doi：10. 16473/j. cnki. xblykx1972. 2022. 05. 023

桔小实蝇作为哈氏肿腿蜂新寄主适生性的初步检测*

ONG Su Ping[1,2]，袁瑞玲[1]，陈鹏[1]
（1. 云南省林业和草原科学院，云南　昆明 650201；2. 马来西亚林业研究所，吉隆坡　雪兰莪州，52109）

摘要：桔小实蝇是一种世界范围内广泛分布的重要检疫性果蔬害虫，也是云南重要的入侵害虫，因其世代时间短，寄主广泛，且对热带和亚热带气候的适应性强，防控非常困难。利用寄生天敌能够长期持续地控制桔小实蝇于较低的种群水平。选取 3 龄实蝇幼虫和 2 日龄蛹，按 3 ∶ 5 的蜂∶虫比进行试验，测试了桔小实蝇幼虫和蛹作为哈氏肿腿蜂寄主的适生性。结果显示，肿腿蜂不攻击实蝇蛹，但可以攻击实蝇幼虫，在其身体上产卵，并造成实蝇幼虫死亡；试验共获得 97 粒蜂卵，其中 53 粒卵成功孵化，但肿腿蜂幼虫存活时间仅为 2~8 d。研究显示，肿腿蜂能攻击实蝇并产卵，但其幼虫未能持续发育完成世代，即哈氏肿腿蜂可以用于防控桔小实蝇，但桔小实蝇不是哈氏肿腿蜂的最佳适生寄主。

关键词：桔小实蝇；哈氏肿腿蜂；寄主；适生性
中图分类号：S 763　　**文献标识码**：A　　**文章编号**：1672-8246（2022）05-0159-05

Preliminary Testing on the Suitability of *Bactrocera dorsalis* (Diptera: Tephritidae) as a New Host of *Sclerodermus harmandi* (Hymenoptera: Bethylidae)

ONG Su Ping[1,2]，YUAN Rui-ling[1]，CHEN Peng[1]
（1. Yunnan Academy of Forestry and Grassland，Kunming Yunnan 650201，P. R. China；
2. Forest Research Institute Malaysia（FRIM），Selangor Kepong 52109，Malaysia）

Abstract：*Bactrocera dorsalis* is a damaging pest on a wide range of agricultural produce worldwide including China. Given its short generation time and high adaptability to the tropical and sub-tropical climates, *B. dorsalis* has become invasive and widespread in Yunnan Province, China. Biological control using parasitoids offers a viable, long-term solution to suppress the population of *B. dorsalis* . In this experiment, we tested the suitability of *B. dorsalis* larvae and pupae as a host of the bethylid parasitoid, *Sclerodermus harmandi*. Results showed that the wasps did not attack the pupa while attack and oviposition were observed on the 3rd instar larvae. A total of 180 wasps were tested on 300 *B. dorsalis* larvae at a ratio of 3 wasps:5 larvae in 6 different treatments. We obtained 97 eggs in which 53 hatched into larvae, nevertheless their survival only lasted 2-8 days. In conclusion, although *S. harmandi* wasps were able to attack and oviposit on the *B. dorsalis* larval host, the wasps' larvae could not develop successfully on the new host. Therefore, *S. harmandi* wasps could kill *B. dorsalis* larvae, but the fruit fly was not a suitable host for *S. harmandi* wasps.

Key words：*Bactrocera dorsalis*；*Sclerodermus harmandi*；host；suitability

* **收稿日期**：2022-03-15
基金项目：云南省 2021 年度专家基层科研工作站（勐腊县）项目，国家自然科学基金（31660208，31160162）。
第一作者简介：ONG Su Ping（1984—），女，硕士，主要从事森林保护研究。E-mail：jensu27@yahoo.com
通信作者简介：陈鹏（1975—），男，研究员，博士，主要从事森林保护研究。E-mail：chenpeng2@hotmail.com

The Oriental fruit fly *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae) is a pest of quarantine concern that has established and become widespread in many tropical and subtropical countries in the Asian and African continents including Hawaii and some Pacific Islands[1]. *B. dorsalis* is known to infest over 300 species of fruits and vegetables whereby the adult females puncture the fruit skin to insert their eggs inside the ripe fruits. The hatched larvae then feed on the fruit pulp causing the fruit to rot and damage[2]. In India, *B. dorsalis* caused considerable yield losses up to 80% in mango and guava orchards[3] while in China, damage rate on fruits such as guava can reach 100% during their peak breeding season[4]. Since the 1980s, *B. dorsalis* has colonized most of the southern provinces in mainland China and gradually expanding its range northwards into the cooler provinces due to increase trade and global warming[2,5-6]. Its widespread dispersal is also aided by its ability to fly long distances[7-8], which is associated with its strong flight muscles[9].

