果 树 学 报 2017,34(11):1467-1474
Journal of Fruit Science

DOI:10.13925/j.cnki.gsxb.20170042

不同杧果品种对杧果小爪螨的抗性评价

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摘 要:【目的】在获得稳定的抗、感杧果小爪螨(*Oligonychus mangiferus*)的杧果种质基础上,以害螨和寄主植物的互作机制为切入点,分析与评价不同杧果品种对杧果小爪螨的抗、感性。【方法】通过田间调查和室内评价方法获得抗、感性稳定的杧果品种,经室内饲养观察,记录杧果小爪螨在抗、感杧果品种上的存活率差异,并进一步通过分光光度计测定分析抗、感杧果品种叶片组织内游离氨基酸含量、游离氮含量、游离糖含量、糖/氮比和总酚含量的差异。【结果】杧果小爪螨只危害杧果的功能叶,不危害嫩叶和老叶;在筛选获得的6个抗、感性稳定的杧果品种中,‘台农一号’和‘红芒Ⅵ号’对杧果小爪螨表现为高抗和抗螨,而‘鸡蛋芒’‘秋芒’‘紫花’和‘粤西Ⅰ号’对杧果小爪螨表现为感螨;抗性品种‘台农一号’和‘红芒Ⅵ号’较感性品种‘紫花’和‘粤西Ⅰ号’功能叶中含有较多的游离糖、较高的糖/氮比和较多的总酚,2者间差异显著,但抗、感性品种的功能叶、嫩叶和老叶中的游离氨基酸含量、游离氮含量及嫩叶、老叶中的游离糖含量、糖/氮比和总酚含量无显著差异。【结论】不同杧果品种对杧果小爪螨存在显著的抗、感性差异,其抗性与杧果功能叶中的游离糖含量、糖/氮比和总酚含量相关,为杧果抗螨种质的挖掘与创新利用、抗螨分子设计育种提供了基础信息、参试材料及理论依据。

关键词:杧果品种;杧果小爪螨;存活率;营养物质;次生代谢物质;防御

中图分类号:S667.7　　文献标志码:A　　文章编号:1009-9980(2017)11-1467-08

Resistance evaluation of different mango cultivars to *Oligonychus mangiferus* (Rahman et Runjab)

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Abstract:【Objective】*Oligonychus mangiferus* is one of the most destructive pests in mango trees. It feeds primarily on the lower surfaces of the leaves. During feeding, the mites penetrate the host plant with their styles and suck out the cell contents, resulting in discoloration and death of the leaf tissues. Heavy infestations result in severe defoliation, causing mango trees to stop growing and also results in fruit yield reduction. If young mango trees have been seriously damaged, their twigs will eventually become dry and die. In recent years, *O. mangiferus* has become one of the most destructive pests throughout most of the mango tree plant areas in China. For a long time, the control of this mite was mainly dependent on the chemical acaricide, however, the question of environmental pollution and "3R" has also become more and more a serious concern. Host plant resistance has been considered as the most active, effective and economic measures against insects and mites, and has already become a directional measure for pest controls both at home and abroad. The planting of a variety of resistances to mites were the most effective and direct approach to control the spider mite, in view of the fact that there's no definitive mite-resistant mango germplasms at home and abroad so far, and also because of the lack of a systematic research theory and technical support of mite-resistant mango germplasms. Furthermore, according to the development and the actual needs of the mango industry, after establishing the mite-resistant evaluation criteria of rubber germ-

