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不同间作枣园害虫的群落结构与动态

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摘要：对 5 种不同间作枣园的害虫群落结构特征进行了研究，结果表明，在不同的间作枣园中，害虫的科、种与个体数是各不相同的，其多样性、均匀度和 Berger-Parker 指数也有明显差异($p<0.05$)。间作牧草或保留杂草的枣园，害虫的科与种以及多样性和均匀度明显($p<0.05$)大于间作小麦、大豆和单作枣园，而个体数和 Berger-Parker 指数则显著($p<0.05$)小于单作枣园。枣园害虫个体数的时序动态随季节交替而有明显($p<0.05$)的变化，4～8 月份害虫的个体数明显($p<0.05$)大于 3 月份、9～10 月份。在枣园间作作物、牧草或者适当保留一定数量的杂草，不仅能够充分有效地利用枣园的空间和自然资源，而且增加了生物的多样性，改善了枣园的生态环境，同时提高了有害生物相互制约的能力和枣园单位面积的纯收入。

关键词：枣园；害虫；群落结构；动态

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The structure and dynamics of pest insect communities in jujube sites of different intercropped systems

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Abstract: Studies on the structure and dynamics of pest insect communities in five jujube sites with different Intercropped systems were conducted in the suburb of Taigu County, Shanxi Province, China from 2000～2002. There were different numbers of families, species and individuals of pest insects, as well as different indices of diversity, evenness and Berger-Parker in the jujube sites of different intercropped. There were larger ($p<0.05$) numbers of families and species in the jujube site with herbage and weeds than in those with wheat, soybean and mono-cultivated jujube site. The smallest ($p<0.05$) numbers of pest insect individuals were found in the jujube site with herbage and weeds, the largest ($p<0.05$) in the mono-cultivated jujube site. Larger ($p<0.05$) indices of Shannon-Wiener and evenness were recorded from the jujube site with herbage and weeds than in those with wheat, soybean and the mono-cultivated jujube. However, larger ($p<0.05$) indices of Berger-Parker were in the mono-cultivated jujube site than in the other four jujube sites. The temporal dynamics of the insect

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pest individuals went through continuous change with the change of seasons. There were larger ($p<0.05$) numbers of insect pest individuals from April to August than in March, September and October. The results suggested that intercropped crops, herbage or properly remaining weeds were beneficial not only in making full use of field space but also in reducing the number of insect pest individuals and increasing net income in the jujube sites.

Key words: jujube sites; pest insects; community structure; dynamics

The structures and dynamics of community of pest insects in jujube orchards intercropped with grain crops or herbage is more complex than those in mono-cultivated forestry or crop eco-systems. Management of the jujube orchards is different from that of forests or crop fields because not only the yield is considered but also the quality of both crop and jujube during the whole jujube-developing period[1~2]. Therefore, in the course of managing jujube orchards, people usually interfered and injured the natural jujube orchard eco-system upon which insects and other animals depended. This management caused the jujube ecological conditions to become extremely unstable and the species and numbers of pest insects to fluctuate frequently. The management made controlling jujube tree pest insects difficult[3~4]. It is necessary that the structures and dynamics of pest insects of jujube tree in different intercropped and managed jujube orchard ecosystems be better understood before exploring integrated pest management (IPM) of pest insects of jujube tree. Shi *et al.* (2002) reported on the insect community and diversity in different intercropped and managed jujube orchard ecosystems[1]. However, the structures and dynamics of pest insects of jujube tree in such orchards are still poorly understood. To better understand these aspects, the establishment of the investigation into different intercropped and managed jujube orchards is essential. Our objectives were to evaluate the influence of differently managed jujube orchards on the community structures and dynamics of pest insects, so as to provide a reliable basis for an ecologically based regulation technology both for control of pests and for protection of beneficial insects.

1 Materials and Methods

1.1 Experimental Sites

The investigations were carried out in a jujube field located 2.5 km west of Taigu (112°8′E, 38°9′N, 780 m elevation). Jujube trees were 18~20 yrs old and in full fruit production, with a height of 5 m and a shading-degree of 0.4~0.6. Five treatments of experimental jujube orchards were set up. Each treatment was replicated three times, each replicated was at least 2666.7 m^2. First one of five treatments was intercropped with wheat (*Triticum aestivum*), and second one was intercropped with soybean (*Glycine max*), and third one was intercropped with herbage (*Lotus corniculatus*), and fourth one had weeds in jujube orchards, and fifth one was mono-cultivated jujube. Before 2000, treatments were managed as any other jujube orchards in the area, using conventional management methods where insecticides, acaricides and herbcides were used 7 or more times per year. Pesticides were applied when overwintering pests resumed activity at the end of March. During the growing season, insecticides were sprayed 4 times to control insects that fed on buds, leaves, blooms and developing fruit. To control fruit borers, insecticides were sprayed in late July and again in the middle of August. From 2000 to 2002, pesticides were sprayed four times every year in the treatments. The treatments were located in the general area with similar natural conditions such as topography, geographical features and soil texture except for different intercropped strategies.

