

不同生草模式对梨园主要害虫及其天敌的影响

李建瑛¹, 孙冰¹, 郭翊蓉¹, 刘锦^{2*}, 迟宝杰², 孔凡来³, 刘永杰^{1*}

(¹山东农业大学植物保护学院, 山东泰安 271018; ²山东农业工程学院, 济南 250100;
³曲阜市吴村镇农业综合服务站, 山东曲阜 273110)

摘要:【目的】探讨不同生草模式对梨园主要害虫及其天敌的影响。【方法】对3种生草模式梨园的树上及树下害虫及天敌的种群动态进行系统调查, 并综合分析多样性指数、动态相关性、时间生态位。【结果】人工生草区的蚜虫及梨木虱与清耕区相比种群数量显著减少; 人工生草区与自然生草区树上天敌的多样性指数(H)和优势度指数(D)平均值分别为1.15、1.00和0.60、0.55, 显著高于清耕区; 人工生草区树上各类天敌的种群数量显著增多, 尤其是龟纹瓢虫, 即使在使用杀虫剂后, 人工生草区数量也是自然生草区的1.21倍, 清耕区的3.31倍; 与自然生草区相比, 草内龟纹瓢虫和草蛉的种群数量显著增多; 果园生草减弱了蚜虫与龟纹瓢虫的相关性, 增强了害虫与其他天敌的相关性; 人工生草区的害虫时间生态位最小, 天敌时间生态位及害虫天敌间生态位重叠和相似性最大。【结论】人工种植长柔毛野豌豆可以明显影响梨园害虫天敌的发生动态和时序特征, 使天敌的数量更稳定, 有利于控制梨园害虫。

关键词:梨园; 生草模式; 长柔毛野豌豆; 种群动态; 多样性指数; 时间生态位

中图分类号:S661.2

文献标志码:A

文章编号:1009-9980(2020)10-1545-10

Effects of different grass-growing patterns on the main pests and their natural enemies in pear orchards

LI Jianying¹, SUN Bing¹, GUO Yirong¹, LIU Jin^{2*}, CHI Baojie², KONG Fanlai³, LIU Yongjie^{1*}

(¹College of Plant Protection, Shandong Agricultural University, Tai'an 271018, Shandong, China; ²Shandong Agriculture and Engineering University, Jinan 250100, Shandong, China; ³Qufu Wucun Agricultural Comprehensive Service Station, Qufu 273110, Shandong, China)

Abstract:【Objective】The grass planting technology in the orchard is usually to plant perennial herbs as cover crops in the ground between the rows of fruit trees. Applying sod system can retain water, increase soil fertility, make growth environment better, and improve fruit quality. Under different ground conditions, there are various suitable types of grasses, and it is very important to choose the appropriate grass species. *Vicia villosa* is an excellent type of forage belonging to the legume genus *Vicia*, annual or over year, with strong adaptability to the environment. It is often used in agriculture to raise animals, rotate crops, and turn over as green manure. Applying sod system in apple orchards can improve soil fertility and increase the number of natural enemies. Therefore, the objective of this study is to examine the effects of different grass-growing patterns on the main pests and their natural enemies in pear orchards, and to determine whether the villous vetch is suitable for planting in pear orchards, so as to improve the ecological environment and control pests effectively.【Methods】The experimental orchards were situated at Qufu city, Shandong province. The pear orchard covered 60 667 m² and the pear trees were 5 to 9 years old. Three grass planting treatments were set up, with each of 10 to 15 667 m². Machines were used for weeding and cutting the natural weeds on the ground between the pear tree rows. Three treatments were as follows: (1) Clean cultivation: there was no grass cover; (2) Natural grass cover: the

收稿日期:2020-04-17 接受日期:2020-06-11

基金项目:国家重点研发计划(2018YFD0201403)

作者简介:李建瑛,男,在读硕士研究生,研究方向为农业昆虫与害虫防治。Tel:15610419207, E-mail:lijianyingcc@126.com

*通信作者 Author for correspondence. Tel:15020810730, E-mail:liujincc612@126.com; Tel:135153891338, E-mail:lyj@sdu.edu.cn

grass was usually cut 2 to 3 times a year, keeping the height of the natural weeds around 20-30 cm. (3) Artificial grass cover: that was to ditch the rows of pear trees and the *V. villosa* was sowed, 2 kg per 666.7 m², which subsequently covered the ground mixed with a small amount of natural weeds. Using visual, yellow board and net sweeping methods, the population dynamics of pests and natural enemies were systematically investigated in three grass-growing treatments. Statistics and calculations were made on the diversity index of natural enemies, the correlation between population dynamics of pests and natural enemies, and the temporal niche of population dynamics of pests and natural enemies. 【Results】 The population of aphids and *Psylla chinensis* in the artificial grass area was significantly controlled compared with the clean cultivation area. The first peak of aphids appeared on May 25, and the number of aphids in the artificial grass-growing area was the lowest (51.7 ± 11.7 per branch), which was significantly lower than that in the clean cultivation area (116.7 ± 20.3 per branch) and the natural grass area (86.2 ± 10.3 per branch). In late October, the number of overwintering *P. pylla* populations was the highest in the year, and the number of occurrences in the artificial grass area was also the lowest (4.8 ± 1.2 per branch), which was significantly lower than that in the clean cultivation area (11.3 ± 2.1 per branch). The average values of the diversity index (*H*) and dominance index (*D*) of the natural enemies in the artificial grass area and the natural grass area were 1.15, 1.00, 0.60, and 0.55, respectively, which was significantly higher than that of the clean cultivation area. The dynamic analysis of the population of natural enemies showed that the populations of *Propylaea japonica*, *Harmonia axyridis*, lacewing, syrphids and parasitic wasps on the trees in the artificial grass area increased significantly. The *P. japonica* was one of the main predatory natural enemies in the orchard. After using pesticides, the number of artificial grass areas was still 1.21 times more than the natural grass areas and 3.31 times more than the clean cultivation area, indicating that planting grass significantly reduced the adverse effects of using a certain amount of pesticides on natural enemies in the orchard. According to the population dynamics of the natural enemies in the grass, the population of the *P. japonica* and the lacewing in the artificial grass area increased significantly, compared with the natural grass area. And a better ecological microenvironment was created, including more pollen nectar and alternative insects. Planting grass in the orchard changed the correlation between the pests and natural enemies in pear orchards, but the correlation between natural grass and artificial grass was not significant. Analysis showed that the orchard grass could reduce the dependence of predatory natural enemies on aphids and other short-term outbreaks of pest resources, while raw grass in the orchard could provide more pollen and nectar, significantly enhancing the relevance of parasitic bees on pests. The grasslands were the most relevant. Planting grass in the orchard changed the temporal niche of the pests and natural enemies in pear orchards. The temporal niche of the insects in the artificial grass area was the lowest and the temporal niche overlap index and temporal niche similarity index between pests and natural enemies in the artificial grass area also increased significantly, compared with the clean cultivation area and the natural grass area. 【Conclusion】 Therefore, artificial planting of *V. villosa* can significantly affect the occurrence dynamics and timing characteristics of natural enemies in pear orchards. Compared with the management modes of clean cultivation and natural grass, the plantation of *V. villosa* in the pear orchard could provide a better extra habitat for natural enemies. The population of natural enemies can be more stable in the pear orchard, and the effect of controlling pests in pear orchard was more significant.

