

# 不同颜色诱捕器对枣叶瘿蚊的田间 诱捕效果及对天敌的选择性\*

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**摘要** 【目的】比较不同颜色(黄、蓝、白)水盆诱捕器对枣叶瘿蚊 *Dasineura jujubifolia* 成虫的诱捕效果以及对天敌昆虫的误伤风险, 探索枣叶瘿蚊监测和物理防治的新方法。【方法】2022 和 2025 年, 在新疆维吾尔自治区阿克苏地区枣园采用不同颜色水盆诱捕器监测了枣叶瘿蚊及天敌昆虫的成虫种群动态, 比较了不同颜色诱捕器对枣叶瘿蚊及天敌昆虫诱捕数量的差异, 采用天敌与枣叶瘿蚊成虫数量的比值(选择性比)评估对天敌昆虫的潜在生态影响。【结果】通过两年对枣叶瘿蚊成虫的监测, 发现枣叶瘿蚊种群存在明显的季节性动态, 越冬代成虫主要发生在 5 月初, 第一代成虫高峰期主要在 5 月中下旬。黄色诱捕器诱捕枣叶瘿蚊成虫数量显著多于其它两种颜色的诱捕器 ( $P < 0.001$ ), 2022 年黄色诱捕器诱捕到越冬代高峰数量[(130.00±67.66)头/诱捕器]约为其它两种颜色诱捕数量[蓝色:(14.67±8.72)头/诱捕器; 白色:(11.67±3.47)头/诱捕器]的 9 倍, 第一代高峰数量[(139.67±34.00)头/诱捕器]约为其它两种颜色诱捕数量[蓝色:(24.33±1.91)头/诱捕器; 白色:(10.67±1.52)头/诱捕器]的 7 倍; 2025 年黄色诱捕器诱捕到越冬代高峰数量[(81.40±25.55)头/诱捕器]约为其它两种颜色诱捕数量[蓝色:14.00±6.94 头/诱捕器; 白色:28.20±8.45 头/诱捕器]的 4 倍, 第一代高峰数量[(98.75±32.51 头/诱捕器)]约为其它两种颜色诱捕数量[蓝色:(8.33±1.91)头/诱捕器; 白色:(15.33±6.28)头/诱捕器]的 8 倍。捕食性天敌(草蛉、瓢虫)数量在 3 种颜色间无显著差异(草蛉:  $P = 0.305$ ; 瓢虫:  $P = 0.580$ ), 黄色诱捕器诱捕到寄生蜂数量多于其它两种颜色 ( $P < 0.001$ )。黄色诱捕器对草蛉 ( $P < 0.001$ ) 和瓢虫 ( $P = 0.002$ ) 的选择性比均显著低于其它两种颜色, 对寄生蜂的选择性比在不同颜色间无显著差异 ( $P = 0.112$ )。【结论】黄色水盆诱捕器诱捕枣叶瘿蚊成虫效果最好, 对天敌昆虫误伤风险较低, 可用于枣叶瘿蚊的监测及物理防治。

**关键词** 水盆诱捕器; 颜色; 枣叶瘿蚊; 天敌; 成虫监测; 物理防治

## Effectiveness and specificity of different colored traps for the jujube gall midge

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**Abstract** [Aim] To compare the effectiveness of different colored (yellow, blue, white) pan traps for trapping the adult jujube gall midges (*Dasineura jujubifolia*) and their by-catch of the natural enemies of plant pests, thereby optimizing the available methods for the monitoring and physical control of this pest. [Methods] In 2022 and 2025, yellow, blue and white pan traps were deployed in jujube orchards in Aksu, Xinjiang to monitor the population dynamics of adult midges and their natural enemies, after which the performance of the different colored traps were compared. The ratio of midges to their natural enemies was calculated to assess the potential ecological impact of yellow, blue and white traps on beneficial species. [Results]