收稿日期:2017-02-21　　接受日期:2017-07-28

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plasms and obtaining the stable resistant and susceptible mango germplasms, this study compared the differences of the survival of *O. mangiferus* feeding on resistant and susceptible mango tree leaves and the contents of nutrients, secondary metabolites products.【Methods】Cultivars were evaluated for resistance at sites in which they were growing vigorously and in fields with the same ecological characteristics. The evaluations were facilitated by natural infestations of *O. mangiferus*. Ratings were based on the following damage scale: 0. No mites or symptoms; 1. a few mites on leaves, some yellow to white speckling on leaves; 2. a large amount of mites on leaves, red speckling on leaves; 3. leaves full of mites, the area percentage of the red speckling on leaves is between 1/3 to 2/3; 4. lots of mites on the entire plant, the area percentage of the red speckling on leaves is beyond 2/3. Since no definitive mite-resistant mango germplasms against *O. mangiferus* exist, this study evaluated the mite resistant cultivars via the rate of dispersion. First, the average values of the index of mite damage (I^*) for all the evaluated cultivars and the highest score of index of mite damage (I) for each cultivar in three replicates were obtained, then we obtained the degree of resistance via I/I^*. After obtaining the cultivars that steadily developed resistant to *O. mangiferus* via the field and laboratory, we compared the differences of the contents of free amino acids, free sugar, nitrogen and the ratio of sugar and nitrogen in different mango cultivar leaves. The contents of free amino acids, the free sugar, the free nitrogen as well as the total phenol were measured by the ninhydrin colorimetry method, anthrone method, the Coomassie brilliant blue G250 staining method and the catechins colorimetric method, respectively.【Results】*O. mangiferus* only damaged the functional leaves but not the tender and the older leaves of the mangos. Two mango cultivars steadily developed resistance to *O. mangiferus*, 'Tainong I' and 'Hongmang VI', and four susceptible cultivars, 'Jidanmang', 'Qiumang', 'Zihua' and 'Yuexi I', were screened from 21 mango core cultivars on the basis of the established mite-resistant evaluation criteria of mango germplasms. 'Tainong I' and 'Hongmang VI' were highly resistant and resistant respectively, while 'Jidanmang', 'Qiumang', 'Zihua' and 'Yuexi I' were susceptible to *O. mangiferus*. Significantly different survivals of *O. mangiferus* were observed among different mango cultivars. The survival rate of *O. mangiferus* fed on functional leaves of 'Tainong I' and 'Hongmang VI' were 5.17% and 32.33%, respectively, significantly lower than those of the other 4 cultivars (58.16% for 'Jidanmang', 62.27% for 'Qiumang', 77.36% for 'Zihua' and 76.67% 'Yuexi I'). The resistance of the eight cultivars against *O. mangiferus* were 'Tainong I' > 'Hongmang VI' > 'Jidanmang' > 'Qiumang' > 'Zihua' > 'Yuexi I' in the field, and were accordant with those in the laboratory. Significant differences for the contents of nutrients and the secondary metabolite products in different mango cultivars were observed and require further comparison. The nutrient contents in the mite resistant mango cultivar leaves were significantly different with those in the susceptible rubber germplasm leaves ($P< 0.05$). There were more free sugar, high ratio of sugar and nitrogen and more total phenols in the functional leaves of the resistant cultivars 'Tainong I' and 'Hongmang VI' than those in the functional leaves of the susceptible cultivars 'Zihua' and 'Yuexi I', which were significantly different between the resistant and the susceptible cultivars; contents of free sugar, ratio of sugar and nitrogen and contents of total phenols in the tender and the older leaves and contents of free amino acids and free nitrogen were not significantly different between the resistant and the susceptible cultivars.【Conclusion】The above results all indicate that the contents of free sugar, ratio of sugar and nitrogen and total phenols in the functional leaves were significantly relative to the resistance of mango cultivars to *O. mangiferus*. We can therefore elucidate the mite-resistant mechanism of the mango germplasms, and at the same time, provide basic information, experimental material, and theory support for the molecular design breeding in mite-resistant mango germplasms.

Key words: Mango cultivars; *Oligonychus mangiferus*; Survival rate; Nutrient; Secondary metabolites; Defense

杧果小爪螨[*Oligonychus mangiferus*(Rahman et Runjab)]是一种危害杧果的重要害螨[1-4],主要以口针刺入植物组织吸取汁液,致使叶片失绿,影响光合作用,严重时可使整叶变黄、干枯、脱落,造成结果树减产、幼树生长发育受到严重影响[4]。近年来,随着海南杧果种植业的快速发展,该螨的发生与危害也日趋严重[1-3]。目前,杧果生产中对于杧果小爪螨的防治仍依赖于化学防治,但化防过程中施药技术落后带来的农药有效利用率不足、农药的使用频率及使用剂量不断加大以及抗药性等问题越来越严重,威胁着人们赖以生存的环境、自然防治资源及人们的身体健康,对热带农业产品的出口将造成严重影响[1-2,5]。因此,寻求符合环保要求的新的防治策略和防治方法,有效地控制杧果小爪螨的发生与危害已成为当前我国热区杧果生产中亟待解决的重要课题。

