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三种捕食性瓢虫成虫对卵的种内自残及其集团内捕食作用

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摘要: 捕食性瓢虫是农田生态系中一类重要的天敌昆虫, 种内自残和集团内捕食现象在捕食性瓢虫中普遍存在。本研究在室内通过选择性和非选择性试验比较分析了异色瓢虫、七星瓢虫及龟纹瓢虫成虫对卵的种内自残和集团内捕食作用以及卵表面的化学物质对集团内捕食作用的影响。结果表明: 在非选择性试验中, 3种捕食性瓢虫成虫对卵表现出相似的取食现象, 即对龟纹瓢虫卵取食最多, 其次为七星瓢虫卵, 对异色瓢虫卵取食相对较少; 在选择性试验中, 七星瓢虫和龟纹瓢虫较偏好取食同种卵, 对异色瓢虫卵取食均较少; 而异色瓢虫喜欢取食异种卵, 对同种卵取食相对较少。3种瓢虫卵经正己烷漂洗后, 异色瓢虫、七星瓢虫和龟纹瓢虫成虫却未对卵表现出取食偏好性。本研究可为捕食性瓢虫组合释放与协调利用、田间集团内捕食作用评定及其在生物防治中的应用提供理论依据。

关键词: 异色瓢虫; 七星瓢虫; 龟纹瓢虫; 种内自残; 集团内捕食

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The intraspecific cannibalism and intraguild predation on eggs among three predacious ladybeetles (Coleoptera: Coccinellidae) adults

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Abstract: The aphidophagous ladybird beetles *Harmonia axyridis*, *Coccinella septempunctata* and *Propylea japonica* are important predatory enemies in the agro-ecosystem. Intraspecific and interspecific predation (IGP) of eggs is a well documented phenomenon amongst the three coccinellids. In the current study, the intraspecific cannibalism and intraguild predation among *H. axyridis*, *C. septempunctata* and *P. japonica* measurement was conducted in non-choice and choice tests in the laboratory. The role of egg surface chemicals on intraspecific cannibalism and intraguild predation were also examined. The main results were summarized as follows. In the non-choice test, the three coccinellid species showed the same predation pattern. All of them had their largest predation amount on *P. japonica* eggs, second on *C. septempunctata* eggs and least on *H. axyridis* eggs. In the choice test, *C. septempunctata* and *P. japonica* preferred to eat conspecific eggs than heterospecific eggs while *H. axyridis* had significantly less conspecific egg predation and preferred to eat heterospecific eggs. However, they did not show preferring to the eggs when the coatings of the three coccinellids eggs were removed using hexane. The research can offer the theoretical evidence for the scientific evaluation of IGP in the field, combined releasing and coordination use of the three

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coccinellids in the future.

Key words: *Harmonia axyridis*; *Coccinella septempunctata*; *Propylea japonica*; cannibalism; intraguild predation

捕食性瓢虫是农田生态系统中一类重要的天敌昆虫,随着有机农业的蓬勃发展,利用其进行生物防治,已经是现代绿色植物保护体系中的重要内容之一(张帆等,2015)。自然界中,种内自残(Intraspecific cannibalism)和集团内捕食(Intraguild predation, IGP)现象在捕食性瓢虫中普遍存在(Yasuda and Shinya, 1997)。集团内捕食可以在多种天敌昆虫间发生,影响着集团内捕食者、被捕食者以及生物防治目标害虫的种群消长动态,从而直接影响生物防治的效果(马克争等,2004; 杨帆等 2014)。而种内自残作为影响昆虫种群消长及逆境定殖的重要因素,已被作为生物入侵定殖机制的重要组成部分而得到广泛研究(Yasuda *et al.*, 2001)。

