

桃园橘小实蝇种群结构与发生危害调查

郭晓军, 徐庆宣, 王 甦, 张 帆*

(北京市农林科学院植物保护环境保护研究所, 北京 100097)

摘要:【目的】橘小实蝇是一种危害严重的蛀果类害虫,近年来在我国桃园有加重发生危害的趋势。弄清我国不同桃产区橘小实蝇种群发生规律,为制定有效的预警和综合防控措施提供参考依据。【方法】从2012年至2019年,利用橘小实蝇性诱剂连续在我国主要桃产区的17个桃园开展了桃园橘小实蝇发生情况的监测和调查,并对不同产区桃园实蝇标本进行了形态学和分子生物学鉴定分析。【结果】通过形态学和分子生物学鉴定分析,明确了北京、石家庄、南京、武汉、成都的实蝇标本为橘小实蝇,且石家庄种群与其他4个种群的遗传距离差距较大;郑州的实蝇标本则为橘小实蝇和番石榴实蝇的混合种群。全国17个桃园监测结果显示,桃主产区几乎均有橘小实蝇危害。【结论】北方桃园2012年开始发现橘小实蝇危害,但发生时期和种群数量在各年份间有所差异,主要危害晚熟桃;南方桃园里橘小实蝇则是一种常发性害虫,对中晚熟桃的危害较大。

关键词: 桃园;橘小食蝇;蛀果;综合防控;番石榴实蝇

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Population structure and occurrence of *Bactrocera dorsalis* in peach orchards

GUO Xiaojun, XU Qingxuan, WANG Su, ZHANG Fan*

(Institute of Plant and Environment Protection, Beijing Academy of Agriculture and Forestry Sciences, Beijing 100097, China)

Abstract: 【Objective】The oriental fruit fly, *Bactrocera dorsalis* Hendel is one kind of serious fruit-boring pests, which makes the damaged fruit yellow before ripening, causes the fruit to rot and drop, and seriously affects the yield and quality of fruit. In recent years, it has occurred in the peach orchards and has a tendency to be aggravated, but we still do not know its occurrence trend in peach orchards in various regions of China. In China, peach is the third largest deciduous fruit tree after apple and pear, and both the cultivation area and yield of peach in China rank the first in the world. The present experiment aimed to clarify the occurrence of *B. dorsalis* populations in different peach producing areas, and to provide a reference for formulating effective early warning and comprehensive prevention measures. It is of great significance to ensuring the quality-safety production of peach. 【Methods】We selected 17 test sites in the main peach producing areas of China, which covered various types of peach production areas, such as Around Bohai sea (Dalian, Liaoning province; Changli, Hebei province; Qingdao, Shandong province), Northern area (Beijing; Shijiazhuang, Hebei province; Tai'an, Shandong province), Yellow River Basin (Zhengzhou, Henan province; Xi'an, Shanxi province; Lanzhou, Gansu province), Yangtze River Basin (Nanjing, Jiangsu province; Hangzhou, Zhejiang province; Wuhan city, Hubei province), Southwest area (Chengdu, Sichuan province; Kunming, Yunnan province; Guizhou province) and Southern area (Fuzhou, Fujian province; Guilin, Guangxi). From 2012 to 2019, the occurrence of *B. dorsalis* in peach orchards was continuously monitored and investigated by using sex attractant traps (17 test sites were uniformly supplied, and the traps were bought from the market). Five

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作者简介:郭晓军,男,副研究员,研究方向桃树主要害虫的绿色防控。Tel:010-51503335, E-mail:guoxj@brcast.org.cn