Key words: Pear orchard; Grass-growing pattern; *Vicia villosa*; Population dynamics; Diversity index; Temporal niche

梨树害虫防治一直是生产管理过程中的重点和难点。使用农药防治梨树害虫,易对自然天敌造成杀伤,破坏梨园生态平衡,害虫危害难以控制。果园生草能提高农业生态系统的多样性,有效控制害虫的种群密度^[1-2]。果园生草可以增强龟纹瓢虫(*Propylaea japonica*)、中华通草蛉(*Chrysoperla sinica*)、蚜茧蜂(*Aphidius gifuensis*)等优势天敌种群对农药的耐受性,扩大生态容量,增加天敌数量,使种群更稳定,优化农业生态系统^[3]。植被类型与昆虫群落之间存在密切关系,梨园人工种植最适宜的植物更有利发挥生草作用^[4]。在梨园间作芳香植物,会改变种群的个体组成、物种丰富度、群落多样性指数、优势度和均匀度指数,主要害虫及其天敌的生态位宽度、生态位重叠都会发生变化^[5-8]。

长柔毛野豌豆(*Vicia villosa*)是豆科野豌豆属的一种优良牧草,也被称作毛苕子,一年生或越年生,对环境适应性强,可用作养畜、轮作倒茬、翻压绿肥。人工种植长柔毛野豌豆可以改善梨园土壤的透气性和土壤肥力,抑制杂草生长,增加果园的植被类型,使主要天敌的种群数量增加^[3,9]。为明确不同梨园的生草模式是否在害虫天敌的动态变化、天敌多

样性和时间分布特征等方面存在差异,从而影响天敌的数量和控制害虫的能力,笔者对3种生草模式梨园的主要害虫及其天敌种群动态和相关特征进行了分析。

1 材料和方法

1.1 试验园概况

试验园选在山东省曲阜市吴村镇百果园农场,面积约23 hm²,梨园面积4 hm²,种植‘七月酥’‘红香酥’‘新月’等品种,树龄5~9 a(年),株行距3 m×4 m,‘红香酥’和‘新月’套膜袋,‘七月酥’不套袋。设置不同生草种植布局区处理,每种处理模式面积0.7~1.0 hm²。清耕区地面采取机器除草,刈割梨园树间地面的自然杂草(主要种类为鼠茅草、狗尾草、小飞蓬、龙葵、鬼针草、马唐等),无生草覆盖;自然生草区一般全年刈割2~3次,保持自然杂草高度在20~30 cm,保持自然生草覆盖;人工生草区在2018年10月梨树行间和株间开沟播种长柔毛野豌豆,每666.7 m²撒播2 kg,为长柔毛野豌豆与少量自然杂草覆盖。

1.2 试验园施药情况

施药情况如表1所示。

表1 试验园用药情况

Table 1 Pesticides used in the test garden

日期 Date	用药浓度、种类及倍数 Pesticide concentration, type and multiple
3月27日 March 27	10%苯醚甲环唑水分散粒剂1 500倍液+22.4%螺虫乙酯悬浮剂3 000倍液 10% difenoconazole water dispersible granules 1 500 times solution and 22.4% spirotetramat suspension 3 000 times solution
4月26日 April 26	5%嘧菌酯悬浮剂1 500倍+60%吡蚜酮水分散粒剂2 000倍液 5% azoxystrobin suspension agent 1 500 times and 60% pymetrozine water dispersible granule 2 000 times solution
5月10日 May 10	40%氟硅唑乳油3 000倍液+5%氯虫苯甲酰胺悬浮剂1 000倍液 40% flusilazole emulsifiable concentrate 3 000 times and 5% chlorantraniliprole suspension 1 000 times solution
6月4日 June 4	3%戊唑醇悬浮剂2 000倍液+20%灭幼脲悬浮剂1 000倍液 3% tebuconazole suspension 2 000 times solution and 20% diflubenzuron suspension 1 000 times solution
8月13日 August 13	25%吡唑醚菌酯乳油2 000倍液 25% pyraclostrobin EC 2 000 times solution

1.3 调查方法

根据梨树生长情况,于2019年4—11月对梨园害虫及天敌种群动态进行调查,每10 d调查1次。

1.3.1 目测观察法 每个梨园调查区选取5个样点,每个点调查2株梨树,每株树在东、南、西、北四个方向各选取1大侧枝,目测观察各侧枝上害虫及天敌种类和数量。合计每个调查区调查10株树,共40个侧枝。

1.3.2 黄板法 采取五点取样法。在每个梨园调查区悬挂5个黄板,调查每个黄板上寄生蜂的数量。

1.3.3 扫网法 采用五点取样法。在果树行间或周边的生草上选取5个长度约10 m的样点,用捕虫网边走边扫,连续扫网,扫网时捕虫网尽量贴近地面,每点扫网20次(1来1回计1次),详细记录捕虫网中主要天敌的种类和数量。

1.4 多样性指数及生态位公式

多样性指数(H)为Shannon-Wiener多样性指数(1963), $H=-\sum(P_i \ln P_i)$ 。式中 $P_i=n_i/N$, n_i 为第*i*个种的个体数, N 为群落中所有种的个体总数。

均匀度指数(J)为Pielou提出的均匀度指数,

$J=H/\ln S$ 。其中 $\ln S=H_{max}$, H 是多样性指数; S 为物种数。

优势度指数(D)为辛普森多样性指数, $D=1-\sum(n_i/N)^2$ 。 n_i 为第 i 个种的个体数, N 为群落中所有种的个体总数。

时间生态位依据调查资料分为 18 个时间单元。采用 Levins(1968)公式计算时间生态位宽度,

其公式为: $B_i=\frac{1}{S\sum_{k=1}^r P_{ik}^2}$ 。 B_i 为物种 i 的生态位宽度 ($B_{max}=1$, $B_{min}=1/S$); S 为资源序列的等级数; P_{ik} 为物种 i 在第 k 等级资源的数量占总资源数量的比例。

