异色瓢虫生物生态学研究进展*

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摘　要　原产于亚洲的异色瓢虫[*Harmonia axyridis* Pallas (Coleoptera: Coccinellidae)]是最重要的捕食性瓢虫种类之一,被广泛应用于农林业害虫的生物防治.本文综合分析了国内外近几十年对异色瓢虫的研究成果,对其重要的生物学及生态学特性进行了归纳,主要涉及生活史、繁殖行为及策略、捕食行为和自残行为等,分析了相关研究对其应用前景的影响.基于异色瓢虫的人工饲养、农药交互作用以及入侵生态影响等的总结,提出了预防异色瓢虫造成生态不平衡的具体措施.

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Research progress on biology and ecology of *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae). WANG Su[1], ZHANG Run-zhi[1], ZHANG Fan[2] ([1]State Key Laboratory of Integrated Management of Pest Insects and Rodents, Institute of Zoology, Chinese Academy of Sciences, Beijing 100080, China; [2]Institute of Plant and Environment Protection, Beijing Academy of Agriculture and Forestry Sciences, Beijing 100089, China). -*Chin. J. Appl. Ecol.*, 2007, **18**(9): 2117-2126.

Abstract: *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae) with its native in Asia is one of the most important predatory ladybird beetles, and used worldwide as a biological control agent. This paper summarized the recent decades research progress at home and abroad on its life history, reproductive strategies, and predatory and cannibalism behaviors, and analysed the prospects of its utilization. Based on the review of its artificial reproduction, insecticide interaction, and impact as an invasive species, some useful measures were suggested to prevent the beetle from its potential risk to ecological banlance.

Key words: *Harmonia axyridis* Pallas; behavioral character; natural enemy; biological control; invasive impact.

1　引　　言

异色瓢虫 *Harmonia axyridis* (Pallas)属鞘翅目(Coleoptera)瓢虫科(Coccinellidae),对蚜虫、叶螨、介壳虫等重要害虫具有很强的捕食能力,目前作为一种重要的生防天敌,在全世界农业生产中广泛应用[35,88].异色瓢虫原产地为亚洲,20世纪初作为天敌引入北美,而后相继在南美洲、欧洲以及大洋洲等地引入释放[35].经过几十年的发展,异色瓢虫已经遍布全球各个主要农业生产区,并且逐渐替代引入地的捕食性瓢虫成为优势种[7].除了在应用过程中获得了显著的经济收益外,异色瓢虫的扩散也带来了一些潜在影响,尤其是对引入地的物种多样性以及对生态系统产生了负面作用,使这一曾深受喜爱的天敌昆虫在某些地区甚至与入侵生物相提并论[2,12,74].近年来,随着异色瓢虫在世界范围内的应用与发展,与其相关的各方面研究也在不断深入,从早期对其原产地生物学、生态学和进化扩散领域的研究逐渐发展到对引入地区的生防应用及潜在危害评估等方面[35].本文对国内外相关领域的研究进展情况进行了总结,为相关研究提供参考.

2　异色瓢虫的形态特征、色斑与多型现象

异色瓢虫属完全变态昆虫,发育过程包括卵期、幼虫期(4个龄期)、蛹期及成虫期,其中在4龄幼虫

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发育后期至蛹期前的一个阶段也被称为预蛹期.异色瓢虫的卵一般呈椭圆形,长 1.2 mm左右,颜色呈现黄色,接近孵化时颜色变深.卵块簇状排列,由数个到数十个卵组成[15].幼虫体长随发育时间逐渐增加,一龄幼虫的体长约为 2.0 mm,发育至 4龄后,体长增长至 6.0~10.0 mm[33].幼虫底色以黑色为主,从 2龄起背脊及腹侧面的某些突起会变为橙色,至 4龄时整个腹侧面的突起均为橙色[15].异色瓢虫将其 4龄幼虫蜕下的表皮作为其蛹体的附着物,蛹的个体形态差异不大.

