果 树 学 报 2021，38（1）：99-106
Journal of Fruit Science

DOI:10.13925/j.cnki.gsxb.20200288

14种杀螨剂对不同地区苹果园二斑叶螨的防治效果评价

洪影雪[1]，李 祥[2]，张金勇[1*]

（[1]中国农业科学院郑州果树研究所，郑州 450009；[2]河南农业大学植物保护学院，郑州 450002）

摘 要：【目的】针对目前二斑叶螨抗性不断提高的事实，进一步了解二斑叶螨的田间抗性情况，并筛选出可供使用的杀螨剂种类。**【方法】**选取了14种我国当前农业生产上广泛使用的杀螨剂，分别对不同地区苹果园中的二斑叶螨进行了室内毒力测定试验，并观察其存活率以及后代的存活情况和性比。**【结果】**14种供试杀螨剂按照田间推荐剂量对二斑叶螨进行毒力测定，多数药剂未能表现出很好的杀虫效果；不同杀螨剂对不同二斑叶螨种群的药效也不同。**【结论】**二斑叶螨抗性积累比较严重，不同地理种群的抗性积累水平也存在较大差别。

关键词：苹果园；二斑叶螨；杀螨剂；抗药性

中图分类号：S661.1 **文献标志码：**A **文章编号：**1009-9980(2021)01-0099-08

Evaluation on the effect of 14 miticides on controlling *Tetranychus urticae* of different populations

HONG Yingxue[1], LI Xiang[2], ZHANG Jinyong[1*]

(*[1]Zhengzhou Fruit Research Institute, CAAS, Zhengzhou 450009, Henan, China; [2]College of Plant Protection, Henan Agricultural University, Zhengzhou 450002, Henan, China*)

Abstract:【Objective】In recent years, Tetranychus urticae has become one of the most harmful pests in apple production. It has a mixed diet and can damage thousands of crops, such as fruit trees, vegetables, flowers and so on. Tetranychus urticae will spoilt the plants by sucking the sap in the plants, which results in the loss of water and necrosis of mesophyll cells, plant growth retardation, stagnation or even death. What's worse, it will lead to premature ripening of fruit, and a marked decrease in quality and yield. At present, the field control of Tetranychus urticae is carried out by integrating agricultural control with chemical control, biological control and other methods. When the damage is serious or the population base is large, application of chemical acaricides is still the main method to control Tetranychus urticae in the field. Due to the long-term, large-amount, single-applied and unreasonable use of chemical acaricides, the problem of increasing resistance is very serious. At the same time, the resistance accumulation of Tetranychus urticae further accelerates because of its characteristic, such as short generation, strong fecundity and so on. In this study, we can realize the resistance of Tetranychus urticae in the field and screen out the suitable acaricides to control Tetranychus urticae in the future.【Methods】We selected 14 kinds of acaricides widely used in agricultural production in China, which were Spirodiclofen, Spirotetramat, Hexythiazox, Lice mite urea, Etoxazole, Avermectins, Fenbutatin oxide, Chlorfenapyr, Pyridaben, Diafenthiuron, Bifenazate, Propargite, Azocyclotin and Bromopropylate. The Tetranychus urticae mites were collected from apple orchards in Lingbao city, Henan province, Shangqiu city, Henan province, and Aksu city, Xinjiang Uygur Autonomous Region. And we fed them with peanut leaves for several generations in the incubator. The incubator temperature was set at (28.0±1.0) ℃, the relative hu-