1.2 Samplied Methods

In each of these replicated sites, five trees were chosen according to the chessboard samplied method to monitor population dynamics of pest insects. The trees were monitored every 10 d from March 1st to October 30th in 2000, 2001 and 2002. On each samplied date, each of five trees at each replicated site was observed from four different directions (East, West, South and North). At each direction, three levels of canopy (upper, middle and lower) were monitored. At each canopy level, the investigators spent approximately 2 min to look for pest insects and record numbers observed. Flitting pest insects were captured with a sweep net (diameter: 30 cm, 50cm deep, made with white nylon yarn). The net-captured pest insects were brought back to the laboratory for identification. In addition, three 50 cm twigs were chosen at each canopy level to check the presence of pest insects. From July to October, 15 fruits were checked at each canopy level on each samplied date to monitor pest insects in the jujube fruits. For unemerged pest insects, hosts of the pest insects were brought back to the laboratory and reared in petri dishes (10 cm in diameter, 2 cm in height) under an ambient photoperiod of 13 : 11 (L : D) h, with room temperature fluctuating between 18℃ and 23℃ and a relative humidity of 60%±10%. Once emerged, pest insects were identified[4].

Besides sampled on trees, soil under the sampled trees was also checked for pest insects on each samplied date. Four samples were taken from each of five samplied trees at each site. Each sample consisted of the top 20 cm of soil from a 100 by 100 cm area. The sampled soil was observed for the presence of pest insects, and then sieved. Any pest insects extracted from the soil were recorded. After counting, all pest insects were returned to the soil at their original sampled site[1].

Jujube fruit, wheat, soybean and herbage in each treated plot were harvested at the end of the season and the averaged yield of 3 yrs was transformed into the net income (RMB (¥) / 666.7 m^2) and then compared.

1.3 Statistical Analyses

All species and individuals of each species of pest insects observed on each samplied date during 3 yrs were calculated as total numbers per 5 trees. The original data were converted into monthly average per sampled site. The Shannon-Wiener diversity index (H) was applied to measure the species diversity of pest insect communities[5~8]: $H = -\sum_{i=1}^{s} p_i \cdot \ln p_i (i = 1, 2, 3, \cdots, s), p_i = N_i/N$, N_i was the total number of the ith species; N was the total number of all species; and s represented ith species. The species evenness (E) of pest insect communities was measured with the formula: $E = H/\ln S$, S was the number of species. Dominant degree index of Berger-Parker[8~10] was calculated: $I = N_{max}/NT$, N_{max} was the total number of the dominant species and NT was the total number of all species including the dominant species. All data were analyzed by a one-way ANOVA followed by Tukey's test to compare the differences among the five different experimental sites at the $p=0.05$ level of significance[11].

2 Results

2.1 Comparison of Families, Species and the Number of Pest Insect Individuals in the Different Jujube Sites

In this 3 year study, 31 families, 56 species and 33498 individuals of pest insects were found in the jujube site with wheat; while the corresponding numbers were 31, 58 and 35862 in the jujube site with soybean; 41, 114 and 25606 in the jujube site with herbage; 31, 52 and 42951 in the jujube site with weeds; and 39, 96 and 24101 in the mono-cultivated jujube site. These findings indicated that the numbers of families, species and individuals within different jujube sites were not the same.

The result from Fig. 1 showed that significantly more ($p<0.05$) families and species were in the jujube sites with herbage and weeds than in those with wheat, soybean or the mono-cultivated jujube site. However, there were no significantly different numbers of families and species between the jujube sites with herbage and weeds, or between jujube sites with wheat and soybean or and the mono-cultivated jujube site. The largest ($p<0.05$) number of pest insect individuals was found in the mono-cultivated jujube site and smaller ($p<0.05$) numbers in the jujube sites with herbage and weeds. There were no significantly different numbers of pest insect individuals between the jujube sites with herbage and weeds, or between jujube sites with wheat and soybean.