*通信作者 Author for correspondence. Tel:010-88463669, E-mail:zf6131@263.net

traps were hung in each peach orchard, and the distance between the traps was at least 20 m. After *B. dorsalis* was found, we investigated and recorded the number every 5-7 days. Then the samples were brought back to the laboratory for morphological and molecular identification, and the phylogenetic relationship analysis was performed on samples from different regions. 【Results】Firstly, the samples collected from each test site were identified. The results of morphological examination showed that the samples from Beijing and Wuhan were quite different from the type of specimens, but the molecular results showed that the samples were *B. dorsalis*. Based on the morphological and molecular biological identification results, the *B. dorsalis* from different producing areas were identified as *B. dorsalis* complex. It was confirmed that the insect sample from Beijing, Nanjing, Wuhan, Shijiazhuang and Chengdu were *B. dorsalis*, and there was maximum genetic distance between Shijiazhuang population and other four populations; the insect sample from Zhengzhou was a mixed population of *B. dorsalis* and *Bactrocera correcta* Bezzi. Secondly, according to the trapping results for 8 consecutive years (2012 to 2019), almost all of the main peach producing areas were harmed by *B. dorsalis*. Especially in the production areas of the Yangtze River basin such as Nanjing, Hangzhou and Wuhan, the occurrence of *B. dorsalis* continued to increase since 2017. Southwest production areas such as Chengdu, Kunming and Guizhou, and southern production areas such as Fuzhou and Guilin showed the same trend as or even more serious than the Yangtze River basin. 【Conclusion】The morphological changes of *B. dorsalis* and its related species were complex, and there were many geographical species. We found *B. dorsalis* complex in the samples from different regions. In addition, the samples were also mixed with other fruit flies, like *B. correcta*. Therefore, it was necessary to strengthen the detection of fruit flies in peach orchards to confirm the proportion of *B. dorsalis*, which was helpful for pest control. Since 2012, the damage of *B. dorsalis* has been found in northern peach orchards, however, the occurrence period and population number vary from year to year, which mainly harms late-ripening peaches. As we know, many studies have shown that the overwintering northern boundary of *B. dorsalis* is at $(30\pm 2)^{\circ}\text{N}$, and areas to the north beyond cannot survive in the winter normally. So where does the initial source of the *B. dorsalis* that harm northern peach orchards come from? The specific reasons for the serious occurrence of *B. dorsalis* in peach orchards in Henan and Hebei provinces need to be further studied; in southern peach orchards, *B. dorsalis* is a common pest, which is more harmful to mid- and late-ripening peaches. *B. dorsalis* has gradually become a common pest in peach orchards, especially in recent three years, it has caused serious damage in most of the main peach production areas. With the increasing frequency and complexity of international trade activities, the probability of fruit fly pests spreading is increasing. At the same time, *B. dorsalis* has been removed from the quarantine objects in the provincial quarantine of fruits and vegetables in China. These changes will increase the threat of fruit flies to ensuring the quality-safety production of fruits and vegetables in northern China.

Key words: Peach orchard; *Bactrocera dorsalis* Hendel; Fruit borer; Comprehensive prevention; *Bactrocera correcta* Bezzi

橘小实蝇(*Bactrocera dorsalis* Hendel)属双翅目(Diptera),实蝇科(Tephritidae),寡鬃实蝇亚科(Dacinae),寡鬃实蝇族(Dacini)。橘小实蝇是实蝇害虫中重要的一种,分布较广,在我国主要发生在福建、广东、海南、台湾、广西、云南、江苏、四川、湖南、贵州等地区^[1-2]。橘小实蝇寄主涉及250余种水果、蔬菜,以卵、幼虫或蛹随寄主果实、包装物或交通工

具等进行远距离的人为传播,1911年在我国台湾被发现,20世纪80年代在广东、广西、云南等芒果和柑橘种植区暴发成灾,后相继出现在四川、福建,2006年分布已达湖北、上海等地,2011年在北京首次发现,扩散蔓延能力极强^[3-5]。

橘小实蝇属于完全变态昆虫,一生要经历4个发育阶段:卵、幼虫、蛹和成虫期。在自然条件下的

发育历期及孵化率与环境的温度、湿度、寄主种类等因素有关^[6]。且在热带、亚热带等高温地区全年可发生和繁殖,在自然种群中世代重叠明显,同期内各虫态并存。橘小实蝇主要是幼虫危害果实,成虫产卵于各类浆果内孵出幼虫,幼虫群集于果肉内蛀食,使被害果未熟先黄,造成果实腐烂落果,严重影响水果的产量和品质^[7]。幼虫随龄期增加而食量增大,逐渐向果肉深层扩展取食,直到果实腐烂^[8-9],这时老熟幼虫才从果内爬出,弹跳落地,弹跳高度10~15 cm,由于老熟幼虫对化蛹场所的选择性,使得橘小实蝇的蛹在土壤中呈聚集分布^[10]。橘小实蝇在柑橘、芒果、木瓜、火龙果等南方水果中危害严重,但在桃园尤其是北方桃主要产区鲜有发生危害的报道。鉴于此,作者依托国家桃产业技术体系的17个综合试验站,在全国桃主产区开展了橘小实蝇发生危害监测,并进行了种群鉴定和结构分析,以期掌握橘小实蝇在桃主产区的发生动态等,及时进行预警防控。

