Structure characteristics of the arthropod community in the jujube orchards with different habitats

SHI Guang-Lu[1], ZHAO Li-Lin[3], MIAO Zhen-Wang[2], LIU Su-Qi[1], CAO Hui[1], Shiyou LI[4], Bruce PIKE[4]

(1. Shanxi Agricultural University, Taigu, Shanxi 030800, China; 2. Forest Pests Control Station of Shanxi Province, Taiyuan 030012, China; 3. Institute of Zoology, Chinese Academy of Sciences, Beijing 100080, China; 4. Natural Resources Canada, Canadian Forest Service, Pest Management Centre, Ottawa, Ontario K1A 0C6, Canada)

Abstract: The structures and characteristics of the arthropod communities of jujube orchards with different habitats were analyzed based on the survey in the suburb of Taigu County, Shanxi Province, Northern China. The results indicated that the largest number of arthropod species and the least number of individuals were in the treatment with weeds ($P < 0.05$), and the least number of arthropod species and the largest number of individuals were in the treatment without weeds ($P < 0.05$). In the comparison of species richness of different groups, the phytophagous group was the largest, but the predatory and parasitoid groups were the smallest in the treatment without weeds; the phytophagous group was the least, but predatory and parasitoid groups were the largest in the treatment with weeds. There were no significant differences ($P > 0.05$) of species and individuals within the parasitoid group between the treatment with soybean and the treatment without weeds. The analysis based on the Shannon-Wiener diversity index and relative stability values suggested that the richer the plant diversity, the better regulation ability among arthropod communities. More crops and properly remaining weeds could reduce the possibility of natural enemies migrating out. In addition, intercropping more crops in jujube orchards was more beneficial not only in getting a larger net return but also in increasing diversity and evenness of beneficial insects and decreasing the degree of pest dominance.

Key words: Arthropods; jujube orchard; soybean; cotton; weeds; intercropping; community structure; species diversity

1 INTRODUCTION

Jujube pests, such as *Ancylis* (*Anchylopera*) *sativa* Liu, *Sucra jujuba* (Yang and Li, 1992), *Carposina niponensis* Walsingham, *Scythropus yasumatrui* Kono *et* Morimoto, *Quadraspidiotus pernisiosus* (Comstock) (Li *et al*., 1992; Shi *et al*., 1994, 1997) and so on, pose a threat to jujube production in North China, both in terms of jujube fruit quality and international market share. When these pests reach large numbers, which may occur during jujube tree sprouting, but more frequently during jujube tree flowering and fruit production, they can inhibited the trees growth, thus reducing yield and net economic returns (Li *et al*., 1992). The biology and control of some of the major pests primarily in cultivated jujube orchards had been tentatively studied (Li *et al*., 1992; Shi *et al*., 1994). Although some coordinative control measures to jujube pests were thought to be among the principle methods in controlling them (Li *et al*., 1992), investigations involving how the community structures and characteristics of the arthropods are influenced by differently intercropped plants in jujube orchards have not been done until this current study.

In recent years, plant diversity and the way it influence pest population dynamics have been widely researched (Altieri and Gliessman, 1983; Risch, 1983; Jiang *et al*., 2000). This is partly due to the effects of residual insecticides that impel researchers to search for ways of controlling pests by using alternative biological and horticultural methods (Bhotnagar and Davies, 1981; Cromartie, 1981; Mayse, 1983; Altieri, 1993). The objective of our study was to compare the differences in arthropod populations in jujube orchards with different interplanted weeds or crops. The study is beneficial to develop and improve methods that are ecologically sound and follow an integrated pest management approach for such jujube arthropod pests.

2 MATERIALS AND METHODS

2.1 Experimental sites

The investigations were carried out from 2000 to 2002 in the jujube orchards located 2.5 km west of

基金项目:国家自然科学基金项目(30170759);山西省归国留学人员基金项目(200447)
作者简介:师光禄,男,1960 年生,教授,从事昆虫生态学与害虫综合治理,E-mail:glshi@126.com
收稿日期 Received:2004-09-30;接受日期 Accepted:2005-04-13