收稿日期：2020-07-10 接受日期：2020-09-03

基金项目：国家现代农业（苹果）产业技术体系专项基金（CARS-27）

作者简介：洪影雪，女，在读硕士研究生，研究方向为农业害虫绿色防控。Tel：18838933517，E-mail：18838933517@163.com

*通信作者 Author for correspondence. Tel：15517103185，E-mail：zhangjinyong@caas.cn

midity was 80.0%±5.0%, and the photoperiod was L∶D = 14∶10. According to the recommended dosage of each acaricide for controlling Tetranychus urticae in the field, the original medicine of acaricide tested was dissolved by a small amount of organic solvent, and diluted with distilled water containing 1‰ Triton-X to the specified concentration. The same amount of the solvent was taken as the control. We selected the female adults with the same age and in the peak period of oviposition, and then transferred them to peanut leaves with brush. Each leaf had 10 mites to serve as a repeat, and there were 4 repeats. 1 mL diluted solution was used to spray evenly onto the mite and the leaf surface of the Potter spray tower. After spraying, it was put into the artificial climate box for observation. After 48 hours, the survival rate of Tetranychus mites was recorded. After the removal of female adults, we continued feeding them for about one week. Then, we counted the survival number and sex ratio of the second generation of Tetranychus mites.【Results】The survival rate of Tetranychus erythematosus was observed after 9 kinds of acaricides were applied for 48 hours, including Avermectins, Fenbutatin oxide, Chlorfenapyr, Pyridaben, Diafenthiuron, Bifenazate, Propargite, Azocyclotin and Bromopropylate. Bifenazate showed good acaricidal effect on three populations, while Bromopropylate had no significant effect on Tetranychus mites in three populations. For Lingbao population, the other six acaricides showed 90% killing effect, except Pyridaben and Propargite; The survival rate of Tetranychus erythematosus was observed after 9 kinds of acaricides were applied for 48 hours, including Avermectins, Fenbutatin oxide, Chlorfenapyr, Pyridaben, Diafenthiuron, Bifenazate, Propargite, Azocyclotin and Bromopropylate. Bifenazate showed good acaricidal effect on three populations, while Bromopropylate had no significant effect on killing Tetranychus mites in three populations. For Lingbao population, the other six acaricides showed 90% killing effect, except Pyridaben and Propargite. However, both the lethal effects of Fenbutatin oxide, Pyridaben, Propargite, Azocyclotin on Aksu population and Avermectins, Fenbutatin oxide, Pyridaben, Diafenthiuron and Propargite on Shangqiu population were all lower than 50%. Compared with the CK, the other 7 agents could reduce the number of females in the offspring of Tetranychus urticae except for Pyridaben and Bromopropylate. For the population of Tetranychus urticae in Shangqiu, only four kinds of acaricides, including Chlorfenapyr, Bifenazate, Propargite and Azocyclotin, had significant effects on reducing the number of female offspring. For sake of Aksu population, only Avermectins, Chlorfenapyr, Bifenazate and Propargite were effective. In this study, the effects of acaricides on female offspring and male offspring were similar, and there was no significant gender difference. Only 5 kinds of acaricides, including Spirodiclofen, Spirotetramat, Hexythiazox, Lice mite urea and Etoxazole-had the activity of killing eggs or larvae. The results indicated that only Spirodiclofen showed nearly 100% control effect on the three populations of Tetranychus urticae, and the controlling effect of Lice mite urea on the offspring of Tetranychus urticae was not good. After the treatment with Spirotetramat, Hexythiazox and Etoxazole, the number of female mites in the progeny of Lingbao population was significantly lower than the previous generation, but the growth of progeny of Shangqiu and Aksu populations were not inhibited.【Conclusion】The resistance accumulation of Tetranychus urticae was serious, and there were significant differences among different geographical populations. Most of the miticides had good controlling effect on the population of Tetranychus urticae of Lingbao, and they also had good controlling effect on the population number of its offspring. However, the resistance accumulation of Akesu and Shangqiu populations was serious, the lethal effect of most acaricides on the populations was weak, and the controlling effect on offspring was also poor.

Key words: Apple orchard; Tetranychus urticae; Acaricide; Resistance

苹果因其风味优美、营养丰富，已成为世界上栽培面积最广、产量最高的果树种类，其中，我国苹果产量约占世界总产量的三分之一。然而，每年由于叶螨为害可导致苹果减产10%~30%，严重时甚至绝收[1]。二斑叶螨（*Tetranychus urticae* Koch.）属叶螨科（Tetranychoidea），叶螨属（Tetranychus），广泛分布于世界各地的温带和亚热带地区[2]。二斑叶螨的寄主植物广泛，能为害果树、蔬菜、花卉等上千种植物[3-4]。近年来，二斑叶螨也已经上升为苹果生产上危害最大的害螨之一[5-7]。危害时，通过吸食植物茎叶部汁液使叶肉细胞失水坏死，严重时造成叶片枯黄、脱落，影响植物的光合作用，破坏植物的正常生理机能，导致农作物的品质明显下降[8]。

目前二斑叶螨的田间防治采用农业防治、化学防治、生物（天敌）防治等多种方式相结合的方法。但是二斑叶螨因为其体型较小（体长不足1 mm），隐蔽性高，在发生初期不易被察觉而错过最佳防治时期。因此，当为害较重或种群基数较大时，使用化学杀螨剂仍是田间防治二斑叶螨的主要手段。然而，由于近年来长期、大量、单一且不合理地使用化学农药已经造成了二斑叶螨非常严重的抗药性问题。同时，由于二斑叶螨世代历期短、繁殖力强等特性，进一步加速了其抗性积累[9-10]。据报道，二斑叶螨传入我国不到20年的时间，就已对近百种杀虫活性成分产生了不同程度的抗药性[11]，包括神经毒素类（如有机磷类、氨基甲酸酯类、拟除虫菊酯类）、线粒体电子传递链抑制剂类（哒螨灵）和有机锡类（三唑锡）等[2,12]。基因组测序发现，二斑叶螨存在多达39个抗性基因，而昆虫仅有14个抗性基因[6]，这也进一步解释了二斑叶螨抗性广泛、治理困难的原因。

针对目前二斑叶螨抗性不断提高的事实，为了进一步了解二斑叶螨的田间抗性情况，筛选出可供使用的杀螨剂种类，笔者选取了14种我国当前农业生产上广泛使用的杀螨剂，对分别采自河南省灵宝市、河南省商丘市、新疆维吾尔自治区阿克苏市苹果园的二斑叶螨进行了室内毒力测定试验，观察其存活率以及后代的存活情况和性比，以期为今后田间防治二斑叶螨筛选出适宜的杀螨剂种类。

