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蚧虫化学生态学研究进展

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摘要：概述了蚧虫性信息素、植物-蚧虫-天敌三者关系中的化学联系研究进展，介绍了蚧虫化学生态学在生物防治上的应用，并探讨了蚧虫化学生态学的发展前景。

关键词：蚧虫；性信息素；信息化学物质；植物挥发物

Research progress on the chemical ecology of scale insects

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Abstract: Progress in the study of sex pheromones of scale insects, as well as the semiochemical interactions among plants, scale insects and natural enemies is summarized. Application of these findings in biological control is introduced, and the future of scale insect chemical ecology is discussed.

Key words: scale insects; sex pheromone; semiochemicals; plant volatiles

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蚧虫属于同翅目 Homoptera、蚧总科 Coccoidea，全世界记录 20 科 7000 余种，我国约 1000 种，除白蜡虫 *Ericerus pela*、紫胶虫 *Laccifer lacca* 属于资源昆虫外，其余大部分是林木、果树和花卉的害虫。蚧虫虫体具有蜡腺，分泌大量蜡质，在虫体表面形成蜡壳，对虫体起保护作用，防治十分困难。随着环境恶化和污染加剧，很多生物由于不适应恶劣的环境而成群减退或消亡，而蚧虫由于其繁殖力强、生活隐蔽、体壁被蜡质保护，显示出强大的抗逆性和抗污染能力，成为现代农、林、果树和花卉业的世界性危险害虫类群。特别是在林业上，蚧虫为害尤为严重。我国首发林业危险性有害生物名单中有害虫和螨类 156 种，其中蚧虫为 30 种，包括吹绵蚧 *Icerya purchasi*、中华松梢蚧 *Sonsaucoccus sinensis*、竹巢粉蚧 *Nesticoccus sinensis*、白蜡绵粉蚧 *Phenacoccus fraxinus*、皱绒蚧 *Eriococcus wangi*、紫薇绒蚧 *E. lagerostroemiae*、华栗绛蚧 *Kermes nawae*、日本龟蜡蚧 *Ceroplastes japonicus*、红蜡蚧 *C. rubens*、朝鲜球坚蚧 *Didesmococcus koreanus*、瘤大球坚蚧 *Eulecanium gigantea*、槐花球蚧 *E. kuwanai*、思茅壶蚧 *Cerococcus schimae*、栗链蚧 *Asterolecanium castaneae*、檫树白轮蚧 *Aulacaspis sassafris*、松针蚧 *Fiorinia japonica*、柳蛎盾蚧 *Lepidosaphes salicina*、沙枣密蛎蚧 *Mytilaspis conchiformis*、橄榄片盾蚧 *Parlatoria olea*、香樟袋盾蚧 *Phenacaspis camphora*、柽柳原盾蚧 *Prodiaspis tamaricicola*、蛇眼臀网盾蚧 *Pseudaonidia duplex*、桑白蚧 *Pseudaulacaspis pentagona*、杨圆蚧 *Quadraspidiotus gigas*、梨圆蚧 *Q. perniciosus*、杨齿盾蚧 *Q. slavonicus*、柽柳晋盾蚧 *Shansiaspis ovalis*、中国晋盾蚧 *S. sinensis*、卫矛蜕盾蚧 *Unaspis euonymi*、西安矢尖蚧 *U. xianensis*。