植物抗虫性(plant resistance to insects)是指同种植物在昆虫危害较严重的情况下,某些植株能避免受害、耐害、或虽受害却有补偿能力的特性[5]。利用抗虫(螨)种质防治害虫(螨)在害虫防治中具有无可比拟的优越性:(1)利用抗虫(螨)种质防治害虫(螨)可以避免或减轻虫害损失;(2)抗虫(螨)种质对害虫(螨)种类的影响是明确、持久和累积性的,常可大面积地把害虫(螨)的种群数量压低在经济损害水平以下[6]。美国曾将约930万美元投资用以研究4种作物害虫的抗虫性,并在10 a内利用所研究出的抗虫种质资源挽回高达30亿美元的经济损失[7]。植食性昆虫依赖于寄主植物获得养分,寄主植物对植食性昆虫的营养效应主要决定于取食部位所含成分的质和量。植物对植食性昆虫的作用一般以变动着的次生物质和营养成分来影响昆虫的行为、生长发育和繁殖[8-17]。营养物质可能在下述情况下引起植物对植食性昆虫的抗生作用:(1)缺乏某些营养物质,如维生素或主要氨基酸;(2)某些营养物质,特别是氨基酸或特定的固醇含量不足;(3)有效营养物质不平衡[18-21]。寄主本身某种营养物质的缺乏或搭配比例不当,同样会影响害虫(螨)的正常发育,降低害虫(螨)的生存率而获得抗虫(螨)性[22]。研究表明,不同茶树种质新梢中游离氨基酸的组成及含量显著影响茶橙瘿螨对其种质的选择[23]。水稻植株体内游离氨基酸总量、可溶性糖含量、可溶性蛋白质含量与灰飞虱若虫的存活率均呈极显著正相关[24]。高感螨的美洲黑杨及其杂种无性系含有大量诱导瘿螨取食的营养物质,包括糖类、脂肪和维生素[25]。美洲黑杨苗期叶片可溶性糖和总酚含量等性状差异与抗杨四瘿螨有密切关系[26]。

目前,有关植物抗虫性研究国内外均有大量报道,但主要集中在小麦、棉花、豆类、花生、苹果、葡萄、木薯、橡胶等作物[27-32]。针对目前国内外尚无确定的杧果抗螨品种,加之杧果种质抗螨性系统研究理论与技术的缺乏,已无法继续支撑杧果产业发展与实际需求,因此,笔者以目前发生与危害最严重的杧果小爪螨为研究对象,在建立了切实可行的杧果种质抗螨性评级标准并获得稳定的抗、感种质基础上,以害螨和寄主植物的互作机制为切入点,进一步从杧果抗性种质对杧果小爪螨存活的影响以及营养物质与次生代谢防御效应方面阐明了杧果种质的抗螨性机制,为杧果抗螨种质的挖掘与创新利用、抗螨分子设计育种提供了基础信息、参试材料及理论与技术依据。

1　材料和方法

1.1　材料

1.1.1　螨类来源　杧果小爪螨采自中国热带农业科学院杧果品种资源圃,采回后在室内(28±1)℃、RH(75±5)%及14 h(光照):10 h(黑暗)下用'粤西I号'杧果功能叶饲养繁殖1代。

1.1.2　杧果品种　用于抗、感螨性鉴定的杧果品种为'台农一号''红芒VI号''鸡蛋芒''秋芒''紫花'和'粤西I号',均为经田间抗性初步筛选后的成年树,栽培和管理水平一致。经田间和室内抗性鉴定后,分别采集抗、感特性稳定的'台农一号''红芒VI号''紫花'和'粤西I号'的嫩叶、功能叶和老叶,用于各品种叶组织中游离氨基酸、糖、氮及酚含量的测定。