研究表明瓢虫未成熟阶段(特别是卵)更易被捕食(Sato and Dixon, 2004; Cottrell, 2007),其种内自残和集团内捕食的发生受多种因素的影响。一般的,食物短缺(Michaud, 2003; Yasuda *et al.*, 2004; Omkar *et al.*, 2005a)、体型差异较大(Agarwala *et al.*, 2003; Omkar *et al.*, 2006)、种群密度过高(Pervez *et al.*, 2006)均可以加剧种内自残和集团内捕食的发生。但也有一些特殊现象,如在异色瓢虫 *Harmonia axyridis*、七星瓢虫 *Coccinella septempunctata*、会纹长足瓢虫 *Hippodamia convergens* 和横斑瓢虫 *Coccinella transversoguttata* 幼虫两两之间的集团内捕食中,增加蚜虫数量并未降低集团内捕食水平;甚至有个体较大的种类在集团内捕食中反而处于弱势(Snyder *et al.*, 2004)。此外,瓢虫被捕食的危险还与体表或体内释放的有毒或趋避性化学物质有关。如体型较小的二星瓢虫 *Adalia bipunctata* 卵和幼虫利用表面的化学物质可抵御体型较大的七星瓢虫的攻击(Hemptinne *et al.*, 2000); 十四星裸瓢虫 *Calvia quatuordecimguttata* 卵利用表面化学物质乙烷能成功抵御异色瓢虫的捕食(Ware *et al.*, 2007)。除上述主要因素以外,捕食者和被捕食者所处生境的复杂程度(Lucas, 1998)、捕食者的饥饿程度和取食专化性(Hemptinne *et al.*, 2000)以及捕食者和被捕食者发育阶段、年龄结构、进攻性和易受害性(Yasuda and Kimura, 2001; Nedvď

et al., 2013)等均会对种内自残和集团内捕食作用产生影响。

异色瓢虫、七星瓢虫和龟纹瓢虫 *Propylaea japonica* 是我国北方地区常见的蚜虫的捕食性天敌。自然界中,异色瓢虫发生时间长,种群数量大,生态位宽度高,且在田间释放时表现出很强适应定殖和种间竞争作用(王甦等,2007, 2012);且可以通过较高的种间捕食及攻击防御能力提高自身在营养水平低下情况时的生存概率(王甦等, 2010)。在前期研究基础上,鉴于异色瓢虫、七星瓢虫、龟纹瓢虫在农田生态系统和生物防治中的重要性,本研究在室内通过选择性和非选择性试验比较分析了3种捕食性瓢虫成虫对卵的种内自残和集团内捕食作用以及卵表面的化学物质对集团内捕食作用的影响。本研究可为捕食性瓢虫组合释放与协调利用、田间集团内捕食作用评定及其在生物防治中的应用提供理论依据。

1 材料与方法

1.1 供试虫源

异色瓢虫、七星瓢虫和龟纹瓢虫成虫均采集自北京市昌平区流村镇王家园有机果园(E116°23'09", N40°10'42"),采回后挑选健康成虫在昆虫繁育室内饲养。饲养方法如下:将成虫在养虫笼(规格:50 cm×50 cm×50 cm; 100 目)内集中饲养,每笼50头,笼内放置带有足量豆蚜 *Aphis curviness* Koch 的蚕豆苗,每48 h更新一次。待成虫交配产卵后,将带有新鲜卵块的叶片移入另一洁净塑料培养皿(D=9.0 cm)中,待卵孵化后转移至另一养虫笼内继续饲养至成虫羽化。养虫室环境条件分别为:温度25℃±1℃、湿度70%±5%、光周期16 L:8 D,光照强度3000 lux。室内3种瓢虫均饲养3代以上用于试验。

1.2 非选择性条件下3种瓢虫成虫对卵的取食

将异色瓢虫、七星瓢虫和龟纹瓢虫的新鲜卵块(每种瓢虫的卵均为50粒)分别放入3个洁净的塑料培养皿(D=9.0 cm)中,然后在培养皿中分别放入1头饥饿24 h的异色瓢虫成虫(羽化7 d),皿口覆盖Parafilm封口膜并用解剖针扎取通