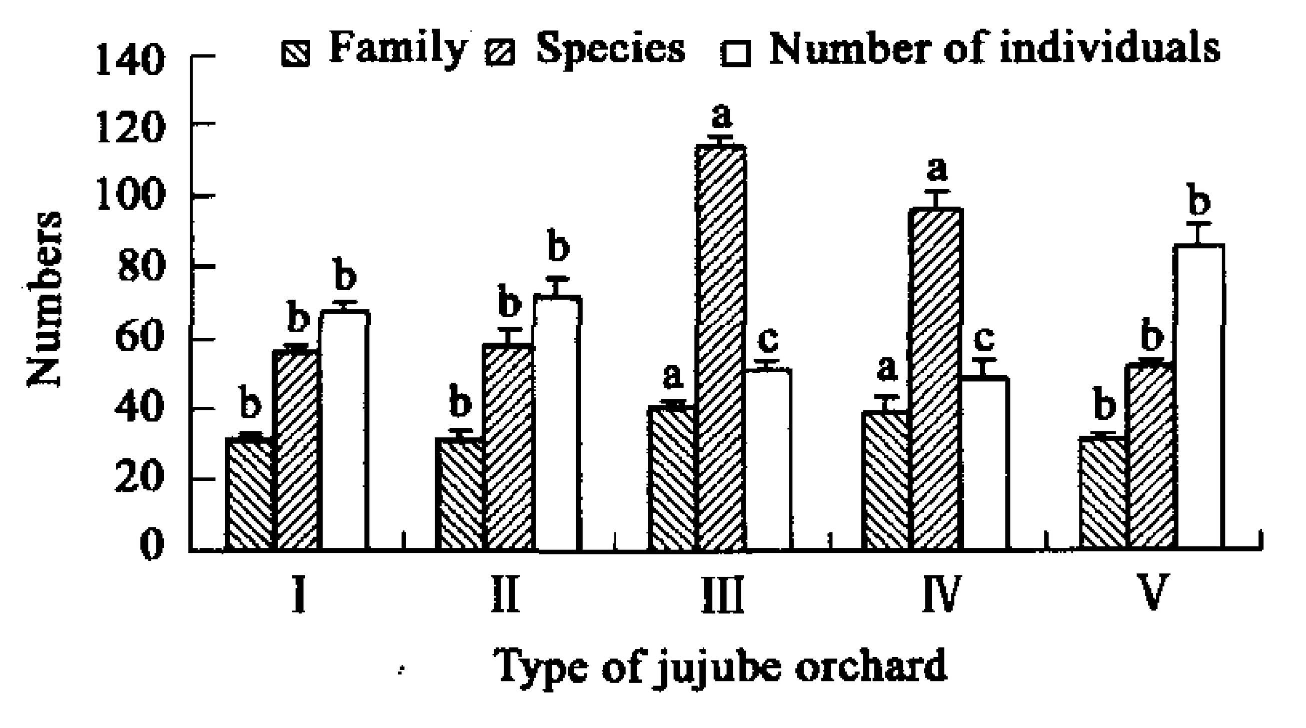

Fig. 1 Comparison of Families, Species and the Number of Pest insect individuals in the Different Jujube Sites

I Jujube site with wheat, Ⅱ Jujube site with soybean, Ⅲ Jujube site with herbage, Ⅳ Jujube site with weeds, Ⅴ mono-cultivated jujube site; All Numbers of individual insect pests were trasformed by (x/500); The same bar followed by the same letter means not significantly different (ANOVA followed by LSD, $p<0.05$)

2.2 Comparison of the Groups of Pest Insects in the Different Jujube Sites

The pest insects in the jujube sites were in seven orders, i.e. Homopterans, Coleopterans, Lepidopterans, Orthopterans, Hemipterans and Dipterans from the class Insecta as well as Acarina from the class Arachnida because *Tetranychus cinnabarinus* (Boisduval) and *Tetranychus fruncatus* Ehara were important jujube tree pest mites. The results from Table 1 indicated that there were no significant differences of family number in the groups of Orthopterans, Dipterans and Acarina in different intercropped jujube sites. However, significantly larger ($p<0.05$) family numbers of Lepidopterans, Homopterans and Hemipterans were recorded in the jujube site with herbage, and significantly larger ($p<0.05$) numbers of Coleopteran families were recorded in the jujube site with weeds. There were no significant differences in numbers of families of Lepidopterans, Coleopterans, Homopterans and Hemipterans between the jujube sites with wheat, soybean or the mono-cultivated jujube site (Table 1).

The number of species in the groups of Orthopterans, Dipterans and Acarina was not significantly different among the different intercropped jujube sites. However, significantly larger ($p<0.05$) species numbers of Homopterans and Coleopterans were recorded in jujube sites with herbage or weeds, and the smallest ($p<0.05$) number of species was from Coleopterans in the mono-cultivated jujube site. There were no significant differences in species number in Homopterans in the jujube sites with wheat, soybean or the mono cultivated jujube trees, or in the group of Coleopterans in the jujube sites with wheat or soybean. In the group of Hemipterans, the largest ($p<0.05$) species number was found in the jujube site with herbage, and the smallest ($p<0.05$) in the mono-cultivated jujube site, with no significant differences in species number between the jujube sites with wheat and soybean. In the group of Lepidopterans, the largest ($p<0.05$) species number was found in the jujube site with herbage, followed by the jujube site with weeds. There were no significant differences of species number between the jujube sites with wheat, soybean or the mono cultivated jujube trees (Table 1).

Table 1 The comparison of pest insect groups in five different jujube sites

Index	Sites	Orthoptera	Homoptera	Coleoptera	Hemiptera	Lepidoptera	Acarina	Diptera
Number of families	Ⅰ	3±0.12a	9±0.12b	6±0.12b	2±0.12b	6±0.12c	2±0.00a	1±0.00a
	Ⅱ	3±0.12a	9±0.24b	6±0.12b	2±0.12b	8±0.24b	2±0.12a	1±0.00a
	Ⅲ	3±0.00a	12±0.24a	7±0.00ab	4±0.12a	12±0.12a	2±0.00a	1±0.00a
	Ⅳ	3±0.00a	11±0.12ab	9±0.12a	3±0.12ab	9±0.00b	2±0.00a	1±0.00a
	Ⅴ	2±0.20a	9±0.12b	6±0.20b	2±0.00b	7±0.24bc	2±0.12a	1±0.00a
Number of species	Ⅰ	6±0.20a	15±0.31b	14±0.20b	6 ±0.24b	11±0.24c	3±0.12a	1±0.00a
	Ⅱ	6±0.31a	13±0.12b	15±0.12b	7±0.31b	12±0.24c	3±0.12a	1±0.00a
	Ⅲ	7±0.20a	27±0.59a	29±0.41a	10±0.20a	36±0.35a	4±0.00a	1±0.00a
	Ⅳ	7±0.12a	25±0.24a	28±0.24a	7±0.20b	24±0.54b	4±0.00a	1±0.00a
	Ⅴ	5±0.31a	14±0.12b	10±0.31c	4±0.12c	11±0.31c	4±0.12a	1±0.00a
Number of individuals	Ⅰ	32±0.74c	4568±11.95c	3188±12.04b	373±1.39b	1930±68.71b	767±34.22b	308±9.47b
	Ⅱ	35±0.74c	6233±22.15b	2353±16.84c	403±5.56b	2030±24.09b	653±25.69b	247±15.50c
	Ⅲ	54±1.31b	3588±20.24d	2188±12.43d	318±1.23c	1668±15.67c	521±3.92c	198±9.63d
	Ⅳ	171±1.08a	3394±3.29e	2207±21.85d	311±2.26c	1139±25.27d	576±6.84c	236±4.56cd
	Ⅴ	18±1.12d	6633±35.93a	3563±31.95a	450±24.09a	2356±75.22a	855±34.51a	442±61.92a