Taigu (112°8 'E, 38°9 'N, 780 m in elevation). Trees were 18 – 20 years old and in full fruit production, with a height of 5 m and a shading-degree of 0.4 – 0.6°. Four jujube orchards were surveyed: the first one was intercropped with soybean (*Glycine max*) and cotton (*Gossypium hirsutum*), the second one intercropped with soybean, the third one had weeds cleared (clearing the weeds one time every 10 days), and the fourth one had weeds left. The crops or weeds covered 70% of every surveyed jujube orchard. Before 2000, sampled sites were managed as any other jujube orchard in the area with conventional management methods, in which insecticides (Decamethrin) and acaricides (Fenbutatin) were applied 5 times per year. Pesticides were applied when overwintering pests resumed activity at the end of March. During the growing season, insecticides were sprayed 3 times to control insects that fed on buds, leaves, blooms and developing fruit. To control fruit borers, insecticides were sprayed in the middle of August. From 2000 to 2002, pesticides were sprayed four times (in the end of March, the middle of May, the end of June and the beginning of August respectively) every year in the treatments. These treatments were located in the conventional management area with similar natural conditions such as topography, geographical features and soil texture except with different intercrop strategies. Each of the treatments was replicated three times; for each replicate at least 666.7 m^2 was surveyed. The distance between treatments was at least 500 m.

2.2 Sampling methods

In each treatment, five jujube-trees were chosen according to the chessboard sampling method to monitor the population dynamics of the arthropods. The jujubes of each treatment were monitored every 10 days from March 1st to October 30th every year. On each sampling date, each of the five jujubes at each treatment 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, first, the investigators spent approximately 2 min to look for arthropods and record numbers observed. Flitting arthropods were captured with a sweep net (diameter 30 cm, 50 cm deep, made with white nylon yarn). The net-captured arthropods were brought back to the laboratory for identification. Secondly, three 50 cm twigs were chosen at each canopy level to check the presence of arthropods. Thirdly, 15 jujube-fruits were checked from different directions at each canopy level of jujube at each sampling date to monitor arthropods in the jujube fruit from July to October. For unemerged arthropods, hosts of arthropods 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, arthropods were identified (Liu *et al*., 1995; Shi *et al*., 1998).

Besides sampling on trees, soil under the sampled jujubes was also checked for arthropods on each sampling date. Four samples were taken from each of five sampled jujubes at each treatment. Each sample consisted of the top 20 cm of soil from a 100 cm by 100 cm area. The sampled soil was observed for the presence of arthropods, and then sieved. Any arthropods extracted from the soil were recorded. After counting, any arthropods were returned to the soil at its original sample site.

Arthropod was divided into phytophages, predators, parasites, and other groups according to Root's concepts (Adans, 1985). The other groups included those neutral insects and scavenging insects (Shi *et al*., 2002a, 2002b, 2003).

Jujube fruit, cotton and soybean in each treated plot were harvested at the end of the season and the averaged yield of 3 years was transformed into the net return (RMB (¥)/666.7 m^2) and then compared (Shi, 2001).

2.3 Statistical analyses

All species and individuals of each species of arthropod observed during each sampling date in 3 years were calculated as total numbers per 5 jujubes. 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 arthropod communities (Simpsom, 1949; Simpson and Cracraft, 1995): $H = -\sum_{i=1}^{s} p_i \cdot \ln p_i$ ($i = 1, 2, 3, \cdots, s$), $P_i = N_i/N$, N_i was the total number of the ith species; N was the total number of all species; s represented ith species. The species evenness (E) of arthropod communities was measured with the formula: $E = H/\ln S$, S was the number of species. Dominant degree index of Berger-Parker (Odum, 1983) was calculated: $I = N_{max}/NT$, N_{max} was the total number of the dominant species; NT was the total number of all species including the dominant species. Relative stability value was calculated by using S_s/S_i (the number of species/the number of individuals) and S_n/S_p (the species of natural enemy/the species of phytophagous group) (Gao *et al*., 1992). All data were analyzed by a one-way ANOVA followed by Tukey's test to compare the differences among the four different experimental sites at the $P = 0.05$ level of significance (SPSS, 1999).

3 RESULTS

3.1 Comparison of arthropod community in four

different treatments

The results from Table 1 showed that there were significant differences ($P < 0.05$) of species numbers of arthropods in the four different experimental sites. The species numbers of arthropods in the treatment with weeds were the largest ($P < 0.05$), this was followed by the treatments of interplanted soybean/cotton, soybean and that without weeds. The total number of individuals of all species of arthropods was the largest ($P < 0.05$) in the treatment without weeds, while the corresponding were not obviously different in the other three different treatments.