异色瓢虫成虫的鞘翅颜色变化丰富,形成各种各样的色斑,这些色斑是一系列等位基因综合表达的结果[30].成虫色斑通常是由黑色或者淡黄色作为底色,镶嵌以黑色或者红色圆点状色块构成,类型多样,在亚洲许多地区的色斑种类都在数十种以上,其中黑底型(melanic)和非黑底型(non-melanic)的比例会伴随季节变化而变化[30,32,101].异色瓢虫的色斑变化在不同地区之间更为明显,在其原产地亚洲中部及东部地区,异色瓢虫的色斑以黑底为主;而在其引入地北美地区,则以黄色等非黑底型为主[27].

最近 10年来,关于异色瓢虫形态特征、色斑和多型现象的研究,似乎更多地关注来自业余昆虫爱好者的喜好和欣赏.但异色瓢虫丰富的色斑变化对于遗传学家来说,可能仍然不失为一种很有价值的研究材料.

3 异色瓢虫的生活史、猎物与天敌

3.1 生活史

异色瓢虫的发育历期在不同地区、不同环境条件下差异较大.在北美地区, LaManna等[37]在 26 ℃下饲喂豌豆蚜[*Acyrthosiphon pisum* (Harris)]观察的发育历期为:卵期 2.8 d,1龄幼虫 2.5 d,2龄幼虫 1.5 d,3龄幼虫 1.8 d,4龄幼虫 4.4 d,蛹期 4.5 d.在欧洲,以 10.5 ℃为起点温度条件下,异色瓢虫完成 1个世代需要 231.3日度[35].在我国异色瓢虫 1年可以发生 2~8代,代数随纬度的降低而增加[88].何继龙等[26]以棉蚜(*Aphis gossypii* Glover)为食物,在室内比较了异色瓢虫在不同温度条件下的全世代发育历期,发现发育历期长短与温度呈反比,24 ℃时全世代历期为 31.37 d,而荆英等[33]在室内测得全世代发育历期为 25.12 d,并认为这种差异可能是由于实验条件及食物的差异造成的.在实验室条件下,怀卵雌虫每次产卵大约 30粒[80],整个生命周期可以累计产卵 1 500粒以上[78].

3.2 猎物

异色瓢虫的捕食对象包括各种蚜虫、螨和介壳虫等同翅目昆虫以及鞘翅目、膜翅目、双翅目和鳞翅目昆虫的幼虫和蛹,其中蚜虫是主要的猎物(表 1).

异色瓢虫取食不同种蚜虫的功能反应可以分为Ⅰ型、Ⅱ型和Ⅲ型.Ⅰ型即取食量与猎物密度呈线性

表 1 异色瓢虫猎物表(部分)
Tab.1 Prey list of *H. axyridis* (in part)

猎物 Prey	猎物 Prey
豌豆蚜 *Acyrthosiphon pisum* Harris[18]	黑松松干蚧 *Matsucoccus matsumurae* Kuwana[95]
铁杉云杉球蚜 *Adelges tsugae* Annand[100]	巢菜修尾蚜 *Megoura viciae* Buckton[82]
绣线菊蚜 *Aphis citricola* Van der Goot[45]	苹果疣蚜 *Myzus malisuctus* Matsumura[47]
豆蚜 *Aphis craccivora* Koch[98]	烟蚜 *Myzus nicotianae* Blackman[10]
豆卫矛蚜 *Aphis fabae* Scopoli[76]	桃蚜 *Myzus persicae* Sulzer[47]
大豆蚜 *Aphis glycines* Matsumura[43]	欧洲玉米螟 *Ostrinia nubilalis* Hubner[55]
棉蚜 *Aphis gossypii* Glover[39]	杜鹃绵粉蚧 *Phenacoccus azaleae* Kuwana[93]
芦笋小管蚜 *Brachycorynella asparagi* Mordvolko[41]	小菜蛾 *Plutella xylostella* L.[5]
甘蓝蚜 *Brevicoryne brassicae* L.[82]	中国梨木虱 *Psylla chinensis* Yang et Li[21]
白毛蚜 *Chaitophorus populialbae* Boyer de Fonscolombe[42]	苹果缢管蚜 *Rhopalosiphum insertum* Walker[105]
蔷薇斜条卷叶蛾(玫瑰色卷蛾) *Choristoneura rosaceana* Harris[44]	禾谷缢管蚜 *Rhopalosiphum padi* L.[98]
梨黄粉蚜 *Cinacium iakusuiense* Kishida[47]	玉米缢管蚜 *Rhopalosiphum maidis* Fitch[69]
落叶松大蚜 *Cinara laricicola* Borner[31]	麦二叉蚜 *Schizaphis graminum* Rondani[104]
苹果绵蚜 *Eriosoma lanigerum* Hausmann[47]	麦长管蚜 *Sitobion avenae* Fabricius[98]
桃一点斑叶蝉 *Erythroneura sudra* Distant[103]	梨二叉蚜 *Toxoptera piricola* Mats[47]
棉铃虫 *Helicoverpa armigera* Hübner[40]	山楂叶螨 *Teranychus viennensis* Zacher[103]
桃粉蚜 *Hyalopterus amygdali* Blanchard[47]	橘声蚜 *Toxoptera aurantii* Boyer de Fonscolombe[24]
紫苜蓿叶象 *Hypera postica* Gyllenhal[18]	桃瘤蚜 *Tuberocephalus momonis* Matsumura[47]
蔷薇长管蚜 *Macrosiphum rosae* L.[20]	