1.2　方法

1.2.1　田间抗性鉴定　参考周明牂[6]的方法。以自然感螨为主,螨害高峰期采用目测法进行调查,每个品种5株,每株按东、南、西、北、中5个方位分别调查各供试杧果品种的嫩叶、功能叶和老叶各100枚,然后根据螨害指数进行抗性评价。

田间螨害级别分为5级:0级为叶片无螨危害;1级为叶片上有零星螨,叶面出现黄白斑;2级为叶片上有较多螨,叶面出现红斑;3级为叶片布满螨,红

斑占全叶的1/3~2/3;4级为全株螨量极多,红斑占全叶的2/3以上。由于本试验无确定的抗、感螨品种,故只能采用离中率方法进行评价。首先求出所有参鉴品种螨害指数的平均值I*,根据每个品种3次重复中螨害指数最高值I与I*的比值确定其抗性程度。田间抗性评级标准参考陈青等[33]的标准。螨害指数(I)=Σ(严重度级别×该级株数)/(调查株数×4)×100。

1.2.2 不同杧果品种对杧果小爪螨存活率的影响 分别从中国热带农业科学院杧果品种资源圃留种多年的'台农一号''红芒VI号''鸡蛋芒''秋芒''紫花'和'粤西I号'成年树上采集叶龄与大小一致的功能叶,分别取在(28±1)℃、RH (75±5)%及14 h(光照):10 h(黑暗)条件下饲养的繁殖1代,发育程度和大小一致的成螨各100头,接种于不同杧果品种上待其产卵,24 h后除去成螨,每叶留存100粒卵用于观察记录各品种上杧果小爪螨的存活情况,并计算存活率。

1.2.3 抗、感杧果小爪螨叶组织游离氨基酸、游离糖、游离氮、总酚含量测定 游离氨基酸含量的定量测定参考陈青[20]的茚三酮法。游离糖含量的定量测定参考陈青[20]的蒽酮法。游离氮含量的定量测定参考陈青[20]的蛋白质考马斯亮蓝G250法。游离氮含量根据N=蛋白质含量×16%求得。总酚含量测定参考李庆等[34]的儿茶酚比色法。

1.3 数据处理

用SPSS软件Duncan's新复极差法比较分析取食不同杧果品种后杧果小爪螨存活率差异以及抗、感杧果品种营养物质含量差异。

2 结果与分析

2.1 不同杧果品种对杧果小爪螨抗性的田间调查

田间调查发现,对于同一杧果植株,杧果小爪螨只危害功能叶,不危害嫩叶和老叶(表1)。各供试杧果品种对杧果小爪螨的敏感性也不同,其中'台农一号'和'红芒VI号'对杧果小爪螨表现为高抗和抗螨,而'鸡蛋芒''秋芒''紫花'和'粤西I号'对杧果小爪螨均表现为感螨。

表1 不同杧果品种对杧果小爪螨抗性的田间调查

Table 1 Identification of different mango cultivar resistance to *Oligonychus mangiferus* in the field

品种 Cultivar	I/I*			螨害级别 Damage scales			抗性程度 Levels of resistance		
	嫩叶 Young leaves	功能叶 Functional leaves	老叶 Elder leaves	嫩叶 Young leaves	功能叶 Functional leaves	老叶 Elder leaves	嫩叶 Young leaves	功能叶 Functional leaves	老叶 Elder leaves
台农一号 Tainong Ⅰ	0	0.15	0	0	0	0	HR	HR	HR
红芒VI号 Hongman VI	0	0.28	0	0	2	0	HR	R	HR
鸡蛋芒 Jidanmang	0	0.55	0	0	4	0	HR	S	HR
秋芒 Qiumang	0	0.53	0	0	4	0	HR	S	HR
紫花 Zihua	0	0.62	0	0	4	0	HR	S	HR
粤西I号 Yuexi Ⅰ	0	0.69	0	0	4	0	HR	S	HR

注:I 为螨害指数,I*为平均螨害指数。HR. 高抗;R. 抗病;S. 感病。

Note: I is the damage index of spider mites; I* is the average damage index of spider mites. HR. High resistant; R. Resistant; S. Susceptible.

