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水杨酸甲酯缓释调控果园捕食性瓢虫控害效果

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摘　要：【目的】利用化学信息素调控天敌昆虫是害虫绿色防控的重要措施之一。明确应用新型缓释材料释放水杨酸甲酯对苹果园捕食性瓢虫的调控作用，以及对苹果绣线菊蚜的防治效果。**【方法】**连续2 a（年）调查了苹果园内苹果绣线菊蚜的种群消长动态以确定水杨酸甲酯的使用时间，处理区采用5×5的布局均匀悬挂水杨酸甲酯PE缓释管防治绣线菊蚜，分别以未做任何防治的果园和化学防治的果园为对照，调查捕食性瓢虫及苹果绣线菊蚜种群发生动态以及检测水杨酸甲酯缓释速率，并使用5种常用聚集度指标参数法分析水杨酸甲酯对捕食性瓢虫及苹果绣线菊蚜空间分布特征的影响。**【结果】**北京地区苹果园苹果绣线菊蚜的发生高峰期在5月底至6月中旬，在发生高峰期前1周悬挂水杨酸甲酯PE缓释管，处理区内捕食性瓢虫数量显著高于化学防治区，并且显著降低了苹果绣线菊蚜的发生数量；空间分布结果显示苹果绣线菊蚜在各苹果园区内均表现出边缘型聚集分布的特征。此外，研究结果也表明水杨酸甲酯PE缓释管的释放速率约为0.68 g·周$^{-1}$。**【结论】**水杨酸甲酯PE缓释管在果园持效期可超过4周，可以提高捕食性瓢虫的种群数量并降低苹果绣线菊蚜的发生数量，最高密度的苹果绣线菊蚜出现在水杨酸甲酯PE缓释管处理园区的边缘。

关键词：苹果绣线菊蚜；捕食性瓢虫；水杨酸甲酯；调控作用；空间分布

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Evaluation of the biocontrol capacity of slow-release methyl salicylate by mediating abundance of predatory ladybirds in orchards

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Abstract:【Objective】Utilizing semiochemicals to mannipulite the foraging behaviors of natural enemy is avital measure to control pests. As a synergistic means, semiochemical solw-release is gradually popularized and applied in biological control management in the modern agricultural green protection system. Methyl salicylate (MeSA), is a kind of semiochemical, which is widerly released in the crops infected by herbivorous insects, and it can also attract ladybirds and other natural enemies from a long distance. As an effective compound, the MeSA is commonly used as an attractant for predatory ladybirds. The study aimed to clarify the regulation effect of the MeSA released by new sustained-release materials on predatory ladybirds and the control effect on the aphid, *Aphis citricola* in apple orchards. Compared with traditional pesticides, slow-releasing semiochemicals are efficient, non-toxic, non-resistant and harmless to the natural enemies. The slow releasing material is the major factor that affects the pest control effienicy of semiochemical in the field. At present, the main slow-releasing materials include gels, photosensitive compounds and lures, and some products have been commercialized. In our present