1 材料和方法

1.1 监测器具

橘小实蝇性诱剂诱捕瓶(统一提供,购自漳州市英格尔农业科技有限公司)。

1.2 监测地点

国家桃产业技术体系在全国桃主产区17个综合试验站橘小实蝇监测桃园的分布见表1。

1.3 调查方法

2011年,首次在北京、石家庄、郑州等综合试验站的示范桃园中发现其危害。2012年开始,在国家桃产业技术体系的17个综合试验站开展了统一的监测工作。用对角线法在桃园内部选择5个监测点,将带有诱芯的橘小实蝇诱捕器挂置在监测点桃树中上部外围枝条上。诱捕器之间相距至少在20 m以上,离地高1.5 m左右。发现橘小实蝇后每5~7 d调查记载各个诱捕装置中的诱集数量,每30 d更换1次诱芯。

标本鉴定:选取北京、石家庄、郑州、武汉、南京、昆明、成都7个综合试验站,将诱捕器内的目标实蝇成虫或疑似目标实蝇成虫全部收集,装入75%乙醇溶液,标记采集编号及收集日期。诱集到实蝇成虫样本,送至中国科学院动物研究所进行形态学鉴定。选取北京、石家庄、郑州、武汉、南京、成都6个

表1 国家桃产业技术体系17个综合试验站桃园的区位
Table 1 Location of peach garden, in 17 comprehensive experimental stations of the National Peach Industry Technology System

产区 Region	试验站 Experimental station	果园坐标 Orchard location
环渤海 Around Bohai sea	大连 Dalian (DL)	E: 121°24', N: 38°59'
	昌黎 Changli (CL)	E: 119°16', N: 39°71'
	青岛 Qingdao (QD)	E: 120°55', N: 36°08'
北方 Northern area	北京 Beijing (BJ)	E: 116°12', N: 39°58'
	石家庄 Shijiazhaung (SJZ)	E: 115.53', N: 38°02'
	泰安 Tai'an (TA)	E: 117°05', N: 36°11'
长江流域 Yangtze River Basin	南京 Nanjing (NJ)	E: 118°52', N: 32°02'
	杭州 Hangzhou (HZ)	E: 119°09', N: 29°69'
	武汉 Wuhan (WH)	E: 114°14', N: 30°29'
西南 Southwest area	成都 Chengdu (CD)	E: 103°65', N: 30°86'
	昆明 Kunming (KM)	E: 103°30', N: 23°73'
	贵州 Guizhou (KZ)	E: 108°86', N: 27°35'
黄河流域 Yellow River Basin	郑州 Zhengzhou (ZZ)	E: 113°71', N: 34°71'
	西安 Xi'an (XA)	E: 108°07', N: 34°29'
	兰州 Lanzhou (LZ)	E: 103°41', N: 36°06'
南方 Southern area	福州 Fuzhou (FZ)	E: 118°78', N: 26°71'
	桂林 Guilin (GL)	E: 109°29', N: 24°04'

地点样品,送至中国农业科学院植物保护研究所进行分子生物学鉴定。

1.4 橘小实蝇分子生物学鉴定及分析

对每头橘小实蝇雄虫进行单头提取全基因组DNA。每个样点各提取30头橘小实蝇COI引物(mtDNA COI- F: CAACATTTATTTTGATTTTTT-GG, mtDNA COI- R: TCCATTGCACTAATCTGC-CATATTA),扩增目的片段为759 bp,电泳检测PCR产物的浓度和纯度,进行序列测定。然后用Mega Version6对序列进行比对,进行系统发育分析,建立UPGMA邻接树。应用Structure v5.0软件进行贝叶斯聚类分析。