1　材料和方法

1.1　供试药剂

14种供试药剂均为当前农业生产中广泛应用在果树、蔬菜、棉花等作物上的杀螨剂。应用范围广，使用量大[13]。大部分药剂具有杀卵、幼螨、若螨及成螨的作用。其中，螺螨酯、螺虫乙酯、噻螨酮、虱螨脲、乙螨唑等5种杀螨剂对成螨无效。参考每种药剂田间防治叶螨时的推荐使用剂量，试验时将供试杀螨剂原药用少量有机溶剂溶解后，用含有1‰ Triton-X的蒸馏水稀释成指定浓度。取等量的相同溶剂作为对照。药剂信息及供试浓度见表1。

表1　供试杀螨剂信息

Table 1　Test insecticides information

药剂 Pesticides	纯度 Purity/%	生产商 Manufacturer	供试剂量 Test dose/(mg·kg^{-1})
阿维菌素 Avermectins	97.2	河北威远生物化工股份有限公司 Hebei Weiyuan Biochemical Co., Ltd.	4
苯丁锡 Fenbutatin oxide	95.0	日本北陆油化株式会社 Japan Hokuriku Petrochemical Co., Ltd.	150
虫螨腈 Chlorfenapyr	97.0	日本北陆油化株式会社 Japan Hokuriku Petrochemical Co., Ltd.	100
哒螨灵 Pyridaben	95.0	江苏克胜集团 Jiangsu Kesheng Group	70
丁醚脲 Diafenthiuron	98.0	日本北陆油化株式会社 Japan Hokuriku Petrochemical Co., Ltd.	60
联苯肼酯 Bifenazate	97.0	陕西上格之路生物科学有限公司 Shanxi shanggezhilu bioscience Co., Ltd.	150
炔螨特 Propargite	90.0	江苏克胜集团 Jiangsu Kesheng Group	300
三唑锡 Azocyclotin	96.0	山东省招远三联化工厂 Shandong Zhaoyuan Sanlian Chemical Factory	150
溴螨酯 Bromopropylate	93.0	日本北陆油化株式会社 Japan Hokuriku Petrochemical Co., Ltd.	500
螺螨酯 Spirodiclofen	95.0	拜耳作物科学有限公司 Bayer Crop Science Co., Ltd.	70
螺虫乙酯 Spirotetramat	97.8	拜耳作物科学有限公司 Bayer Crop Science Co., Ltd.	50
噻螨酮 Hexythiazox	97.1	江苏克胜集团 Jiangsu Kesheng Group	30
虱螨脲 Lice mite urea	97.1	先正达生物科技(中国)有限公司 Syngenta Biotechnology (China) Co., Ltd.	150
乙螨唑 Etoxazole	96.0	日本北陆油化株式会社 Japan Hokuriku Petrochemical Co., Ltd.	20

1.2 供试虫源

供试二斑叶螨分别采自河南省灵宝市、河南省商丘市、新疆维吾尔自治区阿克苏市的苹果园中。将采集的二斑叶螨带回室内在人工气候箱（MLR-351H，SANYO，日本）中用花生叶片进行饲养，设置温度为（28.0 ± 1.0）℃，相对湿度为（80.0 ± 5.0）%，光周期为L∶D=14∶10。

1.3 杀螨剂毒力测定

选取龄期一致且处于产卵高峰期的雌成虫用于杀螨剂的毒力测定。用毛笔将叶螨转移至裁剪成相同大小的花生叶片上，漂浮于盛有清水的培养皿（直径=6 cm）中以防止其逃逸，每个叶片接入10头二斑叶螨雌成虫，设4组重复。处理组选用1 mL稀释好的药剂溶液，利用Potter喷雾塔（Burkard，英国，P=0~200 kPa）将药液雾化并均匀的喷施于叶螨及叶片表面；对照组选用1 mL不含原药的溶剂，利用Potter喷雾塔将溶剂均匀喷施于叶螨及叶片上，喷药完成后重新放入人工气候箱中进行观察。48 h后记录叶螨的存活情况，移除雌成虫后继续饲养约1周，统计第二代叶螨的存活数及性比。存活率/% = 存活虫数（头）/处理总虫数（头）×100。