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1 蚧虫性信息素的研究

1966 年 Doane 首先证实美洲松干蚧 *Matsucoccus resinosae* 雌蚧存在性信息素[1]。他发现处女雌蚧的尾部织成少量的丝状绒毛,将雌蚧移走,绒毛对雄蚧有很强的吸引作用,并试图与之进行交配。雌蚧停留一晚上的滤纸也可以诱导雄蚧试图交配的行为。Rotundo 和 Tremblay 研究了形态上非常相似的橘臀纹粉蚧 *Planococcus citri* 和无花果臀纹粉蚧 *P. ficus* 的信息素种间特异性,发现二者之间在雌成虫性信息素反应上无交互活性,即使生活在同一种寄主植物上也不杂交,性信息素特异性很强,但他们没有对其性信息素组分的化学结构进行研究[2]。1977 年,Roelofs 等首次报道了红圆蚧 *Aonidiella aurantii* 性信息素化学成分为(3S,6R)-3-甲基-6-异丙烯基-9-癸烯-1-基醋酸酯和(3S,6R)-3-甲基-6-异丙烯基-3,9-癸二烯-1-基醋酸酯,这是第一种鉴定出结构的蚧虫类性信息素[3]。之后,黄圆蚧 *Aonidiella citrine*、梨圆蚧、桑白蚧、康氏粉蚧 *Pseudococcus comstocki*、橘臀纹粉蚧 *Planococcus citri*、夹竹桃盾蚧 *Aspidiotus nerii*、无花果臀纹粉蚧等蚧虫的性信息素陆续被确定(见表 1)[3~39]。雄性蚧虫只被特定的几何异构体和光学异构体吸引[10,20],这表明蚧虫性信息素的化学结构在其种间生殖隔离中起着重要作用。

对于蚧虫性信息素,我国从 20 世纪 70 年代开始进行了一系列的研究,主要集中于对我国松林资源构成巨大威胁的两种蚧虫—日本松干蚧 *Matsucoccus matsumurae* 和松突圆蚧 *Hemiberlesia pitysophila*[40]。日本松干蚧雌成虫对雄成虫有召唤行为,并同时释放性信息素。每天释放时间在 5:00～9:00,可以延续 7d。交配直接影响性信息素释放[41]。用日本松干蚧和马尾松干蚧 *M. massonianae* 雌成虫性信息素粗提物对雄成虫进行行为测定,结果发现:同一种类之内的雄成虫对雌成虫反应很强烈,而在不同种类之间的反应则显著降低,松干蚧性信息素在不同种类之间有一定的交互活性[42]。用中国的日本松干蚧雌成虫性信息素对日本的日本松干蚧和美国的红松干蚧 *M. resinosae* 雄成虫进行行为测定,结果为:红松干蚧雄成虫和日本的日本松干蚧雄成虫对中国的日本松干蚧雌成虫信息素有强烈的反应[43]。经过多年的研究,与美国合作,祁云台等鉴定出日本松干蚧性信息素成分为 4,6,10,12-四甲基-2,4-十三碳二烯-7-酮[36]。这是我国鉴定出的第一种同翅目昆虫性信息素。该信息素的 4 个光学异构体的室内和田间引诱试验表明,6R,10R-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮对日本松干蚧的引诱活性最强,因而被确定为该蚧虫天然性信息素的绝对构型[44,45]。松突圆蚧雄蚧多次交配,但雌蚧则为单次交配。雌蚧性成熟后即开始释放性信息素以引诱雄蚧,未经交配的性成熟雌蚧能持续释放性信息素 3d 以上。松突圆蚧未交配雌蚧和去壳处女蚧对雄蚧具引诱作用,而交配 1h 后的雌蚧逐渐失去引诱雄蚧的能力,雌蚧分泌的性信息素能被正己烷和二氯甲烷溶剂有效地抽提,滴有正己烷或二氯甲烷粗提物的滤纸同样能诱发雄蚧的性行为,性信息素主成分带有酯基功能团[46,47]。利用日本龟蜡蚧的活雌虫及其粗提物在田间进行诱捕,发现无论是活雌虫还是粗提物均可引诱雄虫,表明性信息素在日本龟蜡蚧觅偶行为中发挥着重要作用[48]。

