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Comparison of structure and dynamics of spider community in organic, abandoned and conventional litchi orchards

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Abstract: The structures and characteristics of spider communities were analyzed based on surveys in organic, abandoned and conventional litchi plantations at Doumen, Zhuhai, Guangdong Province, from July 2004 to June 2005. The results of visual searching indicated that the species richness (S) of the spider communities was in the order abandoned > organic > conventional litchi zone. The diversity (H') was in the order organic > abandoned > conventional litchi region. Evenness (E) was in the order organic > abandoned > conventional litchi plantation. These findings showed that the impact of organic management practices on the diversity of spider communities was less than other two management methods. Three families, Araneidae, Linyphiidae and Theriodiidae, comprised the dominant groups among organic, abandoned and conventional plantations. The richness and number of Salticidae individuals in the abandoned litchi orchard also increased. Besides weather factor, the disturbance level of farming activity was important for diversity of spider community. The number of species and individuals of spiders was high in the organic litchi orchard, where no chemical pesticides were used, but was lower in the conventional litchi orchard, where chemical products were used frequently. These results indicated that the excessive use of pesticides had a negative effect on the spider community.

Key words: Biodiversity; litchi orchard management; organic cultivation; spider community

有机荔枝园、常规荔枝园和天然荔枝园蜘蛛类群的比较

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摘要: 2004~2005年,对珠海市斗门区有机、常规和天然荔枝园的蜘蛛群落进行了系统的调查和分析,结果表明,不同类型荔枝园蜘蛛群落丰富度S值天然>有机>常规荔枝园;多样性指数H'值有机>天然>常规荔枝园;均匀度E值有机>天然>常规荔枝园。说明进行有机管理的荔枝园对蜘蛛群落的多样性影响较小,有利于保护和发挥天敌的自然控制力。有机、常规荔枝园的优势类群均为园蛛科、皿蛛科和球蛛科,而天然荔枝园除这三者外,跳蛛科也明显增加。除天气因素外,更重要的还与人为农事活动干扰程度直接相关。有机荔枝园不使用化学农药,蜘蛛种类多,个

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体数也较多。而常规荔枝园由于频繁地使用了化学合成物质，蜘蛛种类和数量较少。说明施用大量的化学农药，对蜘蛛的影响较大。

关键词：生物多样性；荔枝园管理；有机耕作；蜘蛛群落
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Spiders are important natural predators of crop pests. Both the juveniles and the adults of spiders can prey on live insects, and their scope of food and appetite is huge. The results of many studies have proved that spiders have an important role in the suppression of orchard pests. Hukusima and Kondo (1962), and Mansour *et al.* (1980b) found that the ability of spiders to regulate pests was extremely strong. By preserving spider biodiversity, the numbers of pest species can be controlled (Marc and Canard, 1997); for example, it is advantageous to use spiders to control the pests in a citrus orchard ecosystem (Yan and Wan, 1987; Yan, 1990). Management practices for example, planting, irrigation, pruning and the use or non-use of pesticides, can have diverse effects, positive or negative, on spider communities (Feber *et al.*, 1998; Miliczky *et al.*, 2000; Cárdenas *et al.*, 2006). Integrated pest management (IPM) practices have beneficial effect on the diversity of spiders in apple orchards (Pekár, 1999), and Cárdenas *et al.* (2006) observed that spider numbers in organic olive orchards were higher than those in conventional olive orchards. Han (2005) studied the composition of communities in organic, non-polluted tea and conventional tea gardens, and his research result showed that species richness and abundance of spiders were lower in the conventional tea garden, owing to the regular application of pesticides, than those of spiders in the organic tea garden, where chemical control was not used. Liu *et al.* (1999) analyzed the dynamics of richness, diversity and evenness of arthropod communities in two litchi orchards and found that those of arthropods were higher in complex zones (an area planted with litchi and evergreen trees or shrubs) than in single zones(an area planted with litchi trees). However, little attention has been paid to the abundance, diversity and dynamics of spiders and pests in organic litchi orchards specifically.

