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枣园害虫、捕食性和中性昆虫群落结构及动态研究*

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【摘要】 对山西省太谷地区枣园的害虫、捕食性和中性昆虫群落结构及动态进行研究,结果表明,不同年份枣园的害虫、捕食性和中性昆虫种类与数量均有明显差异($P<0.05$),且树上明显大于地面.不同年份捕食性和中性昆虫与害虫的物种数和个体数比例也不同,其物种数和个体数随季节的暖和冷而增加和减少.相同亚群落不同季节的垂直分层结构相似程度不同,不同亚群落在同一季节的垂直分层相似性也不同.总体上垂直分层明显.枣园害虫、捕食性和中性昆虫的多样性指数随季节变化而波动.捕食性和中性昆虫与害虫数量起伏跟随紧密,总体呈极显著相关($r=0.9833$, $P<0.05$).层次间差异明显,以中层相关最显著($r=0.9887$, $P<0.01$).

关键词 群落结构 害虫 捕食性昆虫 中性昆虫 枣园
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Community structure and its dynamics of pest, predatory and neutral insects ina jujube ecosystem. SHI Guanglu[1,2], ZHAO Lilin[3], LIU Suqi[1], CAO Hui[1], LI Shiyou[4], PIKE Bruce[4] ([1]*Shanxi Agricultural University, Taigu* 030800, *China*; [2]*Key Laboratory of New Technology of Agricultural Application of Beijing, Beijing* 102206, *China*; [3]*Institute of Zoology, Chinese Academy of Sciences, Beijing* 100080, *China*; [4]*Pest Management Centre, Forest Service Bureau, Natural Resources Department of Canada, Ottawa, Canada* K1A 0C6). -*Chin. J. Appl. Ecol.*, 2006, **17**(1):80~86.

An investigation on the insects in the jujube ecosystem in Taigu District of Shanxi Province, Northern China showed that more species and individual numbers of pest, predatory and neutral insects were found on the tree than on the ground. The ratio of the species and individual numbers of predatory and neutral insects to those of pest insects fluctuated from year to year. Homoptera, Coleoptera and Lepidoptera were the dominant groups of pest insects, while those of predatory insects were Coleopteran, Hemiptera, Diptera and Hymenoptera. The vertical distribution of the community structure of the same or different subcommunity was different in different seasons, as was the case of the same or different subcommunity in the same season. The diversity indexes of pest, predatory and neutral insects fluctuated with seasons, and the populations of predatory and neutral insects had a significant correlation ($r=0.9833$, $P<0.05$) with the fluctuation of pest insects. There was also a significant correlation between the pest, predatory and neutral insects in different stratums of tree canopy, especially in the middle stratum of tree canopy ($r=0.9887$, $P<0.01$).

Key words Community structure, Pest insects, Predatory insects, Neutral insects, Jujube tree.

1 INTRODUCTION

In China, a wide range of pest insects can attack jujube tree, and their management almost exclusively depends on repeated application of synthetic insecticides[1,2,5~8,11,15,25,31]. The over-reliance on synthetic insecticides is undesirable, because of insecticide resistance, environmental pollution, occupational health and safety risks, production costs, and disruption to the activity of natural enemies[3,13,28~30,33].

Some natural enemies, predatory insects in particular, have been recorded in jujube ecosystem[1,6,14,25], but their potential value has not been fully exploited in integrated pest management of jujube tree, due to the lack of understanding their community structure and dynamics. For the long-term sustainability of jujube fruit production in China, it is crucial to develop an integrated pest management (IPM) program which places much more emphasis on the role of natural enemies of jujube tree pest insects,

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and minimizes insecticide use. To effectively utilize natural enemies, it is crucial to put in place the strategies that can establish and concentrate the predatory insects in the jujube tree crop ecosystem. Such an IPM program should be developed in a step-wise fashion, commencing with the methods of establishing, concentrating and stabilizing natural populations, followed by integrating other control methods which are the least disruptive to natural enemy activity. In such an IPM system, understanding the community structure and dynamics of pest, predatory and neutral insects in jujube tree crop ecosystem is obviously very important[4,27,32,35].

In this paper, the community structure and its dynamics of pest, predatory and neutral insects in jujube ecosystem in Taigu District of Shanxi Province, Northern China, as well as their relationships with ecological environment were investigated, aimed to understand the dynamics of these insect communities, and the functions of beneficial insects in controlling pest insects.