The species numbers of the phytophagous group in the four different treatments were significantly different ($P < 0.05$). The species numbers were the largest ($P < 0.05$), but total number of individuals was the least ($P < 0.05$) in the treatment with weeds. However, total number of individuals was the largest ($P < 0.05$), but the number of species was the least ($P < 0.05$) in the treatment without weeds. The species numbers of the phytophagous group were significantly larger ($P < 0.05$), but total number of individuals was significantly less ($P < 0.05$) in the treatment interplanted with soybean/cotton than that in the treatment only interplanted with soybean (Table 1).

The results from Table 1 indicated that the species numbers and total number of individuals of all species of the predatory group was the largest ($P < 0.05$) in the treatment with weeds. The species number was less ($P < 0.05$) in the treatment without weeds. The differences of predatory group species numbers were not obvious between the treatment interplanted with soybean/cotton and that only with soybean. The total number of individuals of the predatory group was larger ($P < 0.05$) in the treatment interplanted with soybean/cotton than that in the treatment without weeds and only interplanted with soybean.

The species numbers and total number of individuals of all species of the parasitoid group were the largest ($P < 0.05$) in the treatment with weeds, while the corresponding were larger ($P < 0.05$) in the treatment interplanted with soybean/cotton than the treatments without weeds and only interplanted with soybean. The differences of species numbers and total number of individuals were not obvious between the treatment interplanted with soybean and that without weeds (Table 1).

The species numbers and total individuals of all species of the other groups that did not belong to phytophagous, predatory and parasitoid group were the largest ($P < 0.05$) in the treatment with weeds, while the corresponding were not obviously different in the other three different treatments (Table 1).

Table 1 Comparison of arthropod community in four different treatments

Treatments	Phytophages		Predators		Parasites		Other groups	
	SN	IN	SN	IN	SN	IN	SN	IN
Ⅰ	56.33 ± 0.51 c	11109.33 ± 32.06 b	33.67 ± 0.51 c	629.67 ± 11.78 c	13.67 ± 0.51 c	289.33 ± 7.71 c	5.67 ± 0.19 b	102.67 ± 1.68 b
Ⅱ	62.67 ± 0.51 b	10412.33 ± 178.42 c	42.33 ± 0.38 b	734.67 ± 16.44 b	20.33 ± 0.38 b	511.67 ± 7.86 b	5.33 ± 0.19 b	105.67 ± 2.41 b
Ⅲ	49.67 ± 0.38 d	15098.00 ± 279.54 a	23.67 ± 0.51 d	608.33 ± 17.55 c	13.67 ± 0.19 c	283.00 ± 5.57 c	4.67 ± 0.19 b	105.33 ± 2.22 b
Ⅳ	87.33 ± 0.69 a	9586.00 ± 105.67 d	53.67 ± 0.84 a	1055.33 ± 25.28 a	30.67 ± 0.51 a	822.67 ± 11.44 a	13.00 ± 0.33 a	130.33 ± 5.42 a

SN: Species number; IN: Individual number. Ⅰ: Treatment intercropped with soybean; Ⅱ: Treatment intercropped with soybean/cotton; Ⅲ: Treatments without weeds; Ⅳ: Treatments with weeds; the same for Table 2–3; the other groups included neutral insects and scavenging insects. Values within columns are the mean ± *SE* in 3 years. Values within columns followed by the same letter are not significantly different ($P = 0.05$).

3.2 Comparison of the diversity, evenness and dominant degree of arthropod community in four different treatments

The species diversity in the different treatments differed. The results from Table 2 indicated that the diversity indices of arthropods in the treatment with weeds were the largest ($P < 0.05$), this was followed by the treatment intercropped with soybean/cotton ($P < 0.05$). There were no differences between the treatment intercropped with soybean and that without weeds. In phytophages, the diversity indices in the treatment with weeds were the largest ($P < 0.05$), but they were significantly different ($P < 0.05$) between the treatment intercropped with soybean/cotton and that without weeds. There were no differences between the treatment intercropped with soybean and the treatments without weeds or soybean/cotton and soybean. Significant differences ($P < 0.05$) of predators were recorded in the four different treatments. The diversity indices of parasites and the other groups in the treatment with weeds were the largest ($P < 0.05$), and a significantly larger ($P < 0.05$) diversity was obtained in the treatment intercropped with soybean/cotton than in those intercropped with soybean and without weeds. The differences were not obvious between the treatment intercropped with soybean and that without weeds (Table 2).