2 结果与分析

2.1 橘小实蝇鉴定

2.1.1 实蝇标本形态学鉴定结果 7个地点的实蝇标本形态学鉴定结果表明,送检标本均有橘小实蝇存在,且为橘小实蝇复合种。石家庄、郑州、南京、昆明、成都的5个样本与橘小实蝇模式标本差异较小或无差异,北京、武汉2个样本则与模式标本差异较大,也可能仍为橘小实蝇的种内变异类型(表2)。

2.1.2 实蝇标本分子生物学鉴定结果 通过与已知

表 2 不同地域及其个体间的形态特征

Table 2 Morphological characteristics between different regions and individuals

标本编号 Samples No.	特征 Characteristic						结论 Conclusion
	I	II	III	IV	V	VI	
北京-1 BJ-1	√					√	特征 I 在 BJ 种群中较频繁出现 More frequent in characteristic I populations in BJ
北京-2 BJ-2	√					√	
北京-3 BJ-3	√					√	
北京-4 BJ-4	√					√	
北京-5 BJ-5	√			√			
北京-6 BJ-6			√			√	
北京-7 BJ-7			√			√	
北京-8 BJ-8						√	
石家庄-1 SJZ-1	√			√		√	特征 IV 在 SJZ 种群中较频繁出现 Characteristics IV is more frequent in the SJZ populations
石家庄-2 SJZ-2	√			√		√	
石家庄-3 SJZ-3		√				√	
石家庄-4 SJZ-4			√			√	
石家庄-5 SJZ-5			√	√		√	
郑州-1 ZZ-1	√					√	特征 IV 在 ZZ 种群中未出现 Characteristics IV does not appear in the ZZ populations
郑州-2 ZZ-2	√					√	
郑州-3 ZZ-3			√			√	
郑州-4 ZZ-4			√			√	
郑州-5 ZZ-5						√	
南京-1 NJ-1	√					√	特征 IV 在 NJ 种群中少量出现 Characteristics IV is appear small in the NJ populations
南京-2 NJ-2	√						
南京-3 NJ-3			√			√	
南京-4 NJ-4		√				√	
南京-5 NJ-5				√			
南京-6 NJ-6						√	
成都-1 CD-1			√		√	√	特征 I 和 IV 在 CD 种群中未出现 Characteristics I and IV does not appear in the CD populations
成都-2 CD-2					√	√	
成都-3 CD-3					√	√	

注:BJ(北京):北京综合试验站样品;ZZ(郑州):郑州综合试验站样品;NJ(南京):南京综合试验站样品;CD(成都):成都综合试验站样品;SJZ(石家庄):石家庄综合试验站样品。特征: I 中胸背板后缘有一淡黄色长斑; II 中胸背板后缘有二淡黄色斑; III 中胸背板后缘有二淡黄色小圆斑; IV 中胸背板前缘中部有 2 淡黄色侧纵条; V 腹部第 4 背板有深褐色较大侧斑; VI 翅臀带端部具有 1 淡褐色不规则斑。

Note: BJ(Beijing): Samples from Beijing; ZZ (Zhengzhou): Samples from Zhengzhou; NJ(Nanjing): Samples from Nanjing; CD(Chengdu): Samples from Chengdu; SJZ(Shijiazhuang): Samples from Shijiazhuang. Characteristic: I. A long pale yellow spot on the posterior edge of the midrib; II. Two pale yellow spots on the posterior edge of the midrib; III. Two small pale yellow round spots on the posterior edge of the midrib; IV. Two pale yellow lateral longitudinal strips in the middle of the anterior edge of the midrib; V. A large dark brown lateral spots on the fourth midrib of the abdomen; VI. A light brown irregular spot on the end of the wing buttock band

橘小实蝇和番石榴实蝇序列分析比较及系统发育关系分析,显示北京、南京、武汉、石家庄、成都的实蝇样本为橘小实蝇,且石家庄种群与其他 4 个种群的遗传距离差距较大;郑州试验站的样本则为橘小实蝇和番石榴实蝇的混合种群。