2 MATERIALS AND METHODS

2.1 Investigation sites

The investigation was carried out in the jujube field at 2.5 km of west Taigu (112°8′E, 38°9′N, 780 m elevation). The jujube trees were 10 years old and in full fruit production, with a height of 5 m and a shading-degree of 0.4~0.6. The field was intercropped with wheat (*Triticum aestivum* L.). Before 2001, the sampling site was managed as other jujube orchards in this area, where insecticides, acaricides and herbcides were applied 7 times or more annually. Pesticides were applied when overwintering pest insects resumed their activity in late March. During growth season, insecticides were sprayed 4 times to control the pest insects feeding on buds, leaves, blooms, and developing fruits. To control fruit borers, insecticides were sprayed in late July and mid August. From 2001 to 2002, pesticides were sprayed 4 times every year. The area of sampling site was at least 6 667 m^2.

2.2 Sampling methods

In investigation sites, five trees were chosen according to the chessboard sampling method. The trees were monitored every 10 days from March 1st to October 30th every year. On each sampling date, 5 trees at each site were observed in 4 directions (East, West, South and North). In each direction, three stratums of canopy (upper, middle and lower) were monitored, where the investigators spent approximately 2 min to look for pest insects and record the numbers observed. Flitting pest insects were captured with a sweep net (30 cm in diameter and 50 cm in depth, made with white nylon yarn). The net-captured pest, predatory and neutral insects were brought back to the laboratory for identification. Furthermore, three 50 cm twigs were chosen at each canopy stratum to check the presence of these insects. From July to October, 15 fruits were checked at each canopy stratum on each sampling date to monitor the pest insects in jujube fruits. Non-destructive sampling protocols were used. In the case of difficulty encountered in identifying rare species, an identical specimen was located from another tree in the site, and brought back to the laboratory for identification. For unemerged insects, the hosts of the insects were brought back to the laboratory, and reared in petri dishes (10 cm in diameter and 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, the insects were identified[16~24].

Besides sampling on trees, the soil under sampling trees was also checked for insects during sampling days. Four samples were taken from each of 5 sampled trees at each site. Each sample consisted of the top 20 cm soil from a 100 cm × 100 cm area. The sampled soil was observed for the presence of insects, and then sieved. Any insects extracted from the soil were recorded[7].

2.3 Statistical analyses

All species and individuals of each insect species observed during each sampling date in each year were calculated as the total numbers per 5 trees. The original data were converted into monthly average per sampling site.

Shannon-Wiener diversity index (H) was applied to measure the species diversity of pest insect communities:

$$H = -\sum_{i=1}^{s} p_i \cdot \ln p_i (i = 1,2,3,\cdots,s)$$

where $p_i = N_i/N$, N_i is the total number of the ith species, N is the total number of all species, and s represents the ith species.

A different stratum similarity index (I) of pest, predatory and neutral insects in jujube site was calculated:

$$I = 1 - 1/2\left(\sum_{1}^{s} | a_i - b_i |\right)$$

where s is any species in the community, a_i and b_i are the structural proportion of species between upper and middle, middle and lower, or upper and lower strata. All data were analyzed by one-way ANOVA followed by Tukey's test to compare the differences in the investigation sites at $P = 0.05$ or $P = 0.01$ level of significance[9,12,26,35].

3 RESULTS

3.1 Dominant species and individual numbers of pest, predatory and neutral insects on ground and tree

Over 2 years of investigation, it was found that there were different species and individual numbers of pest, predatory and neutral insects within the jujube site, both on the ground and on the tree in each year. The ratio of the species and individual numbers of predatory and neutral insects to those of pest insects fluctuated between years (Table 1).

Table 1 Community structure of pest, predatory and neutral insects in jujube ecosystem

Insect group		Year	On ground and tree		On ground		On tree	
			No.	(%)	No.	(%)	No.	(%)
Pest	NS	2001	52	55.3	17	51.5	35	57.4
		2002	49	52.1	15	51.7	34	50.7
	NI	2001	10234	88.5	1395	74.5	8839	91.2
		2002	9896	85.6	1103	72.3	8793	91.3
Predator	NS	2001	28	29.8	11	33.3	17	27.9
		2002	31	33.0	8	27.6	23	34.3
	NI	2001	876	7.6	264	14.1	612	6.3
		2002	832	7.2	233	15.3	599	6.2
Neutral	NS	2001	14	14.9	5	15.2	9	14.8
		2002	16	17.0	6	20.7	10	14.9
	NI	2001	453	3.9	213	11.4	240	2.5
		2002	428	3.7	189	12.4	239	2.5
Total	NS	2001	94	100	33	100	61	100
		2002	96	100	29	100	67	100
	NI	2001	11563	100	1872	100	9691	100
		2002	11156	100	1525	100	9631	100
RS		2001	1:1.238		1:1.06		1:1.35	
		2002	1:1.043		1:1.07		1:1.03	
NI		2001	1:7.701		1:2.92		1:10.37	
		2002	1:7.854		1:2.61		1:10.49	