Evenness indices of arthropods and the other groups were the largest ($P < 0.05$) in the treatment with weeds, while it was the lowest ($P < 0.05$) in the treatment without weeds. There were no differences of arthropods and the other groups between the treatments intercropped with soybean/cotton and soybean. The evenness of phytophages was the largest ($P < 0.05$) in the treatment with weeds. There were significant differences ($P < 0.05$) of phytophages between the treatments intercropped with soybean/cotton and without weeds. There were no differences of phytophages between the soybean and without weeds treatments or soybean/cotton and soybean treatments. The evenness of parasites were the largest ($P < 0.05$) in the treatment with weeds, this was followed by the treatment intercropped with soybean/cotton ($P < 0.05$). The differences were not obvious between the treatment intercropped with soybean and the treatment without weeds. Significant differences ($P < 0.05$) of evenness of predators were recorded in the four different treatments (Table 2).

Table 2 Comparison of the diversity, evenness and dominant degree of arthropod community in four different treatments

Index	Treatments	Arthropods	Phytophages	Predators	Parasites	Other groups
H	Ⅰ	1.259 ± 0.020 c	1.419 ± 0.013 cb	1.450 ± 0.0204 c	1.339 ± 0.005 c	1.329 ± 0.013 c
	Ⅱ	1.425 ± 0.010 b	1.496 ± 0.015 b	1.568 ± 0.0107 b	1.416 ± 0.009 b	1.410 ± 0.004 b
	Ⅲ	1.167 ± 0.007 c	1.180 ± 0.015 c	1.131 ± 0.0052 d	1.119 ± 0.002 c	1.043 ± 0.025 c
	Ⅳ	1.583 ± 0.028 a	1.654 ± 0.014 a	1.843 ± 0.0314 a	1.638 ± 0.025 a	1.830 ± 0.039 a
E	Ⅰ	0.289 ± 0.012 b	0.221 ± 0.005 bc	0.256 ± 0.0010 c	0.269 ± 0.008 c	0.276 ± 0.009 b
	Ⅱ	0.333 ± 0.010 b	0.261 ± 0.008 b	0.327 ± 0.010 b	0.312 ± 0.013 b	0.312 ± 0.013 b
	Ⅲ	0.195 ± 0.003 c	0.181 ± 0.006 c	0.168 ± 0.003 d	0.181 ± 0.002 c	0.173 ± 0.006 c
	Ⅳ	0.527 ± 0.015 a	0.481 ± 0.024 a	0.592 ± 0.049 a	0.511 ± 0.012 a	0.616 ± 0.016 a
D	Ⅰ	0.083 ± 0.001 b	0.174 ± 0.004 b	0.125 ± 0.002 c	0.123 ± 0.004 c	0.171 ± 0.002 a
	Ⅱ	0.074 ± 0.002 bc	0.152 ± 0.003 bc	0.152 ± 0.002 b	0.159 ± 0.003 b	0.151 ± 0.001 a
	Ⅲ	0.135 ± 0.003 a	0.230 ± 0.004 a	0.119 ± 0.002 c	0.125 ± 0.002 c	0.155 ± 0.001 a
	Ⅳ	0.068 ± 0.002 c	0.117 ± 0.003 c	0.228 ± 0.005 a	0.236 ± 0.003 a	0.115 ± 0.003 b

H: Diversity index; E: Evenness index; D: Dominant degree. The other groups included neutral insects and scavenging insects. Results are the mean ± SE of 3 years. H, E or D values within columns followed by the same letter are not significantly different ($P = 0.05$).