(1)组内遗传距离差异分析。从表 3 可以看出河南试验站实蝇样本个体间的差异比较大(2%),应

为两个种,即橘小实蝇和番石榴实蝇。

(2)组间遗传距离差异分析。组间遗传距离分析结果显示,河南试验站样本个体与其他地理种群间的遗传距离差异比较大(表 4)。

(3)桃园橘小实蝇的种群分化。采用系统发育关系分析-邻接法,将测序所得到的碱基序列与数据库中得到的 9 条序列共同建树,由系统发育树可以

表3 同一地域不同个体间的遗传距离分析

Table 3 Analysis of genetic distance between different individuals in the same region

试验站 Experimental station	样本数 Number of samples	时间 Time/d	标准误 SE
北京 BJ	10	0.006 6	0.001 9
郑州 ZZ	10	0.052 3	0.006 5
南京 NJ	13	0.006 6	0.002 0
石家庄 SJZ	10	0.007 2	0.002 4
武汉 WH	6	0.004 3	0.002 1
成都 CD	3	0.002 7	0.001 8

注:BJ(北京):北京综合试验站样品;ZZ(郑州):郑州综合试验站样品;NJ(南京):南京综合试验站样品;CD(成都):成都综合试验站样品;WH(武汉):武汉综合试验站样品;SJZ(石家庄):石家庄综合试验站样品,下同。

Note: BJ(Beijing): Samples from Beijing; ZZ (Zhengzhou): Samples from Zhengzhou; NJ(Nanjing): Samples from Nanjing; CD(Chengdu): Samples from Chengdu; WH(Wuhan): Samples from Wuhan; SJZ(Shijiazhuang): Samples from Shijiazhuang, the same below.

表4 不同地域间遗传距离分析

Table 4 Genetic distance analysis between different regions

试验站 Experimenta station	北京 BJ	郑州 ZZ	南京 NJ	石家庄 SJZ	武汉 WH	成都 CD
北京 BJ		0.004	0.002	0.004	0.002	0.002
郑州 ZZ	0.037		0.004	0.005	0.004	0.004
南京 NJ	0.007	0.035		0.004	0.002	0.002
石家庄 SJZ	0.013	0.040	0.013		0.003	0.004
武汉 WH	0.006	0.035	0.006	0.009		0.002
成都 CD	0.006	0.034	0.005	0.011	0.005	

看出,6个地理种群的橘小实蝇聚为两大分支,其中河南试验站标本个体HN5、HN8和HN10与番石榴实蝇聚为一支;其余的与橘小实蝇复合种聚为一支(图1)。

2.2 橘小实蝇在我国桃主产区的发生危害情况

从监测调查结果可以看出,大连、昌黎和青岛等产区在2018年前偶尔发现橘小实蝇,且监测诱剂的种群数量小,基本未见危害桃果,但2018年后成为常发害虫,特别在青岛产区发生危害有加重趋势;在北京、石家庄和泰安等北方产区,2012年突然暴发危害,但之后发生较轻,2017年后发生危害加重,以泰安产区尤为突出,具有年份间跳跃式发生的特点;南京、杭州和武汉等长江流域产区,橘小实蝇在桃园各年份均监测到,在2017年以来发生危害持续加重;成都、昆明和贵州等西南产区,橘小实蝇在桃园各年份也均监测到,2017年后才发现其在连片桃园