NS: Numbers of species; NI: Numbers of individuals; Neutral insects were those that did not belong to pest and predatory insects; RS: Ratio of the species numbers of neutral and predatory insects to pest insects; RI: Ratio of the individual numbers of neutral and predatory insects to pest insects; (%): Insect group number/Total insect group number. The same below.

In the jujube site, the subcommunity of pest insects consisted of Orthoptera, Homoptera, Coleoptera, Hemiptera, Lepidoptera, Diptera and Acarina. On the ground of the jujube site, the dominant species of pest insects were *Gryllotalpa unispina* Saussure, *Acrida chinensis* (Westwood), *Agriotes fuscicollis* Miwa, *Holotrichia diomphalia* Bates, and *Agriotis ypsilon* Rottemberg, while those on the tree were *Pseudococcus comstock* Kuwane, *Quadraspidiatus perniciosus* Comstock, *Scythropus yasumatsui* Kono et Morimoto, *Adelphocoris fasciaticollis* Reuter, *Lygus lucorum* Meyer-Dur, *Chihuo zao* Yang, *Ancylis sativa* Liu, *Contarinia* sp., and *Tetranychus cinnabarinus* (Boisduval). The dominant groups of pest insects were Homoptera, Coleoptera and Lepidoptera. In the jujube site, the individual numbers of pest insects fluctuated between the positions on jujube tree (Table 2). A comparison of the results in Table 2 and Table 3 indicated that there were more groups in the predatory insect subcommunity than in the pest insect subcommunity. On the ground of the jujube site, the dominant species of predatory insects were *Labidura japonica* DE Geer, *Carabus maderae chinensis* Kirby, *Orius. minutu* L., *Lasius fuliginosus* Latr., *Chrysopa shansiensis* Kuwayama, *Anax parthenope* Selys, and *Paratenodera sinensis* Saussure, while those on the tree were *Coccinella septempunctata* (Linn.), *O. minutu* L., *Metasyrphus corollae* (Fabricius), *Lasius fuliginosus* Latr., *Inocellia* sp., *C. shansiensis* Kuwayama, *A. parthenope* Selys, and *P. sinensis* Saussure. The dominant groups of predatory insects were Coleopteran, Hemiptera, Diptera and Hymenoptera (Table 3). The individual numbers of predatory insects were higher on the tree canopy than on the ground, because of the corresponding higher individual numbers of pest insects on the tree canopy. There were 3 groups in the subcommunity of neutral insects, *i.e.*, Dermaptera, Coleoptera and Hemiptera. The dominant species of neutral insects were little beetles, *Sarcophaga carnaria* (Linn.), and *Apis cerana* Fabricius, both on the tree and on the ground (Table 4).

3.2 Temporal dynamics of similarity index of pest, predatory and neutral insects in different stratum of jujube site

Table 5 suggested that the vertical distribution of the community structure of the same or different subcommunity was different in different seasons, as was the case of the same or different subcommunity in the same season. The similarity index in pest insect group varied from 0.25 ± 0.15 to 0.69 ± 0.06, with corresponding index from 0.27 ± 0.03 to 0.50 ± 0.07 in predatory insect group, and from 0.24 ± 0.06 to 0.47 ± 0.02 in neutral insect group, depending on the seasons and stratum structures. In general, the vertical stratum structures of the three subcommunities were obvious, and the average values of similarity index in each stratum were between 0.35 ± 0.05 to 0.61 ± 0.03. The similarity index value between two strata was the highest ($P<0.05$) in pest insect group, and the lowest ($P<0.05$) in neutral insect group.