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Distinct seasonal dynamics were observed over the two years of the study. Overwintering adults peaked in early May and the first generation peaked in mid-to-late May. Yellow traps captured significantly more adult midges than the other colored traps ( $P < 0.001$ ). In 2022, the average peak capture of overwintering adults in yellow traps [ $(130.00 \pm 67.66)$  ind./trap] was approximately nine times higher than that in blue [ $(14.67 \pm 8.72)$  ind./trap], or white [ $(11.67 \pm 3.47)$  ind./trap], traps. The maximum number of the first generation captured in yellow traps [ $(139.67 \pm 34.00)$  ind./ trap] was approximately 7 times higher than was captured in blue [ $(24.33 \pm 1.91)$  ind./ trap], or white [ $(3.56 \pm 0.65)$  ind./ trap], traps. In 2025, the peak number of overwintering individuals captured in yellow traps [ $(81.40 \pm 25.55)$  ind./ trap] was approximately four times that captured in blue [ $(14.00 \pm 6.94)$  ind./ trap], or white [ $(28.20 \pm 8.45)$  ind./ trap], traps. Peak abundance of the first generation captured in yellow traps [ $(35.91 \pm 7.80)$  ind./ trap] was about 8 times that captured in blue [ $(8.33 \pm 1.91)$  ind./ trap], or white [ $(15.33 \pm 6.28)$  ind./ trap], traps. There was no significant difference in the number of predatory natural enemies (lacewings, ladybugs) captured by the different colored traps (lacewings:  $P = 0.305$ ; ladybugs:  $P = 0.580$ ), however, yellow traps captured significantly more parasitic wasps than the blue or white traps ( $P < 0.001$ ). Yellow pan traps had significantly lower selectivity ratios for lacewings ( $P < 0.001$ ), and ladybugs ( $P = 0.002$ ) compared to the other two colors. There were no significant differences in selectivity ratios for parasitic wasps among the three trap colors ( $P = 0.112$ ). [Conclusion] Yellow pan traps capture significantly more adult jujube gall midges than blue, or white, traps, and also capture fewer of their natural enemies.

**Key words** pan trap; color; jujube gall midge; natural enemy; adult monitoring; physical control

枣叶瘿蚊 *Dasineura jujubifolia* 属双翅目 Diptera 瘿蚊科 Cecidomyiidae, 是枣树上一种重要害虫, 广泛分布于新疆、河北、山东、山西等地 (Jiao *et al.*, 2017)。在新疆, 随着红枣产业的快速发展, 枣叶瘿蚊对枣树的危害日益严重 (贺鹏鹏等, 2021)。枣叶瘿蚊成虫喜在枣吊顶端未展开的嫩叶空隙产卵, 孵化的幼虫通过刮吸式口器取食叶片, 受害嫩叶呈现浅红色或紫红色褶皱的筒状, 不能伸展, 质硬而脆, 最后变黑枯萎脱落。花蕾受害后, 花萼畸形膨大, 花蕾不能正常开放, 逐渐枯黄脱落 (宋建伟等, 2006)。有研究表明, 虫瘿的形成阻碍了叶片的光合作用, 抑制了叶片的生长, 使更多的能量传递到虫瘿组织, 以保证致瘿昆虫的生长发育 (Fay *et al.*, 1993)。枣叶瘿蚊幼虫为害枣树致使树体不能获得充足的养分, 严重影响果实产量与品质, 一般年份若不进行防治, 其造成的产量损失可达 20%-30% (克热曼·赛米等, 2013; 阎雄飞等, 2022)。

枣叶瘿蚊在新疆一年可发生 4-5 代, 对枣树幼嫩时期的叶片为害尤为严重。在南疆小海子垦区枣叶瘿蚊幼虫种群主要有 3 个高峰期, 4 月中下旬开始在枣树上发生危害, 5 月下旬达到最高峰 (安尼瓦尔·斯力木, 2015; 王凡等, 2016;

Li *et al.*, 2025)。在新疆阿克苏地区的调查显示, 越冬代枣叶瘿蚊成虫于 4 月中下旬羽化, 羽化约一周后幼虫开始为害, 经 2-3 周发育可羽化为下一代成虫。枣树叶片受害高峰期与枣叶瘿蚊幼虫发生高峰期相吻合, 成虫数量是影响下一代幼虫发生为害的重要因子 (王海诺等, 2024)。因此, 精准掌握枣叶瘿蚊种群消长动态, 提前在成虫发生的关键时期开展预防控制, 是减轻枣叶瘿蚊幼虫为害的有效策略。