相关[46],如异色瓢虫取食小米蚜虫(*Rhopalosiphum prunifoliae*);多数情况为Ⅱ型,即蚜虫种群增长为非密度制约而异色瓢虫的种群增长为线性密度制约,例如:当异色瓢虫取食萝卜蚜(*Lipaphis erysimi* Kaltenbach)、棉蚜(*Aphis gossypii* Glover)、大豆蚜(*Aphis glycines* Matsumura)以及玉米缢管蚜(*Rhopalosiphum maidis* Fitch)时,其功能反应为Type Ⅱ型[26,39,43,102];Ⅱ型的主要特点是:在蚜虫爆发的早期阶段,由于食物短缺造成异色瓢虫因饥饿而进行自残,导致捕食能力下降;当蚜虫密度上升至一定水平后,异色瓢虫的捕食能力不再下降,保持稳定水平.如异色瓢虫取食落叶松大蚜(*Cinara laricicola* Borner)[31].

3.3 天敌

异色瓢虫的天敌包括微生物、捕食或寄生性昆虫、哺乳动物、食虫鸟类及蜥蜴等爬行动物等[49].寄生性天敌基本为昆虫类,主要是寄生蜂、寄生蝇、茧蜂等,可寄生于异色瓢虫的各个虫态[63].寄生异色瓢虫蛹的一种寄生蜂 *Phalacrotophora philaxyridis* 广泛分布在亚洲和北美洲[11,69];寄生蝇 *Degeria luctuosa* 在韩国寄生异色瓢虫的幼虫、蛹及成虫[69],在美国很多地区,寄生蝇 *Stringygaster triangulifera* 寄生异色瓢虫幼虫及蛹,并且在限制其扩散速度方面发挥一定作用[57].茧蜂也是异色瓢虫的重要天敌,在其原产地亚洲地区(中国北京),其寄生瓢虫成虫,在其体内结茧,迫使瓢虫无法自由行动,并使其无法正常取食,最终饥饿致死[99].

异色瓢虫的捕食者种类很多. Majerus[49]认为,鸟类活动对田间异色瓢虫的种群变化有显著影响.爬行类和哺乳动物也会在进入冬眠前的能量补充活动中取食异色瓢虫,例如黄石公园(美国及加拿大)的大灰熊(*Ursus arctos horribilis*)会在入冬前大量取食群聚在其冬眠地点附近的异色瓢虫成虫[50].在捕食性昆虫中,蚁类的影响最为重要,蚂蚁对异色瓢虫的攻击行为通常是基于其与一些同翅目昆虫(如蚜虫)协同共生关系所产生的结果.也有少数种类的切叶蚁,如红火蚁(*Solanopsis invicta* Buren)会主动攻击异色瓢虫,并且把它当作食物取食[14].