1.4 数据处理

采用SPSS 16.0对试验数据进行统计分析，差异显著性检验采用Tukey's HSD法和*t*检验法，所有数值采用平均值±标准误的形式。

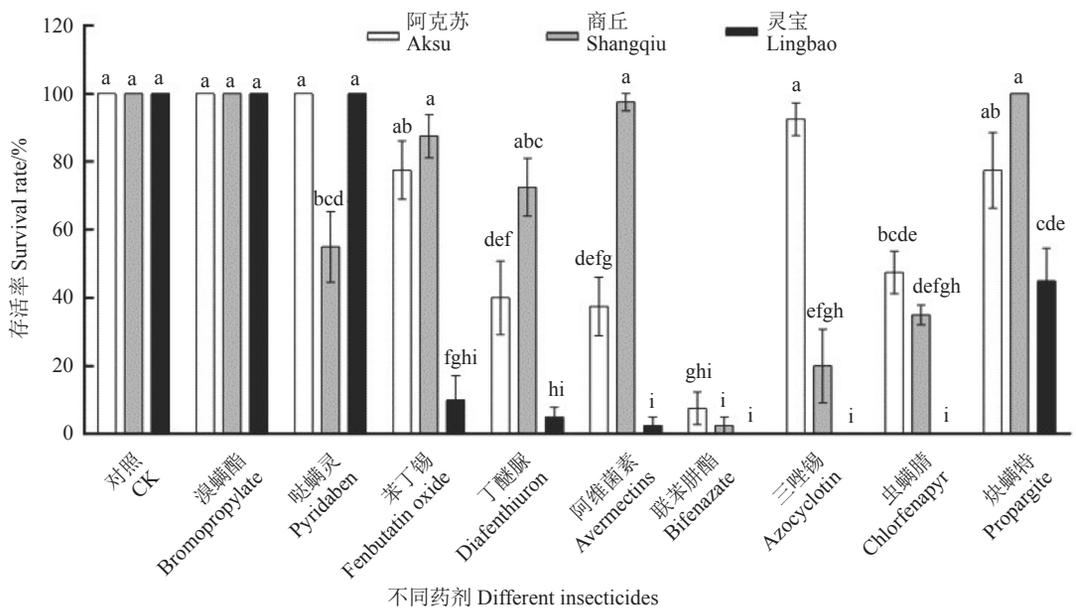
2 结果与分析

2.1 9种杀螨剂对二斑叶螨的致死效果

以每种药剂田间防治叶螨时的推荐使用剂量为依据，分别评价了14种杀螨剂对3个不同地区二斑叶螨种群的杀伤效果。鉴于螺螨酯、螺虫乙酯、噻螨酮、虱螨脲、乙螨唑这5种杀螨剂对成螨无效，首先观察了喷施阿维菌素、苯丁锡、虫螨腈、哒螨灵、丁醚脲、联苯肼酯、炔螨特、三唑锡、溴螨酯等9种药剂48 h后供试二斑叶螨的存活情况。其中，联苯肼酯对3个种群都表现出了很好的杀螨效果，而对照处理及溴螨酯在供试剂量下对3个种群的二斑叶螨未见明显效果，存活率达到100%。除溴螨酯、哒螨灵和炔螨特外，其余6种药剂对灵宝种群都表现出高达90%的杀灭效果；而溴螨酯、哒螨灵、苯丁锡、三唑锡、炔螨特5种杀螨剂对阿克苏种群的致死效果以及溴螨酯、哒螨灵、苯丁锡、丁醚脲、阿维菌素、炔螨特6种杀螨剂对商丘种群的致死效果均低于50%。此外，苯丁锡、丁醚脲、阿维菌素、三唑锡及虫螨腈对3个不同地理种群的二斑叶螨的致死效果差异明显（图1）。

2.2 9种杀螨剂对二斑叶螨后代的影响

二斑叶螨既可以两性生殖，又可以孤雌生殖。



不同小写字母表示药剂间、地理种群间差异显著（$p < 0.05$）。下同。

Different small letters indicate significant differences between insecticides and geographic populations ($p < 0.05$). The same below.

图1 不同杀螨剂对二斑叶螨的致死效果

Fig. 1 Lethal effect of different insecticides on *Tetranychus urticae*

因此，施药后的后代数量，尤其是雌性后代的数量，关系着种群能否迅速恢复甚至扩张。相比于对照组，9种供试药剂都能够使二斑叶螨后代中的雌螨数量及雄螨数量有所减少。经过苯丁锡、丁醚脲、阿维菌素、联苯肼酯、三唑锡、虫螨腈和炔螨特处理后，灵宝种群雌性后代的数量比上一代有所减少，即雌性后代数少于10只。对于商丘二斑叶螨种群，仅有联苯肼酯、三唑锡、虫螨腈、炔螨特这4种杀螨剂对于降低雌性后代数量具有明显的效果，而对于阿克苏种群，仅阿维菌素、联苯肼酯、虫螨腈、炔螨特有效。此外，除丁醚脲、阿维菌素、三唑锡对3种二斑叶螨雌性后代的影响差异较大，其余药剂未见明显差异（图2）。尽管雄螨不直接生育后代，但两性生殖能大大提高后代中的雌螨比例。本研究中，供试杀螨剂对雌性后代和雄性后代的影响效果较为相似，作用效果未见明显的性别差异（图3）。