采用 Horn(1966)公式计算时间和空间生态位重叠,公式为

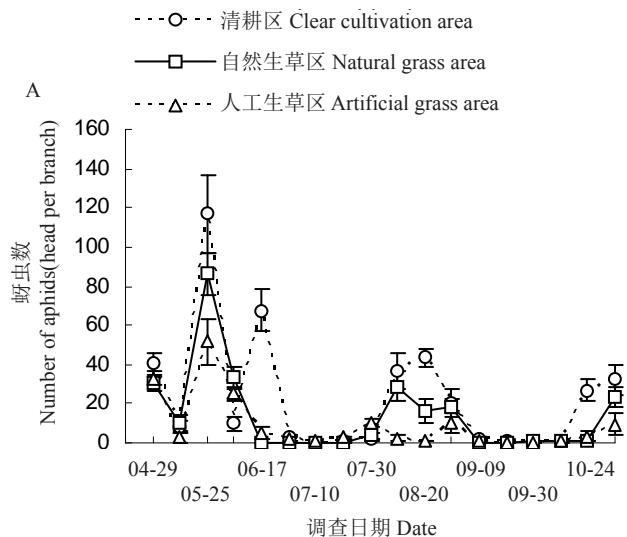
$$Q_{ik} = \frac{\sum_{j=1}^r (P_{ij} + P_{kj}) \lg (P_{ij} + P_{kj}) - \sum_{j=1}^r P_{ij} \lg P_{ij} - \sum_{j=1}^r (P_{kj} \lg P_{kj})}{2 \lg 2}.$$

式中 Q_{ik} 为 i 的资源利用曲线与物种 k 的资源利用曲线的重叠指数; P_{ij} 和 P_{kj} 分别代表 i 和 k 物种利用 O 资源占利用总资源等级的比例; r 为资源序列等级数。

采用 Morisita-Horn 公式计算生态位相似性

$$(Wolda, 1981), \text{公式为: } S_{ik} = \frac{2 \sum_{j=1}^r P_{ij} P_{kj}}{\sum_{j=1}^r P_{ij}^2 + \sum_{j=1}^r P_{kj}^2}.$$

为生态位相似性指数,其他含义与上同。



1.5 统计与分析

折线图用 Microsoft Excel 2010 作柱形图,其中调查时间为横坐标,害虫及天敌数量为纵坐标。使用 IBM SPSS Statistics 17.0 双变量相关性分析软件分析不同昆虫种群动态之间的相关性,使用 ANOVA 的 tukey 法检验昆虫整体数量平均值之间的差异性。

2 结果与分析

2.1 不同生草模式对梨园主要害虫种群动态的影响

通过目测观察法得知不同生草模式梨园中主要害虫种类有蚜虫类与梨木虱(*Psylla chinensis*)。梨园蚜虫全年发生主要种类有绣线菊蚜(*Aphis citricola*)、梨二叉蚜(*Schizaphis piricola*)及梨黄粉蚜(*Aphanoostigma jakusuiense*)。不同生草模式梨园蚜虫发生动态(图1)显示,全年蚜虫类共 3 个发生高峰:5 月下旬第一个高峰,主要为绣线菊蚜,人工生草区蚜虫发生数量最低平均为 (51.7 ± 11.7) 头•枝⁻¹,自然生草区高于人工生草区,为 (86.2 ± 10.3) 头•枝⁻¹,清耕区发生数量最高,为 (116.7 ± 20.3) 头•枝⁻¹,三种模式梨园之间差异性均显著($p < 0.05$);在发生高峰前后,3 个梨园均使用过两次杀虫剂,清耕园的蚜虫种群恢复速度最快,在 6 月中旬又出现一个小高峰。8 月中下旬第二个高峰,主要为绣线菊蚜及梨黄粉蚜。10 月下旬为第三个发生高峰,主要为越冬代的梨二叉蚜,均为人工生草区发生数量最低,清耕区最高(图1-A)。

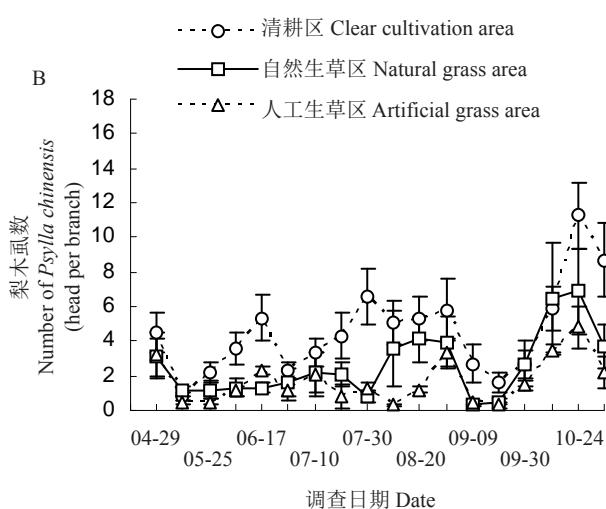


图 1 不同生草模式对梨园主要害虫发生动态的影响

Fig. 1 Dynamics effects of main pests in pear orchards with different grassing patterns

不同生草模式梨园梨木虱发生动态显示,全年梨木虱在梨园各个月份均有发生,人工生草区梨园梨木虱发生程度较轻,在各个高峰期发生数量均低于自然生草区和清耕区。10月下旬越冬代梨木虱种群数量为全年最高,清耕区发生数量为 (11.3 ± 2.1) 头·枝⁻¹,自然生草区为 (6.9 ± 2.5) 头·枝⁻¹,人工生草区发生数最低,为 (4.8 ± 1.2) 头·枝⁻¹,清耕区与自然生草区间差异不显著($p>0.05$),人工生草区与清耕区和自然生草区差异均显著($p<0.05$)(图1-B)。

2.2 不同生草模式对梨园主要天敌种类及多样性指数的影响

调查结果表明,梨园主要有9种天敌,即龟纹瓢虫(*Propylaea japonica*)、异色瓢虫(*Harmonia axyridis*)、中华通草蛉(*Chrysoperla sinica*)、大草蛉(*Chrysopa pallens*)、黑带食蚜蝇(*Episyphus balteata*)、短翅细腹食蚜蝇(*Sphaerophoria scripta*)、大灰优食蚜蝇(*Metasyrphus corollae*)、烟蚜茧蜂(*Aphydius gifuensis*)和梨木虱跳小蜂(*Psylladintus insidiosus*)。不同生草模式梨园主要天敌的多样性指数显示,人工生草区与自然生草区的多样性指数 H 和优势度指数 D 均显著大于清耕区,但二者均匀度指数 J 没有显著差异(表2)。

2.3 不同生草模式对梨园龟纹瓢虫和异色瓢虫发生动态的影响

人工生草区梨树上龟纹瓢虫及异色瓢虫总量多于自然生草区和清耕区,而3种模式梨园龟纹瓢虫整体发生数量均高于异色瓢虫。龟纹瓢虫有3个明

表2 不同生草模式对梨园主要天敌多样性指数的影响

Table 2 Diversity index of the natural enemies in pear orchards with different grassing patterns

多样性指数 Diversity index	清耕区 Clear cultivation area	自然生草区 Natural grass area	人工生草区 Artificial grass area
H	0.68 ± 0.11 b	1.00 ± 0.09 a	1.15 ± 0.07 a
J	0.76 ± 0.02 a	0.78 ± 0.02 a	0.72 ± 0.03 a
D	0.39 ± 0.06 a	0.55 ± 0.04 b	0.60 ± 0.03 b

注:不同小写字母表示差异达0.05显著水平。

Note: The different small letters mean significant difference at $p < 0.05$.

