第 22 卷第 12 期 2002 年 12 月 生 态 学 报 ACTA ECOLOGICA SINICA Vol. 22, No. 12 Dec., 2002

亚致死剂量杀虫剂对异色瓢虫捕食作用的影响

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摘要:为探讨害虫化学防治与生物防治的协调技术,提高综合防治水平,测定了吡虫啉、鱼藤酮、氰戊菊酯和阿维菌素 4 种杀虫剂亚致死剂量对异色瓢虫成虫捕食桃蚜功能反应的影响。亚致死剂量杀虫剂对异色瓢虫功能反应模型的基本结构没有改变,但影响到了模型的各项参数。药剂处理后异色瓢虫最大日捕食量降低,处理猎物的时间延长,捕食速率和寻找效应一般也被减弱。影响结果还与异色瓢虫受药的方式有关。4 种药剂中以氰戊菊酯的影响最大,鱼藤酮的胃毒作用也较明显。研究结果表明亚致死剂量的杀虫剂对天敌异色瓢虫的捕食作用存在着不良影响,这为害虫治理中如何协调利用化学防治和生物防治措施、指导科学用药提供了一定的理论基础。

关键词:异色瓢虫;桃蚜;捕食作用;杀虫剂;亚致死效应;生态毒理学

Effects of Sublethal Doses of Insecticides on Predation of Multicolored Asian Ladybird *Harmonia axyridis* (Pallas) (Coleoptera: Coccinelliodae)

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Abstract: Insecticides and natural enemies are the two main means to control insect pests at present. A problem is coming that after spraying of insecticides in the field, some natural enemies were inevitably influenced at lethal or sublethal degree. In order to seek better techniques for coordinating the chemical and biological control measures, and improve the level of integrated pest management, effects of sublethal doses of four insecticides, i.e., imidacloprid, rotenone, fenvalerate and abamectin, on the functional response of multicolored Asian ladybird *Harmonia axyridis* (Pallas) preying on green peach aphid *Myzus persicae* (Sulzer) were determined.

The functional response tests of *H. axyridis* were conducted in *Petri* dishes with cubage about 73.78cm^3 in laboratory. And the density of prey *M. persicae* was set as 20, 40, 60, 80 and 100 head/dish. The tests were divided into two groups. In the first group, the ladybirds were pretreated with sublethal doses of insecticides by contact method (exposed to the filter paper with compounds), while the aphids as prey were untreated. In the second group, the prey aphids were pretreated with sublethal doses of insecticides by immersing method, but the predator ladybirds were not treated with any insecticides beforehand. The experimental data were simulated with the model of Holling's disc equation.

Results revealed that the functional response models of ladybird preying on aphid were all still conformed to Holling's type II curve in spite of pretreated with sublethal doses of insecticides; just only the parameters of models had some changes. But the predatory action of ladybirds on aphids was influenced to some extent, and the effects were related to the exposure route of predators obtained toxin.

基金项目:国家自然科学基金资助项目(39870493)

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收稿日期:2001-09-13;**修订日期**:2002-01-17

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The discovery rates of ladybirds treated with imidacloprid and fenvalerate by contact method and abamectin by feeding method decreased, whilst those of other treatments were a litter higher than untreated ladybirds. But the discovery rates in all treatments were very close, range from 0.9 to 1.2.

The handling time of *H. axyridis* pretreated with sublethal dosages of insecticides all prolonged. And those treated with fenvalerate in two groups, abamectin by contact method, imidacloprid and rotenone by feeding method showed the most serious influence. Ladybirds in these treatments spent 1.93, 2.37, 1.93, 1.72 and 3.19-fold times to handle the prey compared with the untreated predators, respectively.

The maximal predatory capacities of ladybird pretreated with four sublethal insecticides all reduced. Those treated with fenvalerate in two groups, abamectin by contact method, imidacloprid and rotenone by method of feeding poisonous aphids, decreased pronouncedly. The reduction rates were 48.16%, 57.74%, 48.14%, 41.87% and 68.69%, respectively. While those treated with imidacloprid and rotenone by contact method and abamectin by feeding method were relatively close to that of control, reduction percentages were just 8.16%, 2.74% and 2.69%.

The predatory rates of ladybird pretreated sublethal insecticides were declined except in those treated with abamectin by feeding method. Up to 18 hours after treatment, predatory rates of all treatments were lower than that of control, those treated with fenvalerate by two methods and rotenone by feeding method reached significant levels. The predatory rates decreased 47.14%, 42.14% and 48.22% on the 24h after treatment, respectively.