Table 2 Subcommunity structure and dominant species of pest insects in jujube site

Group	Year	On ground and tree		On ground		Tree canopy						On ground	On tree
						Upper		Middle		Lower			
		NI	(%)	NI	(%)	NI	(%)	NI	(%)	NI	(%)		
Orthoptera	2001	42	0.41	31	12.35	0	0.00	0	0.00	11	0.31	*G. unispina*	
	2002	38	0.38	28	13.15	0	0.00	0	0.00	10	0.29	*A. chinensis*	
Homoptera	2001	4338	42.39	121	48.21	1347	42.01	1444	44.06	1426	40.74		*P. comstock*
	2002	4309	43.54	89	41.78	1242	43.59	1436	42.70	1542	44.43	*A. fuscicollis*	*Q. perniciosus*
Coleoptera	2001	3643	35.60	56	22.31	1124	35.06	1142	34.85	1321	37.74	*H. diomphalia*	*S. yasumatsui*
	2002	3556	35.93	48	22.54	1021	35.84	1242	36.93	1245	35.87	*H. diomphalia*	*S. yasumatsui*
Hemiptera	2001	290	2.83	11	4.38	57	1.78	113	3.45	109	3.11		*A. fasciaticollis*
	2002	303	3.06	21	9.86	63	2.21	98	2.91	121	3.49		*L. lucorum*
Lepidoptera	2001	1078	10.53	32	12.75	327	10.20	287	8.76	432	12.34	*A. ypsilon*	*C. zao*
	2002	940	9.50	27	12.68	248	8.70	336	9.99	329	9.48	*A. ypsilon*	*A. sativa*
Diptera	2001	390	3.81	0	0.00	138	4.30	129	3.94	123	3.51		*Contarinia* sp.
	2002	347	0.04	0	0.00	102	0.04	117	0.03	128	0.04		*Contarinia* sp.
Acarina	2001	453	0.04	0	0.00	213	0.07	162	0.05	78	0.02		*T. cinnabarinus*
	2002	403	0.04	0	0.00	173	0.06	134	0.04	96	0.03		*T. cinnabarinus*
Total	2001	10234	100	251	100	3206	100	3277	100	3500	100		
	2002	9896	100	213	100	2849	100	3363	100	3471	100		

Table 3 Subcommunity structure and dominant species of predatory insects in jujube site

Group	Year	On ground and tree		On ground		Tree canopy						On ground	On tree
						Upper		Middle		Lower			
		NI	(%)	NI	(%)	NI	(%)	NI	(%)	NI	(%)		
Dermaptera	2001	18	2.055	16	10.26	0	0.00	0	0.00	2	0.69	*L. japonica*	
	2002	16	1.923	13	9.09	0	0.00	0	0.00	3	1.03	*L. japonica*	
Coleoptera	2001	162	18.49	11	7.05	38	20.99	45	18.15	68	23.37	*C. maderae chinensis*	*C. septempunctata*
	2002	166	19.95	13	9.09	32	17.49	39	18.22	82	28.08	*C. maderae chinensis*	*C. septempunctata*
Hemiptera	2001	75	8.562	14	8.97	17	9.39	21	8.47	23	7.90	*O. minutu*	*O. minutu*
	2002	72	8.654	11	7.69	21	11.48	19	8.88	21	7.19	*O. minutu*	*O. minutu*
Diptera	2001	71	8.105	5	3.21	23	12.71	21	8.47	22	7.56		*M. corollae*
	2002	64	7.692	4	2.80	19	10.38	15	7.01	26	8.90		*M. corollae*
lymenoptera	2001	168	19.18	84	53.85	21	11.60	32	12.90	31	10.65	*L. fuliginosus*	*L. fuliginosus*
	2002	172	20.67	83	58.04	35	19.13	26	12.15	28	9.59	*L. fuliginosus*	*L. fuliginosus*
Rhaphdiodae	2001	156	17.81	0	0.00	31	17.13	56	22.58	69	23.71		*Inocellia* sp.
	2002	136	16.35	0	0.00	29	15.85	51	23.83	56	19.18		*Inocellia* sp.
Neuroptera	2001	113	12.9	7	4.49	25	13.81	39	15.73	42	14.43	*C. shansiensis*	*C. shansiensis*
	2002	95	11.42	4	2.80	24	13.11	32	14.95	35	11.99	*C. shansiensis*	*C. shansiensis*
Odonata	2001	30	3.425	8	5.13	5	2.76	11	4.44	6	2.06	*A. parthenope*	*A. parthenope*
	2002	27	3.245	6	4.20	6	3.28	6	2.80	9	3.08	*A. parthenope*	*A. parthenope*
Mantodea	2001	83	9.475	11	7.05	21	11.60	23	9.27	28	9.62	*P. sinensis*	*P. sinensis*
	2002	84	10.1	9	6.29	17	9.29	26	12.15	32	10.96	*P. sinensis*	*P. sinensis*
Total	2001	876	100	156	100	181	100	248	100	291	100		
	2002	832	100	143	100	183	100	214	100	292	100		