显的发生高峰,人工生草区均为最高。在6月4日使用杀虫剂后,人工生草区数量最高,为 (1.16 ± 0.51) 头·枝⁻¹,是自然生草区的1.21倍,清耕区的3.31倍,3个区之间均差异显著($p < 0.05$),之后龟纹瓢虫数量达到第二个高峰,人工生草区恢复速度最快,清耕区恢复速度最慢。至8月下旬第三个高峰期前,人工生草区和自然生草区仍然存在一定数量的龟纹瓢虫。异色瓢虫也有三个发生高峰,第三个发生高峰数量最多。在第一个发生高峰时,3种生草模式异色瓢虫发生数量分别为清耕区 (0.85 ± 0.02) 头·枝⁻¹,自然生草区为 (0.77 ± 0.03) 头·枝⁻¹,人工生草区为 (0.83 ± 0.02) 头·枝⁻¹,3个区数量差异均不显著($p > 0.05$)。在第三个高峰,人工生草区最多,为 (1.11 ± 0.12) 头·枝⁻¹,自然生草区与清耕区数量接近且差异不显著($p > 0.05$),分别为 (0.75 ± 0.05) 头·枝⁻¹和 (0.81 ± 0.06) 头·枝⁻¹(图2-A、图3-A)。

草内龟纹瓢虫较异色瓢虫仍为优势,人工生草

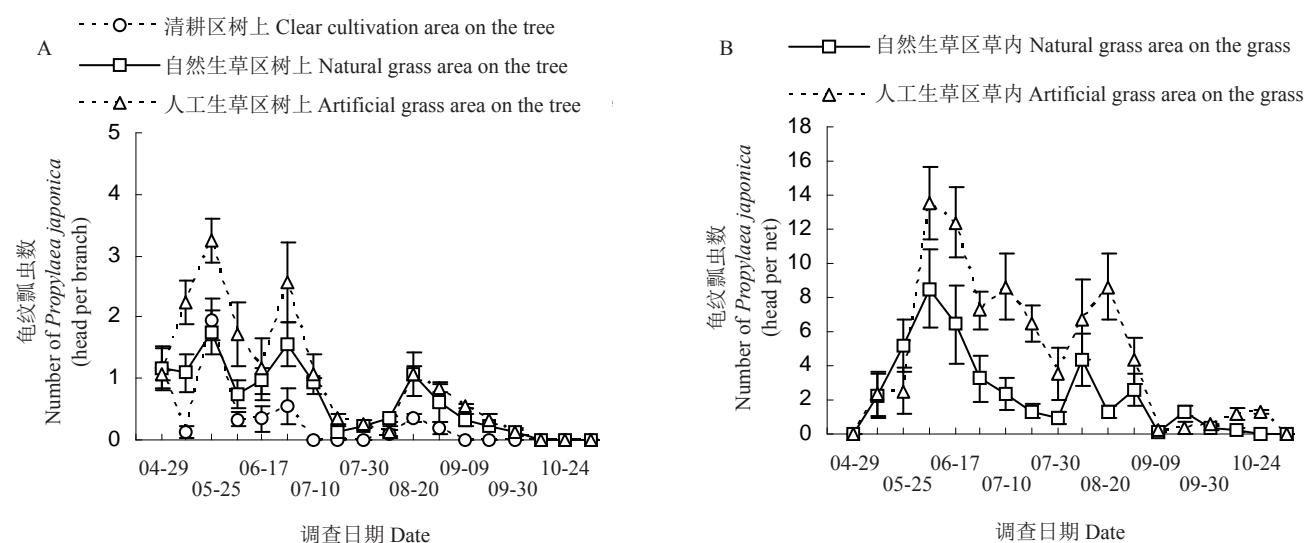


图2 不同生草模式对梨园龟纹瓢虫发生动态的影响

Fig. 2 Dynamics effects of *Propylaea japonica* in pear orchards with different grassing patterns

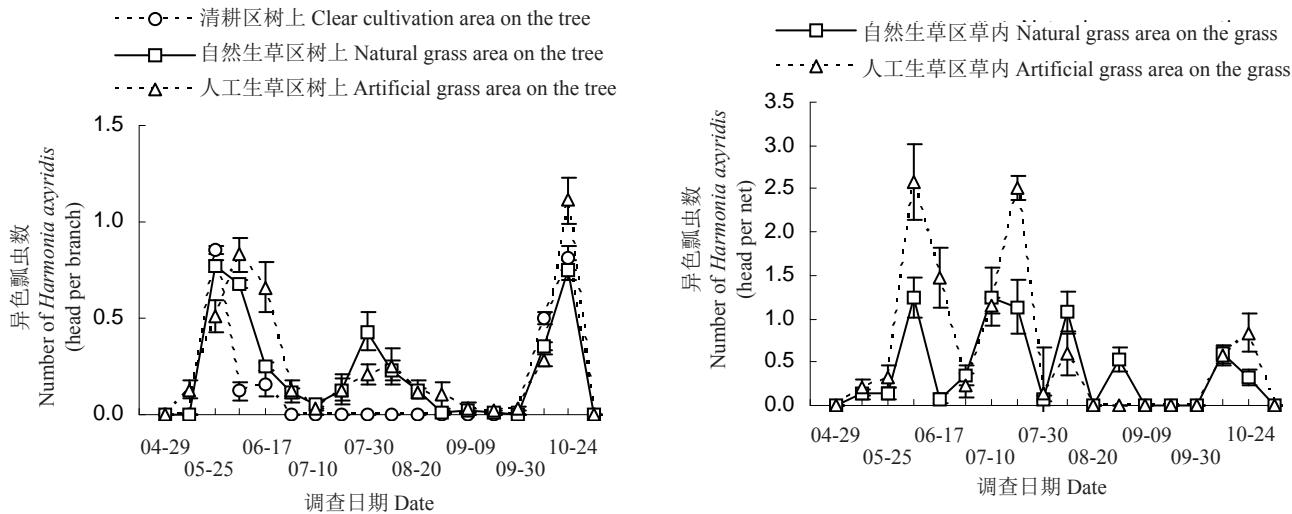


图3 不同生草模式对梨园异色瓢虫发生动态的影响

Fig. 3 Dynamics effects of *Harmonia axyridis* in pear orchards with different grassing patterns

区多于自然生草区。龟纹瓢虫6月之后的发生高峰与树上相同,而6月上旬的发生高峰略延迟,推测因6月5日使用杀虫剂且随着蚜虫数量的下降,部分龟纹瓢虫转移到草内栖息、觅食。人工生草区龟纹瓢虫全年均值为 (5.10 ± 4.33) 头·网 $^{-1}$,自然生草区为 (2.27 ± 2.32) 头·网 $^{-1}$,二者差异显著($p=0.035$);人工生草区异色瓢虫全年平均数量为 (0.59 ± 0.20) 头·网 $^{-1}$,自然生草区为 (0.38 ± 0.47) 头·网 $^{-1}$,二者差异显著($p=0.029$):因此龟纹瓢虫和异色瓢虫人工生草内的全年平均数量均高于自然生草区(图2-B、图3-B)。