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work, we selected a commercial slow-release lures material, PE tubes, to test its stabilization for long-term slow-release, and whether it can maximize the effect of the MeSA on attracting the natural enemies to control the aphids.【Methods】We consecutively investigated the population dynamics of *A. citricola* in the apple orchards for two years to determine the use time of the MeSA. In the treatment area, the slow-releasing MeSA PE tubes were suspended evenly in 5 × 5 design. While the orchards without pest control and the orchards with chemical control were used as controls. The population dynamics of the predatory ladybirds and *A. citricola* were investigated and detected for the release rate of the MeSA. And the effects of the MeSA on the spatial distribution characteristics of the predatory ladybirds and *A. citricola* were analyzed by five commonly used aggregation index parameters. For ensuring the field application time of the MeSA PE tubes, a five points method was used to investigate the occurrence dynamics of the *A. citricola* and natural enemis in the orchard from May to July in 2020 and 2021. Two fruit trees were selected at each point, each tree had two branches fixed in five directions: east, south, west, north and middle, in an orchard in Changping District, Beijing (116°02′ E, 40°10′ N). The number of the *A. citricola* and predatory ladybird were investigated once a week. For investigating the effects of the slow-releasing MeSA on the dynamics and spatial distribution of the predatory ladybird and *A. citricola,* three apple orchards were selected as methyl salicylate slow-release area, chemical pesticide area and blank control area in 2022. The orchard with MeSA PE tubes; the orchard with imidacloprid insecticides; the orchard without chemical insecticide and the Methyl salicylate PE tubes were used as control. In each orchard, 25 fruit trees were investigated, the number of the *A. citricola* and predatory ladybird were investigated once a week. The slow releasing rate of the MeSA PE tubes in the field was monitored. The temperature was automatically recorded every two hours, and the weights of the PE tubes weighed every week. The release of the MeSA PE tubes at the initial stage and 5 weeks after the field test was detected, respectively. The 100 μm PDMS extraction head was inserted into the sampling bag containing the MeSA PE tubes to extract for 30 min, and then GC-MS detection was performed. The data were processed by the statistical software SPSS 23 and Excel. The investigation results of the *A. citricola* and predatory ladybirds were used to caculate the aggregation index and spatial correlation analysis.【Results】The occurrence peak of the *A. citricola* in the apple orchards was found from the end of May to mid-June. The number of predatory ladybirds in the treatment area was significantly higher than that in the chemical control area, and the number of the *A. citricola* was significantly reduced by applying the slow-releasing MeSA PE tubes one week before the occurrence peak. The spatial distribution showed that the *A. citricola* was in marginal aggregation distribution in each apple orchard. In addition, the release rate of the slow-releasing MeSA PE tubes was about 0.68 g per week. The results for two consecutive years in the apple orchard showed that the large-scale occurrence or peak occurrence of the *A. citricola* and predatory ladybirds was found between the end of May and the middle of June, and the appropriate time point of setting the MeSA PE rubber was May 30. The release rate of the MeSA was about 0.68 g per week. After 5 weeks of application, the remained effective MeSA could still be detected by GC-MS. After two weeks of utilization of the MeSA PE tubes, the number of apple aphids began to decrease, in the third week, the number of predatory ladybirds were significantly higher than theose of the others treatment areas. The aggregation index analysis result of the *A. citricola* showed that the aphids were clustered in the treatment area and control area. The spatial correlation analysis result of the predatory ladybirds and *A. citricola* showed the much higher distribution density of the ladybirds in the MeSA PE tube treatment area, the much lower occurrence density of the *A. citricola* than those in the others areas, and the marginal distribution pattern was more obviously.【Conclusion】The slow-releasing MeSA PE tubes could last for more than 4 weeks in the orchard, and increase the population of the predatory ladybirds to reduce the density of the *A. citricola* in the apple orchard. The application of slow-releasing MeSA PE tubes resulted in the highest density of the *A. citricola* on the edge in the apple orchard. The pest control effectness on the *A. citricola* was formed by regulating the spatial density of the predatory ladybirds, leading to the number reduction and the marginalization distribution range of the *A. citricola*. The application of green prevention and control technologies, such as semiochemicals slow-releasing technology, would reduce the population density or damage degree of the pests and increase the number of the natural enemies. The MeSA PE tube treatment had the equivalent control effect as imidacloprid treatment on the *A. citricola*, and more predatory ladybirds were attracted and conserved, which is conducive to improving the ecological stability of the orchard. Considering the slow release and storage capacity of materials, as well as the requirements for temperature, humidity and other external conditions, our results confirmed that PE tubes could be suitablly used as slow-releasing carriers of the MeSA, with long-term, economic and excellent control effects in the orchards in northern China. In addition, we also discussed the impact of the MeSA on the distribution of the pests and natural enemies, which would enrich the theoretical basis for the field application of semiochemicals and promote the application of related products. In our future work, we will expand the application area of the MeSA tubes and, test its release efficiency and control effect under different temperature and humidity environments, and also pay attention to the slow-releasing effect of PE tubes on other semiochemicals.

Key words: *Aphis citricola*; Predatory ladybirds; Methyl salicylate; Regulatory effect; Spatial distribution

苹果绣线菊蚜(*Aphis citricola*)属半翅目蚜科，是苹果生产期重要的害虫之一。目前主要的防治措施仍然是化学防治[1-2]，而化学防治导致害虫抗药性增强等问题，因此，研究者不断寻求其他控制害虫的方法。伴随果品安全质量的要求以及生态环境保护意识的提高，生物防治的应用范围逐渐扩大，生物防治技术也在有机生产管理中得到重视[3-5]，其中以化学信息素为关键组分的天敌引诱剂作为增效手段，在生物防治管理中逐渐推广应用。