利用昆虫对颜色与光波段的趋性行为诱捕害虫, 是实施物理防治的重要策略之一。黄色粘虫板被用于枣叶瘿蚊成虫的田间监测及物理防治, 但相关技术在诱杀害虫的同时常对天敌昆虫造成误伤, 以及诱捕粘贴的枣叶瘿蚊成虫识别困难等局限性制约了其广泛应用 (Hallett and Heal, 2012; 安尼瓦尔·斯力木, 2015)。盘式、水盆式等诱捕器可通过随机拦截和正向吸引相结合的方式捕捉昆虫, 诱捕效率会受到目标昆虫对颜色趋性的影响 (Brødsgaard, 1989; Chu *et al.*, 2000)。这些诱捕器广泛适用于双翅目、膜翅目、鞘翅目及半翅目等多种害虫的诱捕 (Vrdoljak and Samways, 2012; Scriven *et al.*, 2013)。例如, 黄色水盆诱捕器被用于双翅目害虫萝卜蝇 *Delia planipalpis* 的田间种群调查 (Disney *et al.*,

1982) 和样本采集 (Lasa *et al.*, 2024)。前期研究发现, 水盆诱捕器诱捕枣叶瘿蚊成虫效果较好 (Wang *et al.*, 2023), 但水盆诱捕器的最佳诱捕颜色有待进一步评估遴选。

本研究在新疆阿克苏地区枣园, 系统评估不同颜色水盆诱捕器对枣叶瘿蚊成虫的诱集效果以及对非靶标天敌的误伤风险, 以期对枣叶瘿蚊的精准监测及绿色防控技术开发提供科学依据。

## 1 材料与方法

### 1.1 试验样地

新疆阿克苏地区属于暖温带干旱气候, 4-6 月气温介于 12-27 °C, 天气干燥多风, 沙尘较多。该区域农业生产系统是以果树为主的农林复合系统, 红枣为其中最常见的果树种类之一。本研究于 2022 和 2025 年 4 月底至 6 月底, 在阿克苏地区分别选择了 3 块和 5 块常规管理的长方形枣园开展调查, 所选果园的枣树树龄在 15 年左右, 品种主要为骏枣, 枣叶瘿蚊发生程度相近, 农户采用常规管理措施, 果园平均面积为 (0.73 ± 0.09) hm<sup>2</sup> (范围为 0.34-1.62 hm<sup>2</sup>)。

### 1.2 枣叶瘿蚊及天敌采样

本试验中水盆诱捕器由白色的塑料桶(上口直径 17.2 cm, 底部直径 13.4 cm, 高度 11.5 cm,

体积为 2 L) 喷荧光黄、荧光蓝、荧光白 3 种颜色的漆(广东三和化工科技有限公司)制作而成(图 1: A-C)。相较三脚支架上放置塑料盆的传统水盆诱捕器, 塑料桶便于在枣园悬挂, 同时能够储存足够水量以有效应对当地强烈的自然蒸发, 也有助于避免大风天气吹倒诱捕装置的常见问题。桶内外涂有颜色相同的荧光色, 以最大限度的减少偏差。在每个果园内选取一块面积为 0.20 hm<sup>2</sup> 的区域, 距离果园边界 10 m 以上, 以降低边缘效应对试验的影响。在选择区域的两条对角线上随机布设诱捕器, 每种颜色各 3 个, 任意两个诱捕器之间距离大于 30 m, 以减少干扰。诱捕器悬挂在枣树枝干上, 高度统一为 1.6 m, 桶内加入 1.5 L 稀释的 0.012% 洗涤剂溶液以降低表面张力。诱捕器每 7 d 检查一次, 收集诱捕到的昆虫, 并更换洗涤剂溶液。2022 年共调查 10 个周期, 2025 年共调查 9 个周期。