2 植物-蚧虫-天敌化学联系的研究

近几年,国外开始对植物-蚧虫-天敌三者之间的化学联系进行研究。木薯绵粉蚧 *Phenacoccus manihoti* 是非洲木薯 *Manihoti esculenta* 上的重要害虫。跳小蜂 *Apoanagyrus lopezi*(Hymenoptera: Encyrtidae)是 1981 年由南美引入撒哈拉沙漠以南的非洲地区,用来防治木薯绵粉蚧的一种寄生蜂。Nadel 和 van Alphen 证明 *A. lopezi* 雌蜂能够被木薯绵粉蚧为害的木薯植株吸引,但不能被单独的寄主气味或健康木薯植株吸引[49],而 van Baaren 则报道雌蜂能够被受寄生的寄主和未受虫害的木薯植株释放的气味所吸引[50]。Soussi 等证实未被寄生的木薯绵粉蚧的气味对该蜂具有引诱作用,其作用甚至强于健康木薯植株对该蜂的作用[51,52]。该蜂能够辨别上面有未被寄生的绵粉蚧和被寄生的绵粉蚧的木薯植株,被寄生的木薯绵粉蚧侵染的木薯的引诱力显著低于被未被寄生的木薯绵粉蚧侵染的木薯的引诱力,可能是被寄生的木薯绵粉蚧比未被寄生的木薯绵粉蚧对木薯植株造成的危害小,结果是植物产生的互利素相应地减少了。Langenbach 和 van Alphen[53]的研究表明该寄生蜂对绵粉蚧蜡质中一种利它素有反应,用触角刺探被蜡质污染过的叶片的时间长于未被污染的叶片。

木薯绵粉蚧的不同寄主植物释放的挥发物对其寄生蜂的引诱效果不同。Souissi[54]研究了木薯绵粉蚧的 4 个寄主植物种类或品种释放的挥发物对该寄生蜂的引诱效果。这 4 种植物品种有 3 个属于 Eupchorbiaceae 科,其中 2 个属于木薯 *M. esculenta* 种,分别为 Incoza 和 Zanaga 品种,Faux caoutchouc(FC)为 *M. esculenta* 和 *M. galziovii* 的杂交品种,第 4 种植物是 *Talinum triangularae* (Talinum)。而这 4 种植物对粉蚧具有不同的抗性水平。抗异性(antixenosis)水平,以 Talinum 最高,其次为 FC,Incoza, Zanaga ;抗生性(antibiosis)水平,以 Zanaga 最低,其次是 Talinum、FC,Incoza 的抗生性水平最高[55]。在 2 个木薯品种上粉蚧 1 年仅发生 3～5 个月,而在杂交品种 FC 上则全年都有较大的绵粉蚧种群[56]。Talinum 是木薯田里常见的杂草,有时上面也会有较大的绵粉蚧种群。室内试验证明寄主植物既影响绵粉蚧的发育和繁殖,又影响该寄生蜂的发育和繁殖[56~59]。被绵粉蚧寄生的植物对雌蜂的吸引力强于健康植物或者粉蚧。雌蜂能够辨别受虫害或未受虫害的不同物种或品种的植物,对于未受绵粉蚧为害的植株,其对木薯 *M. esculent* 的选择性强于对杂草 Talinum 的选择性,但是对木薯的不同品种 Incoza 和 Zanaga 的选择没有差别,而 Zanaga 对该蜂的吸引力强于杂交品种 FC。受绵粉蚧为害,Incoza 和 Zanaga 对该蜂的吸引力强于 Talinum 和 FC。*A. lopezi* 的选择与木薯绵粉蚧对 4 种所选植物的抗性水平有关,4 种植物对木薯绵粉蚧表现出不同的抗性水平,可能会释放出在质量和数量组成上不同的挥发物,造成寄生蜂选择性的不同。