在利用异色瓢虫进行生物防治的早期阶段,这些天敌被作为阻碍因素而加以控制,以便异色瓢虫可以更加迅速地建立种群,因而人们把这些天敌归入有害生物之列.近年来,随着异色瓢虫种群规模不断扩大,潜在威胁和危害愈发明显,很多天敌被作为控制异色瓢虫种群的因素而加以利用.在不久的将来,这些天敌甚至可能会在很多引入地区被当作专门针对异色瓢虫这一外来物种的"经典生物防治工具"而引入释放.

4 异色瓢虫的重要行为特性

4.1 交配与产卵

瓢虫科昆虫具有较为频繁的性行为并且易于观察,众多学者对此类问题进行了大量研究[7,29,59,61,65].虽然瓢虫倾向于通过增加交配次数与性伴侣数量来获取较高的繁殖量[27,60-62],但是异色瓢虫自身会表现出对雄性交配权的一种限制行为:雌虫会通过拒绝交配这种较为极端的方式来选择"心仪"的交配对象[58].这种选择作用对于种群结构可能存在一定影响,在亚洲除少数日本种群外,其雌雄性比基本维持在1∶1的水平[27].对于异色瓢虫来说,色斑类型对其交配几率有着重要影响.野外观察结果显示:在春季,非黑底型与黑底型雌虫倾向于选择非黑底型雄虫进行性行为;而在夏季,黑底型雄虫的交配成功几率远大于非黑底型.总的来说,色斑型对繁殖活动的影响主要发生在雌虫对雄虫的选择上[67].

雌虫的产卵活动发生于其整个生命周期[78],其繁殖能力(产卵量及孵化率,下同)随成虫年龄增加而降低.这被认为是新陈代谢能力下降的一种表现[13,48,70,77].当怀卵雌虫受到某些环境变化影响时,它的产卵策略会发生明显改变,这些改变直接影响着繁殖活动的进行.异色瓢虫的产卵量会随着猎物种群密度的变化而变化,其产卵时间会集中在猎物种群密度达到峰值之前[64].当猎物种群进入衰退期后,怀卵异色瓢虫的产卵量随猎物密度降低而逐渐降低,直到停止产卵.猎物种群密度不仅对雌虫产卵量有影响,对产卵场所的选择同样有重要影响.怀卵雌虫会对周围环境的猎物密度水平进行评估,然后通过迁飞寻找能够满足自身繁殖要求的最佳繁殖地点,而这些迁飞往往是和雌虫对猎物的搜索行为相伴的[30].同样,雌虫的产卵量及孵化率也随同种幼虫密度的变化而变化,某些同种幼虫留下的信息素会强烈地影响雌虫产卵率,并且这种影响会扩散到整个瓢虫种群,这可能是异色瓢虫为了减少卵期因食物匮乏产生自残而形成的一种繁殖策略[97],这种影响随幼虫龄期的增加而显著增强[22].这种针对同胞卵自残而产生的变化也会在产卵地点的选择上表现出来,雌虫通过增大卵堆的相对距离来平衡卵堆密度,增加自残风险[64].另外,捕食过程中较高的能

量消耗会极大地影响繁殖力[18].

在人工大量繁殖异色瓢虫过程中,一些人工条件的变化会对雌虫的繁殖能力产生较大影响[27].杨洪等[94]以猪肝及蔗糖为基础的人工饲料饲养的异色瓢虫产卵 343.8粒,最高为 1 029粒.孵化率以喂食鳞翅目昆虫蛹的效果最好,可达到 84.9%.滕树兵等[81]比较了 4种产卵基质对异色瓢虫繁殖能力的影响,认为蚕豆叶片和甘蓝叶片有利于其增强繁殖能力.

异色瓢虫的繁殖活动及繁殖能力受温度、食物及本身色斑型的影响,在不同环境条件下会适当改变其繁殖策略.人们一直努力通过开发人工饲料及进行异色瓢虫商业化饲养来加大异色瓢虫生产规模,但通过调整其它影响因素(如光照、温度等)来获得理想的繁殖效率,也是重要手段.