化学信息素驱动害虫和天敌对周边环境做出可变的响应策略，从而调控害虫和天敌的分布[6-8]。而昆虫化学信息素的田间效果的最大影响因素在于其缓释技术，目前缓释技术的研究主要包括分子凝胶、光感应缓释和诱芯等，其中，诱芯、微胶囊与微球等产品已实现商业化[9]。水杨酸甲酯是许多植物自然释放的挥发性气味物质，并在诸多被害虫侵染的作物中大量释放，可以远距离吸引瓢虫等天敌[10-11]，常用作天敌引诱剂的有效成分[12-13]。但对水杨酸甲酯缓释材料的田间效果测评缺乏研究，也缺乏水杨酸甲酯调控害虫和天敌空间分布的研究。

地统计分析可以对害虫或天敌的空间分布模式进行推断，更直观有效地获得害虫和天敌的分布状态等重要信息[14]。明确害虫和天敌的种群消长动态和分布范围有助于后续进行害虫综合治理，优化管理措施，为害虫的有效防治提供理论依据[15-17]。

因此，笔者在本研究中首先调查了苹果园内苹果绣线菊蚜的种群消长动态以确定水杨酸甲酯的施用时间，使用5种常用聚集度指标参数法分析水杨酸甲酯处理对果园捕食性瓢虫及苹果绣线菊蚜空间分布的影响，明确水杨酸甲酯PE缓释管对苹果绣线菊蚜的防控效果。

1 材料和方法

1.1 供试材料

水杨酸甲酯PE缓释管以聚乙烯(PE)为外部缓释材料，内部填充5 g水杨酸甲酯(AR，99%)，委托南京新安中绿生物科技有限公司加工。化学药剂选用70%吡虫啉水分散粒剂(拜耳作物科学有限公司，市售)用于后续田间试验。

1.2 试验方法

1.2.1 水杨酸甲酯PE缓释管田间应用时间分析 为了明确水杨酸甲酯的果园使用时期，调查了苹果园苹果绣线菊蚜的种群消长动态并确定发生高峰期。2020和2021年5—7月，在北京市昌平区流村

镇（116°2′ E，40°10′ N）采用五点法调查苹果园内苹果绣线菊蚜以及捕食性瓢虫（主要为异色瓢虫和七星瓢虫）的种群消长动态。每点选取2株果树，每株树按照东、南、西、北、中5个方位，每个方位固定2个果枝，每周调查1次苹果绣线菊蚜及其捕食性瓢虫的数量。

1.2.2　*水杨酸甲酯PE缓释管对捕食性瓢虫及苹果绣线菊蚜种群消长动态和空间分布的影响*　2022年选取3个苹果园，分别作为水杨酸甲酯PE缓释管处理区、化学防治区和对照区，水杨酸甲酯PE缓释管处理区和空白对照区内树龄约为10 a（年），园区面积约1 hm^2，化学防治区内树龄约为8 a，园区面积约0.67 hm^2，主要品种为富士，种植密度约为900株•hm^{-2}，各园区之间间隔100 m以上。水杨酸甲酯PE缓释管处理区内按5列×5行网格法（约为3 m×4 m）均匀悬挂水杨酸甲酯PE缓释管，且园区内部保留自然生草；化学防治园区内喷施吡虫啉杀虫剂，按照4 g·666.7 m^{-2}兑水40 L进行喷雾施用；以未喷施化学杀虫剂和未悬挂水杨酸甲酯PE缓释管的果园为对照，对照区内保留自然生草，无其他防治蚜虫措施。在各园区内均匀采点并定株调查，把果园按5列×5行网格法排列，记录各点坐标，每个园区共调查25株果树，调查方法同1.2.1。

1.2.3　*水杨酸甲酯PE缓释管的田间缓释速率监测*　室外悬挂水杨酸甲酯PE缓释管和电子温度计，间隔2 h自动记录温度，每周称量记录水杨酸甲酯PE缓释管的质量。分别于悬挂初期和悬挂5周后检测水杨酸甲酯PE缓释管的释放情况，将100 μm PDMS萃取头插入装有水杨酸甲酯PE缓释管的采样袋中，顶空萃取30 min，然后进行GC−MS检测。载气为高纯氦气（纯度不小于99.99%），进样口温度250 ℃，不分流进样。程序升温：40 ℃保持3.5 min，以10 ℃·min^{-1}升至100 ℃，再以7 ℃·min^{-1}升至180 ℃，最后以25 ℃·min^{-1}升至280 ℃，保持5 min。

1.3　数据统计分析

试验所获数据由统计软件SPSS 23和Excel处理。以不同处理区作为处理因子，对2022年苹果绣线菊蚜和捕食性瓢虫发生量进行单因素方差分析，采用Duncan’s检验法比较不同处理间差异显著性（$p<0.05$）。