表 1 蚧虫性信息素

Table 1 Sex pheromones of some scale insects

种名 Species	性信息素组分 Components	参考文献 References
红圆蚧 *Aonidiella aurantii*	(3S,6R)-3-甲基-6-异丙烯基-9-癸烯-1-基醋酸酯 (3S,6R)-3-methyl-6-isopropenyl-9-decen-1-yl acetate (3S,6R)-3-甲基-6-异丙烯基-3,9-癸二烯-1-基醋酸酯 (3S,6R)-3-methyl-6-isopropenyl-3,9-decadien-1-yl acetate	Roelofs *et al.* [3,4] 1977,1978, Gieselmann *et al.* [5] 1980, Tashiro *et al.* [6~9] 1967,1968,1969, 1979
黄圆蚧 *Aonidiella citrina*	反-3,9-二甲基-6-异丙基-5,8-癸二烯-1-基醋酸酯 (5E)-6-isopropyl-3,9-dimethyl-5,8-decadienyl acetate	Gieselmann *et al.* [10] 1979, Grafton-Cardwell *et al.* [11] 2000
梨圆蚧 *Quadraspidiotus perniciosus*	顺-3,7-二甲基-2,7-辛二烯-1-基丙酸酯 (Z)-3,7-dimethyl-2,7- octadien-1-yl propanoate, 7-甲基-3-甲叉-7-辛烯-1-基丙酸酯 7-methyl-3-methylene-7-octene-1-yl propanoate, 反-3,7-二甲基-2,7-辛二烯-1-基丙酸酯 (E)-3,7-dimethyl-2,7-octadiene-1-yl propanoate	Anderson *et al.* [12] 1981, Peri *et al.* [13] 2002, Rice and Hoyt[14] 1980, Gieselmann *et al.* [15] 1979b
桑白蚧 *Pseudaulacaspis pentagona*	(3S,6R)-3,9-二甲基-6-异丙烯基-3,9-癸二烯-1-基丙酸酯 (3S,6R)-3,9-dimethyl-6-isopropenyl-3,9- decadien-1-yl propanoate	Heath *et al.* [16] 1979
康氏粉蚧 *Pseudococcus comstocki*	2,6-二甲基-1,5-庚二烯-3-基醋酸酯 2,6-dimethyl-1,5-heptadien-3-yl acetate	Bierl-Loenhardt *et al.* [17] 1980
橘臀纹粉蚧 *Planococcus citri*	(+)-(1R)-顺-2,2-二甲基-3-异丙烯基环丁烷甲基醋酸酯 (+)-(1R)-cis-2,2-dimethyl-3-isopropenylcyclobutanemethanol acetate	Gravitz and Willson[18] 1968, Wolk *et al.* [19] 1986, Bierl-Leonhardt *et al.* [20] 1981, Dunkelblum *et al.* [21,22] 1987, 2002, Zada *et al.* [23] 2004
木槿曼粉蚧 *Maconellicocus hisutus*	(R)-薰衣草基(S)-2-甲基丁酸酯 (R)-lavandulyl (S)-2-methylbutanoate [(R)-2,2-二甲基-3-(1-甲基乙叉基) 环丁基]甲基 (S)-2-甲基丁酸酯[(R)-2,2-dimethyl-3-(1-methylenthylidene) cyclobutyl] methyl (S)-2-methylbutanoate	Serrano *et al.* [24] 2001, Zhang *et al.* [25] 2004
夹竹桃盾蚧 *Aspidiotus nerii*	(1R,2S)-顺-2-异丙烯基-1-(4'-甲基-4'-戊-1-烯基)环丁烷乙醇醋酸酯(1R,2S)-cis-2-isopropenyl-1-(4′-methyl-4′-penten-1′-yl)cyclobutaneethanol acetate	Einhorn *et al.* [26] 1998, Boyer and Ducrot[27,28] 1999, 1999, Peri *et al.* [13] 2002