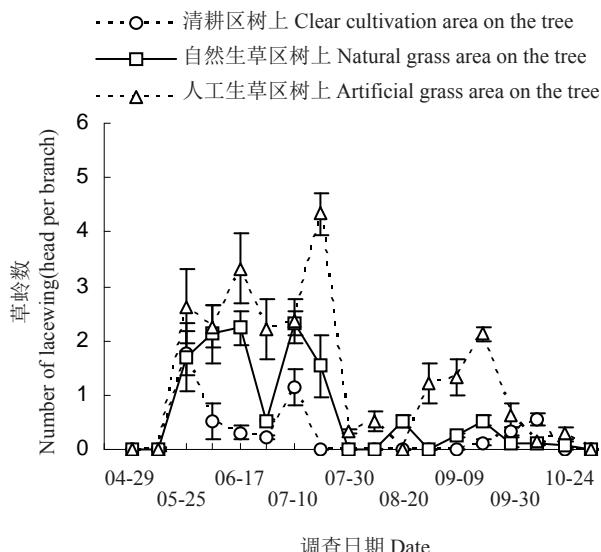
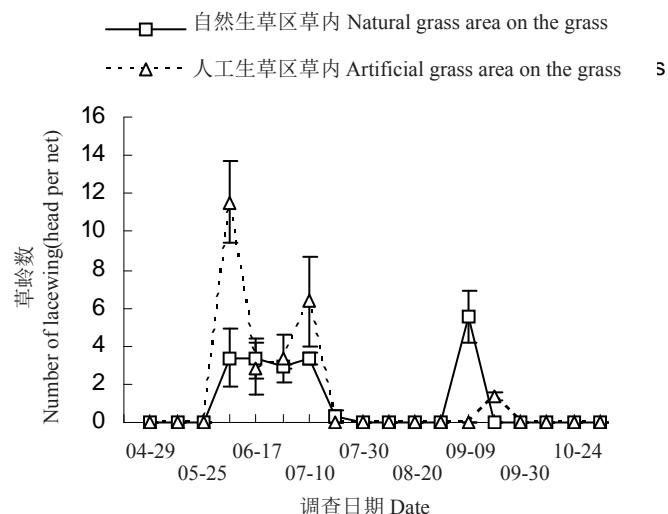


图4 不同生草模式对梨园草蛉发生动态的影响

Fig.4 Dynamics effects of lacewing in pear orchards with different grassing patterns

2.4 不同生草模式对梨园草蛉种群动态的影响

人工生草区树上草蛉在6月上旬、7月中旬、9月中旬3个发生高峰均高于清耕区和自然生草区,使用杀虫剂后在6月27日的低谷人工生草区仍为最多,清耕区仍为最低。9月下旬,自然生草区和清耕区树上草蛉数量较少,平均分别为 (0.53 ± 0.08) 头·枝 $^{-1}$ 和 (0.12 ± 0.05) 头·枝 $^{-1}$,而人工生草区又出现一个高峰且数量较多,为 (2.12 ± 0.13) 头·枝 $^{-1}$,3个区之间差异显著($p<0.05$)(图4-A)。人工生草区草蛉草内的种群数量全年均值差异不显著($p>0.05$)(图4-B)。



2.5 不同生草模式对梨园食蚜蝇种群动态的影响

人工生草区和自然生草区食蚜蝇种群数量较多,而清耕区数量很少。人工生草区有两个发生高峰,而自然生草区和清耕区只有一个。在第一个高峰,人工生草区树上的食蚜蝇为 (0.50 ± 0.08) 头·枝 $^{-1}$,自然生草区为 (0.33 ± 0.12) 头·枝 $^{-1}$,清耕区为 (0.16 ± 0.08) 头·枝 $^{-1}$,3个区之间均差异显著($p < 0.05$)。

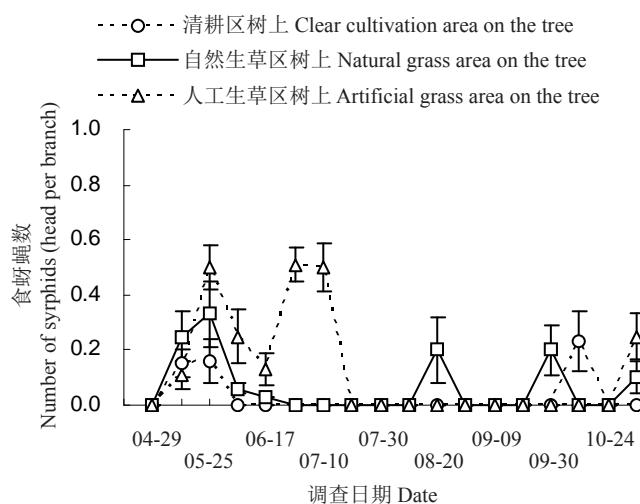


图5 不同生草模式对梨园食蚜蝇发生动态的影响

Fig. 5 Dynamics effects of syrphids in pear orchards with different grassing patterns

2.6 不同生草模式对梨园寄生蜂种群动态的影响

3种生草模式梨园中,人工生草区树上寄生蜂整体数量最多,自然生草区与清耕区较为接近。在5月下旬高峰期,人工生草区的寄生蜂数量为 (22.20 ± 1.30) 头·板 $^{-1}$,为自然生草区的1.51倍,清耕

0.05)。6月下旬至7月下旬,人工生草区树上仍存在一定量的食蚜蝇,平均为 (0.50 ± 0.12) 头·枝 $^{-1}$,而自然生草区及清耕区没有食蚜蝇种群存在(图5-A)。在6月上旬及10月上旬两个高峰时,人工生草区草内食蚜蝇的种群数量均高于自然生草区,分别为3.5倍和0.15倍,全年均值差异显著($p = 0.031$)(图5-B)。

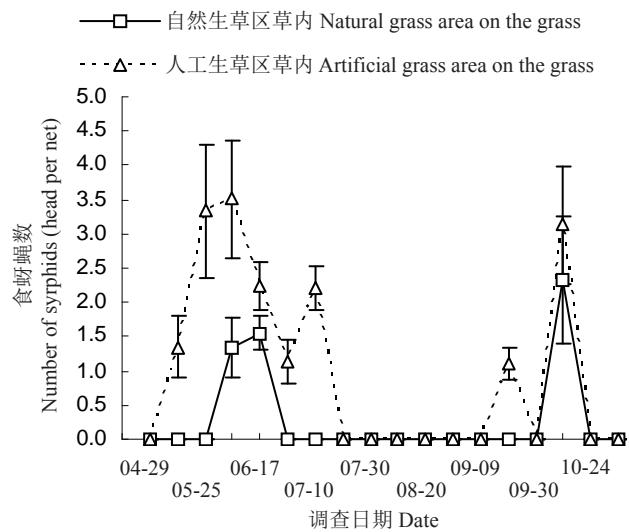


图5 不同生草模式对梨园食蚜蝇发生动态的影响

Fig. 5 Dynamics effects of syrphids in pear orchards with different grassing patterns