4.2 猎物搜索行为

作为捕食性昆虫,异色瓢虫对其猎物具有很强的追踪猎食能力[17,24,66].异色瓢虫的幼虫和成虫都具有很强的群集性.这在很大程度上是对猎物呈斑块分布的反应,并由环境异质性所致[73,102].当某一区域内的植物受到侵害时,会释放引诱异色瓢虫的挥发性物质[72],瓢虫在感受到这些信息素或者追踪到猎物后其搜索方式会从早期的广域性搜索向限域性搜索转变[17,72].除了化学信息物质以外,瓢虫还会利用颜色信息来判断寄主植物上猎物的丰度,异色瓢虫对黄色茎叶的敏感度营大于绿色.雌性成虫更喜欢有猎物的植株,而雄虫喜欢在猎物较少的植株上进行频繁的搜索[54].不过少数植物如紫藤(*Wisteria sinensis* Sims),受到蚜虫为害后产生的化学物质并不会吸引异色瓢虫,相反会对其产生排斥作用[72].

4.3 自残行为

自残现象在瓢虫中十分常见,很多捕食性瓢虫在自身种群密度过高或者食物量不足的情况下都会出现自残[30],这种现象的产生在很大程度上是遗传和适应变化的结果[83-84].同胞之间的自残在幼虫刚刚孵化时就开始了[64],但异色瓢虫对同胞卵的自残率一般低于非同胞卵[53].研究发现,被杀雄细菌螺原体 *Spiroplasma*感染的 1龄幼虫个体取食同胞卵的个数却要远大于未被感染个体,虽然感染与否对自残开始的时间影响不大,但自残行为会扩大细菌传播的范围[56].种群内自残比例会随着幼虫龄期的增加而不断上升,这可能是其对低营养水平环境的适应策略[34].异色瓢虫幼虫对同胞幼虫具有识别能力,通过正确识别姊妹幼虫来降低同胞自残率[53].在全部幼虫龄期中,异色瓢虫的 1龄幼虫及 4龄幼虫因自残导致的死亡率最高[64].自残会对各龄期幼虫体长和体质量的增量以及龄期长短产生重要影响[96],并且会持续影响成虫产卵量及孵化率.目前有研究表明,异色瓢虫会通过生产营养卵和个体迁移来降低自残发生的概率[71,74],但从根本上避免自残现象是十分困难的.在大规模异色瓢虫人工繁殖中,自残情况是最主要的影响因素之一.在早期对异色瓢虫幼虫进行分离是减少种内自残的有效方法,而在发育过程中食物的充足供应以及保证足够的饲养空间也十分必要.

5 异色瓢虫在生物防治中的应用

应用瓢虫科昆虫对有害生物进行控制已经有将近 120年的历史[68].异色瓢虫作为捕食性瓢虫的一员,在其引入地及原产地都发挥了重要的控害作用[35,88]. Gordon[23]总结了异色瓢虫在美国引入释放的情况,自 1916年在美国加利福尼亚州开始释放异色瓢虫以来,经过近百年的发展,这种瓢虫已经分布于美国各个主要农业区中,覆盖区域达 15个州以上.在美国东北部及加拿大东南部地区,异色瓢虫可以对美洲山核桃(*Carya illinoensis* Wangenheim)及红松(*Pinus koraiensis* Siebold et Zuccarini)上的有害生物进行有效防治[35], Cardinale等[4]通过对农业生态系统多样性调查后发现异色瓢虫对于紫花苜蓿(*Medicago sativa* L.)上的豌豆蚜(*Acyrthosiphon pisum* Harris)有极佳的控害效果.在美国南部地区异色瓢虫已经成为棉田中棉蚜(*Aphis gossypii* Glover 的)主要天敌,并且应用面积正在不断扩大[91].异色瓢虫可以对黄瓜(*Paraixeris denticulata* Houtt.)上的棉蚜进行防治[22],还会对玫瑰色卷蛾(*Choristoneura rosaceana* Harris)以及蔷薇长管蚜(*Macrosiphum rosae* L.)产生极佳的防治效果[44].在防治豌豆上的蚜虫时,异色瓢虫的控制能力也是远高于本地捕食性瓢虫[76].另外,异色瓢虫还被应用于象虫(Curculionidae)的防治,如美国佛罗里达州利用异色瓢虫控制柑橘(*Citrus reticulata* Blanco cv. Reticulata)上的根象(*Diaprepes abbreviatus* L.),效果十分明显[79].