无花果臀纹粉蚧 *Planococcus ficus*	(S)-薰衣草基异戊烯酸酯 (S)-lavandulyl isovalerate (S)-薰衣草基异戊烯酸酯(S)-lavandulyl senecioate	Zada *et al.* [29,30] 2001,2003
以色列松干蚧 *Matsucoccus josephi*	(2E,4Z,8E)-4,6-二甲基-2,4,8-癸三烯-7-酮 (2E,4Z,8E)-4,6-dimethyl-2,4,8-decatrien-7-one, (2E,5R,6E,8E)-5,7-二甲基-2,6,8-癸三烯-4-酮 (2E,5R,6E,8E)-5,7-dimethyl-2,6,8- decatrien-4-one, (2E,5S,6E,8E)-5,7-二甲基-2,6,8-癸三烯-4-酮 (2E,5S,6E,8E)-5,7-dimethyl-2,6,8- decatrien-4-one, (2E,5R,6E,8E)-5,7-二甲基-2,6,8-癸三烯-4-酮 (2E,5R,6E,8E)-5,7-dimethyl-2,6,8- decatrien-4-one	Mendel *et al.* [31] 1990, Dunkelblum *et al.* [32,33] 1993, 1995, Zegelman *et al.* [34] 1993
日本松干蚧 *Matsucoccus matsumurae*	(2E,4E)-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮 (2E,4E)-4,6,10,12-tetramethyl-2,4- tridecadien-7-one	Lanier *et al.* [35] 1989, Hibbard *et al.* [36] 1991
海岸松干蚧 *Matsucoccus faytaudi*	(3R,7R)-(8E,10E)-3,7,9-三甲基-8,10-十二碳二烯-6-酮 (3R,7R)-(8E,10E)-3,7,9-trimethyl-8,10-dodecadien-6-one (3S,7R)-(8E,10E)-3,7,9-三甲基-8,10-十二碳二烯-6-酮 (3S,7R)-(8E,10E)-3,7,9-trimethyl-8,10-dodecadien-6-one (2E,4E))-4,6,10-三甲基-2,4-十二碳二烯-7-酮 (2E,4E)-4,6,10-trimethyl-2,4-dodecadien-7-one (2E,4Z))-4,6,10-三甲基-2,4-十二碳二烯-7-酮 (2E,4Z)-4,6,10-trimethyl-2,4- dodecadien-7-one	Jactel *et al.* [37] 1994, Einhorn *et al.* [38] 1990
美国红松干蚧 *Matsucoccus resinosae*	(2E,4E))-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮 (2E,4E)-4,6,10,12-tetramethyl-2,4- tridecadien-7-one	Lanier *et al.* [35] 1989, Hibbard *et al.* [36] 1991
朝鲜黑松干蚧 *Matsucoccus thunbergianae*	(2E,4E))-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮 (2E,4E)-4,6,10,12-tetramethyl-2,4-tridecadien-7-one, (6R,10R)-(2E,4E)-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮 (6R,10R)-(2E,4E)-4,6,10,12-tetramethyl-2,4-tridecadien-7-one, (6S,10S)-(2E,4E)-4,6,10,12-四甲基-2,4-十三碳二烯-7-酮 (6S,10S)-(2E,4E)-4,6,10,12-tetramethyl-2,4-tridecadien-7-one	Lanier *et al.* [35] 1989, Hibbard *et al.* [36] 1991, Park *et al.* [39] 1994