区的1.78倍,人工生草区与自然生草区和清耕区差异均显著($p < 0.05$)(图6-A)。在6月上旬高峰期,人工生草区草内的寄生蜂数量最多,为 (35.33 ± 3.86) 头·板 $^{-1}$,自然生草区为 (11.35 ± 2.43) 头·板 $^{-1}$,差异显著($p = 0.026$)(图6-B)。

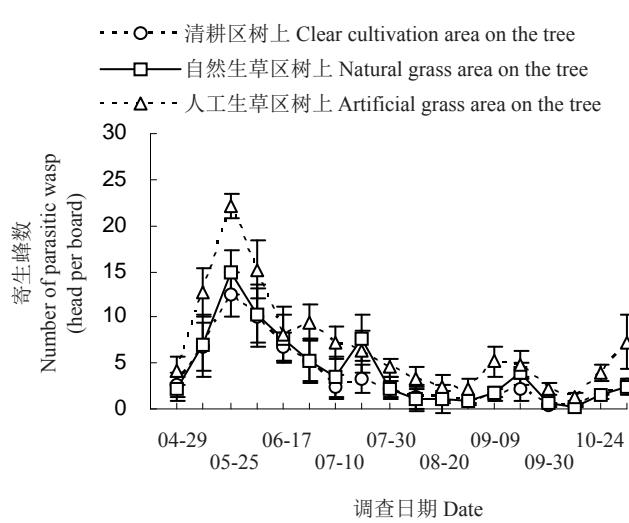
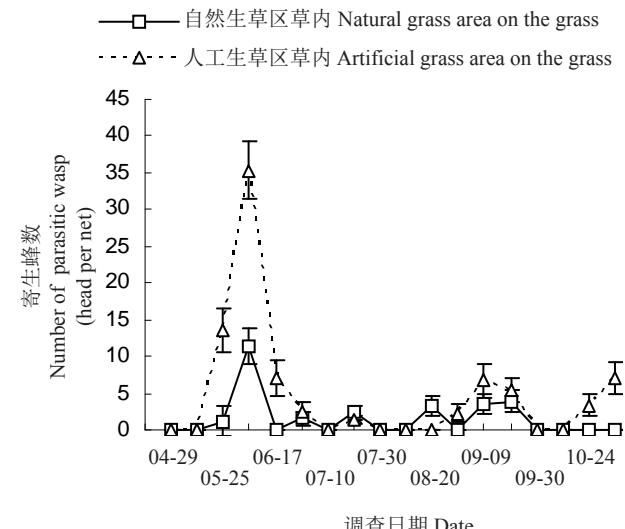


图6 不同生草模式对梨园寄生蜂发生动态的影响

Fig. 6 Dynamics effects of parasitic wasps in pear orchards with different grass patterns



2.7 主要害虫及天敌动态的相关性分析

3种生草模式梨园龟纹瓢虫和寄生蜂与蚜虫都呈显著正相关,龟纹瓢虫清耕区决定系数最高,寄生蜂人工生草区决定系数最高。清耕区的中华通草蛉与蚜虫具有显著正相关性。人工生草区异色瓢虫、寄生蜂和自然生草区寄生蜂与梨木虱具有显著相关性,异色瓢虫为正相关,而寄生蜂与梨木虱为负相关。

表3 不同生草模式梨园主要害虫天敌相关性分析

Table 3 Correlation analysis of natural enemies of main pests in pear orchards with different grassing patterns

类别 Category	生草模式 Grass pattern	龟纹瓢虫 <i>Propylaea japonica</i>	异色瓢虫 <i>Harmonia axyridis</i>	草蛉 Lacewing	食蚜蝇 Syrphids	寄生蜂 Parasitic wasps
蚜虫 Aphids	清耕 Clear cultivation	0.786*	0.358	0.491*	0.214	0.511*
	自然生草 Natural grass	0.509*	0.458	0.213	0.286	0.579*
	人工生草 Artificial grass	0.563*	0.242	0.115	0.279	0.674*
梨木虱 <i>Psylla chinensis</i>	清耕 Clear cultivation	-0.264	0.335	-0.306	-0.194	-0.373
	自然生草 Natural grass	-0.376	0.214	-0.397	-0.155	-0.526*
	人工生草 Artificial grass	-0.326	0.491*	-0.316	-0.253	-0.531*
草内天敌 Natural enemies in the grass	自然生草 Natural grass	0.484*	0.205	0.498*	-0.195	0.628*
	人工生草 Artificial grass	0.642*	0.493*	0.597*	0.413*	0.617*

注:表中数字为树上天敌的种群动态与害虫及草内自身的种群动态相关性分析的决定系数,标注*为相关性显著($p < 0.05$)。

Note: The numbers in the table are the determination coefficients of the correlation analysis between the population dynamics of natural enemies on the tree and the population dynamics of pests and natural enemies in the grass, marked with * for significant correlation ($p < 0.05$).

2.8 不同生草模式对梨园树上主要害虫及树上天敌时间生态位的影响

3种生草模式中,梨园害虫清耕区时间生态位最大,人工生草区及自然生草区较小(表4)。人工

生草区天敌的时间生态位明显大于自然生草区及清耕区,其中食蚜蝇差距最明显,人工生草区时间生态位较高,为0.359,清耕区及自然生草区分别为0.106和0.130。3种生草模式梨园蚜虫与天敌时间生态位

表4 不同生草模式对梨园主要害虫和天敌时间生态位的影响

Table 4 Temporal niche of main pests and natural enemies in pear orchards with different grass-planting patterns

种类 Category	生草模式 Grass pattern	瓢虫 Ladybug	草蛉 Lacewing	食蚜蝇 Syrphids	寄生蜂 Parasitic wasps	蚜虫 Aphids	梨木虱 <i>Psylla chinensis</i>
瓢虫 Ladybug	清耕 Clear cultivation	0.287	0.645	0.207	0.745	0.835	0.639
	自然生草 Natural grass	0.560	0.699	0.240	0.872	0.639	0.731
	人工生草 Artificial grass	0.596	0.763	0.639	0.874	0.805	0.751
草蛉 Lacewing	清耕 Clear cultivation	0.752	0.256	0.227	0.668	0.505	0.470
	自然生草 Natural grass	0.674	0.395	0.382	0.813	0.463	0.516
	人工生草 Artificial grass	0.677	0.505	0.757	0.714	0.617	0.796
食蚜蝇 Syrphids	清耕 Clear cultivation	0.130	0.186	0.106	0.206	0.074	0.201
	自然生草 Natural grass	0.434	0.330	0.130	0.601	0.601	0.178
	人工生草 Artificial grass	0.691	0.779	0.359	0.677	0.611	0.496
寄生蜂 Parasitic wasps	清耕 Clear cultivation	0.723	0.677	0.142	0.515	0.763	0.751
	自然生草 Natural grass	0.864	0.800	0.579	0.530	0.719	0.666
	人工生草 Artificial grass	0.722	0.497	0.518	0.625	0.858	0.767
蚜虫 Aphids	清耕 Clear cultivation	0.861	0.640	0.030	0.732	0.370	0.741
	自然生草 Natural grass	0.738	0.486	0.663	0.713	0.313	0.630
	人工生草 Artificial grass	0.739	0.484	0.559	0.734	0.305	0.672
梨木虱 <i>Psylla chinensis</i>	清耕 Clear cultivation	0.395	0.271	0.162	0.491	0.526	0.762
	自然生草 Natural grass	0.552	0.317	0.090	0.379	0.374	0.655
	人工生草 Artificial grass	0.611	0.429	0.342	0.557	0.366	0.635