气口若干。4 h、24 h 后在解剖镜下观察 3 种瓢虫卵被取食情况, 其中卵未被损坏或者部分被损坏, 卵壳被破坏但大量卵黄仍存在的记录为未被取食或者部分被取食; 卵完全被吃掉或只有少量卵黄残留的记录为完全被取食 (Ware *et al.*, 2008)。非选择性条件下七星瓢虫和龟纹瓢虫成虫对卵的取食处理异色瓢虫。以上各处理重复 20 次。试验环境条件为: 温度 $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$ 、湿度 $70\% \pm 5\%$ 、光周期 16L:8D, 光照强度 3000 lux。

1.3 选择性条件下 3 种瓢虫成虫对卵的取食

将异色瓢虫、七星瓢虫和龟纹瓢虫的新鲜卵块 (每种瓢虫的卵均为 50 粒) 放入同一洁净的塑料培养皿 ($D = 9.0 \text{ cm}$) 中供 1 头饥饿 24 h 的异色瓢虫成虫 (羽化 7 d) 取食, 皿口覆盖 Parafilm 封口膜并用解剖针扎取通气口若干。4 h、24 h 后在解剖镜下观察 3 种瓢虫卵被取食情况, 检查记录方法同 1.2。选择性条件下七星瓢虫和龟纹瓢虫成虫对卵的取食处理同异色瓢虫。

参照 Ware 等 (2008) 用正己烷 (色谱纯) 漂洗 3 种瓢虫的新鲜卵块 (每种瓢虫的卵均为 50 粒) 后放入同一培养皿中供 1 头饥饿 24 h 的异色瓢虫成虫 (羽化 7 d) 取食, 皿口覆盖 Parafilm 封口膜并用解剖针扎取通气口若干。24 h 后在解剖镜下观察 3 种瓢虫卵被取食情况, 检查记录方法同 1.2。正己烷漂洗后七星瓢虫和龟纹瓢虫成虫对卵的取食处理同异色瓢虫。以上各处理重复 20 次。试验环境条件为: 温度 $25^{\circ}\text{C} \pm 1^{\circ}\text{C}$ 、湿度 $70\% \pm 5\%$ 、光周期 16L:8D, 光照强度 3000 lux。

1.4 数据分析

利用统计软件 SPSS 17.0 for windows 对所得数据进行统计分析, 获得平均值和标准误。对不同处理间的差异进行单因素方差分析 (One-Way ANOVA) 和 Duncan 氏多重比较。

2 结果与分析

2.1 3 种瓢虫成虫对卵的种内自残及集团内捕食

在非选择性条件下, 异色瓢虫、七星瓢虫和龟纹瓢虫成虫对卵的取食表现出相似现象, 均为取食龟纹瓢虫卵最多, 其次为七星瓢虫卵, 对异色瓢虫卵取食最少 (见图 1)。