Dominant degrees of Berger-Parker of arthropods and phytophages were the largest ($P < 0.05$) in the treatments without weeds. The differences were significantly larger ($P < 0.05$) in the treatments intercropped with soybean than in that with weeds. There were no significant differences of dominant degrees of arthropods and phytophages between treatments intercropped with soybean/cotton and that with weeds or between soybean/cotton and soybean treatments. The dominant degrees of predators and parasites appeared largest ($P < 0.05$) in the treatment with weeds; this was followed by the soybean/cotton treatments. There were no significant differences of dominant degrees of predators and parasites between the treatments intercropped with soybean and the treatment without weeds. In the other groups, a significantly lower ($P < 0.05$) dominant degree was recorded from the treatments with weeds and there were no obvious differences in the other three different treatments (Table 2).

3.3 Comparison of the relative stability value of arthropod community in four different treatments

The results from Table 3 indicated that the relatively stable S_s/S_i values were largest ($P < 0.05$) in the treatments with weeds in each month of the 3 year study. In March, April, July, August and October significantly larger S_s/S_i values were in the treatments with soybean/cotton than in the treatments without weeds and the treatments with soybean. There were no differences of S_s/S_i values between the treatments without weeds and with soybean. There were significant differences ($P < 0.05$) of S_s/S_i in May and June values but not in September among the treatments with soybean, soybean/cotton, and without weeds.

Table 3 Comparison of the relative stability value of arthropod community in four different treatments

Index	Treatments	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.
S_s/S_i value	Ⅰ	0.037 ± 0.001 c	0.022 ± 0.001 c	0.014 ± 0.001 b	0.018 ± 0.001 c	0.014 ± 0.001 bc	0.018 ± 0.001 bc	0.027 ± 0.001 b	0.019 ± 0.001 c
	Ⅱ	0.067 ± 0.001 b	0.038 ± 0.001 b	0.031 ± 0.002 a	0.029 ± 0.002 b	0.020 ± 0.002 b	0.026 ± 0.002 b	0.041 ± 0.002 b	0.054 ± 0.002 b
	Ⅲ	0.035 ± 0.001 c	0.017 ± 0.004 c	0.003 ± 0.001 c	0.006 ± 0.001 d	0.009 ± 0.001 c	0.010 ± 0.001 c	0.033 ± 0.002 b	0.023 ± 0.001 c
	Ⅳ	0.455 ± 0.002 a	0.052 ± 0.002 a	0.037 ± 0.002 a	0.039 ± 0.002 a	0.053 ± 0.002 a	0.065 ± 0.003 a	0.071 ± 0.002 a	0.090 ± 0.003 a
S_n/S_p value	Ⅰ	0.462 ± 0.011 c	0.287 ± 0.006 c	0.389 ± 0.014 c	0.351 ± 0.007 c	0.512 ± 0.005 c	0.527 ± 0.015 b	0.253 ± 0.015 b	0.390 ± 0.006 b
	Ⅱ	0.641 ± 0.021 b	0.474 ± 0.007 b	0.560 ± 0.018 b	0.875 ± 0.011 b	0.849 ± 0.019 b	0.694 ± 0.019 b	0.364 ± 0.008 b	0.457 ± 0.008 b
	Ⅲ	0.243 ± 0.002 d	0.286 ± 0.006 c	0.311 ± 0.003 c	0.319 ± 0.013 c	0.341 ± 0.010 d	0.305 ± 0.011 c	0.199 ± 0.011 c	0.156 ± 0.003 c
	Ⅳ	0.842 ± 0.006 a	0.839 ± 0.008 a	0.836 ± 0.023 a	1.235 ± 0.045 a	1.291 ± 0.075 a	0.861 ± 0.021 a	0.816 ± 0.016 a	0.849 ± 0.027 a

S_s/S_i value: Number of species/Number of individual; S_n/S_p value: Species of natural enemy group/Species of phytophagous group. Results are the mean ± SE of 3 years. S_s/S_i or S_n/S_p values (mean ± SE of 3 years) within columns followed by the same letter are not significantly different ($P = 0.05$).

The relatively stable S_n/S_p values were largest ($P < 0.05$) in the treatments with weeds for each month in all 3 years. There were significant differences ($P < 0.05$) of S_n/S_p values in May and July among the treatments intercropped with soybean, soybean/cotton and without weeds. In April, May and June S_s/S_i values were significantly larger ($P < 0.05$) in the treatments with soybean/cotton, but there were no differences between the treatments with soybean and without weeds. In August, September and October S_s/S_i values were significantly lower ($P < 0.05$) in the treatments without weeds but there were no differences between treatments with soybean/cotton and only soybean (Table 3).