聚集度指数：采用以下5种常用的聚集度指标测定苹果绣线菊蚜和捕食性瓢虫的空间分布型，即聚块性指标（m^*/m）、扩散系数（C）、丛生指标（I）、Cassie指标（C_A）和负二项分布值（K指标），参考朱莹等[18]聚集度指标范围确定各特征值含义，其中，当$C<1$、$I<0$、$C_A<0$、$m^*/m<1$、$K<0$时为均匀分布；当$C=1$、$I=0$、$C_A=0$、$m^*/m=1$、$K\geq8$时为随机分布；当$C>1$、$I>0$、$C_A>0$、$m^*/m>1$、$0<K<8$时为聚集分布。

空间相关性：用SPSS 23统计软件进行正态分布检验。用GS+7.0软件对数据进行最适模型拟合。用ArcGis 10.2软件进行Kriging空间插值，得到苹果绣线菊蚜和捕食性瓢虫直观空间分布图。将调查期间内各样本点苹果绣线菊蚜的数量累加计算总和，在空间分析之前，首先对数据进行充分转换，使其近似于正态分布，调查数据进行对数$\lg(x+1)$正态转换，其中x是每个调查点苹果绣线菊蚜数量。通过半方差分析得到地统计参数，并确定调整后的最佳拟合模型，使用Kriging插值法结合地统计参数得到苹果绣线菊蚜和捕食性瓢虫的空间分布图。

2　结果与分析

2.1　水杨酸甲酯PE缓释管田间应用时间分析

2020和2021年苹果绣线菊蚜在5月23日之后开始快速增长，2020年苹果绣线菊蚜的发生数量在5月30日达到峰值，而2021年在6月13日达到峰值。2020和2021年捕食性瓢虫的发生数量分别在6月6日和6月20日达到峰值，之后逐渐减少。连续2 a调查结果显示，苹果园中苹果绣线菊蚜的大规模发生或峰值出现时间在5月底至6月中旬（图1），水杨酸甲酯PE缓释管的悬挂时间定在5月30日。

2.2　水杨酸甲酯PE缓释管对捕食性瓢虫及苹果绣线菊蚜种群消长动态和空间分布的影响

水杨酸甲酯PE缓释管悬挂7 d后，对不同园区进行调查，不同处理区内捕食性瓢虫和苹果绣线菊蚜的种群消长动态如图2所示。水杨酸甲酯PE缓释管处理区和对照区在整个试验期间捕食性瓢虫的发生数量均高于化学防治区，在悬挂第3周发现水杨酸甲酯PE缓释管处理区内捕食性瓢虫（4.1±0.7）的发生数量同时显著高于对照区（2.7±0.4）和化学防治区（0.3±0.2）（$F=16.044$，$p<0.001$）（图2-A）。悬挂水杨酸甲酯PE缓释管2周后，苹果绣线菊蚜的发生数量开始降低，水杨酸甲酯PE缓释管处理区