There is a long cultivation history of the *Litchi chinensis* Sonn tree in China. Varieties of litchi are abundant. The Guangdong area also is the leading production region of litchi, accounting for 60% of the litchi cultivation area in China (Huang, 2002; Chen and Su, 2005). Unfortunately, many insect pests infest cultivated varieties of litchi. They cause direct yield losses and economic injury by damaging to leaves, flowers and fruits. For the reason many chemical pesticides are used in litchi orchards and pesticide residues of litchi are very serious. In recent years, much attention has been paid worldwide to food safety problems, and many countries have increased their efforts to develop organic agriculture. Thus, it is necessary to develop organic litchi in China. In the present study, performed in variable management practices, a survey was carried out to investigate the diversity of spider communities and insect pests. The purpose of the study was to assess the diversity of spider communities in the three kinds of litchi orchards (organic litchi orchard, conventional litchi orchard and abandoned litchi orchard), and to investigate the relationship between spiders and insect pests.

1 Study areas and methods

1.1 Experimental sites

The study was conducted from July 2004 to June 2005 in three litchi orchards located in Doumen, Zhuhai, China (113°09′51.9″W, 22°11′53.0″N), under similar microclimates. The areas were about 3.33 ha and were organic (Hong Kong Organic Certification Center base OIC013), abandoned or conventional. The plants used in the organic plantation were varieties of litchi ('Fei Zixiao', 'San Yuehong', 'Gui Wei' and 'black leaf'), longan ('Shi Xia' and 'Chu Liang') and other fruits (banana, guava, *Mangifera indica* and Carambola). Organic management methods that comply with the Organic Cultivation Rules and Organic Certification Regulations of the Hong Kong Organic Certification Center (which are in accordance

with international organic certification standards) were applied in the organic litchi orchards studied. During the production process, no chemical applications were used, and biological control, in addition to farming management, was adopted to protect the litchi from pests and diseases. This included releasing *Trichogramma* and *Anastatus japonicus*, and using azadirachtin and light trapping. No chemicals were used in the organic litchi orchard; the abandoned litchi orchard was unmanaged and no chemical products were used in it. 'Shi Xia', 'Chu Liang', 'Fei Zixiao', 'Gui Wei' and 'black leaf' were used in the abandoned plantation. There were no harvests in it, where no pesticide or other practice was applied. 'Shi Xia', 'Chu Liang', 'Fei Zixiao', 'Gui Wei' and 'Nuo Mici' were used the conventional plantation. In the conventional litchi orchard, however, chemical pesticides such as omethoate, dicofol, dipterex, chlorfluazuron, shachongshuang, lambda-cyhalothrin, methomidophos and ripcord were used frequently, approximately eight times during the year.

1.2 Sampling methods

In the organic, abandoned and conventional litchi orchards, three litchi trees were chosen for study respectively, with visual searching to monitor the number of spiders from July 2004 to June 2005. The litchi trees of each treatment were monitored approximately every seven days from July to October 2004 and from March to June 2005, and every 14 days from November 2004 to February 2005. On the sampling date, each of the three litchi orchards at each treatment was observed from five different directions (east, west, south, north and middle). At each direction, two branches about 30 cm in length (from stern upward) were monitored by the investigators to look for spiders and to record the numbers observed. All spiders collected were stored in 70% alcohol for subsequent identification in the laboratory.