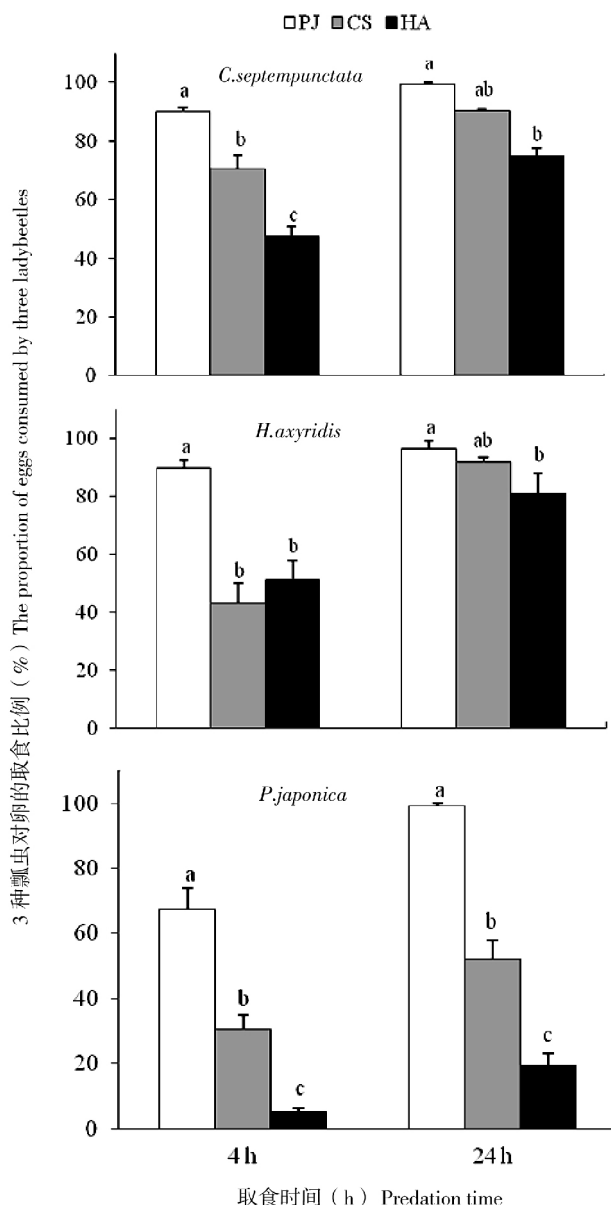


图 1 非选择性条件下七星瓢虫、异色瓢虫和龟纹瓢虫对卵的取食

Fig. 1 Eggs consumed by *Coccinella septempunctata*, *Harmonia axyridis* and *Propylaea japonica* in non-choice tests

注: PJ 指龟纹瓢虫的卵; CS, 指七星瓢虫的卵; HA, 指异色瓢虫的卵。图中各数据均为平均值 $\pm$ 标准误, 不同色系柱顶相同小写字母表示经 One-way ANOVA, Duncan's 多重比较在 0.05 水平下无显著差异 ($P > 0.05$)。下同。Note: PJ, refers to *Propylaea japonica* eggs; CS, refers to *Coccinella septempunctata* eggs; HA, refers to *Harmonia axyridis* eggs. The data in the figure are mean $\pm$ SE. Histograms with the same letters indicate no significant difference at 0.05 level ($P > 0.05$) by One-way ANOVA / Duncan's multiple range test. The same below.

由图 2 可以看出,在选择性试验中,七星瓢虫和龟纹瓢虫偏好取食同种卵,对异色瓢虫卵的取食均较少;而异色瓢虫喜欢取食异种卵,即喜欢取食七星瓢虫和龟纹瓢虫的卵,对同种卵取食相对较少。

