alfalfa (*Medicago sativa* L) field in Dingxi County, Gangsu Province in northwest China. There were three treatments consisting of 1) a single application of 5% imidacloprid EC 3000 x solution (Kesheng Inc, Jiangsu, China), 2) a single mowing, and 3) a control without insecticide application or mowing. The three treatments were arranged in a randomized complete block (RCB) design with 4 replications (blocks). The plot size was 667m^2 with 3 m gaps between plots and 40 m gaps between blocks. The insecticide treatment was applied at the end of May, and the mowing at the beginning of June. No other management practices were applied during the experimental period.

Methods

The initial data collection was conducted in late May before mowing or insecticide treatments. The subsequent measurments were conducted once every 10 days until late August. For each measurement, 5 sampling areas in each plot were randomly selected and the insects were caught using sweep nets (diameter 33 cm, depth 1 m), with 10 sweeps at 180°angle. The number and species of aphids and their predators were recorded. Major aphid species and their natural enemies found in this study included the spotted alfalfa aphids, pea aphids, coccinellids, green lacewings, syrphid flies and parasitic wasps. Species not easily recognizable in the field, were brought back to the lab for identification.

Data analysis

Tests of single factor and dual factor effects were used to determine the contribution of mowing and insecticide application to the population composition (species and abundance) of aphids and their predators. The analysis tested for quantitative changes in both aphid and predator populations over time, and for interactions between survey dates and treatment effects Data with inhomogeneous variation were log-transformed prior to ANOVA. Means of the survey data were compared among the treatments using the Duncan shortest significant range test (SSR, α = 0.05). All analyses were performed using Microsoft Excel and DPS programs (Tang & Feng 2002).

RESULTS AND DISCUSSION

Aphid species composition, abundance, and population dynamics

The impacts of mowing and insecticide application appeared similar whether spotted alfalfa aphids, pea aphids, or the total aphid population were considered (Fig.1). Numbers of aphids were significantly affected by both mowing and spraying insecticide (Table 1). Species composition and overall aphid abundance also varied greatly among two treatments. During the survey period from July, 6 to August, 20, average numbers of spotted alfalfa aphid and pea aphid were 852.5 and 1010.8 per 50 sweeps, respectively, in the insecticide treated field, both significantly higher than in the control (Table 1). In contrast, the average numbers of aphids of both species were lower in the mowed field than in the control at 121.2 and 114.5, respectively. Significantly more aphids were observed in the insecticide-treated field than in the mowed field, the difference reaching 7.0 and 8.8 fold more spotted alfalfa aphids and pea aphids, respectively.

The temporal dynamics of the aphid populations were differentially affected by each treatment (Fig.1, Table 1). After insecticide application on May 30, spotted alfalfa aphids and pea aphids in the control field were 4.23, and 4.01 fold higher than in th insecticide-treated field on June 6. Thereafter, aphid numbers in the treated field began to recover, and

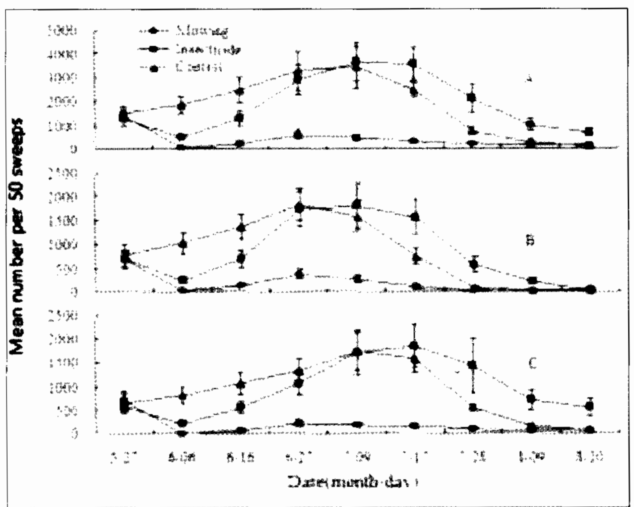

Fig. 1 Impact of mowing and insecticide application on mean numbers of aphids per 50 sweeps. Error bars represent ±1 SD. (A) Means of total aphids; (B) Means of *T. trifolii* (C) Means of *A. pisum*

Table (1): Analysis of aphid population responses to mowing versus insecticide application or control

		Total aphids		Spotted alfalfa aphid		Pea aphid	
Source of variation	d.f.	*F*	*P*	*F*	*P*	*F*	*P*
Between treatments							
Insecticide	1	18.02	< 0.01	13.04	< 0.01	13.68	< 0.01
Mowing		487.02	< 0.01	432.47	< 0.01	609.72	< 0.01
Insecticide vs. mowing	1	624.45	< 0.01	541.28	< 0.01	630.80	< 0.01
Within treatments							
Date × insecticide	7	29.72	< 0.01	32.61	< 0.01	5.23	< 0.01
Date × mowing	7	36.21	< 0.01	38.27	< 0.01	35.230	< 0.01
Date × insecticide × mowing	7	4.00	< 0.01	35.32	< 0.01	2.87	0.02

Note: Analysis of variance was performed on log-transformed values of the dependent variables.