### 1.3 样品鉴定

在实验室内, 依据形态特征对诱捕器每次诱捕到的枣叶瘿蚊成虫、寄生蜂、草蛉和瓢虫进行分类和统计(林祥海, 2005; Jiao *et al.*, 2017; 赖艳和刘星月, 2020)。其中, 枣叶瘿蚊成虫及体型较小的寄生蜂通过体式显微镜(SMZ180-LT, 凤凰光学集团有限公司)进行观察鉴定。



图 1 不同颜色水盆诱捕器

Fig. 1 Different-colored pan traps

A. 蓝色诱捕器; B. 黄色诱捕器; C. 白色诱捕器。

A. Blue trap; B. Yellow trap; C. White trap.

## 1.4 数据分析

所有数据经 Excel 2019 整理后,采用 R 4.5.0 软件进行统计分析 (R Core Team, 2025)。将 2022 和 2025 年每个枣园各调查周期中 3 个相同颜色诱捕器的重复观测数据 (枣叶瘿蚊、寄生蜂、草蛉和瓢虫数量) 进行合并累计求和。为分析颜色对诱捕效果的影响,构建广义线性混合模型 (GLMM),以颜色为固定效应,站点与年份的嵌套结构为随机效应,并采用一阶自回归结构 [AR (1)] 处理同一枣园内多次调查间的时间自相关 (Zuur *et al.*, 2010)。通过似然比检验评估颜色效应的显著性,多重比较采用 Tukey's HSD 法 ( $\alpha = 0.05$ )。所用模型通过 nlme 软件包实现 (Pinheiro *et al.*, 2025),基于 DHARMA 和 lmtest 软件包完成模型诊断 (Zeileis and Hothorn, 2002; Hartig, 2024)。为进一步评估不同颜色诱捕器对天敌的误伤程度,合并各枣园相同颜色诱捕器的重复观测数据,计算天敌昆虫与枣叶瘿蚊数量的比值作为对天敌误伤风险的评价指标。若不同天敌的选择性比在年份之间没有差异,则将两年数据合并后采用 Kruskal-Wallis 非参数检验,分析颜色对诱捕器天敌误伤的影响。当检验结果显著 ( $P < 0.05$ ) 时,使用 Dunn 检验进行多重比较,显著性水平为  $\alpha = 0.05$ 。所有统计结果均使用 GraphPad Prism 10.1.2 软件及 R 语言的 ggplot2 包进行可视化。

## 2 结果与分析

### 2.1 枣叶瘿蚊及天敌昆虫种群发生动态

**2.1.1 枣叶瘿蚊成虫种群消长动态** 2022 与 2025 年阿克苏地区枣叶瘿蚊成虫种群动态基本一致。2022 年枣叶瘿蚊成虫的发生高峰期在 5 月初 [黄色诱捕器诱捕数量为 (130.00±67.66) 头/诱捕器/周;蓝色诱捕器为 (14.67±8.72) 头/诱捕器/周;白色诱捕器为 (11.67±3.47) 头/诱捕器/周] 和 6 月初 [黄色诱捕器诱捕数量为 (139.67±34.00) 头/诱捕器/周;蓝色诱捕器为 (24.33±1.91) 头/诱捕器/周;白色诱捕器为 (10.67±1.52) 头/诱捕器/周], 5 月中下旬和 6 月中旬成虫数量减少 (图 2: A)。

2025 年枣叶瘿蚊成虫的发生高峰期在 5 月初 [黄色诱捕器诱捕数量为 (81.40±25.55) 头/诱捕器/周;蓝色诱捕器为 (14.00±6.94) 头/诱捕器/周;白色诱捕器为 (28.20±8.45) 头/诱捕器/周] 和 5 月中旬 [黄色诱捕器诱捕数量为 (98.75±32.51) 头/诱捕器/周;蓝色诱捕器为 (4.22±0.86) 头/诱捕器/周;白色诱捕器为 (15.33±6.28) 头/诱捕器/周], 5 月下旬及 6 月中下旬成虫数量减少 (图 2: B)。