Ⅰ Jujube site with wheat, Ⅱ Jujube site with soybean, Ⅲ Jujube site with herbage, Ⅳ Jujube site with weeds, Ⅴ mono-cultivated jujube site; Results from Table 1 are the mean±SE of 3 a; Number of families, species or individuals within columns followed by the same letter means not significantly different (ANOVA followed by LSD, $p<0.05$)

The largest ($p<0.05$) numbers of pest insect individuals from six groups and the smallest from a single group were collected in the mono-cultivated jujube site (Table 1). In the Orthopterans group, the largest ($p<0.05$) number of pest insect individuals was recorded from the jujube site with weeds, followed by the jujube site with herbage, and the smallest from the mono-cultivated jujube site. There was no significant difference between the jujube sites with wheat and soybean (Table1). A significantly larger ($p<0.05$) number of pest insect individuals from the Homopteran group was recorded from the jujube site with soybean than from that with wheat, this was followed by the jujube sites with herbage and weeds (Table1). In the groups of Coleopterans and Dipterans, significantly larger ($p<0.05$) numbers of pest insect individuals were found in the jujube site with wheat than in that with soybean, this was followed by the jujube sites with herbage and weeds with no significant differences between the latter two. Significantly larger ($p<0.05$) numbers of pest insect individuals from Hemiptera and Acarina were found in the jujube sites with wheat and soybean than in those jujube sites with herbage and weeds, but there were no differences between the jujube sites with wheat and soybean or between those with herbage and weeds. Significantly larger ($p<0.05$) numbers of pest insect individuals from the Lepidoptera were recorded in the jujube sites with wheat and soybean than in the jujube sites with herbage and weeds, with the smallest ($p<0.05$) number was in the jujube sites with weeds. There were no differences between the jujube sites with wheat and soybean (Table 1).

2.3 Temporal Dynamic of Number of Pest Insect Individuals in Different Jujube Sites

A significantly smaller ($F=19.79$, $df=4$, $p<0.05$) number of pest insect individuals were collected from these jujube sites in March (Fig. 2) because they were in the overwintering stages. However, there were significantly larger ($p<0.05$) numbers of pest insect individuals from soybean and mono-cultivated jujube sites than in those jujube sites with wheat and weeds, with the smallest ($p<0.05$) numbers in the jujube site with herbage (Fig. 2).