在我国,人们释放异色瓢虫对烟草、桃、苹果及棉花种植地的蚜虫种群进行生物防治,能够针对目标害虫麦二叉蚜(*Schizaphis graminum* Rondani)[104]、梨二叉蚜(*Toxoptera piricola* Mats)[47]、桃蚜

(Myzus Persicae Sulzer)[92]、苹果绵蚜(Eriosoma lanigerum Hausman)及桃大尾蚜(Hyalopterus arundimis Fabricius)[47]等提供有效控制. 建立异色瓢虫种群可以很好的控制草莓(Fragaria ananassa Duchesne)和金盏菊(Calendula officinalis L.)上的棉蚜[86]; 在江西, 通过有条件的释放异色瓢虫可以对芦笋(Asparagus officnalis L.)上的芦笋小管蚜(Brachycorynella asparagi Mordvolki)进行防治[41]. 同样, 对于一些规模稍小的农业生产系统如温室蔬菜及观赏植物来说, 异色瓢虫也是很好的生物防治工具. 在上海等经济发达地区, 很多园林机构利用异色瓢虫防治木槿(Hibiscus syriacus L.)上的棉蚜[85]及大棚蔬菜上的各种蚜虫. 在林业害虫防治上, 异色瓢虫对松树上的辽宁松干蚧(Matsucoccus liaoningensis Tang)和梨树上的梨木虱(Psylla chinensis Yang et Li)[21]具有十分显著的防治效果. 李照会等[42]报道异色瓢虫对毛白杨(Populus tomentosa Carr.)上的白毛蚜(Chaitophorus populialbae Boyer de Fonscolombe)有很好的防治效果. 此外, 异色瓢虫对于近年来在我国危害严重的铁杉云杉球蚜(Adelges tsugae Annand)虫也具备一定的防治潜力[100].

对于异色瓢虫来说, 无论在其原产地亚洲地区[6,90], 还是在引入地[3,52,55], 关于农药影响的相关研究工作一直在深入开展. 这些研究工作一般涉及农药对异色瓢虫死亡率、繁殖力、捕食功能反应及行为学特征等方面. 王小艺等[90]测定了吡虫啉等6种杀虫剂亚致死剂量对异色瓢虫成虫繁殖力的影响, 发现这几种杀虫剂对于卵孵化率以及各龄幼虫发育历期有很大的影响. 而吡虫啉、鱼藤酮、氯戊菊酯和阿维菌素A对异色瓢虫捕食桃蚜的功能反应有一定影响, 在处理后异色瓢虫成虫最大捕食量降低, 处理猎物的时间延长[87]. 在对这几种杀虫剂的选择毒性进行比较后发现, 其安全性为阿维菌素>鱼藤酮>印楝素>吡虫啉[89]. 赫小草等[25]测量了13种杀虫剂对异色瓢虫成虫的毒力, 发现几种常用的拟除虫菊酯类杀虫剂对异色瓢虫毒力较高, 而抑太保、卡死克和灭幼脲相对而言十分安全, 可以用于进行综合防治(IPM).

6 异色瓢虫的潜在危害

随着异色瓢虫在世界范围内的不断扩散, 其造成的生态影响不断加剧[16]. 有证据显示, 异色瓢虫对引入地瓢虫多样性产生重要影响. 通过比较异色瓢虫对两种本地瓢虫科物种横斑瓢虫(Coccinella transversoguttata Faldermann)和锚斑长足瓢虫(Hippodamia convergens Guérin-Méneville)的非靶标作用, 发现其影响十分明显[59,76]. 异色瓢虫会对 Coleomegilla maculate Timberlake和 Olla v-nigrum Mulsant种群变化趋势产生决定性影响[9]. Brown等[2]在对苹果园捕食性瓢虫物种多样性的调查工作中发现: 异色瓢虫对其它瓢虫(如 Cycloneda sanguinea L.)的替代作用十分明显. 七星瓢虫(Coccinella septempunctata L.)、多异瓢虫(Hippodamia variegata (Goeze))、龟纹瓢虫(Propylaea japonica Thunberg)以及两星瓢虫(Adalia bipunctata L.)也会在异色瓢虫的侵入过程中大量减少[38,75], 甚至当目标虫害密度较高时, 异色瓢虫的非靶标作用仍然十分明显[74]. 取食其它物种的卵是异色瓢虫进行种间捕食活动的主要方式[8], 但异色瓢虫的攻击行为并不影响十一星瓢虫(Coccinella undecimpunctata L.)的种群水平[19].