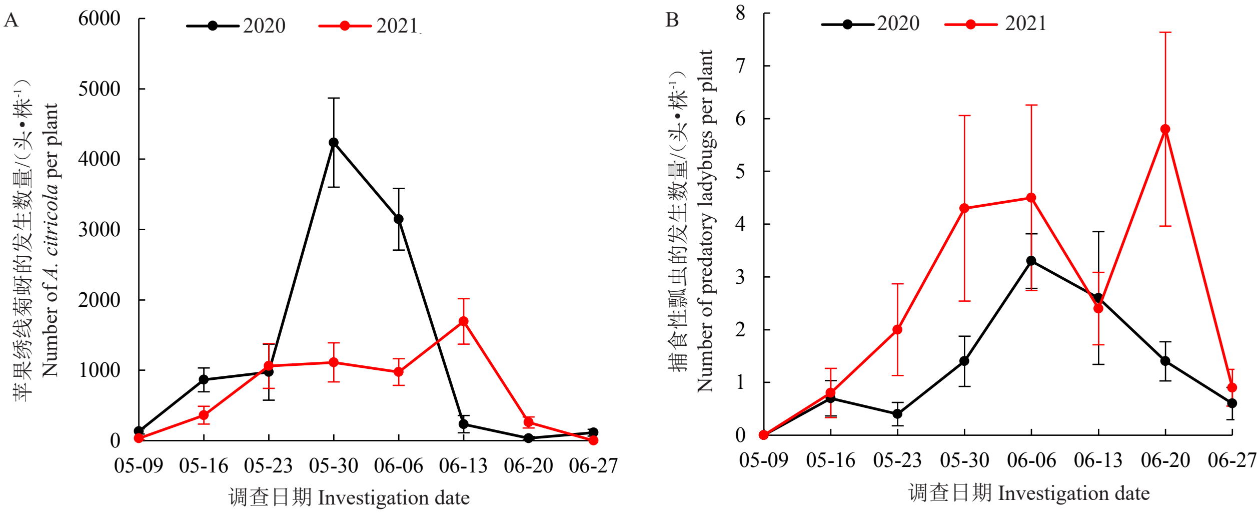
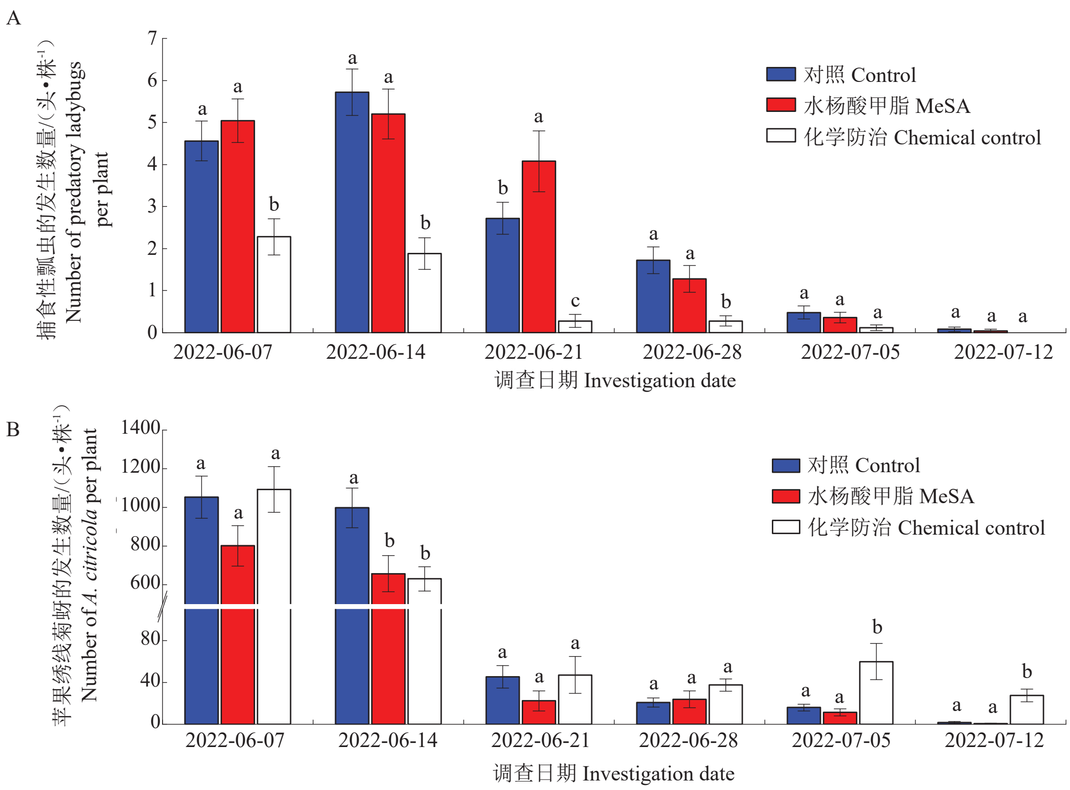


图1 2020、2021年苹果绣线菊蚜和捕食性瓢虫的种群消长动态

Fig. 1 Population dynamics of *A. citricola* and predatory ladybirds in 2020 and 2021



图中数据为(平均值±标准误),不同小写字母表示同一日期下不同处理之间的捕食性瓢虫(苹果绣线菊蚜)发生数量在0.05水平差异显著(Duncan's多重检验法)。

Data are (mean ± SE), and different lowercase letters indicate significant differences ($p<0.05$) in number of predatory ladybugs (*A. citricola*) under different treatments on the same date by Duncan's multiple range test.