Table (2): Analysis of natural enemy population responses to mowing versus insecticide application or control

		Total natural enemies		Coccinellids		Green lacewings		Syrphid flies		Parasitic wasps	
Source of variation	d.f.	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*	*F*	*P*
Between treatments											
Insecticide	1	116.13	< 0.01	90.41	< 0.01	95.89	< 0.01	25.09	< 0.01	2.58	0.12
Mowing	1	51.03	< 0.01	97.48	< 0.01	0.79	0.40	52.10	< 0.01	6.95	0.01
Insecticide vs. mowing	1	3.22	0.08	2.69	0.11	60.39	< 0.01	0.58	0.45	2.44	0.13
Within treatments											
Date × insecticide	7	14.48	< 0.01	4.73	< 0.01	2.15	0.07	3.33	< 0.01	4.97	< 0.01
Date × mowing	7	17.58	< 0.01	26.36	< 0.01	8.67	< 0.01	19.79	< 0.01	2.87	0.02
Date × insecticide × mowing	7	4.01	< 0.01	10.34	< 0.01	6.03	< 0.01	4.82	< 0.01	1.97	0.09

difference in aphid numbers between the insecticide treatment and control diminished by the end of June. By mid July, the abundance of spotted alfalfa aphids were 2.1 fold higher in the insecticide treatment and, by late July, pea aphids were 2.6 fold higher. These differences increased further to 5.4 and 4.4 fold more aphids in early August. Although aphid abundance during peak season was not different between treated and control fields, the insecticide treatment only delayed the peak for about 10 days.

Five days after mowing on June 1, the number of spotted alfalfa aphids and the pea aphids in the treatment field was 52.0 and 77.6 times fewer than control ($P < 0.01$). Both aphid populations continued to increase after mowing, but total numbers remained less than in control fields ($P < 0.01$). Both spotted alfalfa aphid and pea aphid populations reached their peak in late June and early July in the control field when they were 5.0 and 8.0 fold higher, respectively, than that in the mowed field.

Differences between the mowing and insecticide application treatments were also evident. During the first survey after treatment, means of 242 spotted alfalfa aphid and 200 pea aphids were tallied in the insecticide-treated field, compared to only 19.7 and 10.3, respectively, in the mowed field ($P < 0.01$). Thereafter, both aphid species in the insecticide-treated field remained higher than in the mowed field. The spotted alfalfa aphids and pea aphids were 7.2 and 8.5 fold higher than the mowed field, respectively, when they reached peak populations in early to Mid July.

Species composition and abundance of natural enemies

The impact of the mowing and insecticide treatments on aphid predators was different from that on aphids (Fig. 2). There were significant differences in the number of the predators between the two treatments (Table 1). From June 6 to August 20, the mean number of natural enemies of all species recorded was 98.5 and 77.5 in the mowing and insecticide treated fields, respectively. Both treated fields had fewer predators than the control with 127.1 predators.

Natural enemy species composition also differed between mowing and insecticide application (Fig. 2, Table 2). In the mowed field, the average number of coccinellids, green lacewings, syrphid flies, and parasitic wasps was 34.9, 12.0, 10.6 and 40.9 respectively. The corresponding numbers in the insecticide-treated field were 23.1, 4.3, 9.5 and 40.6, and in the control field were 50.3, 12.6, 16.2, and 48.0. There was no significant difference in numbers of green lacewings between the mowed field and the control, or the number of parasitic wasps between insecticide-treated and control ($P > 0.05$). However, all other predators were less abundant in treatment fields than in control fields. In addition, the number of green lacewings varied significantly between mowing and insecticide treatments ($P < 0.01$), but differences were not significant for coccinellids, syrphid flies or parasitic wasps ($P > 0.05$).