The lower the prey density was, the higher the searching efficiency of predator was. The searching efficiencies of ladybird treated with four insecticides in two groups reduced than that of untreated predators. Especially to those treated with imidacloprid and fenvalerate by contact method, and rotenone by feeding method, the searching capability of natural enemy was influenced more seriously. The searching efficiencies of these three treatments decreased 16.73%, 19.44% and 16.85%, respectively, when compared as prey density 20.

These findings suggested that insecticides at sublethal level had harmful influence on the predation of *H. axyridis*. The predatory capability of multicolored Asian ladybird to aphid was weakened at different degrees after treated with sublethal doses of insecticides. The results will give better directions for using pesticides rationally and scientifically, and also contribute to coordinate the chemical and biological control measures against insect pests.

Key words: *Harmonia axyridis*; *Myzus persicae*; predation; insecticides; sublethal effect; ecotoxicology

文章编号:1000-0933(2002)12-2278-07　**中图分类号**:S482.3;Q968.1　**文献标识码**:A

近年来由于化学农药的大量使用,很多地区蔬菜和果树上桃蚜的抗药性迅速提高,所以有必要寻求一些相应的替代措施,如生物防治方法的应用等,以缓解害虫抗药性的发展。异色瓢虫是农业和林业上一种重要的捕食性天敌,对为害蔬菜、果树、花卉、森林的各类蚜虫具有较强的控制能力,还可捕食蚧壳虫、粉虱、木虱、螨类、某些鳞翅目和鞘翅目昆虫的卵、低龄幼虫和蛹等,在世界范围内得到广泛的应用[1]。如法国曾从中国引进异色瓢虫防治果园蚜虫[2]。

一定时期内化学杀虫剂还不可能完全摒弃不用,那么如何协调化学防治和生物防治二者间的矛盾,使之在害虫控制中发挥各自的优势,就成为综合防治成功的关键。因为田间施用杀虫剂,在防治害虫的同时,不可避免也会影响到害虫天敌。药后其活动能力、捕食量、搜索行为、繁殖率等方面有何变化,是值得深入探讨的。杀虫剂对寄生性天敌如蚜茧蜂[3],捕食性天敌如蜘蛛等[4~6]的功能反应具有减弱影响已有报道,异色瓢虫对某些药剂的敏感性也有研究[7,8],但有关杀虫剂对瓢虫捕食作用的亚致死效应尚未见文献。本研究试图通过测定几种杀虫剂在亚致死剂量下对异色瓢虫捕食作用的影响,明确各类药剂对天敌瓢虫的安

全程度，为协调化学防治与生物防治作出积极的探索。使这 2 种主要的害虫控制措施能够取长补短，充分发挥各自的优势，产生“强强联合”的效应，从而更加有效、合理地防治害虫，提高农作物的产量和品质，维护生态健康和环境安全，最终达到维护人类自身健康、保障生态环境可持续发展的目的。

1 材料与方法

1.1 材料

1.1.1 试虫 桃蚜 *Myzus persicae* (Sulzer)，饲养于温室内小白菜上；异色瓢虫 *Harmonia axyridis* (Pallas)，采自北京植物园，然后贮藏于 4℃左右的冰箱中，试验前在 29℃下用桃蚜饲养 1d 后供试。

1.1.2 杀虫剂 10%吡虫啉(imidacloprid)WP，江苏省吴县市农药厂产品；2.5%鱼藤酮(rotenone)EC，广州农药厂产品；20%氰戊菊酯(fenvalerate)EC，江苏省镇江市镇江农药厂生产；29833r/g 阿维菌素(abamectin)浓缩液，深圳市瑞德丰农药公司提供。