注:对角线上数字加粗的为时间生态位,对角线以上为时间生态位重叠,对角线以下为时间生态位相似性。

Note: The bold numbers on the diagonal are the temporal niche, the diagonals above are the temporal niche overlaps, and the diagonals below are the temporal niche similarity.

重叠最大的均是瓢虫和寄生蜂,蚜虫与瓢虫时间生态位重叠清耕区最大,为0.835,其次为人工生草区(0.805),自然生草区最小(0.639),蚜虫与寄生蜂、草蛉、食蚜蝇生态位重叠最大的均是人工生草区。梨木虱与瓢虫、草蛉和寄生蜂生态位重叠较大,而食蚜蝇较小,且人工生草区2种害虫与4种天敌时间生态位重叠均为最大。天敌之间生态位重叠值中瓢虫与寄生蜂最大,食蚜蝇与瓢虫最小,3种生草模式梨园天敌之间时间生态位重叠清耕区均为最小,其中食蚜蝇与瓢虫、食蚜蝇与草蛉和食蚜蝇与寄生蜂清耕区生态位重叠与人工生草区的生态位重叠差值最大。

三种生草模式梨园蚜虫与天敌生态位相似性中最大的也为瓢虫和寄生蜂,而蚜虫与瓢虫及草蛉时间生态位相似性均为清耕区最大。人工生草区梨木虱与4类天敌生态位相似性均为最大。食蚜蝇与其他3种天敌之间生态位相似性清耕区与人工生草区的差值也最大。

3 讨 论

人工生草可以改变农业生态系统的生态环境,增加天敌数量,丰富群落多样性^[10]。果园种植开花植物可以吸引天敌,为其提供蜜源和食物,拥有更适宜的生态环境,天敌种类和数量均会增加^[11-13]。4—6月为长柔毛野豌豆开花期,调查发现此时人工生草区草内天敌数量多于自然生草,尤其是黑带食蚜蝇和中华通草蛉,草内天敌数量的增多与树上天敌增多之间存在密切关系,部分天敌可以在人工生草内较好地越夏。梨园使用杀虫剂不仅杀死大多数梨园害虫,还会影响梨园主要天敌的种群数量,果园生草可为天敌提供栖息地,从而躲避和减轻杀虫剂对天敌的影响^[14-16]。对梨园主要害虫天敌的动态分析表明,杀虫剂不仅会对天敌造成直接杀伤作用,由于害虫数量迅速减少,天敌食物短缺,会进一步降低天敌的种群数量。在使用杀虫剂后人工生草区天敌的下降幅度最小,且后期恢复速度较快,而清耕区害虫会出现第二个高峰。此外,人工生草区害虫的高峰期数量均低于清耕区和自然生草区。因此,人工生草可以提供适宜的栖息环境和食物,减轻杀虫剂对梨园天敌的影响,发挥天敌稳定控制害虫的能力。

梨园生草可以改变果园的群落结构特征^[17-18]和时序分布^[19],笔者发现果园种植生草改变了梨园害

虫与天敌之间的相关性,果园生草减少了龟纹瓢虫、异色瓢虫和中华通草蛉对蚜虫的依赖,但生草区由于有较多开花植物的存在,显著增强了寄生蜂对害虫的相关性。人工生草区提高了异色瓢虫对梨木虱的相关性,当越冬代梨木虱出现时,人工生草区较多数量的异色瓢虫可以有效控制其发生。果园人工生草显著降低了害虫的时间生态位,并提高了天敌的时间生态位,并且害虫与天敌之间的生态位重叠指数和生态位相似性指数增大。根据相关性分析及时问生态位,人工生草区改变了天敌与害虫之间的相关性和时序特征,减少了天敌对个别害虫资源的依赖性,提高了天敌种群的稳定性。

4 结 论

不同生草模式显著影响梨园害虫和天敌的发生动态和时序特征,种植长柔毛野豌豆可以为天敌提供更优良的额外栖息、觅食环境,有利于梨园自然天敌种群的稳定,从而发挥其持续控制害虫的能力,减少害虫对梨树的危害。

参考文献 References:

- [1] 侯启昌.黄河故道地区梨园生草栽培的生态效应[J].果树学报,2009,26(5):739-743.
HOU Qichang. Study on the ecological effects of inter-planting herbage in pear orchards in the old flooded area of Yellow River [J]. Journal of Fruit Science, 2009, 26(5): 739-743.
- [2] 龙兴洲,李晓光,高颖,冯辉,郝丽贤,宋彦涛.人工种植光叶紫花苕子对柿园生态环境效应的影响[J].农业科技通讯,2018(9):149-151.
LONG Xingzhou, LI Xiaoguang, GAO Ying, FENG Hui, HAO Lixian, SONG Yantao. The effect of artificial planting light-leaved purple vetch on the eco-environmental effect of persimmon garden [J]. Bulletin of Agricultural Science and Technology, 2018(9): 149-151.
- [3] 陈学森,张瑞洁,王艳廷,王楠,姜生辉,许海峰,刘静轩,王得云,曲常志,张艳敏,姜远茂,毛志泉.苹果园种植长柔毛野豌豆结合自然生草对土壤综合肥力的影响[J].园艺学报,2016,43(12): 2325-2334.
CHEN Xuesen, ZHANG Ruijie, WANG Yanting, WANG Nan, JIANG Shenghui, XU Haifeng, LIU Jingxuan, WANG Deyun, QU Changzhi, ZHANG Yanmin, JIANG Yuanmao, MAO Zhi-quan. Effects of growing hairy vetch (*Vicia villosa*) on the soil nutrient, enzyme activities and microorganisms in apple orchard [J]. Acta Horticulturae Sinica, 2016, 43(12): 2325-2334.
- [4] 刘奇志,张丽娟,杜小引,李振茹,亓丽萍,谢娜,梁林琳.梨园地被植物与天敌的种类及其数量关系[J].中国农学通报,2010,26(12):209-215.