1.3 Data Analysis

Species richness (S), diversity (H'), evenness (E) and dominance (C) was important indices showing the development and characteristic succession of communities (Smith, 1977). All collected spiders were counted. Juveniles were identified at the family or generic level, and adults were identified at the species level whenever possible. All species and numbers of spiders observed at each sampling date were calculated as total numbers per three litchis. The original data were converted into monthly averages per sampled site. The Shannon – Wiener index of diversity (H') was applied to measure the species diversity of spiders:

$$H' = -\sum_{i=1}^{s} PiIn(Pi) \quad (1)$$

where Pi *is* the percentage that accounts for the total numbers of ith species. The species evenness (E) of spider communities was measured with the formula

$$E = H'/\ln(S) \quad (2)$$

where S is the number of species. The Simpson's dominance index was calculated:

$$C = \sum_{i=1}^{s} (n_i/N)^2 \quad (3)$$

where N_i is the total number of ith species and N is the total number of all species (including the ith species). All of the index were calculated using the Data Processing System (DPS) (Tang and Feng, 2003). Some data dealt with using Excel 2003.

2 Results

2.1 Comparison of spider communities between litchi plantations

A total of 2704 spiders, identified as 75 species of 43 genera and 15 families, were collected from the organic litchi orchard during the year. Of these, *Hylyphantes graminicola* (Linyphiidae) and *Neoscona punctigera* (Araneidae) were the dominant species. There were 5220 spiders, which were appraised as 74 species belonging to 46 genera and 15 families, in the abandoned litchi plantation, with the dominant species being *Hylyphantes graminicola* and 1358 spiders, identified as 43 belonging to 34 genera and 14 families in the conventional litchi plantation, with the dominant species being *Hylyphantes graminicola* and *Coleosoma blandum* (Theriodiidae) (Table 1).

2.2 Comparison of the diversity, evenness and dominance of spider communities in different types of litchi plantations

Because of changes in the environmental condi-

tions of the orchards and the physiological growth of the spiders, the spider communities in the litchi orchards fluctuated seasonally (Fig. 1). The dynamics of S, H' and E of the spider communities were similar in the organic, abandoned and conventional litchi orchards, but these indices were significantly higher in the organic and abandoned orchards than in the conventional zone (Fig. 1). The S value of spider communities displayed multi-peaks in the organic and abandoned litchi orchards; the first peak appeared between May and June, the second continued from early August to October, and the third peak appeared from the end of November to early December. Following a gradual decrease in temperature, the S value decreased to a minimum in January (10 in the organic litchi orchard, 12 in the abandoned litchi orchard and 2 in the conventional litchi orchard). The H' value was markedly lower in the conventional litchi orchard than in the organic and abandoned orchards. During overwintering, H' decreased continually for three months (from January to March) in the organic and abandoned litchi orchards. Yet, values for the conventional litchi plantation increase over this time span. During the year, $E > 0.49$ in the organic region and $E > 0.33$ in the conventional region, the fluctuation scope of H' and E was significantly smaller in the organic and abandoned areas than in the conventional area. The C value was higher in the conventional litchi orchard than in the other orchards. These results indicate that the stability of spider communities in the organic and abandoned plantations was significantly higher than in the conventional litchi plantation.

The diversity of spiders in the organic and conventional litchi plantations correlated significantly with species richness (correlation coefficients $r = 0.6044$, $P < 0.05$ in the organic litchi plantation; $r = 0.6044$, $P < 0.05$ in the conventional litchi plantation), whereas the diversity of spiders in the abandoned litchi plantation did not ($r = 0.0937$, $P > 0.05$). There was a significant positive correlation between the diversity and the evenness of spiders in the organic litchi orchard ($r = 0.7063$, $P < 0.05$), whereas the diversity of spiders in the abandoned and conventional litchi plantations did not correlate significantly with the evenness ($r = 0.5367$, $P > 0.05$ in the abandoned litchi plantation; $r = 0.3948$, $P > 0.05$ in the conventional litchi plantation). A strong negative correlation was detected between the diversity and the dominance degree in litchi orchards ($r = -0.9414$, $P < 0.05$ in the organic litchi plantation; $r = -0.6665$, $P < 0.05$ in the abandoned litchi plantation; $r = -0.9468$, $P <$