In China and elsewhere, management strategies rely heavily on chemical control besides other prevention and control measures which include fruit bagging, quarantine for exported fresh agricultural commodities, methyl eugenol-baited traps and sterile insect technique. Since *B. dorsalis* developed insecticide resistance[10], exploration of biological control agents becomes important as the alternative, long-term solution to the *B. dorsalis* problem. For example, the introduction and establishment of the egg-pupal parasitoid, *Fopius arisanus* to control *B. dorsalis* in Hawaii was a remarkable success, which serves as a biocontrol model to other countries[11]. In China, techniques to improve mass rearing and parasitism efficiency of parasitoids such as *F. arisanus* and *Diachasmimorpha longicaudata* on *B. dorsalis* egg, larva and pupa are continuously developed[12-15], so as to increase the quality and performance of the parasitoids in the laboratory and field.

While these species of braconid wasps are well-known endoparasitoids of *B. dorsalis* in China, the lesser-known parasitoid e.g. *Spalangia endius*, which is mainly used as a biological control agent of the house fly *Musca domestica*[16], has also been studied for its suitability to control *B. dorsalis* in Thailand[17] and China[18]. Natural enemies' diversity can strengthen pest control when different species of natural enemies complement each other by occurring at different niches and times[19]. Therefore, the knowledge on other potential parasitoids of *B. dorsalis* can potentially help increase the efficiency of its biological control agents.

In this experiment, we tested the potential of *Sclerodermus harmandi*, an ectoparasitoid of the cerambycid larvae, to parasitize and use *B. dorsalis* as a host. Although *Sclerodermus* parasitoid is not known to attack dipterans, it has been reared on non-wood boring coleopteran, lepidopteran and hymenopteran larvae, pupae and adults[12,20-21].

1 Materials and methods

1.1 Testing Insects

Sclerodermus harmandi wasps were obtained from the rearing facility at the Forest Protection Laboratory in Yunnan Academy of Forestry and Grassland. The wasps were divided into two groups: one group without feeding, other group was fed with 30% honey-soaked cotton wool placed at the top of the glass vials prior to the experiment.

The *Bactrocera dorsalis* test insects were obtained from laboratory-reared colonies at the Forest Protection Laboratory in Yunnan Academy of Forestry and Grassland. The colonies have been maintained on an artificial diet[9] (see Chen et al. 2015) for at least 20 generations. The larvae of *B. dorsalis* were reared in rectangular plastic containers (17 cm length×12 cm width×7 cm height) and kept in a controlled environment at 28-30℃, 40% relative humidity and a photoperiod of 16 : 8 (L : D) h. In consideration of the sufficient nutrients needed by parasitic wasps for reproduction, we selected the 3rd instar larvae and 2-day-old pupae as host materials for this experiment.

1.2 Suitability of *B. dorsalis* as a host of *S. harmandi* wasp

In this no-choice test, three female wasps from two groups (1 week old and over 6-month-old), maintained on without honey solution and honey solution for 1-, 3-, 5-, 7-, 9- and 11 days respectively, were introduced into each glass vial (4.8 cm height×0.9 cm width, flat bottom) with five 3rd instar *B. dorsalis* larvae. The adult wasps were removed from the vials once oviposition occurred to reserve the host resources for the hatched wasps' larvae. Ten replicates were set up and each replicate was paired with a negative control, which contained only *B. dorsalis* larvae. We also observed the general behaviour of the wasps as they were introduced into the test arenas for about 10 minutes.