3.4 Comparison of the net income in the different treatments

Significantly larger ($P < 0.05$) net income ((3 401.5 ± 30.76) ¥/666.7 m^2) was recorded from the treatments with soybean/cotton than the other three treatments. This was followed by the treatments with soybean ((3 110.5 ± 22.27) ¥/666.7 m^2), and the treatments without weeds ((2 841.0 ± 26.87) ¥/666.7 m^2). The treatments with weeds ((2 804.5 ± 30.76) ¥/666.7 m^2) had the lowest net return (Shi, 2001).

4 DISCUSSION

The community structures of arthropods in the four different treatments were different in family, species and number of individuals. Over the 3 year study, we found that the number of species were largest ($P < 0.05$) in the treatments with weeds, followed by the treatments interplanted with soybean/cotton, while the corresponding were least ($P < 0.05$) in the treatment without weeds. On the contrary, the number of individuals of arthropods and the phytophagous group were largest ($P < 0.05$) in the treatment without weeds. The individuals within the phytophagous group were larger ($P < 0.05$), but that of predators and parasites less ($P < 0.05$) in the treatment intercropped with soybean than that in treatments intercropped with soybean/cotton. More crops and remaining weeds in the treatments were beneficial for setting up a diverse jujube orchard agro-ecosystem and kept the competition between species in balance. The weeds and crops provided the arthropods with enough medial hosts, food (prey, pollen and honey), and places for concealing, inhabiting and overwintering. The weeds and crops also help lure arthropods around other plants into the interplanted jujube orchards.

In different treatments, diversity and evenness of predators were significantly different ($P < 0.05$), but that of parasites was not obvious between treatments intercropped with soybean and without weeds (Table 2). This result further indicated that more crops and remaining weeds could reduce the possibility of natural enemies migrating out (Root, 1973; Risch, 1981). This result also supports Letournean (1983) who found that larvae number of *Diaphania hyalinata* Walker was larger and that parasitic ratios of natural enemies on the eggs and larvae of *D. hyalinata* were lower in mono-cultivated pumpkin sites than in pumpkin sites intercropped with soybean or maize.

The relationship between diversity and stability has always been an important problem discussed in theoretical ecology (MacArthur, 1955; Elton, 1958; Watt, 1965; Margalef, 1968; Hurb, 1971; Odum, 1971; May, 1973; Emden and Williams, 1974; Goodman, 1975; May, 1976). In agro-ecosystems, the relationship between diversity and stability is, in the final analysis, whether or not increasing plant diversities can result in the decrease of pest populations and maintain little fluctuation in their low level (Hou and Sheng, 1999). There were more studies about the relationship between plant diversity and pest population dynamics. Some experiments proved that phytophagous insects on target host plants could be decreased by a diverse plant system (Tahvanainen and Root, 1972; Root, 1975; Perrin, 1980; Cromartie, 1981; Altieri and Letourneau, 1982; Altirei, 1983; Hou and Sheng, 1999). Combinations of some crops influenced specific pest species (Litsinger and Moody, 1976; Perrin, 1977; Perrin and Phillips, 1978; Andow, 1983), and combinations of specific crops resulted in the decrease of pest numbers (Litsinger and Moody, 1976; Altieri and Letourneau, 1982; Andow, 1983). However, some studies found that some crop combinations resulted in the increase of pest numbers (Latheef and Irwin, 1980; Bhotnagar and Davies, 1981). This study indicated that treatment with weeds had the largest relatively stable S_s/S_i and S_n/S_p values ($P < 0.05$), but the treatments without weeds had the least ($P < 0.05$). Risch (1981) thought that an agro-ecosystem with wild or natural plants such as weeds normally possesses more species of diverse arthropods, especially more species of natural enemy insects because the complicated environment provided refuges for them. The results from the relatively stable S_s/S_i and S_n/S_p values here indicated that there were more species of arthropods and natural enemies in the treatment with weeds. In different stages and different small habitats, there were many species of phytophagous arthropods used as food for predators, which made the populations become relatively stable and allowed broad-spectrum predators to be developed, specifically predator populations with no possibility of large fluctuation (Root, 1973). Plant diversity increase enables natural insect species to increase, therefore, the ability of natural enemies to control pests also strengthens and pest populations can be maintained at low levels without large fluctuation, creating a stable ecosystem (Hou and Sheng, 1999). Our study results also suggested that the ecosystem in the treatment with weeds was relatively stable because the dominant degree index of arthropod and phytophagous groups in the treatment with weeds was just 47.59% and 47.79% respectively the same as the treatment without weeds. Dominant species from the arthropod and phytophagous groups were not obvious in the treatment with weeds. This result also supported researchers who found that a mixed forest could effectively improve the structure of arthropod communities. Specifically the richness of predatory and parasitoid groups significantly increased and caused the ecological superior phytophagous group to decrease, and enhanced the resistance and balance among the arthropod communities (Gao *et al*., 1992).