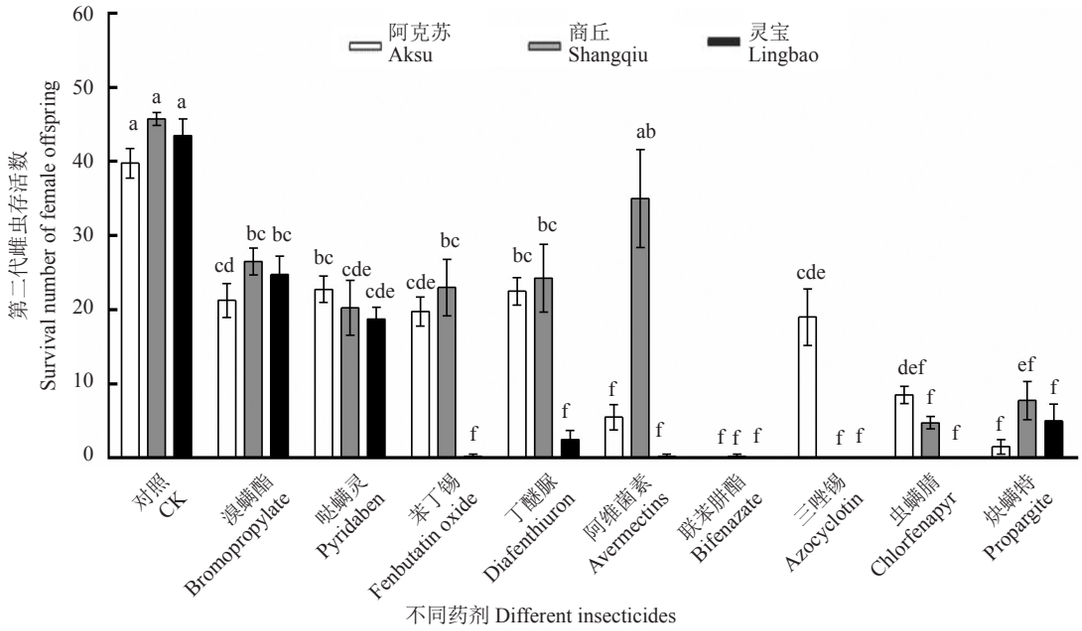


图2　不同杀螨剂对二斑叶螨雌性后代的影响

Fig. 2　Effect of different insecticides on female offspring of *Tetranychus urticae*

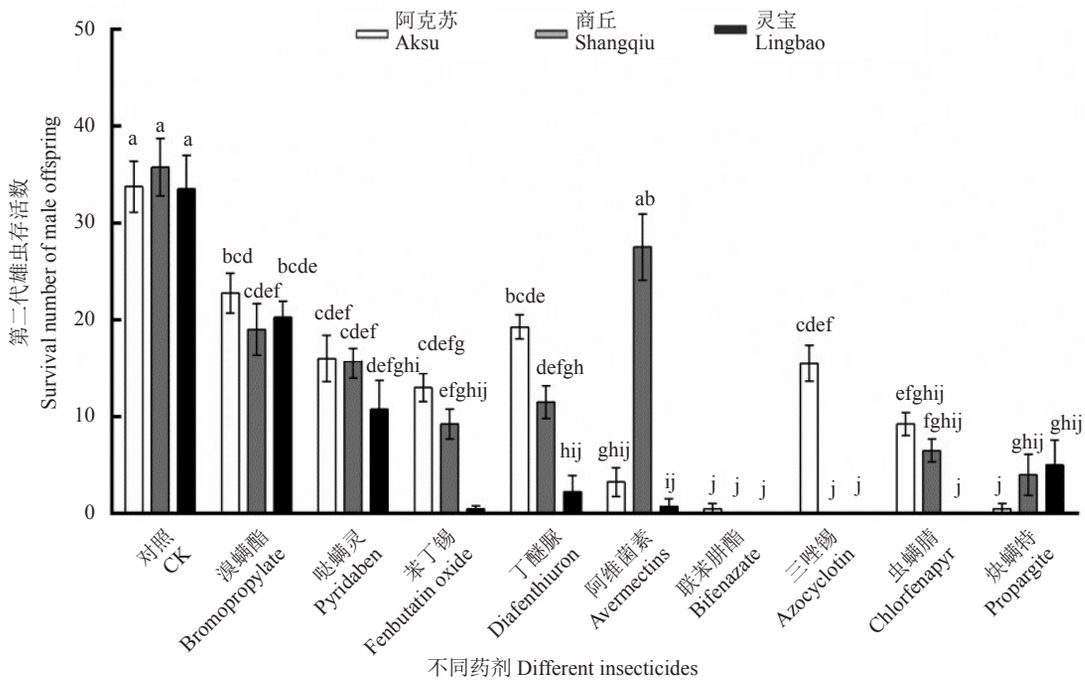


图3　不同杀螨剂对二斑叶螨雄性后代的影响

Fig. 3　Effect of different insecticides on male offspring of *Tetranychus urticae*

2.3 5种杀螨剂对二斑叶螨后代的影响

与上述杀螨剂相似的是，经过螺螨酯、螺虫乙酯、噻螨酮、虱螨脲、乙螨唑这5种仅具有杀卵或杀幼螨活性的杀螨剂处理后，对雌性后代和雄性后代的影响也十分相似（图4，图5）。相比于对照组，5种供试药剂都能够使二斑叶螨后代中的雌螨数量有所减少。其中，仅有螺螨酯对3种二斑叶螨种群后代都表现出近乎100%的防治效果。此外，经过螺虫乙酯、噻螨酮、乙螨唑处理后，灵宝种群的雌螨数量明显低于上一代，但是对商丘种群和阿克苏种群增长不具有抑制效果（图4）。