2.2 不同杧果品种对杧果小爪螨存活率的影响

用不同杧果品种功能叶饲养的杧果小爪螨的存活率存在显著差异($P<0.01$,表2),取食抗性品种'台农一号'和'红芒VI号'功能叶的杧果小爪螨的存活率分别为5.17%和32.33%,显著低于取食感性品种'鸡蛋芒''秋芒''紫花'和'粤西I号'功能叶的杧果小爪螨的存活率(58.16%、62.27%、77.36%和76.67%)。不同杧果品种对杧果小爪螨的抗、感性不同,抗性高低表现为'台农一号'>'红芒VI号'>'鸡蛋芒'>'秋芒'>'粤西I号'>'紫花',与田间

表2 不同杧果品种对杧果小爪螨存活率的影响

Table 2 Effects of different mango cultivars on *Oligonychus mangiferus* livability

品种 Cultivar	处理个体数 Mite numbers of treatment	存活率 Survival rate/%
台农一号 Tainong Ⅰ (HR)	100	5.17±0.27 aA
红芒VI号 Hongmang Ⅳ (R)	100	32.33±1.77 bB
鸡蛋芒 Jidanmang (S)	100	58.16±2.57 cC
秋芒 Qiumang (S)	100	62.27±2.21 cC
粤西I号 Yuexi Ⅰ (S)	100	76.67±2.13 dD
紫花 Zihua (S)	100	77.36±1.07 dD

注:不同小写字母表示 $P<0.05$ 差异显著,不同大写字母表示 $P<0.01$ 差异极显著。下同。

Note: Different small letters in the different cultivars indicate the significant difference at $P<0.05$, different capital letters in the different cultivars indicate the extremely significant differences at $P<0.01$. The same below.

抗性鉴定结果相一致。

2.3 不同杧果品种叶组织中游离氨基酸含量测定与比较

抗、感螨杧果品种嫩叶、功能叶和老叶中的游离氨基酸含量无显著差异（$P > 0.05$，表3），因此说明，杧果对杧果小爪螨的抗性可能与其叶组织中的游离氨基酸含量无关。

表 3 不同杧果品种叶组织中游离氨基酸含量测定与比较

Table 3 Contents of free amino acids in different mango cultivar leaves

品种 Cultivar	ω(平均游离氨基酸) Average free amino acids contents/(mg·g^{-1})		
	功能叶 Functional leaves	嫩叶 Young leaves	老叶 Elder leaves
台农一号 Tainong Ⅰ (HR)	4.60±0.42 aA	4.88±0.31 aA	4.98±0.12 aA
红芒Ⅵ号 Hongmang Ⅳ (R)	4.61±0.29 aA	4.69±0.19 aA	4.99±0.16 aA
紫花 Zihua (S)	4.82±0.31 aA	5.06±0.24 aA	5.07±0.10 aA
粤西Ⅰ号 Yuexi Ⅰ (S)	4.83±0.21 aA	5.17±0.20 aA	5.10±0.17 aA

2.4 不同杧果品种叶组织中游离糖、氮含量及糖/氮比测定与比较

抗性品种‘台农一号’和‘红芒Ⅵ号’较感性品种‘紫花’和‘粤西Ⅰ号’功能叶中含有较多的游离糖和较高的糖/氮比，‘台农一号’和‘红芒Ⅵ号’的游离糖平均质量分数和平均糖/氮比分别为48.78、45.30 mg·g^{-1}和7.64×10^{4}、7.10×10^{4}，而‘紫花’和‘粤西Ⅰ号’的游离糖平均质量分数和平均糖/氮比分别为24.15、23.36 mg·g^{-1}和3.79×10^{4}、3.70×10^{4}，‘台农一号’和‘红芒Ⅵ号’的游离糖分别是‘紫花’和‘粤西Ⅰ号’的1.88、2.09倍，‘台农一号’和‘红芒Ⅵ号’糖/氮比分别是‘紫花’和‘粤西Ⅰ号’的1.879、2.07倍，2者间存在显著差异（$P < 0.01$），但抗、感品种嫩叶和老叶中的游离糖和糖/氮比却无显著差异（$P > 0.05$），且其含量显著高于感性品种。游离氮含量测定结果显示，无论是抗性品种还是感性品种，其功能叶、嫩叶和老叶中的游离氮含量均无显著差异（$P > 0.05$，表4）。因此，杧果对杧果小爪螨的抗性可能与杧果功能叶中的游离糖含量、糖/氮比相关。