2 Results and Analyses

The experiment showed that only wasps fed with 30% diluted honey was observed to lay eggs on the larva of *B. dorsalis* (Table1). Feeding wasps with diluted honey for several days prior to experiment may help to increase fitness and egg production. Our observations showed that the wasps did not attack the pupa of *B. dorsalis* while attack and oviposition were observed on 10-12 days old larvae. Young larvae such as 1st instar and 2rd instar larvea, could possibly provide lower nutrients and resources to the wasps.

Tab. 1 Oviposition by *S. harmandi* wasps on *B. dorsalis* larvae/pupa in the no-choice tests

Age of wasp*	No. of days adult wasps maintained on honey solution	No. of eggs laid on *B. dorsalis* larvae/pupae	No. of eggs hatched	Negative control (*B. dorsalis* adult emergence, per replicate)
1 week	0	0	0	8/10
1 week	1	11	4	8/10
1 week	3	1	0	8/10
1 week	5	11	1	10/10
1 week	7	12	4	10/10
1 week	9	0	0	7/10
1 week	11	62	44	10/10
> 6months	0/1/3/7/9/11	0	0	52/60
		pupae		
1 week	-	10	0	6/10
> 6months	-	10	0	5/10

Note: * Age of wasps were counted from the date where the live samples were obtained

We observed that the wasps started attacking *B. dorsalis* larvae upon introduction into the test arenas by jabbing the larvae repetitively with their ovipositor for about 2 - 3 minutes until the larvae were paralyzed. The wasp begun to examine and probe the paralysed host with its antennae and occasionally resting over the host's body. Host feeding by the wasps occurred for about 5 minutes by biting and lapping on the body tissue of the larva. This feeding activity continued for 3-4 days. Oviposition occurred on day 4-9 after introduction of the wasps into the test arenas (Tab. 1, Fig. 1). The eggs hatched 2-7 days later, however the wasps' larvae were short-lived and only survived between 2-8 days. In the negative controls, emergence of *B. dorsalis* adults was 70-100% (Tab. 1).

The experiment indicated that the pupae of *B. dorsalis* were not attacked by the young (1week) and aged wasps (over 6 months), suggesting wasps were not interested in *B. dorsalis* pupae as the host (Tab. 1).

Fig. 1 Testing of *Bactrocera dorsalis* as a potential host for *Sclerodermus harmandi*

3 Discussion and Conclusion

In this study, we found that honey water satiation of wasp is important for *S. harmandi* to parasitize. Both number of eggs laid on *B. dorsalis* larvae and number of eggs hatched increased with the increased in the number of days adult wasps maintained on honey solution. Feeding wasps with diluted honey for several days prior to experiment may help to increase fitness and egg production. The female of *S. harmandi* paralyses its host by stinging and injecting venom through its ovipositor and acquires the host's nutrient for egg production[21,22]. Despite being able to oviposit on its new host, the eggs and larvae of *S. harmandi* could not complete development on *B. dorsalis* larvae. The small-sized *B. dorsalis* larvae could have provided lower nutrients and resources to the wasps as the wasps are mainly reared on Coleopteran larval hosts[21-22] with large body sizes. Reducing the number of wasps in the test arenas could possibly increase host survival by limiting the frequency of venom injection and host feeding.

In parasitoid rearing experiments, parasitoids such as *Habrobracon hebetor*[23-24] and *Sclerodermus pupariae*[25] that were supplemented with diluted honey were found to have longer lifespan and higher fecundity. This could possibly explain the observations in our experiment in which wasps maintained for 11 days on 30% diluted honey laid the highest number of eggs.

In this study, we also found that mortalities increased with the increased in the number of *B. dorsalis* larvae and parasitoids. This could be due to repeated venom injection and host feeding by multiple wasps. In the testing, the survival rates for the host and wasp were less than 10% and 20%, respectively. Most of the larvae in negative control replicates had successfully pupated and emerged as adults under the same rearing conditions. Nevertheless, mortality of *B. dorsalis* larvae or pupation are likely to occur when they are kept in the experimental vials without any food provided.

Although *S. harmandi* wasps were able to parasitize and lay eggs on the larvae of *B. dorsalis*, the wasps' larvae that hatched from the eggs could not develop successfully. Therefore, *B. dorsalis* is not a suitable host for the development of the betylid wasp.