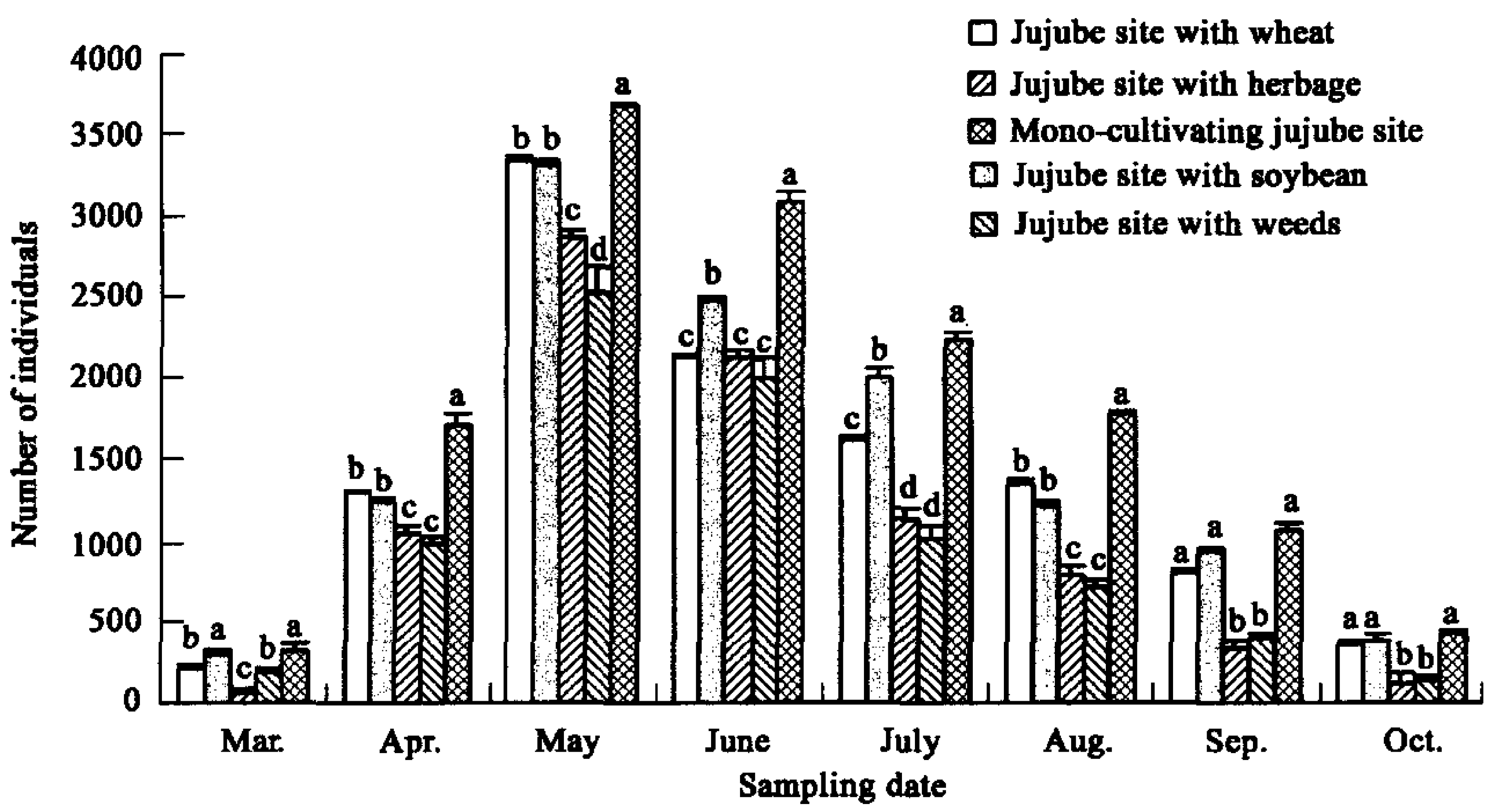

Fig. 2 Temporal Dynamics of Number of Individuals of Pest Insects in Different Jujube Sites. The same bar followed by the same letter means not significantly different (ANOVA followed by LSD, $p<0.05$)

The significantly larger ($F=23.82$, $df=4$, $p<0.05$) numbers of pest insect individuals coincided with resumption of insect development[2] in April than in March (Fig. 2). The largest ($p<0.05$) number of pest insect individuals was found in the mono-cultivated jujube site. Significantly larger ($p<0.05$) numbers of pest insect individuals were recorded in the jujube sites with wheat and soybean than in those with herbage and weeds. There were no obvious differences of numbers of pest insect individuals between the jujube sites with wheat and soybean or between those with herbage and weeds (Fig. 2).

Many leaf-eating pest insects began to cause injury to jujube trees when they sprouted in May, therefore, numbers of pest insect individuals were the largest ($F=191.82$, $df=4$, $p<0.00$) for the whole year. The results from Fig. 2 indicated that the largest ($p<0.05$) number of pest insect individuals was found in the mono-cultivated jujube site. A significantly larger ($p<0.05$) number of pest insect individuals was recorded in the jujube sites with wheat and soybean, but there were no obvious differences in the numbers of pest insect individuals between the jujube sites with wheat and soybean. The smallest ($p<0.05$) number of pest insect individuals was collected in the jujube site with weeds, followed by the jujube site with herbage (Fig. 2).

A significantly larger ($F=74.26$, $df=4$, $p<0.00$) number of pest insect individuals eating blossoms and young fruits occurred during June than in July (Fig. 2). Significantly smaller ($p<0.05$) numbers of pest insect individuals were obtained in the jujube sites with weeds, herbage and wheat, but there were no differences between the three samplied sites. The number of the pest insect individuals in the mono-cultivated jujube site was still the largest ($p<0.05$), followed by the jujube site with soybean (Fig. 2).

In July ($F=50.49$, $df=4$, $p<0.00$), the number of pest insect individuals found in the mono-cultivated jujube site was the largest ($p<0.05$). A significantly larger ($p<0.05$) numbers of pest insect individuals occurred in the jujube site with soybean than in those with herbage and weeds. There were no differences between those with herbage and weeds. In August ($F=33.27$, $df=4$, $p<0.05$), some pest insects began to diapause, for example *S. jujuba*, and *S. yasumatrui*[2]. The mono-cultivated jujube site still had the largest ($p<0.05$) number of pest insect individuals. There were no differences between the jujube sites with wheat and soybean, but the numbers of pest insect individuals in these jujube sites were significantly larger ($p<0.05$) than in those with herbage and weeds. There were no differences between these numbers in the jujube sites with herbage and weeds (Fig. 2).

In September ($F=21.24$, $df=4$, $p<0.05$) and October ($F=19.67$, $df=4$, $p<0.05$), most pest insects in the jujube sites entered diapauses[2]. However, there were significantly larger ($p<0.05$) numbers of pest insect individuals in the jujube sites with wheat, soybean and in the mono-cultivated jujube site than in those with herbage and weeds, but no differences between the jujube sites with wheat, soybean and the mono-cultivated jujube site. The smallest ($p<0.05$) number of pest insect individuals were recorded in the jujube sites with herbage and weeds, with no differences between them (Fig. 2).

2.4 The Temporal Dynamics of the Insect Pest Community Indices in Five Different Jujube Sites

With the changes in season, the index of the diversity, evenness and the dominant degree of insect pest communities all went through continuous change. The results in March and April from Table 2 showed that the smallest ($p<0.05$) diversity index was from the mono-cultivated jujube site, and the largest ($p<0.05$) indices were recorded from those sites with herbage and weeds, followed by the jujube sites with wheat and soybean. However, there were no differences between the jujube sites with herbage and weeds. In May, the jujube sites resumed their development, and most arthropods began feeding[3~4], there were no differences of diversity index in the jujube sites with wheat, soybean, herbage and weeds. However, because there was no intercrop, a significantly smaller ($p<0.05$) diversity index was found in the mono-cultivated jujube site than in the other four jujube sites.