表 4 不同杧果品种叶组织中游离糖、氮含量及糖/氮比测定与比较

Table 4 Contents of free sugar, nitrogen and ratio of sugar and nitrogen in different mango cultivar leaves

品种 Cultivar	ω(平均糖) Average contents of free sugar/(mg·g^{-1})			ω(平均氮) Average contents of free nitrogen/(μg·g^{-1})			平均糖/氮(×10^{4}) Average ratio of sugar and nitrogen		
	功能叶 Functional leaves	嫩叶 Young leaves	老叶 Elder leaves	功能叶 Functional leaves	嫩叶 Young leaves	老叶 Elder leaves	功能叶 Functional leaves	嫩叶 Young leaves	老叶 Elder leaves
台农一号 Tainong Ⅰ (HR)	48.78± 1.17 aA	41.05± 1.39 aA	49.53± 1.07 aA	0.64± 0.14 aA	0.65± 0.13 aA	0.64± 0.06 aA	7.64± 0.23 aA	6.31± 0.26 aA	7.72± 0.62 aA
红芒Ⅵ号 Hongmang Ⅳ (R)	45.30± 0.86 aA	44.31± 2.01 aA	43.81± 1.02 aA	0.64± 0.09 aA	0.63± 0.08 aA	0.64± 0.10 aA	7.10± 0.37 aA	7.01± 0.32 aA	6.90± 0.51 aA
紫花 Zihua (S)	24.15± 0.62 bB	41.61± 2.33 aA	45.24± 0.87 aA	0.64± 0.07 aA	0.64± 0.10 aA	0.64± 0.08 aA	3.79± 0.29 bB	6.47± 0.19 aA	7.04± 0.42 aA
粤西Ⅰ号 Yuexi Ⅰ (S)	23.36± 0.71 bB	49.55± 2.01 aA	45.80± 1.23 aA	0.63± 0.11 aA	0.65± 0.09 aA	0.64± 0.07 aA	3.70± 0.31 bB	7.59± 0.27 aA	7.15± 0.39 aA

2.5 不同杧果品种叶组织中总酚测定与比较

抗性品种‘台农一号’和‘红芒Ⅵ号’功能叶中的总酚含量极显著高于感螨品种‘紫花’和‘粤西Ⅰ号’（$P < 0.01$），而抗、感品种的嫩叶和老叶中总酚含量却无显著差异（$P > 0.05$，表5）。同时发现，感螨品种功能叶中总酚含量远低于嫩叶和老叶，而嫩叶和老叶中总酚含量却与抗性品种功能叶中的相当。因此表明，杧果对杧果小爪螨的抗性可能与杧果功能叶中的总酚含量相关。

表 5 不同杧果品种叶组织中总酚含量测定

Table 5 Contents of total phenols in different mango cultivar leaves

品种 Cultivar	ω(总酚) Contents of total phenols/(mg·g^{-1})		
	功能叶 Functional leaves	嫩叶 Young leaves	老叶 Elder leaves
台农一号 Tainong Ⅰ (HR)	214.01±6.53 Aa	200.18±5.77 Aa	191.68±4.19 Aa
红芒Ⅵ号 Hongmang Ⅳ (R)	195.61±4.79 Aa	195.70±5.21 Aa	192.43±5.07 Aa
紫花 Zihua (S)	43.82±2.97 Bb	192.26±4.78 Aa	191.17±6.21 Aa
粤西Ⅰ号 Yuexi Ⅰ (S)	44.33±3.41 Bb	189.37±5.32 Aa	196.51±4.23 Aa