- LIU Qizhi, ZHANG Lijuan, DU Xiaoyin, LI Zhenru, QI Liping, XIE Na, LIANG Linlin. The Relationship between groundcover plants and natural enemies of species and quantity in a pear orchard[J]. Chinese Agricultural Science Bulletin, 2010, 26(12): 209-215.
- [5] 胡竞辉,王美超,孔云,姚允聪,魏巍,宋备舟,李振茹.梨园芳香植物间作区节肢动物群落多样性时序特征[J].中国农业科学,2010,43(5):1007-1016.
- HU Jinghui, WANG Meichao, KONG Yun, YAO Yuncong, WEI Wei, SONG Beizhou, LI Zhenru. Temporal structures of arthropod community of intercropping aromatic plants in pear orchard [J]. Scientia Agricultura Sinica, 2010, 43(5): 1007-1016.
- [6] 胡竞辉,王美超,孔云,姚允聪,魏巍,宋备舟,李振茹.梨园芳香植物间作区节肢动物群落时序格局[J].生态学报,2010,30(17): 4578-4589.
- HU Jinghui, WANG Meichao, KONG Yun, YAO Yuncong, WEI Wei, SONG Beizhou, LI Zhenru. The dynamic response of arthropod community diversity to the treatments of intercropping aromatic plants in pear orchard [J]. Acta Ecologica Sinica, 2010, 30(17): 4578-4589.
- [7] 宋备舟,王美超,孔云,姚允聪,吴红英,胡竞辉,亓丽萍,毕宁宁.梨园芳香植物间作区节肢动物群落的结构特征[J].中国农业科学,2010,43(4):769-779.
- SONG Beizhou, WANG Meichao, KONG Yun, YAO Yuncong, WU Hongying, HU Jinghui, QI Liping, BI Ningning. The structure characteristics of arthropod community in plots of pear orchard intercropped with different aromatic plants [J]. Scientia Agricultura Sinica, 2010, 43(4): 769-779.
- [8] 宋备舟,王美超,孔云,姚允聪,吴红英,李振茹.梨园芳香植物间作区主要害虫及其天敌的相互关系[J].中国农业科学,2010,43(17): 3590-3601.
- SONG Beizhou, WANG Meichao, KONG Yun, YAO Yuncong, WU Hongying, LI Zhenru. Interaction of the dominant pests and natural enemies in the experimental plots of the intercropping aromatic plants in pear orchard [J]. Scientia Agricultura Sinica, 2010, 43(17): 3590-3601.
- [9] 李晓光,龙兴洲,高颖,冯辉,郭建洲,贾新敏.行间种植长柔毛野豌豆对苹果园生态环境的影响[J].中国果树,2018(6): 24-26.
- LI Xiaoguang, LONG Xingzhou, GAO Ying, FENG Hui, GUO Jianzhou, JIA Xinmin. Effects of planting *Vicia villosa* between rows on the ecological environment of apple orchard [J]. China Fruits, 2018(6): 24-26.
- [10] GONTIJO L M. Engineering natural enemy shelters to enhance conservation biological control in field crops[J]. Biological Control, 2018, 130(77): 155-163.
- [11] GURR G M, WRATTEN S D, LANDIS D A, YOU M S. Habitat management to suppress pest populations: Progress and prospects [J]. Annual Review of Entomology, 2017, 62(1): 91-109.
- [12] 宫永铭,鲁志宏,杨玉霞,张海滨,周瑞军.苹果园生草对病虫害及天敌消长的影响(初报)[J].落叶果树,2004,36(6):31-32.
- GONG Yongming, LU Zhihong, YANG Yuxia, ZHANG Haibin, ZHOU Ruijun. The effect of grass in apple orchards on diseases and insect pests and the growth and decline of natural enemies (preliminary report) [J]. Deciduous Fruits, 2004, 36(6): 31-32.
- [13] 赵雪晴,谌爱东,李向永,赵高慧,龚声信.生草对苹果主要害虫与天敌种群发生的影响[J].中国生物防治学报,2011,27(4):470-478.
- ZHAO Xueqing, CHEN Aidong, LI Xiangyong, ZHAO Gaohui, GONG Shengxin. Effect of cover crops on populations of insect pests and natural enemies in apple orchards [J]. Chinese Journal of Biological Control, 2011, 27(4): 470-478.
- [14] 张硕,陈鹏,刘锦,王晓,李东超,迟宝杰,刘永杰.使用农药对生草苹果园主要害虫及其天敌的影响[J].山东农业科学,2019,51(2):91-96.
- ZHANG Shuo, CHEN Peng, LIU Jin, WANG Xiao, LI Dongchao, CHI Baojie, LIU Yongjie. Effects of pesticides on main pests and natural enemies in grass grown apple orchard [J]. Shandong Agricultural Sciences, 2019, 51(2): 91-96.
- [15] 肖达,郭晓军,王甦,张君明,张帆.三种杀虫剂对几种昆虫天敌的毒力测定[J].环境昆虫学报,2014,36(6):951-958.
- XIAO Da, GUO Xiaojun, WANG Su, ZHANG Junming, ZHANG Fan. The toxicity of three insecticides to natural enemy [J]. Journal of Environmental Entomology, 2014, 36(6): 951-958.
- [16] 王晓,陈鹏,张硕,李振斌,王凡,刘锦,刘永杰.12种杀虫剂对日本通草蛉不同虫态的毒力及安全性评价[J].植物保护,2019,45(2):211-217.
- WANG Xiao, CHEN Peng, ZHANG Shuo, LI Zhenbin, WANG Fan, LIU Jin, LIU Yongjie. Toxicity and safety evaluation of 12 insecticides against *Chrysoperla nipponensis* (Okamoto) [J]. Plant Protection, 2019, 45(2): 211-217.
- [17] 伊兴凯,高正辉,徐义流,陈加红.梨园生草对果树部分害虫天敌的影响[J].中国农学通报,2010,26(13):289-293.
- YI Xingkai, GAO Zhenghui, XU Yiliu, CHEN Jiahong. Effect of interplanting of herbage on the natural enemies of fruit tree in pear orchard [J]. Chinese Agricultural Science Bulletin, 2010, 26(13): 289-293.
- [18] 张学昌,安钊,郭艳艳,冯艳杰,石旺鹏.不同害虫管理措施梨园的天敌群落多样性[J].中国生物防治学报,2014,30(2): 188-193.
- ZHANG Xuechang, AN Zhao, GUO Yanyan, FENG Yanjie, SHI Wangpeng. Biodiversity of natural enemies in pear orchards as affected by pest management methods[J]. Chinese Journal of Biological Control, 2014, 30(2): 188-193.
- [19] ALIGNIER A, RAYMOND L, DECONCHAT M, MENOZZI P, MONTEIL C, SARTHOU J P, VIALATTE A, OUIN A. The effect of semi-natural habitats on aphids and their natural enemies across spatial and temporal scales [J]. Biological Control, 2014, 77(5):76-82.