In June, the largest ($p<0.05$) diversity index was shown in the jujube site with weeds, while the smallest ($p<0.05$) was from the mono-cultivated jujube site. There were no obvious differences of the index in the jujube sites with wheat, soybean or herbage. In July, there was a significantly larger ($p<0.05$) diversity index in the jujube sites with weeds than in those with wheat and soybean. A significantly smaller ($p<0.05$) diversity index was still recorded in the mono-cultivated jujube site than in the jujube sites with weeds, herbage and wheat. There were no differences of diversity index between the jujube site with soybean and the mono-cultivated jujube site. In August, there were no differences of diversity index among the jujube sites with weeds, herbage and soybean, or the mono-cultivated jujube site, and the jujube sites with wheat and soybean. However, significantly larger ($p<0.05$) diversity indexes were recorded from the jujube sites with weeds and herbage than in the site with wheat and the mono-cultivated jujube site. In September and October, diversity indexes from the jujube sites with weeds, herbage and soybean, or between the jujube site with wheat and the mono-cultivated jujube site, or between the jujube sites with wheat and soybean had no differences. But significantly larger ($p<0.05$) diversity indexes were recorded from the jujube sites with weeds and herbage compared to that with wheat and the mono-cultivated jujube site (Table 2).

Table 2 Diversity indexes of pest insect communities in five different jujube yards

Index	Sites	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.
Shannon	Ⅰ	1.87± 0.02ab	1.48±0.01b	1.83±0.05a	2.24±0.04b	2.10±0.02b	1.67±0.02b	1.93±0.07bc	1.87± 0.02ab
-Wiener	Ⅱ	1.69±0.04b	1.49±0.01b	1.92±0.01a	2.21±0.01b	1.98±0.03bc	1.92±0.01ab	2.04±0.03ab	1.69±0.04b
	Ⅲ	1.98±0.04a	1.77±0.01a	1.91±0.01a	2.28±0.03b	2.23±0.02ab	1.97±0.02a	2.14±0.08a	1.98±0.04a
	Ⅳ	1.88±0.01a	1.73±0.02a	2.19±0.02a	2.52±0.05a	2.46±0.02a	2.08±0.03a	2.08±0.02a	1.88±0.01a
	Ⅴ	1.35±0.01c	1.29±0.01c	1.55±0.04b	2.10±0.02c	1.63±0.02c	1.65±0.01b	1.75±0.07c	1.35±0.01c
Evenness	Ⅰ	0.81±0.03b	0.62±0.02b	0.62±0.03b	0.77±0.02bc	0.68±0.01b	0.63±0.03b	0.73±0.03bc	0.81±0.03b
	Ⅱ	0.77±0.02bc	0.66±0.03b	0.66±0.01b	0.74±0.01b	0.78±0.01a	0.64±0.04b	0.74±0.04b	0.77±0.02bc
	Ⅲ	0.88±0.03a	0.74±0.02a	0.73±0.04a	0.85±0.02a	0.79±0.02a	0.73±0.03a	0.79±0.04a	0.88±0.03a
	Ⅳ	0.90±0.02a	0.71±0.01a	0.76±0.02a	0.89±0.02a	0.85±0.01a	0.73±0.03a	0.83±0.04a	0.90±0.02a
	Ⅴ	0.74±0.01c	0.54±0.01c	0.54±0.01c	0.68±0.01c	0.57±0.01c	0.62±0.03b	0.70±0.02c	0.74±0.01c
Berger-Parker	Ⅰ	0.26±0.02b	0.54±0.02b	0.29± 0.01c	0.26±0.03b	0.38±0.03b	0.57±0.02a	0.41±0.03b	0.26±0.02b
	Ⅱ	0.24±0.01b	0.60±0.03b	0.39± 0.03b	0.31±0.02b	0.47±0.02b	0.48±0.03b	0.41±0.02b	0.24±0.01b
	Ⅲ	0.22±0.01bc	0.41±0.02c	0.27± 0.02c	0.23±0.01bc	0.34±0.01bc	0.40±0.02bc	0.40 ±0.03b	0.22±0.01bc
	Ⅳ	0.19±0.01c	0.42±0.01c	0.22± 0.01d	0.17±0.01c	0.24±0.01c	0.36±0.04c	0.28±0.02c	0.19±0.01c
	Ⅴ	0.49±0.01a	0.81±0.03a	0.51± 0.02a	0.41±0.03a	0.60±0.01a	0.58±0.02a	0.50±0.04a	0.49±0.01a

Ⅰ Jujube site with wheat, Ⅱ Jujube site with soybean, Ⅲ Jujube site with herbage, Ⅳ Jujube site with weeds, Ⅴ mono-cultivated jujube site; Results from Table 2 are the mean±SE of 3 a; H, E or I values within columns followed by the same letter means not significantly different (ANOVA followed by LSD, $p<0.05$)

Evenness indexes in jujube sites with weeds and herbage were larger ($p<0.05$) than the other three jujube sites, and there were no differences between jujube sites with wheat and soybean or the soybean and the mono-cultivated jujube site in March (Table 2). From April to May, the largest ($p<0.05$) evenness index was still recorded in the jujube sites with herbage and weeds, and the smallest ($p<0.05$) evenness index in the mono-cultivated jujube site. There were no differences between jujube sites with wheat and soybean or with herbage and weeds (Table 2). In June and September, significantly larger ($p<0.05$) evenness indexes were still found in the jujube sites with herbage and weeds. There were no differences between jujube sites with soybean and wheat or the latter and the mono-cultivated jujube site. In July, the smallest ($p<0.05$) evenness index was still recorded in the mono-cultivated jujube site, this was followed by the jujube site with wheat. There were no differences between jujube sites with soybean, herbage and weeds. Significantly larger ($p<0.05$) evenness indexes were still found in the jujube sites with herbage and weeds, there were no differences between the jujube sites with soybean and wheat or and the mono-cultivated jujube site in August. In October, largest ($p<0.05$) evenness indexes were recorded from the jujube site with herbage, There were no obvious differences between jujube sites with wheat, weeds and soybean or the soybean and the mono-cultivated jujube site (Table 2).