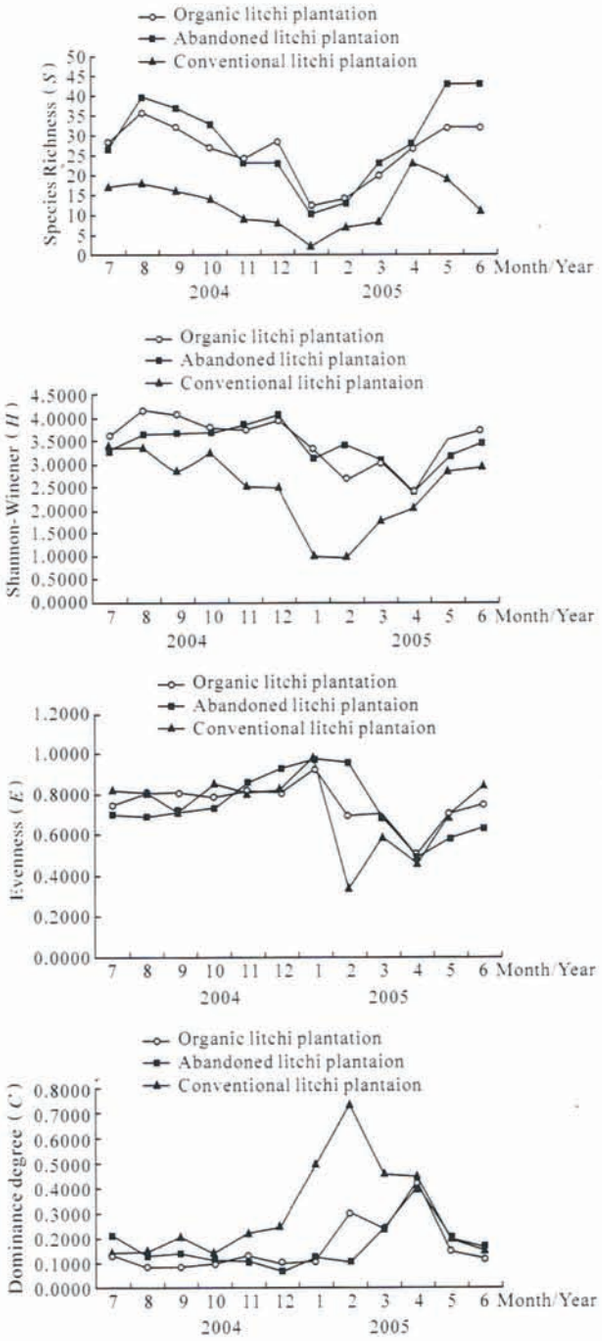

Fig. 1 Dynamics of species richness (S), diversity (H'), evenness (E) and dominance degree (C) of spider communities in different types of litchi plantation

0.05 in the conventional litchi plantation). There was no significant difference in diversity and species richness between the organic and abandoned litchi plantations ($P > 0.05$); however, they were significantly different from those of the conventional litchi plantation ($P < 0.01$).

Table 1　Differences in species richness and population abundance of spiders from three types of litchi plantation

Family	Organic litchi orchard			Abandoned litchi orchard			Conventional litchi orchard		
	Richness(S)	Genera	Numbers	Richness(S)	Genera	Numbers	Richness(S)	Genera	Numbers
Agelenidae	1	1	20	1	1	20	1	1	4
Araneidae	15	6	719	18	8	1115	8	4	234
Clubionidae	1	1	100	1	1	106	1	1	3
Corinnidae	1	1	35	1	1	4	1	1	1
Gnaphosidae	1	1	1	0	0	0	1	1	109
Heteropodidae	1	1	91	1	1	144	1	1	8
Linyphiidae	5	2	770	2	2	1780	3	2	430
Lycosidae	0	0	0	1	1	1	0	0	0
Micryphantidae	1	2	72	2	2	116	1	1	25
Oxyopidae	2	1	50	2	1	164	1	1	4
Philodromidae	1	1	15	1	1	51	0	0	0
Salticidae	16	10	127	17	11	721	9	7	24
Tetragnathidae	4	2	27	5	2	246	3	2	28
Theriodiidae	14	6	479	11	5	603	6	5	423
Thomisidae	10	7	160	10	8	135	6	6	64
Uloboridae	2	1	38	2	1	14	1	1	1
Total	75	43	2704	75	46	5220	43	34	1358