图2 2022年不同处理区内捕食性瓢虫(A)和苹果绣线菊蚜(B)的种群消长动态

Fig. 2 Population dynamics of predatory ladybugs (A) and *A. citricola* (B) in different treatment areas in 2022

(657.0±93.8)内苹果绣线菊蚜的发生数量低于对照区(997.8±102.9),且与化学防治区(630.2±63.0)之间无显著差异(F=5.764,p=0.005),而4周后,化学防治区内苹果绣线菊蚜的发生数量显著高于其他区域(图2-B)。

在测定的聚集度指标数据中(表1),丛生指标I(290.87~598.02)>0,聚块性指标m^*/m(1.15~1.40)>1,Cassie指标C_A(0.15~0.40)>0,扩散系数C

表1 苹果绣线菊蚜的聚集度指标

Table 1 Aggregation index of *A. citricola*

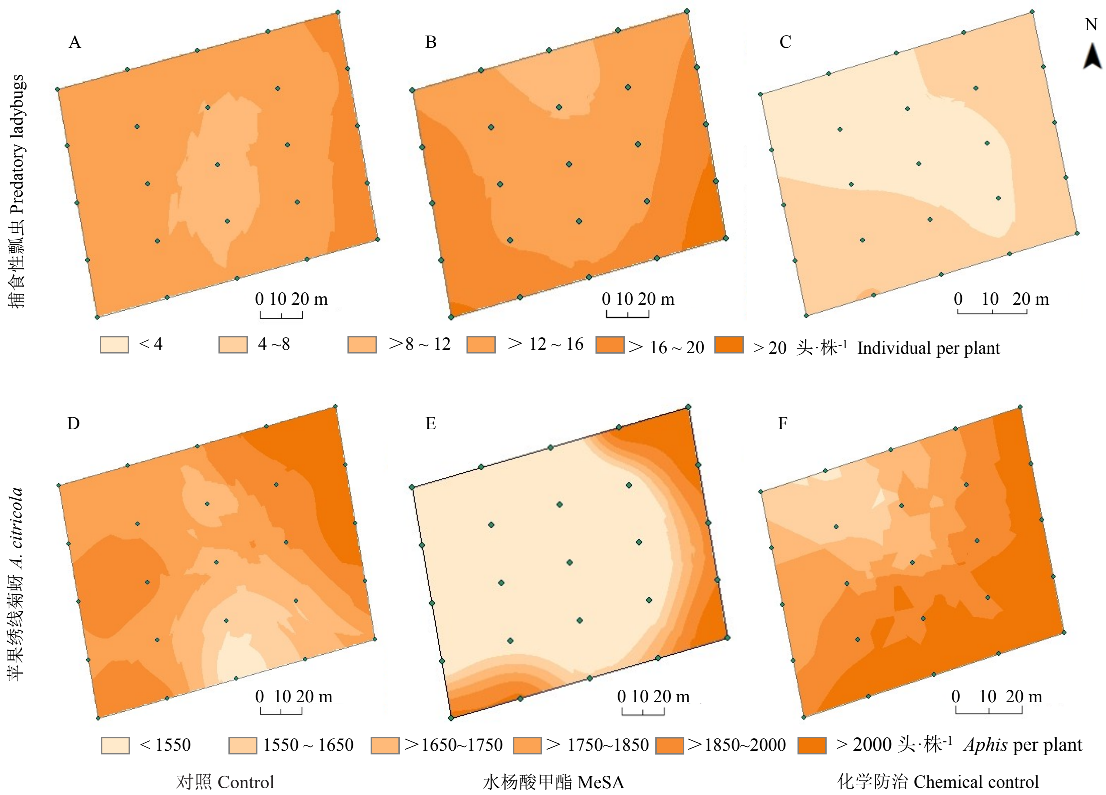
区域 Area	$\bar{x}$	S^2	m^*	I	m^*/m	C_A	C	K
对照 Control	2 114.00	788 540.50	2 486.01	373.19	1.18	0.18	373.01	5.68
水杨酸甲酯 MeSA	1 496.16	894 136.22	2 092.78	598.02	1.40	0.40	597.62	2.51
化学防治 Chemical control	1 895.20	550 963.00	2 184.91	290.87	1.15	0.15	290.71	6.54

注：$\bar{x}$ 为样本均数，S^2 为样本方差。

Note: $\bar{x}$ is the sample mean, S^2 is the sample variance.

（290.71~597.62）＞1，负二项分布值K（2.51~6.54）＞0，说明在水杨酸甲酯PE缓释管处理区、化学防治区和对照区中苹果绣线菊蚜均呈聚集分布。

从空间分布图可以看出水杨酸甲酯PE缓释管处理区内的瓢虫分布密度更高，而化学防治区瓢虫种群密度整体偏低（图3-A~C）。水杨酸甲酯PE缓释管处理区内苹果绣线菊蚜的虫口密度相比其他区域较低，边缘分布模式更加明显，对照区内虫口密度相对偏高。而3个区域内苹果绣线菊蚜均在园区中间分布密度较低，周边或靠近单边的分布密度较高（图3-D~F），结合聚集度指数（表1）可以明确各苹果园区内苹果绣线菊蚜呈现边缘聚集分布。因此，施用水杨酸甲酯PE缓释管可以维持捕食性瓢虫的种群数量，进一步降低苹果绣线菊蚜的发生数量，阻止苹果绣线菊蚜进一步向园区内部扩散。



图中的点代表调查点位，图B和E内调查点位同时是水杨酸甲酯PE缓释管悬挂点位。

The points in the map represent the survey points, the survey points in Figure B and E are also the suspension points of MeSA PE rubber.