木薯绵粉蚧诱导木薯系统释放的挥发物是吸引有经验的怀卵的雌性光瓢虫 *Exochomus flavientris* 向它的猎物定位的主要气味源,该瓢虫在远距离就能估计木薯绵粉蚧种群的产卵适宜性,通过嗅觉判断同种怀卵雌瓢虫的存在和避免选择被寄生的绵粉蚧群,光瓢虫的这种能力可以增大天敌的适宜度,对捕食者和寄生者都有利[60]。

另外一种木薯绵粉蚧 *Phenacoccus herreni* 是南美木薯上的重要害虫。3 种跳小蜂 *Acerophagus coccois*, *Aenasius vexans*、*Apoanagyrus diversicornis* 是该蚧虫的寄生蜂。该蚧虫为害木薯释放的气味对 *A. vexans* 和 *A. diversicornis* 具有较强的吸引力,并且受害的木薯叶片对 *A. diversicornis* 的吸引力强于健康叶片[61]。进一步的研究证明,木薯绵粉蚧 *P. herreni* 危害的木薯植株是引诱 *A. vexans* 和 *A. diversicornis* 的主要味源[62]。木薯绵粉蚧 *P. herreni* 产生的利它素 O-咖啡酰丝氨酸(O-caffeoylserine)是两种跳小蜂 *A. coccois* 和 *A. vexans* 向其定位的刺激剂[63]。

孟氏隐唇瓢虫 *Cryptolaemus montrouzieri* 的幼虫和成虫能够被橘臀纹粉蚧释放的化学物质所吸引[64]。以色列松干蚧 *M. josephi*、日本松干蚧 *M. matsumurae* 和松干蚧 *M. feytaudi* 的性信息素,同时也是吸引其捕食性天敌松干蚧花蝽 *Elatophilus hebraicus* 向其定向的利它素[65~67]。

专食性黄蚜小蜂 *Aphytis chilensis* 长距离寻找寄主夹竹桃盾蚧的过程中,利用夹竹桃盾蚧的性信息素,向其定向[68]。蚧虫蜡泌物中含有多种挥发性的萜类化合物,起信息素的作用,如在蜡蚧属的日本龟蜡蚧、伪角蜡蚧 *C. pseudoceriferus*、红蜡蚧 *C. rubens*、*C. albolineatus* 的蜡壳中检测出一系列大环、双环和三环萜类化合物,甚至在红蜡蚧蜡壳中检测出另外 31 种挥发性萜类[69,70]。已经发现两种萜类混合物对红蜡蚧扁角跳小蜂 *Anicetus beneficus* 寻找寄主产卵起化学诱导作用。盾蚧科的矢尖盾蚧 *Unaspis yanonensis* 介壳的蜡质对矢尖蚧黄蚜小蜂 *Aphytis yanonensis* 发现寄主和产卵具有引诱作用[71]。

印巴黄蚜小蜂 *Aphytis melinus* 利用挥发性物质向虫害和未受虫害的寄主植物材料定位[72]。从红圆蚧 *A. aurantii* 体表分离出来的一种利它素 O-咖啡酰酪氨(O-caffeoyltyrosine),是由咖啡酸(caffeic acid)和酪氨酸(tyrosine)形成的酯,能够调节印巴黄蚜小蜂对寄主的识别并诱导其产卵[73,74]。该蜂用夹竹桃蚧虫 *A. nerii* 作为寄主饲养,而夹竹桃蚧虫是用南瓜饲养的。将夹竹桃蚧虫饲养的印巴黄蚜小蜂给予 O-咖啡酰酪氨酸刺激,与同样条件饲养但没有用 O-咖啡酰酪氨酸刺激的寄生蜂相比,更易于接受红圆蚧的介壳进行探测,用 O-咖啡酰酪氨酸刺激过的印巴黄蚜小蜂品系的后代的数量比预期数多[75]。“经验”和“学习”对该蜂的寻找寄主的行为起着重要的作用。用生长在柠檬果上的红圆蚧给予该蜂“经验”,随后,该蜂就会向柠檬的果实和叶片定向;而用生活在南瓜上的红圆蚧给予印巴黄蚜小蜂经验后,该蜂并不向虫害的柠檬果定向[76]。对于不对其利它素进行处理的介壳,经验对该蜂识别寄主不起作用;而将介壳中的利它素去除后,经验会增强该蜂对寄主的识别;对于大个体寄主有经验的印巴黄蚜小蜂,容易接受有利它素较多的介壳;当将利它素去除后,对在大介壳下的大个体寄主有经验的印巴黄蚜小蜂偏爱选择大的介壳。