除了通过上述种间捕食行为产生影响外, 异色瓢虫还可通过对食物资源的争夺而影响其它瓢虫种群数量, 在相近生态位水平内产生直接或者间接的影响. 异色瓢虫由于其自身的竞争能力, 往往在同资源种团(IGP, intra-guild predation)中充当顶级捕食者角色, 继而替代其它本地瓢虫[35]. Michaud[51]指出, 在柑桔园中, 异色瓢虫无论是捕食量还是繁殖能力都大大强于其它瓢虫种类, 在食物争夺上具有明显优势. 在食物压力的影响下, 一些瓢虫种群在短时间内明显萎缩乃至消亡.

很多学者建议在将异色瓢虫作为生防工具释放前, 应该针对其对与目标害虫有关联的其它昆虫产生的潜在影响进行评估[1]. 这些受非靶标作用影响的物种, 不应仅仅局限于瓢虫科内, 其它昆虫也应该被列入审视的范围. 如 Koch等[36]报道异色瓢虫会主动攻击未成熟的君主蝶(Danaus plexippus L.), 主要为卵和幼虫期.

近年来, 异色瓢虫对人类活动的影响也备受关注. 在世界自然保护联盟(IUCN)所属的物种生存委员会(SSC)的入侵种专家组(ISSG)建立的全球入侵种数据库(GISD, http://www.issg.org/database)中收入的27种入侵昆虫中, 包含了异色瓢虫[86]. 在美国很多地区, 异色瓢虫已经被作为"有害生物"而加以控制, 甚至会出现在除虫公司的服务手册上[71]. 某些涉及人类生活的问题主要是异色瓢虫的越冬群集性造成的. 在晚秋, 异色瓢虫会在其越冬地点大量聚集, 异色瓢虫会选择民居或建筑物作

为聚集地,而这种聚集行为会使人们产生厌恶感,人们会使用合成除虫菊酯和薄荷醇来驱赶异色瓢虫[28].

在很多国家和地区,异色瓢虫已经被视为入侵生物而加以控制.对于异色瓢虫的研究重心也从单纯的释放应用向同资源种团竞争以及非靶标作用等方面转变,并且有关其危害评估工作也不断得到加强.

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通过释放异色瓢虫,可以防控果木、花卉、蔬菜等农产品上的蚜虫、螨类以及其它多种害虫.随着我国绿色农业规模不断加大,异色瓢虫的应用前景十分广泛.随着对异色瓢虫生物学、生态学以及毒理等方面研究的不断深入,使用异色瓢虫作为天敌昆虫的频率及规模会不断增加.

在继续加大异色瓢虫使用的同时,还必须考虑引入或者释放天敌物种对引入地的农业生态系统生物多样性以及生态系统效率的影响.在物种比较单一的农业生态系统中添加甚至是淹没式释放天敌是否会造成潜在影响,异色瓢虫在北美地区造成的危害就是例证.根据异色瓢虫造成的后果,在引入外来天敌进行生物防治时,进行必要的环境安全性评估是非常重要的.我国学者研究的人工饲料已经开始进行工厂化生产,并且在实际生产中应用,取得了不错的效果[94].与此同时,应该综合考虑异色瓢虫的释放时机、释放范围以及潜在影响等诸多方面,改变传统的覆盖淹没式释放,加强预评估工作,从生态学角度更加完善地利用异色瓢虫,使其安全地发挥应尽的效能.

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