图3 捕食性瓢虫（A~C）和苹果绣线菊蚜（D~F）的空间分布

Fig. 3 The spatial distribution map of predatory ladybirds (A-C) and *A. citricola* (D-F)

2.3 水杨酸甲酯PE缓释管的田间缓释速率

在试验期间平均温度在25 ℃上下波动，水杨酸甲酯PE缓释管的初始质量为7.14 g，5周内水杨酸甲酯PE缓释管的质量共减少3.38 g（图4-A），释放速率约为0.68 g•周$^{-1}$。悬挂初期，其有效物质相对丰度较高（图4-B），悬挂5周后，仍然能检测到水杨酸甲酯PE缓释管内的有效成分（图4-C）。

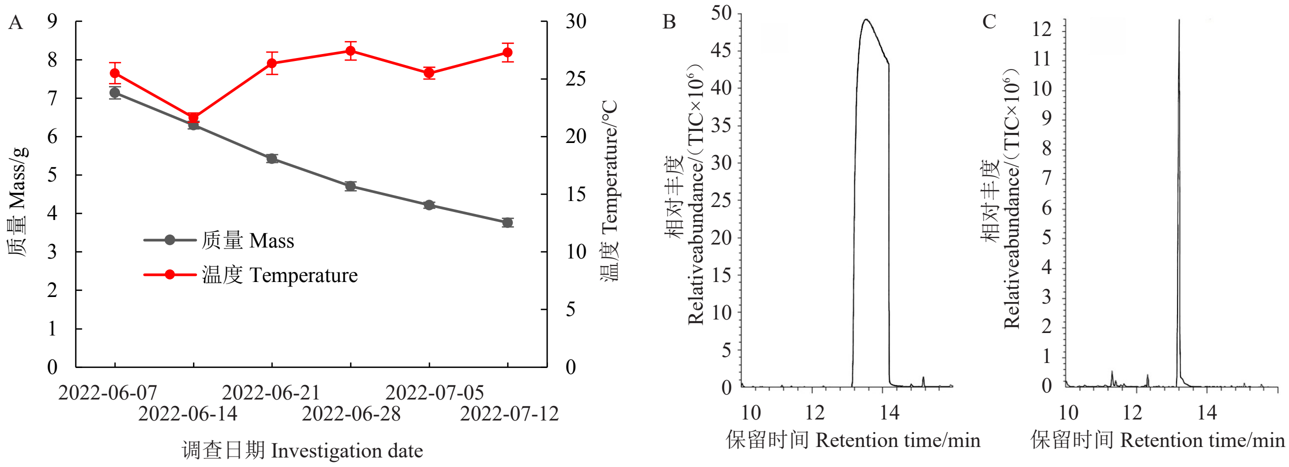


图 4 水杨酸甲酯的田间缓释速率（A）和相对丰度（B、C）

Fig. 4 The sustained release rate (A) and relative abundance (B and C) of MeSA in apple orchard

3 讨 论

笔者在本研究中检测了水杨酸甲酯PE缓释管的缓释速率，同时探究水杨酸甲酯对天敌和害虫的空间分布特征的影响。水杨酸甲酯PE缓释管处理可以有效增加捕食性瓢虫的种群发生量，使苹果绣线菊蚜发生数量减少以及分布范围远离水杨酸甲酯的处理区，苹果绣线菊蚜的高密度危害面积进一步减少，从而增强对苹果绣线菊蚜的控害作用。此外，还明确水杨酸甲酯PE缓释管田间持效在4周以上。