3 蚧虫化学生态学在生物防治上的应用

用昆虫性信息素作虫情测报,准确可靠、使用简便、成本低廉,是当今农林害虫监测的理想技术和方法。Shaw 等[77]利用红圆蚧未交配雌成虫与粘胶板组成性信息素诱捕器来监测该虫的危害程度;Rice[78]等则以天然和合成性信息素来监测梨圆蚧分布危害地区和发生消长情况,作为适时施药的依据;祁云台等[79]利用性信息素诱捕器监测到了日本松干蚧;Grafton-Cardwell 等[11](2000)利用信息素有效地监测黄圆蚧的分布范围。利用载有 100μg 无花果臀纹粉蚧信息素的硅橡胶塞引诱雄蚧,诱芯有效期至少为 12 周,有效距离至少为 50m[80];载有 200μg 橘臀纹粉蚧信息素的诱芯对雄蚧的有效期长达 16 周[24];黄圆蚧诱芯对雄蚧的有效期长达 4 个月[11]。以色列松干蚧和海岸松干蚧田间大量诱捕法的研究表明,信息素剂量、诱捕器大小、诱捕器类型对雄蚧的诱捕效果均有影响[81]:这两种蚧虫反应的最低剂量是 25μg,而当海岸松干蚧种群数量较低时,需要将剂量加大到 50μg,才能保证诱捕到的海岸松干蚧数量显著高于对照,两种蚧虫的诱捕数量随着剂量的增大而增加,使用 1600μg 的以色列松干蚧信息素和 2200μg 的海岸松干蚧信息素,没有发现超剂量引起的驱避作用。对于海岸松干蚧,在中等种群密度下,诱捕数量最大。海岸松干蚧的诱捕数量不受诱捕器类型的影响,以色列松干蚧用 delta 诱捕器诱捕到的数量最大。对于两种蚧虫来说,大的诱捕器可以诱捕到较多的蚧虫。

在松树林中,利用以色列松干蚧性信息素诱芯监测其捕食性天敌松干蚧花蝽种群动态和地理分布,并用来判定以色列松干蚧的其它捕食性天敌[82]。进一步的田间诱捕试验表明:以色列松干蚧 *M. josephi*,海岸松干蚧 *M. feytaudi*,日本松干蚧的性信息素诱捕器可以引诱到两个类群的捕食性天敌:*Elatophilus* 属的花蝽和 *Hemerobius* 、*Sympherobius* 属的褐蛉。在古北区的西部地区诱捕到了 *Elatophilus hebraicus*, *E. nigricornis*, *E. crassicornis*, *Hemerobius stigmaterus* 和 *Sympherobius fuscescens*,在美国诱捕到了 *E. inimica*, *H. stigma*, *H. stigmaterus*。松干蚧花蝽 *E. hebraicus* 能够被 3 种松干蚧的性信息素引诱,其它花蝽种类则只对一种或两种信息素起反应[83]。印巴黄蚜小蜂是防治红圆蚧的有效天敌,在对其的商业化饲养过程中,于释放之前用 O-咖啡酰酪氨酸处理该蜂可以作为提高该蜂对红圆蚧防治效果的一种有效方法[75]。

干扰交配是用性信息素防治害虫的一种方法。用梨圆蚧信息素石蜡油乳液进行的田间干扰交配试验表明,经过两个世代的

处理，干扰交配在一定程度上降低了蚧虫的种群密度，但是成本较高，目前还未进行商业化生产和应用[84]。

用性信息素等信息化学物质防治害虫，高效、无毒、不污染环境[85]。随着人们对环境安全的日益关注，对自身健康的日益重视，化学生态学的研究和应用越来越受到重视。近几年有关蚧虫化学生态研究的报道逐渐增多。随着分析仪器的日益精密，分子生物学技术的迅速发展，蚧虫化学生态学的研究将在深度和广度上得到更快的发展与应用。

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