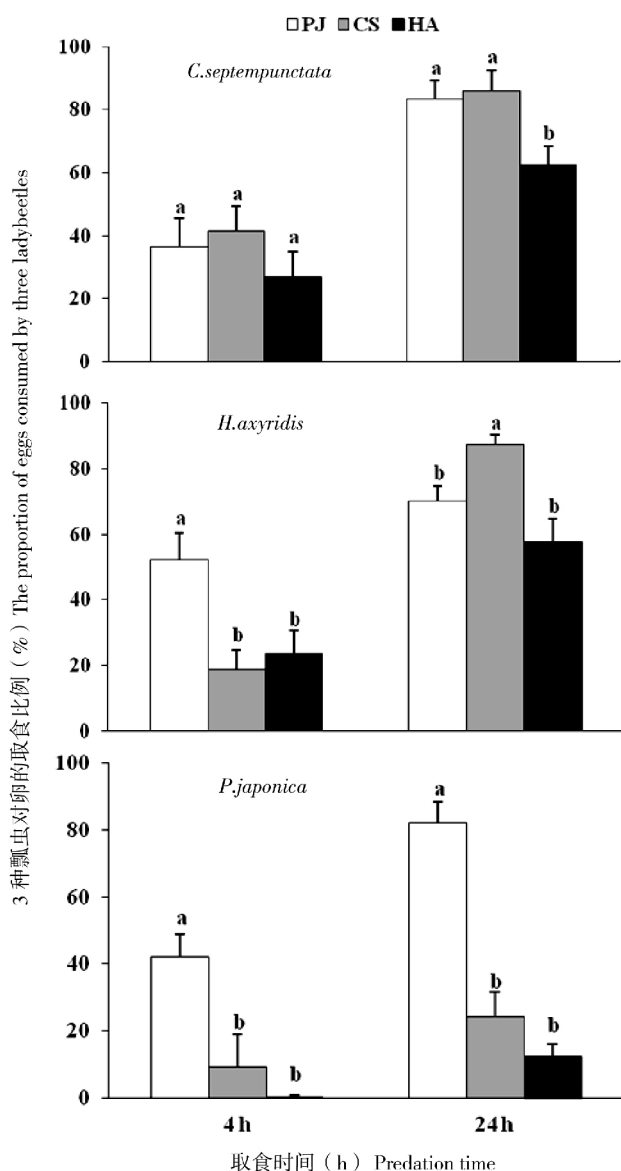


图 2 选择性条件七星瓢虫、异色瓢虫和龟纹瓢虫对卵的取食
Fig. 2 Eggs consumed by *Coccinella septempunctata*, *Harmonia axyridis* and *Propylaea japonica* in the choice tests

2.2 卵表面的化学物质对集团内捕食作用的影响

结果表明,3 种瓢虫卵经过正己烷漂洗后,异色瓢虫、七星瓢虫和龟纹瓢虫对卵的取食均没有显著差异 ($P > 0.05$),即 3 种瓢虫未对正己烷漂洗过的卵表现出取食偏好 (见图 3)。

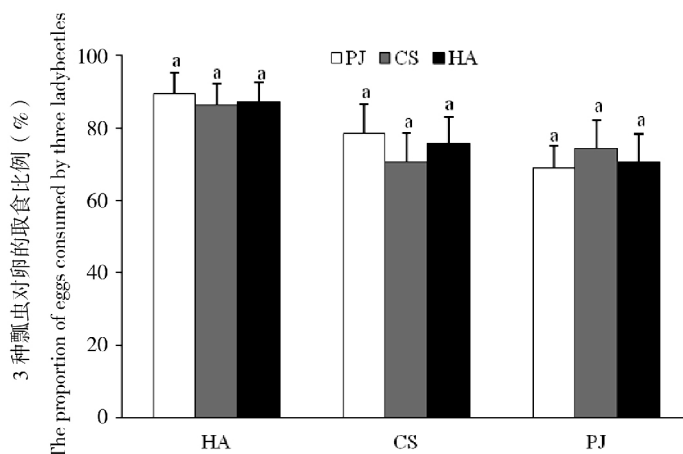


图 3 正己烷漂洗后 3 种瓢虫成虫对卵的取食

Fig. 3 The proportion of eggs washed using hexane consumed by three ladybeetle adults