References:

[1] Chen P, Ye H. Population dynamics of *Bactrocera dorsalis* (Diptera :Tephritidae) in Liuku, Yunnan with an analysis of the influencing factors [J]. Acta Entomologica Sinica, 2007, 50 (1), 38-45. (in Chinese).

[2] Liu H, Zhang D J, Xu Y J, et al. Invasion, expansion and control of *Bactrocera dorsalis* (Hendel) in China [J]. Journal of Integrative Agriculture 2019, 18(4): 771-787. (in Chinese).

[3] Clarke A R, Armstrong K E, Carmichael A E, et al. Invasive phytophagous pests arising through a recent tropical evolutionary radiation: The *Bactrocera dorsalis* complex of fruit flies [J]. Annual Review of Entomology, 2005, 50: 293-319.

[4] Chen J Y, Cai P, Zhang G B, et al. Research progress of occurrence and comprehensive control of Oriental fruit fly (*Bactrocera dorsalis*) (Hendel) [J]. Plant Diseases and Pests, 2011, 2(5): 42-47. (in Chinese).

[5] Wan X, Nardi F, Zhang B, et al. The oriental fruit fly, *Bactrocera dorsalis*, in China: Origin and gradual inland range expansion associated with population growth [J]. Plos One, 2011, 6 (10): e25238.

[6] Qin Y J, Krosch M N, Schutze M K, et al. Population structure of a global agricultural invasive pest, *Bactrocera dorsalis* (Diptera: Tephritidae) [J]. Evolutionary Applications, 2018, 11: 1990-2003.

[7] Chen P, Ye H, Mu Q A. Migration and dispersal of the oriental fruit fly, *Bactrocera dorsalis* in regions of Nujiang River based on fluorescence mark [J]. Acta Ecologica Sinica, 2007, 27: 2468-2476. (in Chinese).

[8] Froerer K M, Peck S L, McQuate G T, et al. Long-distance movement of *Bactrocera dorsalis* (Diptera: Tephritidae) in Puna, Hawaii: How far can they go [J]. American Entomologist, 2010, 56(2): 88-94.

[9] Chen M, Chen P, Ye H, et al. Flight capacity of *Bactrocera dorsalis* (Diptera: Tephritidae) adult females based on flight mill studies and flight muscle ultrastructure [J]. Journal of Insect Science, 2015(1): 1. doi: 10. 1093/jisesa/iev124.

[10] Jin T, Zeng L, Lin Y, et al. Insecticide resistance of the oriental fruit fly, *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidae), in mainland China [J]. Pest Management Science, 2011, 67(3): 370-376. (in Chinese).

[11] Vargas R I, Leblanc L, Harris E J, et al. Regional suppression of *Bactrocera* fruit flies (Diptera: Tephritidae) in the Pacific through biological control and prospects for future introductions into other areas of the world [J]. Insects, 2012, 3: 727-742.

[12] Zhang L, Song S, Fang J. Propagation of scleroderma guani on *Crypthelea variegata* [J]. Chinese Journal of Biological Control, 1987, 3: 114-116. (in Chinese).

[13] Liang G H, Fu L Q, Zheng J X, et al. Molecular characterization of interspecific competition of *Diachasmimorpha longicaudata* (Ashmead) and *Fopius arisanus* (Sonanparasitizing the oriental fruit fly, *Bactrocera dorsalis* (Hendel) [J]. Biological Control, 2018, 118: 10-15.

[14] Cai P, Gu X, Yao M, et al. The optimal age and radiation dose for *Bactrocera dorsalis* (Hendel) (Diptera: Tephritidaeeggs as hosts for mass-reared *Fopius arisanus* (Sonan) (Hymenoptera: Braconidae) [J]. Biological Control, 2017, 108: 89-97.

[15] Cai P, Hong J, Wang C, et al. Radiation of *Bactrocera dorsalis* (Diptera: Tephritidaeeggs to improve the mass rearing of *Diachasmimorpha longicaudata* (Hymenoptera: Braconidae) [J]. Journal of Economic Entomology, 2018, 111(3): 1157-1164.