**2.1.2 天敌昆虫种群消长动态** 诱捕到的捕食性天敌主要包括瓢虫和草蛉,寄生性天敌为寄生蜂。2022 年捕食性天敌的发生高峰期为 5 月中下旬及 6 月初 (图 3: A, B),寄生性天敌的发

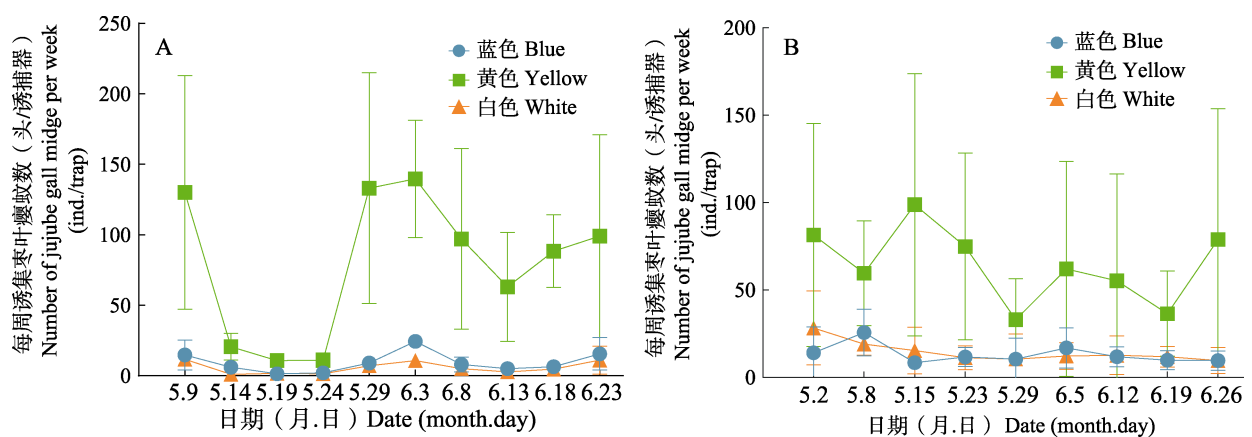


图 2 2022 (A) 和 2025 年 (B) 枣园枣叶瘿蚊成虫种群发生动态

Fig. 2 Population dynamics of jujube gall midge adults in jujube orchards in 2022 (A) and 2025 (B)