Table 4 Subcommunity structure and dominant species of neutral insects in jujube site

Group	Year	On ground and tree		On ground		Tree canopy						On ground	On tree
						Upper		Middle		Lower			
		NI	(%)	NI	(%)	NI	(%)	NI	(%)	NI	(%)		
Dermaptera	2001	121	26.71	46	38.02	21	20.59	23	18.55	31	29.25	Little beetle	Little beetle
	2002	106	24.77	53	44.17	18	21.43	16	14.81	19	16.38	Little beetle	Little beetle
Coleoptera	2001	161	35.54	52	42.98	45	44.12	36	29.03	28	26.42	*S. carnaria*	*S. carnaria*
	2002	143	33.41	46	38.33	38	45.24	38	35.19	21	18.10	*S. carnaria*	*S. carnaria*
Hemiptera	2001	171	37.75	23	19.01	36	35.29	65	52.42	47	44.34	*A. cerana*	*A. cerana*
	2002	179	41.82	21	17.50	28	33.33	54	50.00	76	65.52	*A. cerana*	*A. cerana*
Total	2001	453	100	121	100	102	100	124	100	106	100		
	2002	428	100	120	100	84	100	108	100	116	100		

Table 5 Similarity index (mean ± SE of 2 yrs) of pest, predatory and neutral insects in different stratum of jujube site

Month	Pest insects			Predatory insects			Neutral insects		
	A	B	C	A	B	C	A	B	C
Mar	0.26±0.12	0.25±0.15	0.46±0.11	0.38±0.05	0.35±0.02	0.27±0.03	0.43±0.03	0.28±0.06	0.34±0.03
Apr	0.36±0.08	0.62±0.06	0.54±0.04	0.40±0.06	0.31±0.02	0.30±0.02	0.24±0.06	0.32±0.02	0.47±0.02
May	0.35±0.04	0.30±0.02	0.50±0.10	0.44±0.03	0.37±0.01	0.28±0.04	0.40±0.07	0.33±0.03	0.34±0.03
Jun	0.59±0.11	0.62±0.03	0.54±0.01	0.49±0.04	0.27±0.03	0.40±0.03	0.35±0.10	0.37±0.04	0.45±0.04
Jul	0.69±0.06	0.60±0.08	0.68±0.09	0.50±0.07	0.44±0.03	0.48±0.01	0.43±0.04	0.40±0.05	0.43±0.01
Aug	0.32±0.02	0.42±0.04	0.52±0.02	0.41±0.06	0.48±0.02	0.38±0.02	0.44±0.06	0.45±0.10	0.32±0.05
Sep	0.28±0.05	0.44±0.11	0.59±0.03	0.34±0.03	0.40±0.04	0.47±0.02	0.38±0.04	0.41±0.03	0.42±0.03
Oct	0.57±0.13	0.53±0.02	0.55±0.04	0.27±0.03	0.40±0.02	0.38±0.04	0.40±0.07	0.24±0.04	0.31±0.02
Average	0.43±0.08	0.52±0.07	0.61±0.03	0.46±0.05	0.38±0.02	0.37±0.03	0.38±0.06	0.35±0.05	0.39±0.03

A. Upper and middle canopy strata; B. Middle and lower canopy strata; C. Lower and upper canopy strata.

3.3 Temporal dynamics of diversity index of pest, predatory and neutral insects

Figure 1 indicated that the diversity index of pest, predatory and neutral insects in the jujube site fluctuated with seasons. In March, most of the insects were in overwintering stage, and thus, their diversity index values were small. From April, the diversity index values became larger and larger, because overwintering insects resumed their activity and began to feed and breed with developing plants. In June and July, the diversity index values were the largest ($P<0.05$), and then became smaller and smaller. From March to August, pest insects had the largest ($P<0.05$) diversity index values, followed by predatory ($P<0.05$) and neutral ($P<0.05$) insects, but in September and October, the diversity index values of pest insects became smaller ($P<0.05$), and those of predatory ($P<0.05$) and neutral ($P<0.05$) insects became larger.