通过蚜虫动态调查可以明确，在北京地区苹果园中苹果绣线菊蚜在5月初开始出现，并在5月底至6月中旬达到发生量高峰，这与刘雪莹等[19]关于陕西省苹果绣线菊蚜发生时间的调查结果基本一致，这表明北方地区苹果绣线菊蚜的种群消长动态具有时间上的同步性。针对苹果绣线菊蚜的防治，随着生物技术的发展，生物防治效果愈发明显，如姜莉莉等[20]发现使用生物防治技术与吡虫啉的防治效果相当，吴旭东等[21]发现田间释放异色瓢虫卵卡防控甜菜蚜虫，益害比1∶5与1∶10的处理效果良好，其持效性显著优于吡虫啉处理。笔者在本研究中也发现水杨酸甲酯PE缓释管处理区苹果绣线菊蚜的发生数量在前期与化学防治区无显著差异，且捕食性瓢虫的发生数量更高，化学防治区内捕食性瓢虫的发生数量在前4周内均显著低于水杨酸甲酯PE缓释管处理区，这可能是化学杀虫剂作用的结果[22]。对室内滤纸药膜法研究表明，吡虫啉对2龄异色瓢虫幼虫的致死中质量浓度值达13.511 mg·L^{-1}[23]，且不同温度对亚致死剂量的吡虫啉处理后异色瓢虫的捕食量、寻找效应、捕食功能等方面都有显著影响[24]。

基于化学信息素引诱天敌昆虫实现害虫防治的生态调控措施是现代农业绿色植物保护体系中的持续有效举措[7,25]。水杨酸甲酯是目前研究、应用最为广泛的天敌引诱剂，其对东亚小花蝽、异色瓢虫、龟纹瓢虫等天敌具有引诱作用[26-27]。在本试验中水杨酸甲酯PE缓释管处理区，前2周捕食性瓢虫的种群数量与对照区无显著差异，而第3周显著高于其他处理区，因此，提前2周悬挂水杨酸甲酯PE缓释管，有助于将瓢虫发生峰期提前，增强对果园蚜虫的防控作用。应用化学信息素缓释技术等绿色防控技术，可以降低害虫的种群密度或危害程度，并提高天敌数量，如水杨酸甲酯处理的葡萄园中天敌数量增加、大豆蚜丰度和蓟马密度明显较低[28-30]。本研究中水杨酸甲酯PE缓释管处理区内苹果绣线菊蚜的发生数量相比其他区域更低，且捕食性瓢虫的种群数量更高，都可能与使用化学信息素防治技术有关。化学信息素也被用于其他害虫的防控，如梨小食心虫性信息素用于梨小食心虫的防治[31]等。因此，水杨酸甲酯对害虫和天敌昆虫空间分布的结果可为其他化学信息素的应用研究提供借鉴。此外，化学信息素与功能植物协同可以增强害虫防治效果，Jaworski等[25]发现，在苹果园内协同使用水杨酸甲酯和金盏菊可以显著提升龟纹瓢虫对苹果绣线菊蚜的生物防治效果。

空间密度分析可以反映出害虫和天敌的分布规律。在不同处理措施下苹果绣线菊蚜均在园区周边的分布密度高，而中间部分密度相对偏低，呈现出边缘聚集的分布模式。这与其他害虫的分布规律有相似之处，如在作物周边番茄潜叶蛾的虫害更为严重

且作物区边缘是其产卵聚集地[32]。自然生草有助于增加天敌的种类和数量[33]，水杨酸甲酯处理能够让瓢虫的分布相对更加均匀，而捕食性瓢虫的这种分布状态可能导致苹果绣线菊蚜整体上分布密度低。笔者在本研究中明确了苹果绣线菊蚜和捕食性天敌的具体分布情况，有助于探究昆虫从替代宿主或越冬地点的时空传播规律[34]，同时为果园前期周边的生态管理和生物防治提供参考。

此外，化学信息素缓释技术需考虑材料的缓释、储存等基本能力，还需考虑温湿度等外界条件的作用。分子凝胶技术通过内部的相互作用促使其具备持续缓释的能力，微纳米材料可以载体的优势在于避免有效物质在使用期间内被氧化，光感应技术可以利用不同天气或不同波长光等光敏特性调控活性分子的释放[9]。单纯的水杨酸甲酯释放时间约为4 d，以海藻酸钠为缓释材料的水杨酸甲酯小球持续释放时间在9 d左右[13]，因此缓释材料制备技术的研究前景极广，而本试验中发现田间悬挂5周后，仍然能检测到水杨酸甲酯PE缓释管内的有效成分，表明PE管材可作为长期缓释水杨酸甲酯的载体。

4 结　论

笔者在本研究中发现水杨酸甲酯PE缓释管的田间时效超过4周，提高捕食性瓢虫的数量以及在果园分布更均匀，有效降低了苹果绣线菊蚜的发生数量，降低园区内部苹果绣线菊蚜的虫口密度，使最高密度的苹果绣线菊蚜仅出现在园区的边缘位置，为化学信息素的田间应用和害虫的防治提供理论依据。

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