2.3 Dynamic change in the dominant spider communities in the different litchi plantations

The dominant spider families in the three litchi orchards were Araneidae, Linyphiidae and Theriodiidae. Salticidae abundance and number of individuals in the abandoned litchi orchard also increased clearly compared with the other groups, possibly because the disturbance level caused by farming activity was small. Comparing the dominant families in the three types of litchi orchard, it was found that the tendency for change was relatively similar in the organic and abandoned litchi orchards, being slightly higher than in the conventional litchi plantation (Fig. 2).

The numbers [transformed ln(Number + 1)] of Araneidae in the abandoned and conventional litchi orchards began to increase gradually in July 2004, and declined in September. 2004, reached a small low peak in Jan, whereas those of Araneidae reached a off-peak. The numbers of Araneidae in three types of litchi orchards showed an upward trend. The numbers of Linyphiidae in all of the plantations decreased gradually to a low peak value from Aug, and increase to a peak in April later. Changes in numbers of Theriodiidae in the abandoned and conventional litchi orchards were similar to numbers change of Araneidae in those litchi orchards from July to January. Their numbers began to increase in July 2004, declined to a low peak in September 2004 and kept steadily later. They reached a peak in May. Those of Theriodiidae increased gradually in the organic litchi orchard from July. However, they declined to an off-peak after a month, and subsequently began to increase in January.

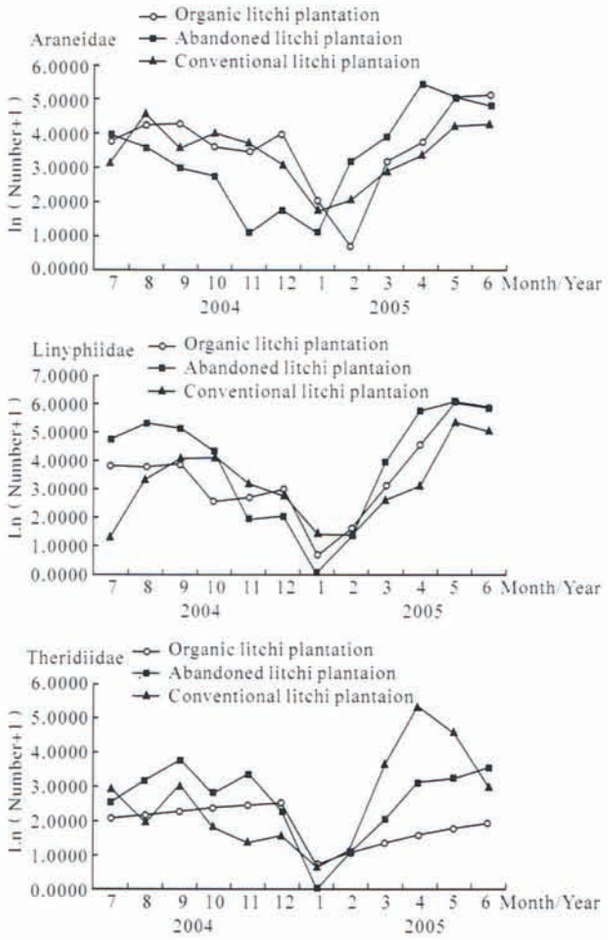

Fig. 2 Dynamics of dominant spider group individuals in different litchi plantations

3 Discussion

The results of systematic investigation indicate that the *S* value of spider communities was in the order abandoned > organic > conventional litchi plantation, the *H'* value was in the order organic > abandoned > conventional litchi plantation. The *E* value was in the order organic > abandoned > conventional litchi plantation. The impact on the diversity of spider communities of adopting organic management patterns was lower compared with the impact of conventional management.