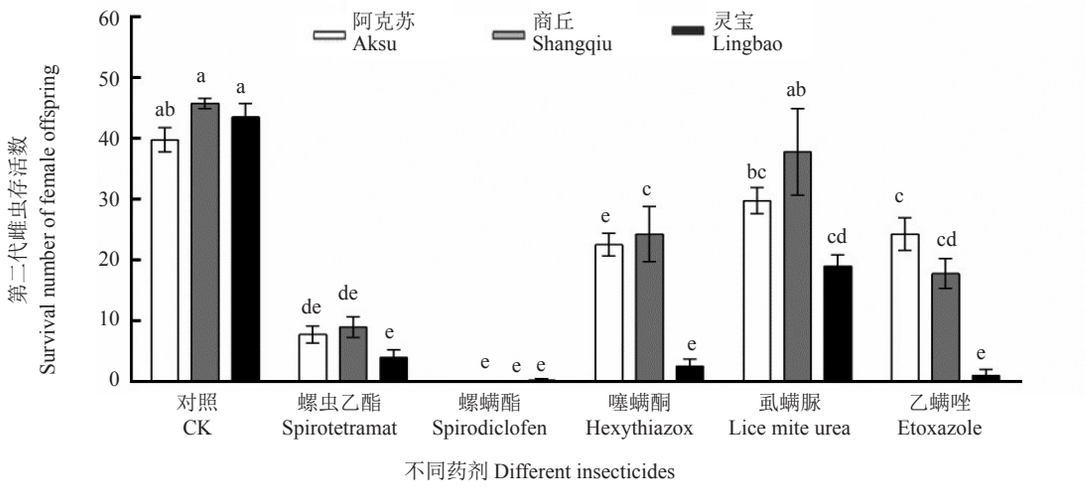


图4 不同杀螨剂对二斑叶螨雌性后代的影响

Fig. 4 Effect of different insecticides on female offspring of *Tetranychus urticae*

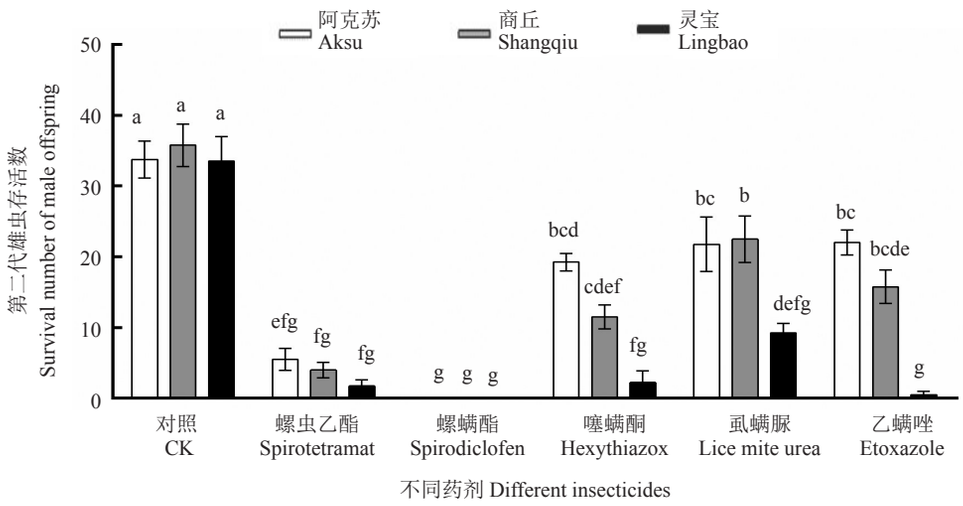


图5 不同杀螨剂对二斑叶螨雄性后代的影响

Fig. 5 Effect of different insecticides on male offspring of *Tetranychus urticae*

3 讨 论

国外很早就出现关于二斑叶螨对阿维菌素产生抗药性的报道，甚至有种群达到了668倍的抗性水平[14]。近年来，我国山东昌乐、山东寿光、以及北京的海淀、昌平、密云、怀柔地区的二斑叶螨种群均对阿维菌素产生了高达百倍的抗性[15-17]。此外，甘肃兰州地区的二斑叶螨种群对菊酯类杀虫剂；山东寿光和烟台种群对哒螨灵和菊酯类杀虫剂；山东烟台种群对甲氰菊酯都产生了明显的抗药性[18-20]。基因遗传、环境因素以及用药不当等因素都可能导致二斑叶螨对杀螨剂的抗性产生[2]，而杀螨剂使用不合理的情况在我国表现得尤为突出。本研究结果表明，当前我国二斑叶螨抗性积累现状已经比较严重。同时，14种药剂的药效差别较大也反映出不同地理种