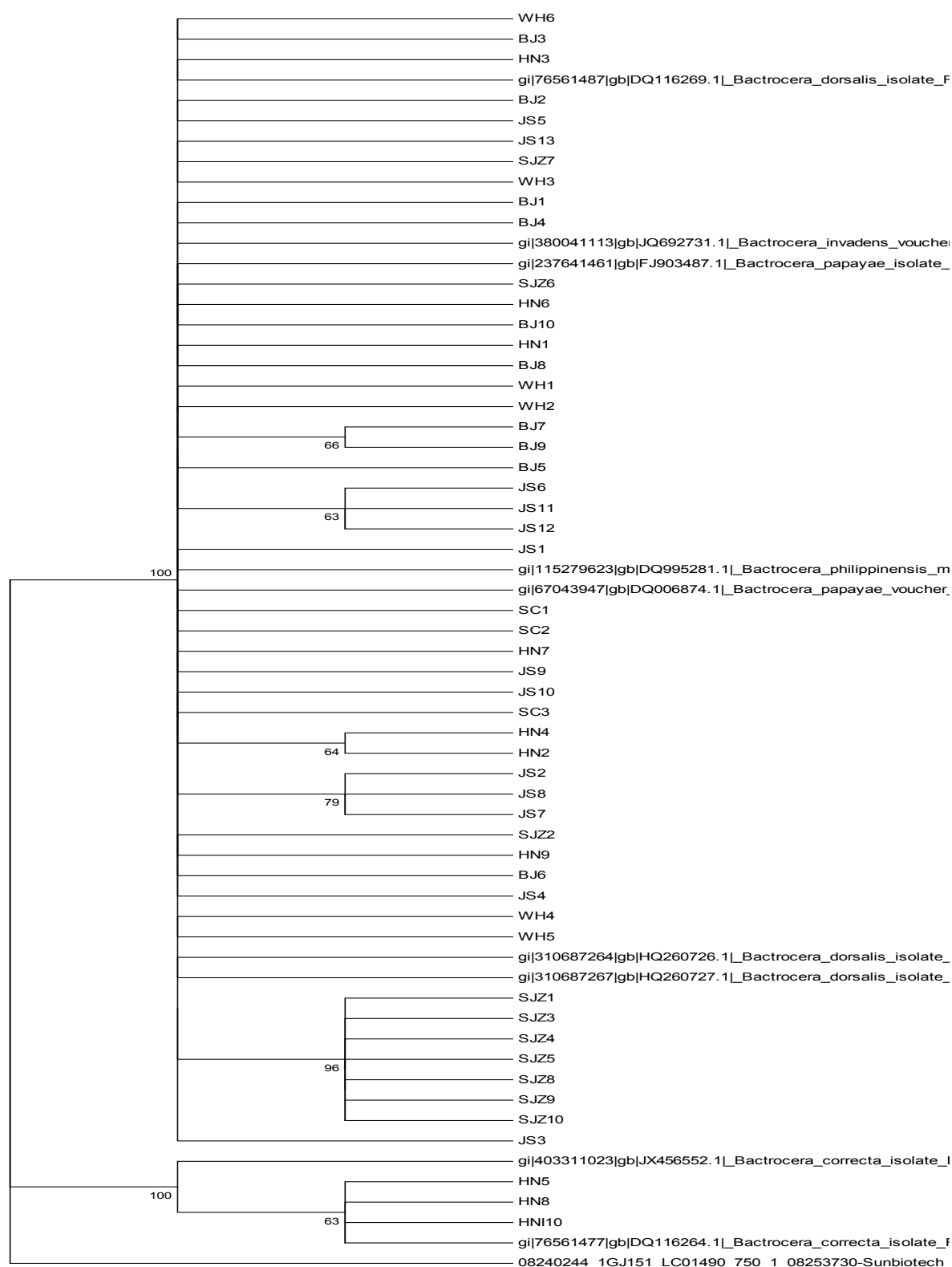
发生危害严重;郑州、西安和兰州等黄河流域产区,郑州产区发生危害普遍,2017年后危害特别严重,但兰州产区至今尚未监测发现,西安产区2016年偶尔监测到成虫,没有危害桃果;福州和桂林等南方产区,发生危害趋势与长江流域产区相似,但危害程度更为严重(表5)。

3 讨论

橘小实蝇及其近缘种形态变化复杂,地理种群众多,而橘小实蝇复合体(*Bactrocera dorsalis complex*)的物种分化与形成、地理种群遗传多样性及其入侵生物学等一直是研究热点^[1]。有研究表明橘小食蝇成虫胸部有突出的黄色和深棕色到黑色的斑纹,胸盾片大部黑色,密被小毛,有一对两侧平行的宽黄沟后条,其前端有一黄色横斑,中后胸背部除正中有一黄斑外皆为黑色^[12-13],另外腹部有两条水平的黑色条纹和一条从第三节基部延伸到腹部顶端的纵向正中条纹。这些斑纹可以形成一个“T”形图案,但图案变化很大^[14]。而在本调查送检的样品中,具有“中胸背板后缘有一个淡黄色长斑”及“中胸背板前缘中部有2个淡黄色侧纵条”特征的个体与橘小实蝇模式标本的原始形态特征描述在形态学上差异较大,应该增加更多形态学特征及分子特征来确定是否为橘小实蝇;不具有“中胸背板后缘有一淡黄色长斑”及“中胸背板前缘中部有2个淡黄色侧纵条”特征的个体与橘小实蝇模式标本的原始形态特征描述在形态学上差异较小,基本可以确定为橘小实蝇。应进一步就橘小实蝇及其近缘种不同地理种群遗传结构,以及与形态学差异的内在联系等进行深入研究,有可能会得出具有一定科学价值的结论。