It has been shown that weather has a relatively significant effect on spider communities (Zhang and Ma, 1996; Marc *et al.*, 1999). Our study showed that, in addition to the weather, the level of disturbance caused by human activity also has an important effect. The degree of diversity tended to diminish with increased disturbance; for example, the application of pesticides, the removal or pruning of branches and the elimination of weeds (Mansour, 1980a; Lenz, 2004). The species abundance and individual numbers of spiders in the organic litchi plantation, where chemical pesticides were not used, were comparable to those in the conventional litchi plantation, where chemicals were frequently used. This result is consistent with the findings by Dondale (1979) and Olszak (1992). In the abandoned litchi plantation, individual numbers of spiders were also higher because no chemical pesticides were used and no branches were pruned.

Predators can significantly reduce numbers of crop pests (Marc and Canard, 1997; Nyffeler and Sunderland, 2003). However, most spiders tend to be sensitive to pesticides (Yardim and Edwards, 1998). Spiders have been used as indicators of pests, what can be linked to changes in a litchi plantation. Species and individual numbers of spiders declined when those of insect pests decreased. This phenomenon was more obvious in the conventional litchi plantation, where the frequent use of chemical pesticides affected some sensitive species of spider.

The dominant groups of spiders found in the three types of litchi plantation were similar because they were located in the same region and under similar climatic conditions. However, spider numbers in the three kinds of plantation were slightly different. This was because of differences in ground vegetation structure and different management practices in the orchards, in addition to the activity of farmers.

4 Conclusion

In this study, field investigations showed that species richness and individual numbers of spiders in conventional litchi orchard were significantly different from those in organic and abandoned orchards because of different management practices. The impact of organic management patterns on the diversity of spider communities was lower than that of conventional management. Furthermore, the diversity of spider communities in the abandoned litchi orchard, where there was no manage-

ment, developed under natural conditions. Thus, management practices do affect the structure of spider communities in litchi orchards.

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参 考 文 献 (References)

Cárdenas M, Ruano F, García P, Pascual F, Campos M, 2006. Impact of agricultural management on spider populations in the canopy of olive trees. *Biological Control*, 38: 188 – 195.

Chen WZ, Su WQ, 2005. Some advice on accelerating industrialized development of litchee in Guangxi. *Journal of Guangxi Agriculture*, 45: 69 – 73. [陈伟强, 苏伟强, 2005. 加快广西荔枝产业化发展的建议. 广西农学报, 45: 69 – 73]

Dondale CD, Parent B, Pitre D, 1979. A six-year study of spiders (Araneae) in a Quebec apple orchard. *Canadian Entomologist*, 111: 377 – 380.

Feber RE, Bell J, Johnson PJ, Firbank LG, Macdonald DW, 1998. The effect of organic farming on surface-active spider (Araneae) assemblages in wheat in southern England, UK. *Journal of Arachnologica*, 26: 190 – 202.

Han BY, 2005. Difference in dynamics and structure of spider communities in organic and non-pollution and common tea gardens. *Acta Arachnologica Sinica*, 14(20): 104 – 107. [韩宝瑜, 2005. 有机、无公害和普通茶园蜘蛛群落结构组成及动态差异. 蛛形学报, 14(20): 104 – 107]

Huang XM, 2002. Produce status and development direction of litchee in Asia Pacific. *South China Fruits*, 31(1): 62 – 65. [黄旭明, 2002. 亚太地区国家荔枝生产状况和发展动向. 中国南方果树, 31(1): 62 – 65]

Hukusima S, Kondo K, 1962. Further evaluation in the feeding potential of the predacious insects and spiders in association with aphids harmful to apple and pear growing, and the ef fect of pesticides on predators. *Japanese Journal of Applied Entomology and Zoology*, 6: 274 – 280.