The Berger-Parker index was largest ($p<0.05$) in the mono-cultivated jujube site, and there were no differences between jujube sites with wheat, soybean and herbage or the latter and with weeds in March, June, July and October. The index was still largest ($p<0.05$) in the mono-cultivated jujube site, and there were no differences between jujube sites with wheat and soybean or with herbage and weeds in April. In May, there were no index differences between jujube sites with wheat and herbage or with soybean and weeds, but a significantly larger ($p<0.05$) index still appeared in the mono-cultivated jujube site. In August, significantly larger ($p<0.05$) indexes were recorded in the mono-cultivated and with wheat jujube site. There were no differences between jujube sites with soybean and herbage or the latter and with weeds. In September, the largest ($p<0.05$) index was still recorded from the mono-cultivated jujube site and the smallest ($p<0.05$) from the jujube site with weeds. There were no differences between jujube sites with wheat, soybean and herbage.

2.5 Comparison of the Net Income in the Different Jujube Sites

Significantly higher ($p<0.05$) net income was obtained from the jujube plot with wheat ((3201.6±34.53)¥/ 666.7 m^2) than from that with herbage ((2901.4±21.98) ¥/666.7 m^2). The latter net income was significantly higher ($p<0.05$) than the soybean jujube site ((2721.7±29.34) ¥ / 666.7 m^2). The mono-cultivated jujube site ((2711.0±26.87) ¥ / 666.7 m^2) had higher ($p<0.05$) net return than the jujube plot with weeds ((2612.3±41.12) ¥ / 666.7 m^2).

3 Discussion

Jujube trees are grown in the North of China as a major economic crop. In most of the jujube-growing area, the surrounding natural vegetation is sparse. As a result, jujube trees serve as a major host crop for some pest insects during the developing season. Beneficial insects also fly onto jujube trees to look for food. Developing an integrated pest management (IPM) program that utilizes natural enemies as basic components for such an agro-ecosystem is very difficult due to lack of ecological diversity. Artificially increasing the habitat diversity in the jujube ecological system by interplanting crops gives beneficial insects a permanent refuge during and after the jujube tree season[1,4,12]. Our study indicated that through the interplanting of wheat, soybean and herbage, or by properly retaining weeds within jujube sites, the community diversity and species abundance of pest insects were increased, but the number of pest insect individuals and dominant pest insect species decreased.

Previous studies have shown that there were 67 species of jujube tree pest insects found in jujube orchards[3]. In our study, the numbers of jujube tree pest insect species varied from 52 to 114 species depending on the intercropped crops (Table 1). Larger ($p<0.05$) numbers of families and species, and indices of diversity and evenness, and smaller ($p<0.05$) numbers of pest insect individual and indices of Berger-Parker were in the jujube sites with herbage and weeds than the other three jujube sites. Homoptera, Lepidoptera and Coleoptera were important groups of pest insects. The occurrence and injuries of jujube tree pest insects were mainly from May to August. Our study results found that sucking pest insects preferred to feed in areas where the jujube trees were intercropped with herbage or weeds, and that natural insect enemies of these pest insects correspondingly increased[1,13]. Many authors stated that vegetationally diverse habitats supported a larger diversity of prey and thus had more stable populations of beneficial insects[14~18]. Our results support this because there were smaller ($p<0.05$) numbers of pest insect individuals in intercropped jujube sites than in the mono-cultivated jujube site. Outbreaks of pest insects are less likely to occur because larger numbers of natural insect enemies have been maintained in the diverse ecosystem. Weeds and herbage in the ecosystem may provide the diversity[1, 13, 19]. The results from this study suggest that herbage and weeds could provide more nectariferous sources, coverage, living spaces and "medial hosts" for arthropods than a single crops. Therefore, there was no increased competition between arthropod species because the herbage and weeds enlarged ecological capacity[20]in this ecosystem. This study also suggested that herbage would be beneficial if intercropped in jujube sites, not only in making full use of space but also in reducing the number of pest insect individuals present. From the present study, we do not know how temperature and precipitation influenced the structure and dynamics of the pest insects because there were different dominant pest insect species present throughout the study, especially some outbreak pest insects such as *Helicoverpa armigera* (Hübner).

Combinations of different plants may have different effects on yield[21 ~ 23], but past research does not evaluate economic returns for the decrease of pest population caused by different plant combinations[24]. Our study suggest that intercropped crops or herbage in jujube sites is more beneficial not only in getting a larger net return but also in increasing diversity and evenness and decreasing the Berger-Parker index of pest insects (Table 2). However, intercropped methods and the most effective interplanted crops need to be further investigated.