群的抗性积累水平存在较大差别，这可能与当地用药情况不同有关，长期单一、大量地使用一些药剂导致二斑叶螨产生了较强的抗药性。这也提示我们应当因地制宜、因虫施药。

另一方面，14种杀螨剂中多数药剂对阿克苏及商丘市二斑叶螨种群的控制效果较差，也提示我们在防治时应注意补充施药，同时避免长期使用单一杀螨剂，与杀卵和杀幼螨效果较好的药剂合理混配、交替使用，一方面有利于控制二斑叶螨的种群数量，有效防止其再次暴发；同时减缓了抗性积累，为研发新型农药或新的防治手段争取时间。大量的研究表明，交替、混配使用化学农药具有降低成本、提升效果、延缓抗性产生以及减少环境污染等诸多好处[21-23]。

此外，二斑叶螨抗性水平不断提高，也警示我们不能单一依赖化学农药进行防治，而应当更加关注不易引起抗性积累的防治途径，例如利用天敌生物将二斑叶螨种群水平控制在经济阈值之下。既能减少化学农药对环境和食品安全的威胁，又能保护生物多样性，有利于维护生态系统的稳定。同时在选用杀螨剂时，可以更加关注对天敌生物毒性较小的杀螨剂种类，以建立长效的生态防控机制。

4　结　论

二斑叶螨抗性积累严重，不同地理种群间存在显著差异。大多数杀螨剂对灵宝市二斑叶螨种群有较好的防治效果，对其后代种群数量也有较好的控制作用；但阿克苏和商丘2个种群的抗性积累严重，多数农药对其种群的致死作用较弱，对后代的控制效果也较差。

参考文献 References:

[1] 明广增，王林建，徐建国，祝服奎，周生桥 . 鲁西南苹果园二斑叶螨的发生与防治[J]. 中国果树，2002(1)：40-41.
MING Guangzeng，WANG Linjian，XU Jianguo，ZHU Fukui，ZHOU Shengqiao. Occurrence and control of *Tetranychus urticae* in apple orchard of Southwest Shandong province[J]. China Fruits，2002(1): 40-41.

[2] VAN LEEUWEN T，VONTAS J，TSAGKARAKOU A，DER MAUW W，TIRRY L. Acaricide resistance mechanisms in the two-spotted spider mite *Tetranychus urticae* and other important *Acari*: a review[J]. Insect Biochemistry and Molecular Biology，2010，40(8): 563-572.

[3] GRBIIĆ M，VAN LEEUWEN T，CLARK R M，……，VAN De PEER Y. The genome of *Tetranychus urticae* reveals herbivorous pest adaptations[J]. Nature，2011，479(7374): 487-492.

[4] DERMAUW W，WYBOUW N，ROMBAUTS S，MENTEN B，VONTAS J，GERBIĆ M，CLARK R M，FEYEREISEN R，VAN LEEUWEN T. A link between host plant adaptation and pesticide resistance in the polyphagous spider mite *Tetranychus urticae*[J]. Proceedings of the National Academy of Sciences of the United States of America，2013，110(2): 393-394.

[5] 周玉书，朴春树，刘池林 . 警惕二斑叶螨在北方果区为害蔓延[J]. 植物保护，1996，22(5)：51-52.
ZHOU Yushu，PU Chunshu，LIU Chilin. Vigilance against the damage by the spread of two spotted mites in the northern fruit area[J]. Plant Protection，1996，22(5): 51-52.

[6] 谌有光 . 警惕二斑叶螨在我国果产区蔓延为害[J]. 植保技术与推广，1997，17(5)：24-25.
SHEN Youguang. Vigilance against the damage by the spread of two spotted mites in fruit producing areas of China[J]. Plant Protection Technology and Extension，1997，17(5): 24-25.

[7] 程立生 . 应重视二斑叶螨在我国的传播危害[J]. 植物保护，1999，25(4)：55-56.
CHENG Lisheng. Should pay attention to the spread of two-spottedmite inourcountry[J]. Plant Protection，1999，25(4): 55-56.

[8] 姚强 . 二斑叶螨对三种重要杀螨剂的抗性选育及抗性风险评估[D]. 广州：华南农业大学，2018.
YAO Qiang. The study on the metabolic resistance and risk assessment of *Tetranychus urticae* Koch to three important acaricides[D]. Guangzhou: South China Agricultural University，2018.

[9] 徐丹丹 . 二斑叶螨抗药性监测及靶标基因突变频率研究[D]. 北京：中国农业科学院，2019.
XU Dandan. Monitoring of pesticide resistance and the mutation frequencies of target genes in *Tetranychus urticae*[D]. Beijing: Chinese Academy of Agricultural Sciences，2019.

[10] 徐丹丹，王少丽，何艳艳，张友军，谢文，吴青君 . 我国二斑叶螨抗药性现状及抗性基因突变频率检测[J]. 中国瓜菜，2019，32(8)：155-156.
XU Dandan，WANG Shaoli，HE Yanyan，ZHANG Youjun，XIE Wen，WU Qingjun. Status of pesticide resistance and associated mutations in the two-spotted spider mite，*Tetranychus urticae*，in China[J]. China Cucurbits and Vegetables，2019，32(8): 155-156.