3 讨 论

钦俊德[35]指出,植物次生物质和营养成分的变动会影响昆虫的行为、生长发育和繁殖。植食性昆虫(螨)依靠寄主植物获得营养成分,但不同寄主植物或同种寄主不同品系叶组织中所含营养物质在质和量方面均有明显的差异,其差异幅度足以影响昆虫(螨)的生殖生长和发育,植物通过改变自身所含的营养物质来抵御昆虫(螨)的侵害,是植物化学防御机制的一种对策[36]。植物的化学防御一方面可引起昆虫的忌避或抑制其取食(排趋作用或拒虫作用),另一方面可对昆虫生长或繁殖产生不利影响或促其死亡(抗生作用),而这些化学防御因素主要包括:(1)存在的各种次生物质,引起昆虫的不良感觉反应或中毒;(2)昆虫所需的营养成分缺乏或含量过低;(3)某些成分不利于昆虫对食物的消化作用[13,35,37]。寄主本身缺乏某种营养物质或所含营养物质的搭配比例不当,都会影响到害虫(螨)的正常生长发育,通过降低害虫(螨)的生存率来获得抗虫(螨)性[38]。植物所含营养物质的质与量在害虫(螨)对寄主的选择中发挥着重要作用,会直接影响害虫(螨)对不同寄主及同一寄主不同无性系的选择[39]。笔者发现杧果小爪螨仅危害杧果功能叶,结合抗、感螨品种的筛选与生化物质测定结果表明,相比嫩叶与老叶,感螨杧果品种功能叶中含有更低的游离糖、总酚以及较低的糖氮比,而抗螨品种功能叶中的游离糖、总酚含量以及糖氮比均显著高于感性品种,且与嫩叶和老叶中的无显著差异,说明杧果小爪螨对杧果的取食具有选择性,更趋向于选择游离糖、总酚含量低且糖氮比亦较低的品种,而在所选择品种上,其存活率显著升高。本研究结果与陈青[20]、董顺文等[28]、雒珺瑜等[40]和周明强等[41]等的研究结果部分一致。董顺文等[28]发现棉花品种受螨害程度与棉叶可溶性糖含量呈负相关;陈青[20]研究发现,相比抗蚜辣椒品种,感蚜辣椒品种叶组织内含有较少的可溶性糖和较低的糖/氮比。雒珺瑜等[40]研究发现,棉花蕾期叶片中可溶性糖含量与绿盲蝽抗性呈负相关。周明强等[41]发现,抗蚜甘蔗品种'选50'叶片中的可溶性糖含量、糖氮比较高,不利于甘蔗绵蚜的生长发育,且与田间甘蔗绵蚜的发生危害情况相吻合,说明甘蔗新品种'选50'是最抗甘蔗绵蚜的品种。研究表明,酚类含量与某些植食性昆虫的危害呈明显负相关[42],因此说明,感性杧果品种中低含量的总酚可能与杧果小爪螨的危害相关。植物利用其次生代谢物质控制害虫的危害,是合理利用植物自然防御能力、减少化学农药使用的重要途径,必将在害虫综合治理中发挥越来越重要的作用[40]。综上说明,杧果对杧果小爪螨的抗性可能与杧果功能叶中的游离糖、总酚含量以及糖/氮比含量相关。在抗螨育种中,应尽量选择具有多种抗螨机制的材料,可望培育出抗螨品种。随着对营养生理物质之间、次生物质之间、次生物质与营养物质之间的互作对叶螨的生物学行为及生理影响的进一步深入研究,将揭示更多的抗螨机制,这将对抗螨育种具有重要的指导意义[20]。本研究结果将为杧果抗螨种质的挖掘与创新利用、抗螨分子设计育种提供基础信息、参试材料及理论与技术依据。

植株体内的生化物质是赋予杧果品种抗螨性的主要因素。深入研究各种生化物质在杧果品种抗螨性中的作用,无疑会给杧果品种抗螨性育种开辟更广阔的前景。笔者仅对游离氨基酸、氮、糖、酚和糖/氮在杧果品种抗螨性中的作用进行了初步探讨,其他营养物质及次生物质在杧果品种抗螨性中的作用还有待进一步研究。

4 结 论

采用离中率方法开展杧果品种对杧果小爪螨的抗性评价,获得抗、感性稳定的品种。进一步研究发现,杧果小爪螨更趋于选择游离糖、总酚含量低且糖氮比较低的感螨品种,其在所选敏感品种上的存活率显著升高。

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