References:

[1] Shi G L, Cao H, Ge F, *et al.* Studies on the diversity and insect community in different intercropped and managed jujube yard ecosystems. *Scientia Silvae Sinicae*, 2002, **38**(3): 94~101.

[2] Shi G L, Zheng W Y, Dang Z P, *et al. Fruit pests.* Beijing: China Agriculture Press, 1994.

[3] Li L C, Li L Z Fan Y L, *et al. China jujube tree pest insects.* Beijing: China Agriculture Press, 1992.

[4] Shi G L, Liu X Q, Wang M Q, *et al.* Studies on the structures of the insect community and the effect of integrated pest management. *Scientia Silvae Sinicae*, 1998, **34**(1): 58~64.

[5] Simpsom E H. Measurement of diversity. *Nature*, 1949, **163**: 688.

[6] Simpson B B, Cracraft J. Systematics: the science of biodiversity. *Bio-science*, 1995, **45**: 670~672.

[7] Mu J Y, Xu H T Li H J. *Insect ecology and forecast of agricultural pests.* Beijing: China Agricultural Science and Technology Press, 1997.

[8] Zhao Z M, Guo Y Q, *Principle and method of community ecology.* Chongqing: The Chongqing Branch of Scientific and Technological Document Press, 1990.

[9] Jiang G F, Yan Z G, & Cen M. Studies of insect community and diversity of mangrove forest in Yingluo harbour. *Chinese Journal Applied Ecology*, 2000, **11**: 95~98.

[10] Odum E P. *Basic ecology.* New York: Saunders College Publishing, 1983.

[11] SPSS Inc. SPSS Base 10.0 *User's Guide.* SPSS, Chicago, IL., 1999.

[12] Liu C Z, Zhou S R. Cutting effects on the insect community structure and dynamics of alfalfa pasture. *Acta Ecologica Sinica*, 2004, **24**(3): 542~546.

[13] Shi G L, Xi Y B, Wang H X, *et al.* Competition among species and the niche of major natural enemies and pests in jujube area ecosystems. *Scientia Silvae Sinicae*, 2003, **39**(5): 78~86.

[14] Andow D A. Vegetational diversity and arthropod population response. *Annu. Rev. Entomol.*, 1991, **36**: 561~586.

[15] Risch S J. Insect herbivore abundance in tropical monoculturees and polycultures: An experimental test of two hypotheses. *Ecology*, 1981, **62**: 1325~1340.

[16] Root R B. Organization of a plain-arthropod association in simple and diverse habitats. The fauna of collards (*B. oleracea*). *Ecol. Monog.*, 1973, **43**: 95~124.

[17] Root R B. Some consequences of ecosystem texture. In: S. A. Ievin ed. *Ecosystem Analysis and Prediction.* Soc. Ind. Appl. Math. Philadephia, 1975. 83~97.

[18] Russell E P. Enemies hypothesis: a review of the effect of vegetational diversity on predatory insect and parasitoids. *Environment Entomology*, 1989, **18**: 590~599.

[19] Lawton J H. Plant architecture and diversity of Phytophagous insects. *Ann. Rev. Entomol.*, 1983, **28**: 28~39.

[20] Norris R F, Kogan M. Interactions between weeds, arthropod pests, and their natural enemies in managed ecosystems. *Weed Science*, 2000. **4**: 48.

[21] Weiner J. *Plant Population Ecology in Agriculture*. McGraw Hill USA, 1990. 235～262.

[22] Way M J, HeongK L. The role of biodiversity in the dynamics and management of insect pests of tropical irrigated rice a review. *Bull Entomol Res.*, 1994, **84**: 567～589.

[23] Wyss E. The effect of artificial weed strips on diversity and abundance of the arthropod fauna in a Swiss experimental apple orchard. Agric. Ecosyst. Environ. Amsterdam, *New York, Elsevier.*, 1996, **60**: 47～59.

[24] Hou M L, Sheng CF. Effect of plant diversity in agroecosystems on insect pest populations. *Chinese Journal Applied Ecology*, 1999, **10** (2): 245～250.

参考文献:

[1] 师光禄，曹挥，戈峰，等.不同枣园生态系统中昆虫群落及其多样性，林业科学，2002，**38**(3):94～101.

[2] 师光禄，郑王义，党泽普，等.果树害虫. 北京:中国农业出版社 1994.

[3] 李连昌，李利贞，范永亮，等. 中国枣树害虫. 北京，中国农业出版社，1992.

[4] 师光禄，刘贤谦，王满全，等.枣园昆虫群落结构及其综合治理效果研究. 林业科学，1998，**34**(1): 58～64.

[7] 牟吉元，徐洪图，李火苟. 昆虫生态与农业害虫预测预报. 北京:中国农业科技出版社，1997.

[8] 赵志模，郭依泉. 群落生态学原理与方法. 重庆:科学技术文献出版社重庆分社，1990.

[9] 蒋国芳，颜增光，岑明. 英罗港红树林昆虫群落及其多样性的研究. 应用生态学报，2000，**11**(1): 95～98.

[12] 刘长仲，周淑荣. 刈草对苜蓿人工草地昆虫群落结构及动态的影响. 生态学报，2004，**24**(3): 542～546.

[13] 师光禄，席银宝，王海香，等.枣园生态系统中主要害虫、天敌生态位及种间竞争的研究. 林业科学，2003，**39**(5):78～86.

[24] 侯茂林，盛承发. 农田生态系统植物多样性对害虫种群数量的影响. 应用生态学报，1999，**10**(2): 245～250.