Combinations of different plants may have different effects, but past research did not evaluate economic returns for the decrease of pest population by plant combination (Shi *et al*., 1998; Hou and Sheng, 1999). Our study suggested that intercropping more crops in jujube orchards was more beneficial not only in getting a larger net return but also in increasing diversity and evenness of beneficial insects and decreasing the degree of pest dominance (Table 2). However, how to intercrop and what crops would be more effective when interplanted need to be further investigated.

In conclusion, the integration of more intercropped crops and properly retaining natural plants systems with selective use of pesticides can be useful strategies to concentrate or establish beneficial insects in jujube orchard eco-systems. With effective utilization, these can be basic components of a successful IPM program.

Acknowledgements We are grateful to P. BRUCE, B. LOIS and SUN Jiang-Hua for reviewing and significantly improving an earlier version of the manuscript. We also thank the National Natural Science Foundation of China (No. 30170759) and the Return Country Foundation of Shanxi Province (No. 200447) for financial support. The senior author would also like to express his appreciation to China Scholarship Council Project Grant 20814019 for funding to study in Canada where this manuscript was written, and to Canadian Forest Service for hosting. Helpful editorial comments from C. RYAN and D. M. STONE are highly appreciated.

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不同生境类型枣园中节肢动物群落结构特征

师光禄[1]，赵莉蔺[3]，苗振旺[2]，刘素琪[1]，曹　挥[1]，Shiyou LI[4]，Bruce PIKE[4]

（1. 山西农业大学，山西太谷　030800；2. 山西省森林病虫害防治检疫站，太原　030012；
3. 中国科学院动物研究所，北京　100080；4. 加拿大自然资源部林务局，渥太华，加拿大　K1A 0C6）

摘要：在山西太谷枣区对不同间作生境组合类型枣园的节肢动物群落结构特征进行了研究，结果表明，在有杂草的枣园与其他枣园相比，节肢动物的物种数最大（$P<0.05$），而节肢动物物种的个体数最小（$P<0.05$），而在单作无杂草的枣园则相反（$P<0.05$）。植食性类群的物种数和个体数在单作无杂草的枣园显著（$P<0.05$）大于其间作类型的枣园，而捕食性和寄生性的物种数和个体数则明显（$P<0.05$）小于其间作类型的枣园，而在有杂草的枣园则相反。枣树与大豆和棉花间作枣园的捕食性和寄生性的物种数和个体数则明显（$P<0.05$）大于枣树与大豆间作的枣园，而枣树与大豆间作的枣园与单作无杂草枣园的寄生性的物种数和个体数则无明显差异（$P>0.05$），但捕食性的物种数有大豆的枣园明显（$P<0.05$）大于单作无杂草枣园，而个体数则无明显差异（$P>0.05$）。多样性均匀度和相对稳定性指数研究结果表明有杂草的枣园明显（$P<0.05$）大于单作无杂草枣园，枣树与大豆和棉花间作的枣园明显（$P<0.05$）大于枣树与大豆间作的枣园，而优势度则相反。研究结果进一步表明，在枣园合理间作多种作物或者适当保留一定的杂草，不仅可以减少天敌昆虫迁出枣园，而且还可以增加枣园天敌的物种数量和节肢动物群落结构的多样性和均匀度，同时还能有效地利用枣园的空间和自然资源，增加单位面积的产量。

关键词：节肢动物；枣园；大豆；棉花；杂草；间作；群落结构；物种多样性

中图分类号：Q968　　**文献标识码**：A　　**文章编号**：0454-6296(2005)04-0561-07

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