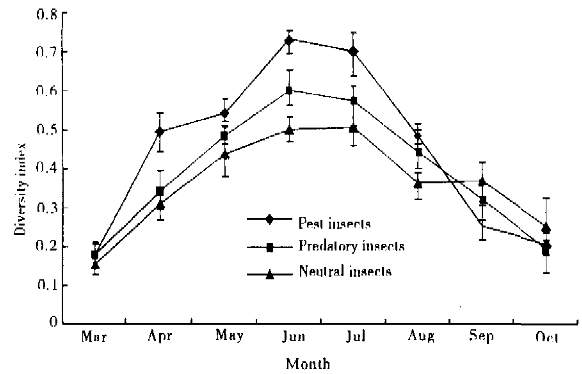

Fig. 1 Seasonal fluctuation of diversity indices of dest, dredatory and neutral insects in iujube site.

3.4 Temporal dynamics of individual numbers of pest, predatory and neutral insects

Figure 2 showed that from March to October, the individual numbers of pest, predatory and neutral insects in the jujube site increased first, and then decreased. Pest insects had the largest ($P<0.05$) fluctuation, while neutral insects had the smallest ($P<0.05$) one. There was a significant ($P<0.05$) difference in the fluctuation between predatory and neutral insects from March to August. The individual numbers of pest insects increased gradually from March to June and decreased then, while those of predatory and neutral insects increased until August and then began to decrease. In general, the predatory and neutral insects followed closely behind pest insects, and there was a significant ($r=0.9833$, $P<0.05$) correlation between them. There was a significant ($r=0.9887$, $P<0.01$) correlation between the pest and the predatory or/and neutral insects in different places of tree canopy, especially in the middle of tree canopy (Table 5).

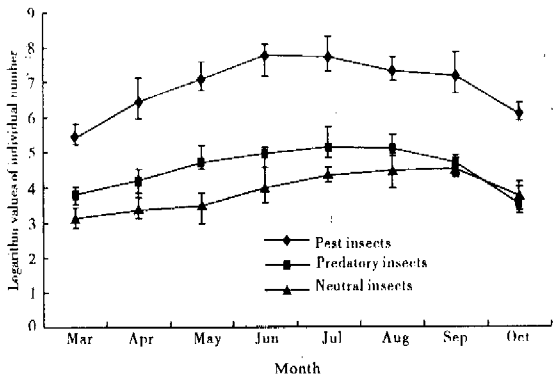

Fig. 2 Seasonal fluctuation of individual number of pest, predatory and neutral insects in jujube site.
Ordinate is natural logarithm values of individual number of pest, predator and neutral insects.

4 DISCUSSION

The composition of insect community structure was rich in the jujube site. A total of 94～96 insect species and 11 563～11 156 insect individuals were recorded over the 2 years (2001～2002) investigation. More insects were found on the tree than on the ground. Sucking pest insects constituted the majority, followed by leaf-feeding and fruit-boring pest insects. Neutral insects were not harmful to jujube trees, and some of them were used as replenishing food for beneficial insects[27]. The results clearly demonstrated that the species and individual numbers of pest, predatory and neutral insects in the jujube site fluctuated between years and between the strata of tree canopy. The species and individual numbers of these insects, and the ratio of the species and individual numbers of neutral and predatory insects to pest insects were significantly larger ($P<0.05$) on the tree than on the ground.

Most pest control decisions are made on the basis of pest number[34,35] rather than the ratio of natural enemies to the pests. With the increasing adoption of pest management program (IPM) worldwide, the use of both pests and natural enemies and neutral insects, especially predator-to-pest ratios, as the thresholds in pest management programs is becoming increasingly important[8,10,20]. The question how many predators and neutral insects are required to maintain the pests such as *C. zao* below thresholds is frequently being asked. Thus, the knowledge of predatory and neutral insects-to-pests ratio is crucial to enable the activities of predatory and neutral insects to be incorporated into decision-making protocols in IPM, while this investigation is the first report to study the predatory and neutral insects-to-pests ratio in jujube orchards.

Our results clearly demonstrated the community structure and its dynamics of pest, predatory and neutral insects in jujube tree crop ecosystems, which may be useful to explore the integrated pest management of jujube trees. Further investigations are needed to understand how the predatory insects act on pest insects, how the neutral insects affect predatory and other insects, and how many predatory and neutral insects to pests are required to maintain pests such as *C. zao* below thresholds.

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