3 结论与讨论

室内种内自残和集团内捕食作用的研究有很高的可控性,因此很多研究都选择在室内进行 (Pervez *et al.*, 2006; Noia *et al.*, 2008; Sato *et al.*, 2009; 杜迎刚等, 2014)。本研究表明异色瓢虫、七星瓢虫和龟纹瓢虫 3 种捕食性瓢虫成虫对龟纹瓢虫卵的取食相对较多,对异色瓢虫卵的取食相对较少,这与 3 种瓢虫幼虫对卵的取食规律一致,这可能与瓢虫卵的大小有关,龟纹瓢虫卵较小易被取食,异色瓢虫卵较大不易被取食 (杨帆, 2014)。七星瓢虫和龟纹瓢虫较偏好取食同种卵,而异色瓢虫喜欢取食异种卵。这可能是由于卵表面化学物质的存在或者同种卵可能是更富有营养的 (Omkar *et al.*, 2005b)。Magro 等 (2007) 研究发现异色瓢虫卵表面含有生物碱,大大减少了其被其他种类捕食的可能性。这也许是本研究中七星瓢虫和龟纹瓢虫较少取食异色瓢虫卵的原因之一。异色瓢虫卵表面含有的化学物质对其他瓢虫甚至是自身有趋避作用, Cottrell (2004) 研究发现异色瓢虫幼虫仅依靠美国当地种 *Coccinella maculata* 或楔斑溜瓢虫 *Ollav-nigrum* 的卵就可完成生长发育,但这两种当地的瓢虫幼虫却不能通过取食外来的异色瓢虫的卵完成生长发育,这可能由于此异色瓢虫卵表面的化学物质对当地瓢虫生长发育不利或卵中缺少生长发育必需的物质所致。3 种瓢虫卵经正己烷漂洗后,可能卵表面的化学物质均被去除,因此异色瓢虫、七星瓢虫和龟纹瓢

虫成虫对卵均未表现出取食偏好性。在集团内捕食作用中, 异色瓢虫一般处于优势 (Félix and Soares, 2004; Ware and Majerus, 2008), 这与本研究结果一致。异色瓢虫对同一生态位捕食性瓢虫的侵害不仅表现在争夺食物及生境资源上 (Obrycki and Kring, 1998), 很多情况下集团内捕食会对其它瓢虫的种群造成极大影响 (Cardinale *et al.*, 2003; Facon *et al.*, 2011)。在北美果园中异色瓢虫造成 90% 以上的瓢虫物种消失 (Brown, 2003)。与此同时, 异色瓢虫自身则会通过自我识别降低种内自残的发生, 减少自身种群规模的损失 (Yasuda *et al.*, 2001; 王甦等, 2010)。除此之外, 异色瓢虫还与处于同一营养级的其它捕食性天敌之间存在集团内捕食现象, 如异色瓢虫能捕食食蚜蝇 *Episyrphus balteatus* 的幼虫及卵 (Alhmedi *et al.*, 2010); 异色瓢虫比较偏好捕食被阿尔蚜茧蜂 *Aphidius ervi* 寄生的蚜虫 (Meisner *et al.*, 2011); 异色瓢虫幼虫还与普通草蛉 *Chrysoperla carnea* 幼虫之间可以相互捕食 (Nedvěd *et al.*, 2013)。

经典型生物防治是引入外来生物防治因子 (biological control agent) 对本地害虫进行防控。但是, 外来生物防治因子可能会通过集团内捕食对本地物种多样性产生影响甚至威胁。异色瓢虫在美洲、欧洲等地的引入就是一个典型例子 (Koch *et al.*, 2006; Brown *et al.*, 2011)。一系列研究表明, 异色瓢虫作为广食性天敌昆虫, 其种内自残及集团内捕食对其在引入地定殖、替代其它本地物种等方面起到了极为显著的促进作用。因此, 在外来生物防治因子释放利用之前, 不仅要考虑控害效果, 同时也需要考虑到外来生物和当地生态系统中其他物种之间的互作关系, 使本地天敌和引入天敌达到协同控害的作用 (杨帆等, 2014)。虽然在引入地异色瓢虫已被视为“有害入侵生物”加以控制 (Roy and Wajnberg, 2008), 但是在原产地仍是一种重要的捕食性天敌, 广泛应用于农林害虫的生物防治 (王甦等, 2007)。集团内捕食作用会直接影响天敌昆虫在释放应用中的工作效能, 如何减轻或避免这一现象的产生、促进多种天敌的协同利用, 是多种天敌昆虫复合释放中一个急需解决的科学问题 (杨帆等, 2014; 张帆等, 2015)。

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