[11] 孟和生，王开运，姜兴印，仪美芹 . 二斑叶螨发生危害特点及防治对策[J]. 应用昆虫学报，2001，38(1)：52-54.
MENG Hesheng，WANG Kaiyun，JIANG Xingyin，YI Meiqin. Occurrence characteristics of *Tetranychus urticae* and its control methods[J]. Chinese Bulletin of Entomology，2001，38(1): 52-54.

[12] VASSILIOU V A，KITSIS P. Acaricide resistance in *Tetranychus urticae* (Acari: Tetranychidae) populations from Cyprus[J]. Journal of Economic Entomology，2013，106(4): 1848-1854.

[13] 高越，王银平，王亚黎，曹克强，王勤英 . 我国苹果主产区苹果

叶螨种类及杀螨剂应用现状[J]. 中国植保导刊，2019，39(2)：67-70.

GAO Yue，WANG Yinping，WANG Yali，CAO Keqiang，WANG Qinying. Species of apple spider mites and application of miticides in main apple-producing areas of China[J]. China Plant Protection，2019，39(2): 67-70.

[14] SATO M E，DA SILVA M Z，ADALTON R，DE SOUZA FILHO M F. Abamectin resistance in *Tetranychus urticae* Koch (Acari: Tetranychidae): selection，cross-resistance and stability of resistance[J]. Neotropical Entomology，2005，34(6): 991-998.

[15] 刘庆娟，刘永杰，于毅，周仙红，马慧 . 二斑叶螨对七种杀螨剂的抗药性测定及其机理研究[J]. 应用昆虫学报，2012，49(2)：376-381.

LIU Qingjuan，LIU Yongjie，YU Yi，ZHOU Xianhong，MA Hui. The study on resistance and its mechanism of *Tetranychus urticae* to several common insecticides[J]. Chinese Bulletin of Entomology，2012，49(2): 376-381.

[16] 唐小凤，张友军，吴青君，谢文，曹增，王少丽 . 杀螨剂对截形叶螨的毒力及助剂对杀螨剂的增效作用研究[J]. 环境昆虫学报，2013，35(3)：322-327.

TANG Xiaofeng，ZHANG Youjun，WU Qingjun，XIE Wen，CAO Zeng，WANG Shaoli. Toxicity of different acaricides and synergy of organosilicone surfactants to *Tetranychus truncatus* Ehara[J]. Journal of Environmental Entomology，2013，35(3): 322-327.

[17] WANG L，ZHANG Y J，XIE W，WU Q J，WANG S L. A bioassay for evaluation of the resistance of *Tetranychus urticae* (Acari: Tetranychidae) to selected acaricides[J]. Systematic & Applied Acarology，1971，20(6): 579-590.

[18] 沈慧敏，杨宝生 . 二点叶螨对 16 种杀虫、杀螨剂的抗药性[J]. 植物保护学报，2001，28(4)：362-366.

SHEN Huimin，YANG Baosheng. Study on the resistance of *Tetranychu surticae* Koch to 16 insecticides and acaricides[J]. Journal of Plant Protection，2001，28(4): 362-366.

[19] 赵卫东，王开运，姜兴印，仪美芹 . 二斑叶螨对常用杀螨剂的抗药性测定[J]. 农药学学报，2001，9(3)：86-88.

ZHAO Weidong，WANG Kaiyun，JIANG Xingyin，YI Meiqin. The monitoring of resistance of *Tetranychus urticae* Koch to several insecticides[J]. Chinese Journal of Pesticide Science，2001，9(3): 86-88.

[20] 王开运，赵卫东，姜兴印，王金花 . 十种杀螨剂对二斑叶螨抗性种群不同发育阶段的毒力比较[J]. 农药，2002，41(3)：29-31.

WANG Kaiyun，ZHAO Weidong，JIANG Xingyin，WANG Jinhua. The toxicity testing of resistance population of *Tetranychus urticae* Koch to several acaricides[J]. Agrochemicals，2002，41(3): 29-31.

[21] 邓博 . 啶虫脒与苦参碱混配剂对烟粉虱毒力测定及田间药效评价[D]. 杨凌：西北农林科技大学，2015.

DENG Bo. Toxicity testing and field efficacy evaluation of Acetamiprid and Matrine mixture used to control *Bemisia tabaci*[D]. Yangling: Northwest A & F University，2015.

[22] 李文林 . 果园绿色、安全使用化学农药的方法[J]. 北方园艺，2017(15)：207-208.

LI Wenlin. Green and safe use of chemical pesticides in orchard [J]. Northern Horticulture，2017(15): 207-208.

[23] 王欢欢 . 九种杀虫剂对瓜蚜的毒力及协同增效药剂筛选[D]. 泰安：山东农业大学，2019.

WANG Huanhuan. Toxicities and screening synergies of nine insecticides against *Aphis gossypii* Glover[D]. Taian: Shandong Agricultural University，2019.