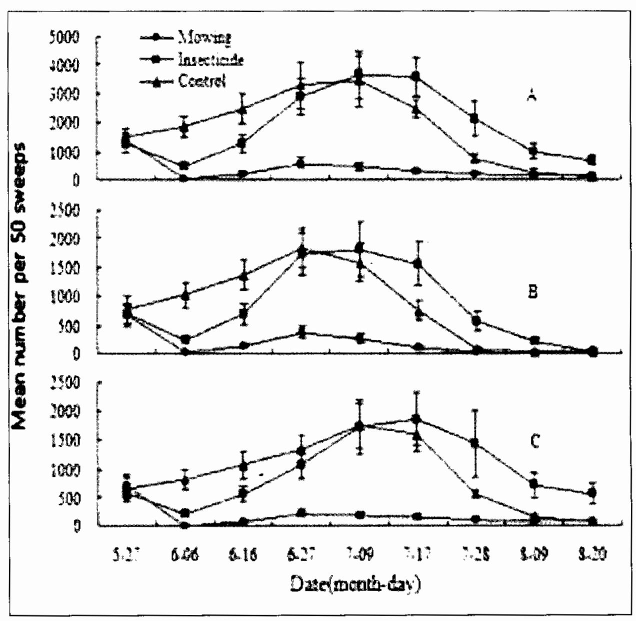

Fig. 1 Impact of mowing and insecticide application on mean numbers of aphids per 50 sweeps. Error bars represent ±1 SD. (A) Means of total aphids; (B) Means of *T. trifolii* (C) Means of *A. pisum.*

Mowing significantly affected the population dynamics of natural enemies (Fig. 2, Table 2). Immediately after mowing, the four groups of aphid predators were significantly lower than that in the control field, but as the crop grew, their populations quickly recovered. By late June, differences between treated and control fields were not significant (P > 0.05).

Insecticide spraying also affected, to varing degrees, the dynamics of green lacewing, syrphid and parasitic wasp populations in the crop (Fig.2, Table 2). After treatment, numbers of all three groups were lower than in the control field, but their population\s gradually increased to reach similar levels by early August. Overall, predator populations in the control field remained higher than that of the insecticide treatment field.

There was no significant difference between mowing and insecticide application in terms of the dynamics of the parasitic wasp population (Table 2, Fig. 2), but there were significant differences in the population dynamics of the other three groups. In the mowed field, numbers of coccinellids and green lacewings were significantly lower than in the control field during the first survey, but from late June to late July, their populations in the mowed field became higher than in the control.

Mowing are effective means for controlling aphids on alfalfa crop. The study confirmed that mowing can delay the aphid peak by 2-4 weeks (Harper *et al.* 1990) and can significantly reduce the seasonal average number of aphids. Five days after cutting in June, the number of spotted alfalfa aphids and pea aphids in the control field was 52.0 and 77.6 times higher than in the mowed field, respectively. Although the total population of these two aphid species increased slightly, it decreased thereafter and became lower than that in the control field. Mowing also affected aphid predator populations, but the impact was much less severe than that on the aphids. Compared with mowing in June, the aphid population in the control field was 11.1 fold higher in mid June, whereas the predator population had only a 2.3 fold increase during the same period. The predator-prey ratio was 1:29.5 in the control field compared to 1:6.2 in the mowed field. When mowing occurred, the aphid population was peaking, but predator populations were still relatively low. However, the predators moved quickly to other plants and their populations recovered quickly on the new growth of the alfalfa plants. Eventually, the aphid population was reduced more significantly than those of their predators by teh mowing treatment.

Chemical treatment has proven to significantly affect coccinellids and predacious stinkbugs (Wu & Liu 1992; Su *et al.* 2003), causing reduction of both populations. Application of fenvalerate can promote growth of cotton aphid population (Wu & Liu 1992). On cotton, the cotton aphid (*Aphis gossypii Glover*) population is usually higher in chemical-treated than in untreated fields (Su et al. 2003). After imidacloprid treatment, the number of both aphid species initially dropped, but then increased tremendously after insecticide efficacy diminished, and exceeded that of the control field by mid July. For the remainder of the study period, aphid numbers were higher in the insecticide treatment than in the control. Both aphid species have a short-life cycle and propagate faster than their natural enemies, enabling them to escape biological control after natural enemy populations were reduced by the insecticide.

The insecticide treatment also caused temporal changes in the effect of natural enemies. From early June to late July, populations of syrphid flies and parasitic wasps remained higher in the control field than in the insecticide-treated field, but by mid August, there were more parasitic wasps in the treated field. Because the insecticide treatment reduced the numbers of coccinellids and predatory stink bugs which have longer life cycles, these predator populations did not recover quickly after the insecticide treatment. Although the population of parasitic wasps was initially small, their faster life cycle enabled them to capitalize on the rebounding aphid populations in the insecticide treated field, and their numbers eventually exceeded those in the control field by mid August.

The average number of predators collectively were not significantly different between mowing and insecticide treatments. However, the predator-prey ratio varied significantly according to distinct population dynamics in each treatment. In mid June, the predator-prey ratio in the mowed field was 1:6.2, while it was 1:50.9 in the insecticide-treated field, and the significantly higher ratio in the mowed field held the aphid populations at lower density.

The results of this study imply that, when aphids are the major pest in an alfalfa field, biological control relying on natural enemies can be relied upon. If the peak aphid populations occur near tharvest , the crop should be cut as early as possible. In seed production fields, effective but more selective insecticides should be used to minimize non-target effects on natural predator populations. By adopting these practices, it should be possible to control aphids while protecting their natural enemies and achieve sustainable crop production.

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