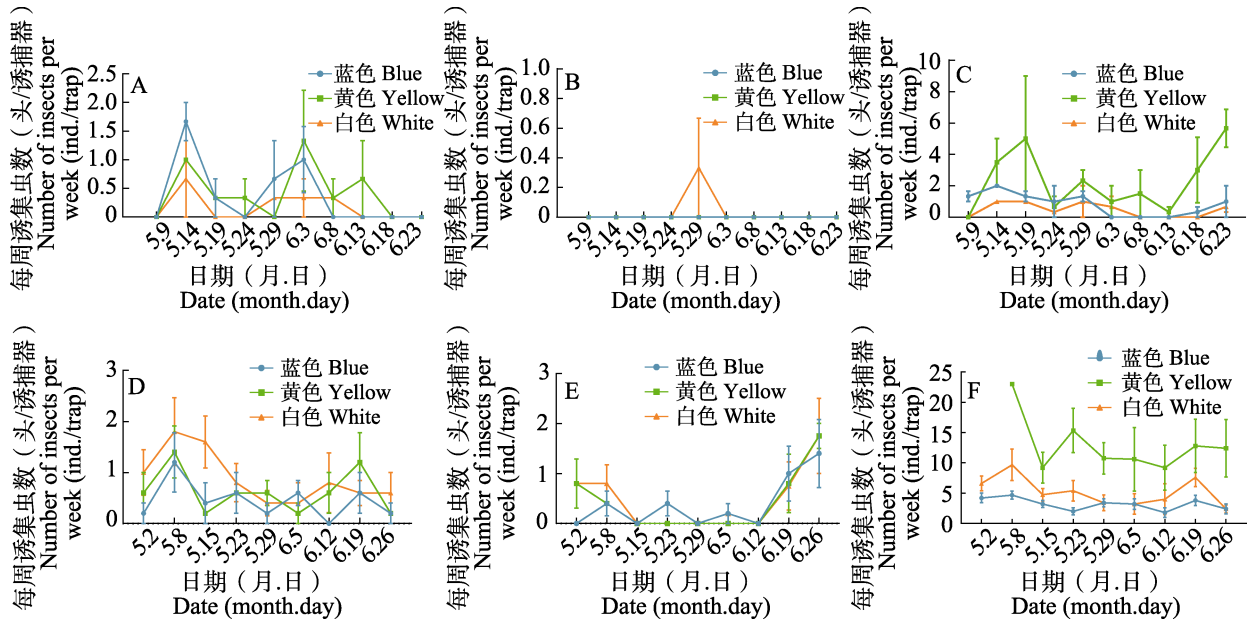


图 3 枣园天敌昆虫种群发生动态

Fig. 3 Population dynamics of natural enemies in jujube orchards

- A. 草蛉 (2022); B. 瓢虫 (2022); C. 寄生蜂 (2022); D. 草蛉 (2025);  
E. 瓢虫 (2025); F. 寄生蜂 (2025)。  
A. Lacewings (2022); B. Ladybugs (2022); C. Parasitoid wasps (2022); D. Lacewings (2025);  
E. Ladybugs (2025); F. Parasitoid wasps (2025).

生高峰期分别为5月中下旬及6月底(图3:C);2025年捕食性天敌的发生高峰期为5月中旬及6月下旬(图3:D,E),寄生性天敌的发生高峰期为5月上旬及6月底(图3:F)。3种颜色诱捕器诱捕捕食性天敌发生及寄生性天敌种群发生动态基本一致。

## 2.2 不同颜色诱捕器诱捕效果比较

### 2.2.1 诱捕器颜色对枣叶瘿蚊和天敌昆虫诱捕量的影响

黄色诱捕器对枣叶瘿蚊成虫诱捕效果最佳,其诱捕数量显著多于蓝色和白色( $\chi^2 = 448.3$ ,  $df = 2$ ,  $P < 0.001$ )(图4:A)。不同颜色诱捕器对草蛉( $\chi^2 = 2.376$ ,  $df = 2$ ,  $P = 0.305$ )和瓢虫( $\chi^2 = 1.090$ ,  $df = 2$ ,  $P = 0.580$ )诱捕数量无显著差异,且总体诱捕量较少(图4:B,C)。黄色诱捕器的诱捕数量也显著多于其它颜色( $\chi^2 = 218.4$ ,  $df = 2$ ,  $P < 0.001$ )(图4:D)。

### 2.2.2 诱捕器颜色对天敌选择性的影响

黄色诱捕器对草蛉( $\chi^2 = 14.632$ ,  $df = 2$ ,  $P < 0.001$ )和瓢虫( $\chi^2 = 12.041$ ,  $df = 2$ ,  $P = 0.002$ )的选择

性比均显著低于蓝色和白色诱捕器(图5:A,B)。不同颜色诱捕器对寄生蜂的选择性比无显著差异( $\chi^2 = 4.386$ ,  $df = 2$ ,  $P = 0.112$ )(图5:C)。

## 3 结论与讨论

本研究通过3种颜色的水盆诱捕器诱捕枣叶瘿蚊及其天敌昆虫,发现黄色诱捕器诱捕枣叶瘿蚊成虫效果最好。Lunau等(2014)研究发现双翅目昆虫具备4种颜色感光细胞,这些细胞具有调控其探测绿色、蓝色、紫色和紫外线波长的能力。颜色是对双翅目昆虫的一种重要视觉引诱剂(Dötterl *et al.*, 2014),彩色盘式等诱捕器正是利用了这一原理来吸引昆虫(Leong and Thorp, 1999)。田间调查进一步证实,枣叶瘿蚊成虫偏好在枣树幼嫩叶片上产卵,同时也会采集花蜜补充营养以支持其繁殖活动(Kolesik *et al.*, 2018; Chavalle *et al.*, 2019)。枣树幼嫩枝叶、花朵、果实通常呈现浅黄色,上述偏好性与枣叶瘿蚊成虫偏好黄色高度一致。