1.2 方法

1.2.1 药剂对异色瓢虫捕食作用影响的测定 参考邹运鼎等[9]和胡玉山等[10]方法。测定在直径为 8.5cm，高 1.3cm(容积约为 73.78cm^3)的培养皿内进行，桃蚜密度设为每皿 20、40、60、80、100 头，取 4 龄若蚜供试。每皿投入异色瓢虫成虫 1 只，重复 4 次，其中 2 头雌虫 2 头雄虫。处理后置于 29±0.5℃、RH 65～75%、L:D=14:10 的光照培养箱内，24h 后检查各处理被食蚜数，统计捕食量并进行功能反应拟合。试验分 2 组进行，第 1 组(以字母后下标 1 表示)用滤纸接触法以亚致死剂量的杀虫剂预处理异色瓢虫，24h 后挑取存活的瓢虫测定其捕食作用，猎物桃蚜不用药剂处理。第 2 组(以字母后下标 2 表示)用浸渍法以亚致死剂量(LC_{25})的杀虫剂预处理猎物桃蚜，24h 后挑取存活蚜虫供试，而异色瓢虫不作药剂处理。CK 组瓢虫和蚜虫均不用药剂处理。本试验中预处理异色瓢虫和桃蚜的各药剂剂量如表 1 所示。

表 1 预处理异色瓢虫和桃蚜的药剂剂量

Table 1 The doses of pretreated ladybirds and aphids

异色瓢虫 Ladybird	浓度(mg/L) Concentration	死亡率(%) Motality	桃蚜 Aphid	浓度(mg/L) Concentration	死亡率(%) Motality
吡虫啉 Imidacloprid (I_1)	33.3	7.5	吡虫啉 Imidacloprid (I_2)	0.6	25.4
鱼藤酮 Rotenone (R_1)	62.5	0	鱼藤酮 Rotenone (R_2)	3.0	24.5
氰戊菊酯 Fenvalerate (F_1)	12.5	26.7	氰戊菊酯 Fenvalerate (F_2)	45.0	22.4
阿维菌素 Abamectin (A_1)	14.4	0	阿维菌素 Abamectin (A_2)	0.01	26.2

* 桃蚜和异色瓢虫的毒力测定工作已预先完成，结果另文发表[11]；在对异色瓢虫的预处理中，当药剂在田间防治蚜虫时的使用浓度仍小于其 LC_{25}时，则以其田间常用剂量为准 The toxicity determinations of four insecticides on the *H. axyridis* and *M. persicae* had been conducted previously, and results had been published in another journal. When pretreated the ladybirds, if the concentrations of insecticides applied in the field for controlling aphids were still lower than the LC_{25} of insecticides to ladybirds, then treated ladybirds using the recommended dosages in the field

1.2.2 药剂对异色瓢虫捕食速率的影响 每皿猎物数量固定为 100 头的处理在第 4、8、12、18、24 小时观察蚜虫的被食量，用于计算捕食速率：

$$\text{捕食速率(head/h)} = \frac{\text{捕食量}}{\text{捕食时间}}$$

1.2.3 药剂对异色瓢虫寻找效应的影响 根据 Holling 方法进行估算[12]，计算公式为：

$$S = \frac{a'}{1 + a' \cdot T_h \cdot N}$$

其中，S 为寻找效应，a' 为瞬时攻击率，T_h 为天敌处理猎物的时间，N 为猎物密度。

1.2.4 数据的统计分析 所有数据的统计分析均采用 SAS(Statistical Analysis System)软件进行[13]。

2 结果与分析

2.1 四种杀虫剂亚致死剂量对异色瓢虫捕食量的影响

各处理间不同猎物密度下的捕食量测定结果详见表 2。除了在猎物密度为 100 的情况下氰戊菊酯接触

处理(F_1)和鱼藤酮饲喂处理(R_2)明显降低外,其余各处理捕食量虽有些变化,但与对照相比差异均不显著。由捕食量与猎物密度的关系可以看出,吡虫啉(I_1、I_2)和阿维菌素(A_1、A_2)及对照 5 组处理随着猎物密度上升其捕食量迅速上升,但当猎物密度高于 80 时,捕食量的变化趋于平缓,功能反应模型符合 Holling II 型。但鱼藤酮(R_1、R_2)和氰戊菊酯(F_1、F_2)4 个处理在高密度时捕食量反而有所降低。为便于比较,现均以 Holling 圆盘方程来拟合试验数据。

表 2　4 种药剂亚致死剂量对异色瓢虫捕食量的影响

Table 2　Effects of sublethal insecticides on the predatory capacities of ladybirds