Lenz M, Molis M, Wahl M, 2004. Experimental test of the intermediate disturbance hypothesis: frequency effects of emersion on fouling communities. *Journal of Experimental Marine Biology and Ecology*, 305: 247 – 266.

Liu DG, Liang WG, Ding Y, Huang MD, 1999. Studies on dynamics of arthropod community in two kinds of litchi orchard habitats. *Acta Ecologica Sinica*, 19(5): 885 – 889. [刘德广, 梁伟光, 丁勇, 黄明度, 1999. 复合荔枝园节肢动物群落动态的研究. 生态学报, 19(5): 885 – 889]

Mansour F, Rosen D, Shulov A, 1980a. A survey of spider populations (Araneae) in sprayed and unsprayed apple orchards in Israel and their ability to feed on larvae of *Spodoptera littoralis* (Boisd.). *Acta Oecologica – oecologia Applicata*, 1: 189 – 197

Mansour F, Rosen D, Shulov A, Plaut HN, 1980b. Evaluation of spiders as biological control agents of *Spodoptera littoralis* larvae on apple in Israel. *Acta Oecologica – oecologia Applicata*, 1/3: 225 – 232.

Marc P, Canard A, 1997. Maintaining spider biodiversity in agroecosystems as a tool in pest control. *Agriculture Ecosystems & Environment*, 62: 229 – 235.

Marc P, Canard A, Yanel F, 1999. Spiders (Araneae) useful for pest limitation and bioindication. *Agriculture Ecosystems & Environment*, 74: 229 – 273.

Miliczky ER, Calkins CO, Horton DR, 2000. Spider abundance and diversity in apple orchards under three insect pest management programmes in Washington State, USA. *Agriculture and Forest Entomology*, 2: 203 – 215.

Nyffeler M, Sunderland KD, 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: a comparison of European and US studies. *Agriculture Ecosystems & Environment*, 95: 579 – 612.

Olazak W, Luczak J, Niemczyk E, Zajac R, 1992. The spider community associated with apple trees under different pressure of pesticides. *Ekologia Polska*, 40: 265 – 286.

Pekár S, 1999. Effect of IPM practices and conventional spraying on spider population dynamics in an appleorchard. *Agriculture Ecosystems & Environment*, 73: 155 – 166.

Simith RL, 1977. Elements of Ecology and Field Biology. New York, Harper & Row, 62 – 184.

Tang QY, Feng MG, 2002. DPS® Data Processing System for Practical Statistic, Beijing: Science Press, 33 – 347. [唐启义, 冯明光, 2002. 实用统计分析及其 DPS 数据处理系统. 北京: 科学出版社, 33 – 347]

Yan HM, 1990. Predation of the spider *Clubiona reichlini* on citrus pests. *Acta Zoologica Sinica*, 36(1): 24 – 31. [颜亨梅, 1990. 斑管巢蛛对柑桔害虫的捕食作用研究. 动物学报. 36(1): 24 – 31]

Yan HM, Wang HQ, 1987. Investigation on the spiders resource in citrus orchard in Changsha. *Bulletin of Biological Control*, 3(9): 15 – 18. [颜亨梅, 王洪全, 1987. 长沙桔园蜘蛛资源调查研究. 生物防治通报, 3(9): 15 – 18]

Yardim EN, Edwards CA, 1998. The influence of chemical management of pests, diseases and weeds on pest and predatory arthropods associated with tomatoes. *Agriculture Ecosystems & Environment*, 70: 31 – 48.

Zhang JH, Ma XX, 1996. Studies on the structure and dynamics of the spider community in early rice field. *Xinjiang Agricultural Science and Technology*, (5): 22 – 23. [张建华, 马雷霞, 1996. 棉田蜘蛛群落结构及数量动态的研究. 植物保护, (5): 22 – 23]