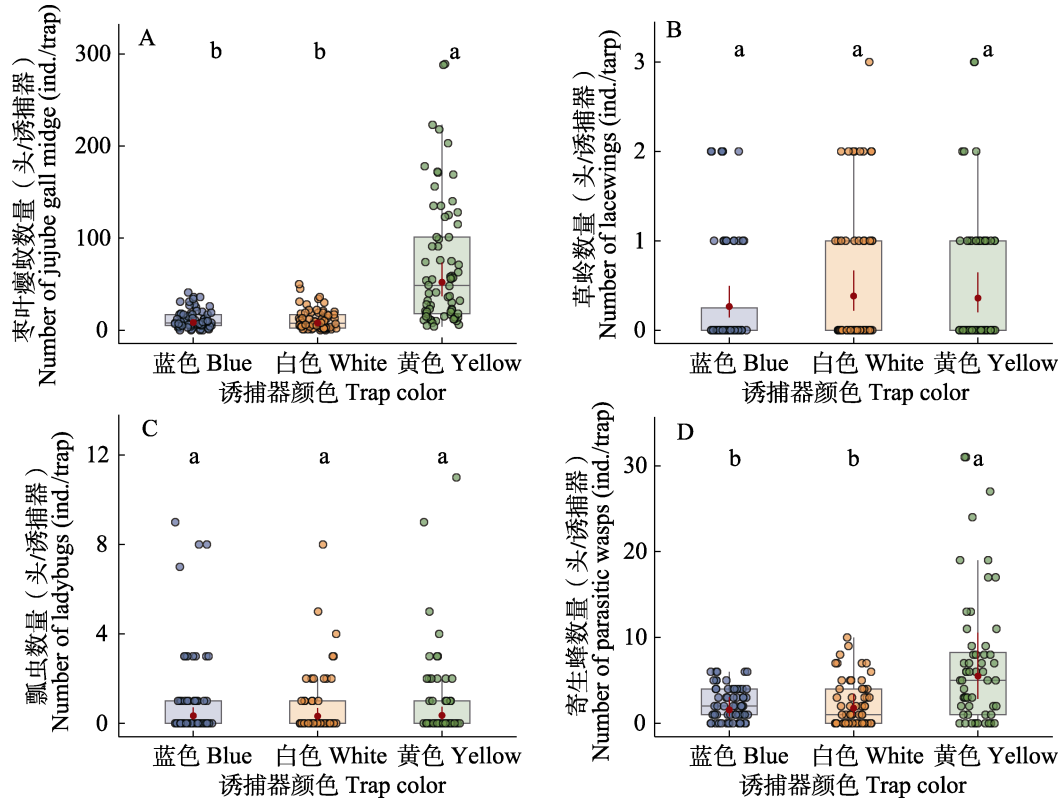


图 4 不同颜色诱捕器对枣园枣叶瘿蚊及天敌昆虫的诱捕效果

Fig. 4 The influence of trap color on capturing jujube gall midge adults and natural enemies

A. 枣叶瘿蚊; B. 草蛉; C. 瓢虫; D. 寄生蜂。

柱上不同字母表示经 Tukey's HSD 多重比较检验在 0.05 水平上差异显著。

A. Jujube gall midges; B. Lacewings; C. Ladybugs; D. Parasitoid wasps.

The different lowercase letters above bars indicate significant difference at the 0.05 level based on Tukey's HSD test.