处理 Treatments	猎物密度 Prey Density (head/*Petri* dish)				
	20	40	60	80	100
I_1	16.25±1.44^{a}	36.25±1.65^{a}	37.50±6.03^{ab}	50.75±9.91^{a}	61.00±9.01^{ab}
R_1	19.75±0.25^{a}	38.50±0.50^{a}	47.25±10.50^{ab}	66.50±2.50^{a}	65.00±9.44^{ab}
F_1	15.75±3.61^{a}	28.50±3.95^{a}	46.25±13.09^{ab}	48.75±6.30^{a}	37.00±14.72^{b}
A_1	19.50±0.50^{a}	33.50±6.50^{a}	42.00±3.00^{ab}	52.75±6.07^{a}	53.75±7.90^{ab}
I_2	19.25±0.75^{a}	31.75±3.64^{a}	51.25±3.35^{ab}	48.75±17.61^{a}	55.25±10.00^{ab}
R_2	16.25±3.42^{a}	30.00±3.81^{a}	29.00±8.55^{b}	43.00±9.01^{a}	36.25±5.92^{b}
F_2	18.50±0.29^{a}	35.50±1.26^{a}	46.75±5.68^{ab}	45.00±7.77^{a}	40.50±2.25^{ab}
A_2	19.25±0.48^{a}	39.00±0.41^{a}	57.50±1.32^{a}	56.25±9.99^{a}	59.67±7.88^{ab}
CK	19.75±0.25^{a}	38.50±0.96^{a}	50.50±3.66^{ab}	58.33±9.24^{a}	70.00±7.00^{a}

* 表中数据为 4 次重复的平均值(头±标准误差(*SE*);同列数据具相同字母者表示在 5%水平差异不显著(DMRT) Data in table were the average values of four replicates (head±standard errors. The data in the same column with the same letters are not significantly different (DMRT)

2.2　亚致死剂量杀虫剂对异色瓢虫功能反应模型参数的影响

功能反应线性方程拟合情况较好,均达到极显著水平(表 3)。亚致死剂量的药剂处理后,异色瓢虫对桃蚜的功能反应模型的结构没有改变,只是模型参数发生了变化。吡虫啉和氰戊菊酯接触处理和阿维菌素饲喂处理的瞬时攻击率比对照降低,其余各处理的反而略高于对照(表 3)。各药剂处理后异色瓢虫处理猎物的时间都比对照延长,特别是氰戊菊酯(F_1、F_2)及阿维菌素接触处理(A_1)和吡虫啉(I_2)鱼藤酮(R_2)胃毒处理方式受到了较大影响,分别为对照处理猎物时间的 1.93、2.37、1.93、1.72 和 3.19 倍。最大日捕食量则均低于对照,也以氰戊菊酯(F_1、F_2)及阿维菌素接触处理(A_1)和吡虫啉(I_2)鱼藤酮(R_2)胃毒处理方式受影响较大,分别比对照降低 48.16%、57.74%、48.14%、41.87%和 68.69%,而吡虫啉和鱼藤酮接触处理及阿维菌素饲喂处理的与对照较接近,仅分别降低 8.16%、2.74%和 2.69%。各药剂以亚致死剂量处理后,模型的参数有所变化,说明异色瓢虫对桃蚜的捕食作用受到了不同程度的影响,且影响结果与异色瓢虫受药的方式有关。如鱼藤酮表现出胃毒作用大于接触毒性,捕食已中毒的猎物后更易使异色瓢虫的功能减弱。

2.3　亚致死剂量杀虫剂对异色瓢虫捕食速率的影响

4 种药剂亚致死剂量处理后,除阿维菌素饲喂方式处理外,其余各处理捕食速率均低于对照。至 18h 后,4 种药剂所有处理的捕食速率都比对照低,其中氰戊菊酯两种处理方式(F_1、F_2)以及鱼藤酮饲喂处理(R_2)的达到显著水平,24h 时分别较对照降低 47.14%、42.14%和 48.22%(表 4)。说明低剂量药剂处理后对异色瓢虫捕食速率有较大的影响。天敌在单位时间内捕食猎物的数量减少,对害虫的控制能力被削弱。

2.4　亚致死剂量杀虫剂对异色瓢虫寻找效应的影响

图 1 为各处理异色瓢虫的寻找效应。从图中趋势来看,猎物密度越小的处理,天敌的寻找效应越高,随着猎物密度的增大,其寻找效应逐渐降低。而经各药剂亚致死剂量处理后异色瓢虫对猎物的寻找效应均低于对照。这表明未受药的异色瓢虫对猎物的搜索活力强,受药剂处理过的试虫搜索能力降低,尤其是吡虫啉(I_1)和氰戊菊酯接触处理(F_1)以及鱼藤酮饲喂处理(R_2)对异色瓢虫寻找效应的影响最明显,以各处理寻找效应最高(当猎物密度为 20)时进行比较,这 3 个处理的寻找效应分别比对照降低 16.73%、19.44%和 16.85%。