[16] Morgan P B. Sustained releases of *Spalangia endius*

(Hymenoptera:Pteromalidaefor the control of *Musca domestica* L. and *Stomoxys calcitrans*(L.)(Diptera:Muscidae)[J]. Journal of the Kansas Entomological Society, 1980, 53(2): 367-372.

[17]Kitthawee S, Sriplang K, Brockelman W Y, et al. Laboratory evaluation of density relationships of the parasitoids, *Spalangia endius*(Hymenoptera:Pteromalidae), with two species of tephritid fruit fly pupal hosts in Thailand[J]. Science Asia, 2004, 30: 391-397.

[18]Tang L D, Lu Y Y, Zhao H Y. Suitability of *Bactrocera dorsalis*(Diptera:Tephritidaepupae for *Spalangia endius*(Hymenoptera:Pteromalidae)[J]. Environmental Entomology, 2015, 44(3): 689-694.

[19]Synder W E. Give predators a complement: Conserving natural enemy biodiversity to improve biocontrol[J]. Biological Control 2019, 135: 73-82.

[20]Yao W J, Yang Z Q. Mass-rearing of *Sclerodermus guani*(Hymenoptera:Bethylidae) with substitute host[J]. Chinese Journal of Biological Control, 2008, 24(3): 220-226.

[21]Hu Z, Zhao X, Li Y, et al. Maternal care in the parasitoid *Sclerodermus harmandi*(Hymenoptera: Bethylidae)[J]. PLoS ONE, 2012, 7(12): e51246. doi: 10.1371/journal.pone.0051246.

[22]Li L, Sun J. Host suitability of a gregarious parasitoid on beetle hosts: flexibility between fitness of adult and offspring [J]. PLoS ONE, 2011, 6(4): e18563. doi: 10.1371/journal.pone.0018563.

[23]Kabore A, Ba N M, Dabire-Binso C, et al. Towards development of a parasitoids cottage industry of the parasitoids wasp *Habrobracon hebetor*(Say): Optimum rearing and releases conditions for successful biological control of the millet head miner *Heliocheilus albipunctella*(De Joannisin the Sahel[J]. International Journal of Tropical Insect Science, 2019, 39: 25-33.

[24]Huang Y, Dai A, Mao Z, et al. Effect of supplementary nutrition on the reproduction and mating behaviour of *Habrobracon hebetor*(Hymenoptera:Braconidae)[J]. European Journal of Entomology, 2020, 117: 393-399.

[25]Wei K, Wang X Y, Yang Z Q. Effects of supplementary nutrition on parasitism ability and developmental process of a gregarious parasitoids, *Sclerodermus pupariae*(Hymenoptera: Bethylidae)[J]. Forest Research, 2016, 29: 369-376.

(编辑: 马建忠)

[上接第 145 页]

[26]Hernandez J, Del Pino A, Vance E D, et al. *Eucalyptus* and *Pinus* stand density effects on soil carbon sequestration[J]. Forest Ecology and Management, 2016, 368: 28-38.

[27]Qian L, Yi S, Li X, et al. Early effects of crop tree management on undergrowth plant diversity and soil physicochemical properties in a *Pinus massoniana* plantation[J]. PeerJ, 2021, 9: e11852.

[28]樊后保,李燕燕,黄玉梓,等. 马尾松纯林改造成针阔混交林后土壤化学性质的变化[J]. 水土保持学报, 2006(4): 77-81.

[29]张勇强,李智超,厚凌宇,等. 林分密度对杉木人工林下物种多样性和土壤养分的影响[J]. 土壤学报, 2020, 57(1): 239-250.

[30]Duan A G, Lei J, Hu X, et al. Effects of planting density on soil bulk density, pH and nutrients of unthinned Chinese fir mature stands in South Subtropical Region of China[J]. Forests, 2019, 10(4): e11456.

[31]吕春花,郑粉莉,安韶山. 子午岭地区植被演替过程中土壤养分及酶活性特征研究[J]. 干旱地区农业研究, 2009, 27(2): 227-232.

[32]Wang C Q, Xue L, Dong Y H, et al. Effects of stand density on soil microbial community composition and enzyme activities in subtropical *Cunninghamia lanceolate*(Lamb.) Hook plantations[J]. Forest Ecology and Management, 2021, 479: e118559.

(编辑: 李甜江)