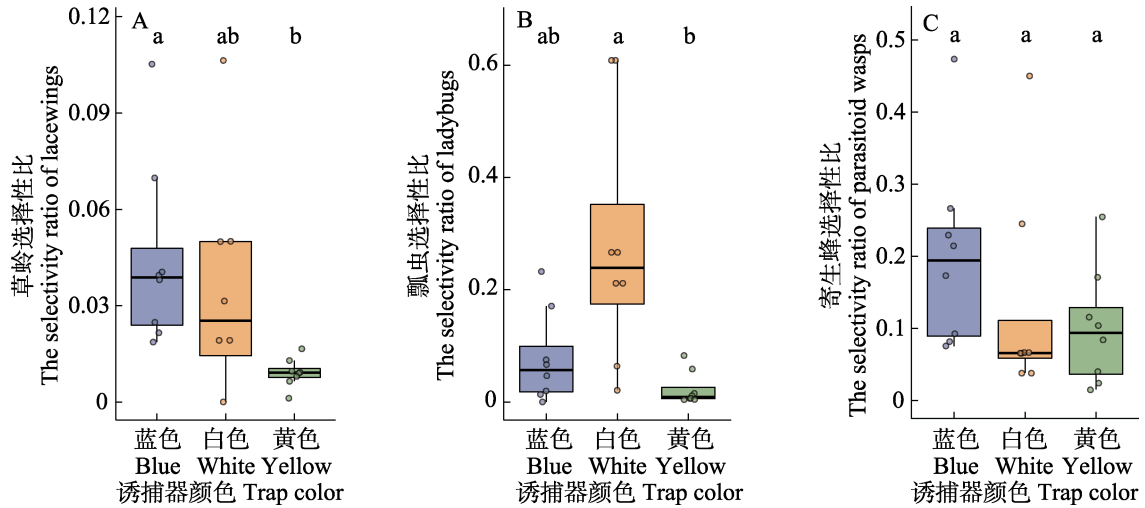


图 5 诱捕器颜色对天敌选择性比的影响

Fig. 5 Effect of trap color on the selectivity ratio of natural enemies

A. 草蛉; B. 瓢虫; C. 寄生蜂。

柱上不同字母表示经 Dunn's 多重比较检验在  $P < 0.05$  水平上差异显著。

A. Lacewings; B. Ladybugs; C. Parasitoid wasps.

The different lowercase letters above bars indicate significant difference at the 0.05 level based on Dunn's multiple comparison test.

天敌昆虫在害虫生物防治服务中发挥着重要作用。尽管基于昆虫趋光性的诱虫技术(如特定波长诱虫灯)在害虫防控中应用广泛(Kim *et al.*, 2019),但其对天敌昆虫的生态安全性还有待深入评估。许多昆虫能够感知单色波长,光源波长是决定害虫行为的关键因素(Wernet *et al.*, 2015),天敌昆虫也对特定波长光源存在明显的趋性行为(Briscoe and Chittka, 2001; Johansen *et al.*, 2011)。因此,选用具有高吸引力波长的多光谱诱捕装置来防治目标害虫时,需要注意其对天敌昆虫的误伤。本研究发现黄色水盆诱捕器诱捕的天敌草蛉、瓢虫数量较少,但是黄色诱捕器诱捕寄生蜂的数量多于其它两种颜色诱捕器,这可能是由于膜翅目蜂类对黄色本身具有明显趋性。Holthouse 等(2021)研究发现,寄生蜂对黄色具有很强的趋性,黄色粘虫板诱捕到的寄生蜂数量是蓝色的 3 倍多。Wang 等(2017)比较了 3 种颜色的盘式诱捕器对黄河中下游地区农田、林地等自然与半自然生境中传粉昆虫的诱捕效果,发现黄色诱捕器对双翅目和膜翅目昆虫最具吸引力,其次是白色和蓝色诱捕器。Buffington 等(2021)和 Csanády 等(2021)比较了膜翅目昆虫与不同颜色的盘式诱捕器的偏好,也发现黄色诱捕器比其它颜色的诱捕器能够吸引更多种类的昆虫。

选择性比能够综合反映诱捕器对靶标害虫的诱捕效率和对非靶标天敌昆虫的潜在风险,是评价物理诱捕工具生态友好性的重要指标(Lioy *et al.*, 2020; Bracalini *et al.*, 2021)。黄色诱捕器对捕食性天敌草蛉和瓢虫的选择性比均显著小于其它两种颜色诱捕器,进一步说明黄色诱捕器对天敌的误伤风险较小。尽管黄色诱捕器对寄生蜂存在一定的非靶向诱集作用,但其选择性比无显著性差异,且该诱捕器对枣叶瘿蚊成虫表现出显著的诱捕效果,因此,黄色水盆诱捕器可用于枣叶瘿蚊成虫的监测及物理防治。然而,该诱捕器在田间防控枣叶瘿蚊的最适密度与空间配置等,尚需进一步研究评估。

综上所述,黄色水盆诱捕器作为一种操作简便、环保安全的枣叶瘿蚊成虫监测及物理防治手

段,具有良好的推广及应用前景。

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