表 3　各处理功能反应模型拟合结果

Table 3　Simulating results of functional response models of all treatments

处理 Treatments	功能反应线性方程 Linear equation $\frac{1}{Na}=a\frac{1}{N}+b$	相关系数 r Correlation coefficient	圆盘方程 Disc equation $Na=\frac{T\cdot a'\cdot N}{1+a'\cdot T_h\cdot N}$	处理猎物时间 T_h(min)	最大捕食量 Na_{max}(头)(head)
I_1	$\frac{1}{Na}=1.095895\frac{1}{N}+0.005355$	0.9852**	$Na=\frac{0.912495N}{1+0.00488642N}$	7.71	186.74
R_1	$\frac{1}{Na}=0.901396\frac{1}{N}+0.005057$	0.9957***	$Na=\frac{1.109390N}{1+0.00561019N}$	7.28	197.75
F_1	$\frac{1}{Na}=1.053718\frac{1}{N}+0.009488$	0.9653**	$Na=\frac{0.949021N}{1+0.00900431N}$	13.66	105.40
A_1	$\frac{1}{Na}=0.832867\frac{1}{N}+0.009484$	0.9987***	$Na=\frac{1.200672N}{1+0.01138717N}$	13.66	105.44
I_2	$\frac{1}{Na}=0.869520\frac{1}{N}+0.008460$	0.9902**	$Na=\frac{1.150060N}{1+0.0097951N}$	12.18	118.20
R_2	$\frac{1}{Na}=0.890535\frac{1}{N}+0.015705$	0.9657**	$Na=\frac{1.122920N}{1+0.01763547N}$	22.62	63.67
F_2	$\frac{1}{Na}=0.808852\frac{1}{N}+0.011637$	0.9615**	$Na=\frac{1.236320N}{1+0.01438706N}$	16.76	85.93
A_2	$\frac{1}{Na}=0.913105\frac{1}{N}+0.005054$	0.9870**	$Na=\frac{1.095164N}{1+0.00553496N}$	7.28	197.86
CK	$\frac{1}{Na}=0.903300\frac{1}{N}+0.004918$	0.9980***	$Na=\frac{1.107052N}{1+0.00544448N}$	7.08	203.33

** $P<0.01$，*** $P<0.001$

表 4　亚致死剂量杀虫剂对异色瓢虫捕食桃蚜速率的影响

Table 4　Effects of sublethal doses of insecticides on predatory rates of ladybirds

处理 Treatments	处理后时间 Time after treatment (h)					24h 降低(%) Reduction
	4	8	12	18	24	
I_1	3.7500 ± 1.1050^{ab}	2.6250 ± 0.4563^{b}	2.2917 ± 0.2217^{ab}	2.5278 ± 0.3089^{abc}	2.5417 ± 0.3754^{ab}	12.86
R_1	3.5825 ± 1.2600^{ab}	2.7813 ± 0.6063^{b}	2.4167 ± 0.5152^{ab}	2.2778 ± 0.3733^{abc}	2.7083 ± 0.3933^{ab}	7.15
F_1	2.4375 ± 2.4375^{ab}	2.0625 ± 1.1213^{b}	1.8542 ± 0.9758^{b}	1.4306 ± 0.7356^{c}	1.5417 ± 0.6133^{b}	47.14
A_1	3.2500 ± 0.9475^{ab}	2.9375 ± 0.4575^{b}	2.5833 ± 0.4575^{ab}	2.1806 ± 0.4573^{abc}	2.2396 ± 0.3292^{ab}	23.21
I_2	3.1875 ± 1.1475^{ab}	3.1875 ± 0.4100^{b}	2.8333 ± 0.4208^{ab}	2.6250 ± 0.4856^{abc}	2.3021 ± 0.4167^{ab}	21.07
R_2	2.2500 ± 1.2825^{b}	1.7188 ± 0.5113^{b}	1.5208 ± 0.4042^{b}	1.3333 ± 0.3706^{c}	1.5104 ± 0.2467^{b}	48.22
F_2	2.1875 ± 0.7800^{b}	2.1563 ± 0.3663^{b}	2.1875 ± 0.1783^{b}	2.0986 ± 0.0767^{bc}	1.6875 ± 0.0938^{b}	42.14
A_2	7.1250 ± 0.9925^{a}	4.4167 ± 0.1275^{a}	3.2778 ± 0.1208^{a}	2.5556 ± 0.0639^{abc}	2.4863 ± 0.3283^{ab}	14.76
CK	4.2500 ± 1.2500^{ab}	3.3750 ± 0.1250^{ab}	3.2500 ± 0.5833^{ab}	3.6944 ± 0.3733^{a}	2.9167 ± 0.2917^{a}	—