橘小实蝇对高温有较强的适应能力,在热带和亚热带地区能常年危害,在温带地区也可以以蛹越冬^[15]。因此,可以理解南京、杭州和武汉等长江流域产区与成都、昆明和贵州等西南产区以及福州和桂林等南方产区橘小实蝇发生趋势一致,在桃园各年份均监测到;詹开瑞等^[16]研究认为橘小实蝇的越冬北界为(30±2)°N,以北都属于安全区。那么危害北方桃园的橘小实蝇初始虫源来自哪里,以及近年来橘小实蝇在河南、河北等地区桃园发生严重的具体原因有待进一步研究。

我国不同桃主产区橘小实蝇的种群结构、年份间和地域间发生危害程度等均有一定的差异,调查



BJ(北京):北京综合试验站样品;WH(武汉):武汉综合试验站样品;HN(河南):郑州综合试验站样品;JS(江苏):南京综合试验站样品;SC(四川):成都综合试验站样品;SJB(石家庄):石家庄综合试验站样品。

BJ(Beijing): Samples from Beijing; WH(Wuhan): Samples from Wuhan; HN(Henan): Samples from Zhengzhou; JS(Jiangsu): Samples from Nanjing; SC(Sichuan): Samples from Chengdu; SJZ: Samples from Shijiazhuang.

图 1 桃园橘小实蝇的种群分化

Fig. 1 Population differentiation of *B. dorsalis* in peach orchards

表5 国家桃产业各综合试验站橘小实蝇监测情况

Table 5 A brief table of monitoring situation of *Bactrocera dorsalis* in different experiment station

产区 Region	试验站 Experiment Station	年份 Year							
		2012	2013	2014	2015	2016	2017	2018	2019
环渤海 Around the Bohai Sea	大连 DL	0	0	-	0	0	0	-	-
	昌黎 CL	0	0	0	0	-	-	-	-
	青岛 QD	0	0	0	0	0	0	-	+
北方 Northern China	北京 BJ	+++	+	-	-	-	++	+	-
	石家庄 SJZ	+++	-	0	0	-	++	++	-
	泰安 TA	+++	+	-	++	-	++	+	++
长江流域 Yangtze River Basin	南京 NJ	++	+	-	+	-	++	+	+
	杭州 HZ	-	-	-	-	-	+	+	++
	武汉 WH	++	+	-	-	-	+++	+	++
西南 Southwest China	成都 CD	0	0	0	-	-	++	+	+
	昆明 KM	-	-	-	-	-	-	++	++
	贵州 GZ	-	-	-	-	-	+	++	++
黄河流域 Yellow River basin	郑州 ZZ	-	++	-	++	-	+++	+++	+++
	西安 XA	0	0	0	0	-	0	0	0
	兰州 LZ	0	0	0	0	0	0	0	0
南方 Southern China	福州 Fuzhou	-	-	-	-	-	+++	++	++
	桂林 Guilin	-	-	+	++	-	+++	++	+

注:+++ . 严重; ++ . 重; + . 中等; - . 轻; 0 . 无。

Note: +++ . Serious; ++ . Heavy; + . Medium; - . Light; 0 . None.

掌握橘小实蝇在我国主要产区桃园发生情况和危害特点等,是制定整体防控策略和选择有效防控技术的前提和基础。橘小实蝇在桃园逐渐成为常发性害虫,特别是近3年来,在我国大多数主产区造成非常严重的危害损失。随着国际贸易活动的日趋频繁及其复杂化,实蝇类害虫传播扩散的概率越来越大^[17],与此同时,国内对水果、蔬菜的省区间的病虫害检疫,已经将橘小实蝇等部分实蝇从检疫对象中删除,这些情况的变化,都将加大实蝇对北方地区果蔬种植业和农业生产安全的威胁。

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