* 表内数据为 4 次重复的平均值(头/h)±标准误差(SE)；同一列数据后面相同字母表示经 DMRT 统计在 5%水平上差异不显著 Data in table were the average values of four replicates (head/h) ±standard errors. The same letters after data in the same column in table showed no significant difference at 5% level based on DMRT

3　讨论

本研究中采用接触法和毒蚜饲喂法的给药方式，是模拟了田间天敌所处的实际环境。当田间施药以后，捕食性天敌异色瓢虫爬行于喷过药剂的叶面而接触到杀虫剂，同时，当它们捕食已中毒的猎物时也获得了药剂。这样的试验结果对于指导生产上合理用药是十分有意义的。

功能反应拟合结果中有 5 个处理的攻击率“反而高于对照”，处理组 2(I_2、R_2、F_2)是用亚致死剂量的药剂预处理桃蚜，猎物受药剂作用后轻微中毒，行为迟缓，对天敌捕食活动的逃避能力减弱，因而导致异色瓢虫对猎物的攻击率有所提高，这是正常的。对于处理组 1 的两个处理(R_1 和 A_1)，其实与对照的攻击率是十分接近的，均在 1.1～1.2 间，因为鱼藤酮和阿维菌素这两种制剂对异色瓢虫的触杀毒性均很低，试验中以

田间推荐用量处理死亡率为 0(表 1)，因此这两个处理对瓢虫的影响可能相对较小，攻击率与对照接近，其差异应该在正常的变动范围之内。当然也可能是瓢虫受到低剂量的药剂作用后产生兴奋，刺激了捕食。

功能反应的减弱是杀虫剂对天敌亚致死影响的一个重要方面。吴进才等曾报道，稻田施用一次杀虫双，拟水狼蛛捕食褐飞虱的功能约需 7 天才能恢复到正常水平，而频繁使用甲胺磷则由于削弱了天敌的功能易导致褐飞虱再猖獗[4]。亚致死剂量的抗蚜威、兴棉宝和乐果可引起蚜茧蜂的功能反应从 Holling II 型变为 S 型，搜索能力下降，攻击效率减弱[3]。Jebanesan 发现亚致死剂量的醚菊酯(etofenprox)对 *Diplonychus indicus* 捕食五带淡色库蚊 *Culex quinquefasciatus* 的能力有不良影响[6]。可见，很多杀虫剂对天敌的捕食作用是有严重影响的。此外，亚致死剂量的杀虫剂还对天敌的生长发育[14,15]、觅食活动[16]以及繁殖活动[17~20]等存在不同程度的影响。研究杀虫剂的的副作用对于指导科学用药是有帮助的。

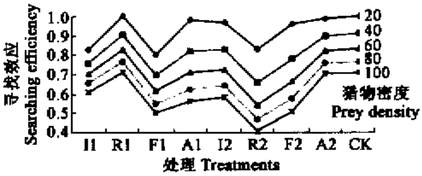

图 1　亚致死剂量杀虫剂对异色瓢虫寻找效应的影响

Fig. 1　Effects of sublethal doses of insecticides on searching efficiencies of ladybirds

事实上，药剂的作用往往与使用的剂量密切相关。同一种药剂，一定剂量以上对生物的影响可达到致死或亚致死程度，而到一定剂量以下，可能药剂的不良作用就降低到了可以忽略的地步。对于多数杀虫剂，都应该可以找到能有效控制害虫但对天敌相对较安全的一个剂量范围，姑且称之为“生/化协调剂量”。显然，这种剂量依不同的药剂、害虫、天敌、环境等因素的组合而有所不同。当然，要求药剂对天敌绝对无副作用是不现实的。杀虫剂对天敌生物的亚致死效应十分复杂，要制订正确的综防计划，合理地使用化学措施和生物措施，尚须做更多更深入的探索。总之，在防治有害生物时，不完全依赖于化学杀虫剂，实行综合治理的计划有助于提高农业生态系统对不利因素的抵抗能力。

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