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葡萄叶片厚度和茸毛密度与其对绿盲蝽抗性的关系

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摘 要:【**目的**】明确葡萄叶片厚度和茸毛密度与其对绿盲蝽抗性的关系。【**方法**】于2012—2014年连续3 a系统研究了不同葡萄品种对绿盲蝽的抗性水平,并在室内测定了葡萄叶片的厚度和茸毛密度。【**结果**】不同葡萄品种对绿盲蝽的抗性水平存在明显差异;不同葡萄品种叶片厚度、上表皮层厚度、下表皮层厚度和刺毛密度、丝毛密度分别呈显著差异($P<0.05$)。叶片厚度、上表皮层厚度、下表皮层厚度与葡萄对绿盲蝽的抗性没有显著相关性(y=-1.935 8+0.011 8x,R^2=0.080 1,P=0.460 6;y=-1.358+0.070 3x,R^2=0.131 1,P=0.338 3;y=9.536 3-0.202 3x,R^2=0.239 0,P=0.181 7);叶片丝毛密度、刺毛密度与葡萄对绿盲蝽的抗性也不存在显著关系(y=2.861 3-0.081 1x,R^2=0.014 9,P=0.754 7;y=2.938 9-0.005 7x,R^2=0.177 3,P=0.259 1)。【**结论**】不同葡萄品种对绿盲蝽的抗性水平差异显著;葡萄叶片厚度和茸毛密度与其对绿盲蝽的抗性之间没有显著相关性。

关键词:葡萄;绿盲蝽;叶片厚度;茸毛密度;抗虫性

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Effects of leaf thickness and trichome density of grapes on their resistance to *Apolygus lucorum*

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Abstract:【Objective】Grapes are one of the important fruits in China. In recent years, the damage by *Apolygus lucorum* is increasing year after year, which results in the reduction of the quality and also decreases of production and leads to greater economic losses. Therefore, it is necessary to study the grape varieties resistance to *A. lucorum*. It is also necessary to evaluate the resistance levels of different grape varieties to *A. lucorum*. We must make clear the relationship between the leaf thickness, leaf upper epidermis thickness, leaf abaxial epidermis thickness, filamentous trichomes density, spinous trichomes density of different grape varieties and their resistance to *A. lucorum*.【Methods】We investigated the damage caused by *A. lucorum* on 9 grape varieties in the field during 2012—2014, and calculated the damage indexes according to the results obtained. The leaf damage level can be divided into 0, 1, 2, 3, corresponding to 0, 0-20%, 20%-40% and 40%-100% of the total leaf area, respectively. The resistance value of each year was set as 1 to 5 and the damage indexes ranged from larger than 20% to smaller than 20%. We then averaged the resistance values of three years to determine the resistance index. The resistance indexes ≤2 were the low resistance varieties, 2-3 were moderate sensitive varieties, 3-4 were moderate resistance varieties, and >4 were high resistance varieties. The grape leaves used were the third leaf of each new shoot at the shoot-growing stage. By making temporary slides, we measured the leaf thickness, leaf upper epidermis thickness and leaf abaxial epidermis thickness under 400 times magnification in a laboratory microscope. The number of filamentous trichomes, with a density of 1 cm on the midrib of the grape leaves, was count-

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ed at 40 times magnification under a microscope. The spinous trichomes were distributed on the back of grape leaves. The spinous trichomes density was divided into 5 levels from low to high. We observed the spinous trichomes density at 100 times magnification under a microscope. All data were analyzed by using DPS 9.50 statistical software. Multiple comparisons of damage index, leaf thickness and trichome density were analyzed using Duncan's methods. The relationship between the leaf thickness, leaf upper epidermis thickness, leaf abaxial epidermis thickness, filamentous trichomes density, spinous trichomes density of different grape varieties and their resistance to *A. lucorum* were analyzed by using the liner regression method.【Results】The resistance levels of the different grape varieties was obviously different ($P < 0.05$). The resistance indexes of 'Red Globe' 'Muscat Hamburg' 'Kyoho' 'Cabernet Sauvignon' 'Cabernet Franc' 'Ruby' 'Cabernet Gernischt' 'Fujiminori' 'Chardonnay' were 1.33, 1.33, 2.00, 2.33, 2.33, 2.67, 2.67, 4.33, 4.33, respectively. 'Fujiminori' and 'Chardonnay' had high resistance to *A. lucorum* (resistance index > 4). 'Red Globe' 'Muscat Hamburg' and 'Kyoho' had low resistance to *A. lucorum* (resistance index≤2). The leaf thickness, leaf upper epidermis thickness and leaf abaxial epidermis thickness of different grape varieties were significantly different ($P < 0.05$). The maximum of leaf thickness, leaf upper epidermis thickness and leaf abaxial epidermis thickness of grape varieties was with 'Kyoho', which was 435.26, 65.60 and 39.87 μm. The minimum of the leaf thickness, leaf upper epidermis thickness and leaf abaxial epidermis thickness was with 'Muscat Hamburg' 'Cabernet Sauvignon' and 'Fujiminori', which were 358.44, 49.37 and 31.24 μm, respectively. The filamentous trichomes density and spinous trichomes density of the grape leaves were found to be different among the various varieties ($P < 0.05$). The leaves of 'Red Globe' and 'Ruby' were smooth and hairless, their filamentous trichomes density were lowest. 'Kyoho' 'Muscat Hamburg' and 'Cabernet Sauvignon' had the highest filamentous trichomes densities. The number of filamentous trichomes per cm of 'Kyoho' 'Muscat Hamburg' 'Red Globe' 'Ruby' 'Fujiminori' 'Cabernet Sauvignon' 'Cabernet Gernischt' 'Chardonnay' and 'Cabernet Franc' were 6.60, 252.67, 18.87, 37.33, 10.87, 32.12, 137.73, 16.20, 40.07, respectively. The spinous trichomes density of 'Muscat Hamburg' was significantly higher than other grape varieties ($P < 0.05$). Through linear regression analysis, we found there were no significant correlations between the leaf thickness, leaf upper epidermis thickness, leaf abaxial epidermis thickness and their resistance to *A. lucorum* ($y=-1.935\ 8+0.011\ 8x$, $R^2=0.080\ 1$, $P=0.460\ 6$; $y=-1.358+0.070\ 3x$, $R^2=0.131\ 1$, $P=0.338\ 3$; $y=9.536\ 3-0.202\ 3x$, $R^2=0.239\ 0$, $P=0.181\ 7$), and the filamentous trichomes density and spinous trichomes density showed non-significant correlations with the grape resistance to *A. lucorum* ($y=2.861\ 3-0.081\ 1x$, $R^2=0.014\ 9$, $P=0.754\ 7$; $y=2.938\ 9-0.005\ 7x$, $R^2=0.177\ 3$, $P=0.259\ 1$).【Conclusion】'Fujiminori' and 'Chardonnay' had the highest resistance levels to *A. lucorum*, and 'Red Globe' and 'Muscat Hamburg' had the lowest resistance levels to *A. lucorum*. The leaf thickness, leaf upper epidermis thickness, leaf abaxial epidermis thickness, filamentous trichomes density and spinous trichomes density of the different grape varieties were shown to have significant differences. There were no significant correlations between the leaf thickness, leaf upper epidermis thickness, leaf abaxial epidermis thickness and their resistance to *A. lucorum*. The filamentous trichomes density and spinous trichomes density had no significant correlations with the grape's resistance to *A. lucorum*.

Key words: Grape; *Apolygus lucorum*; Leaf thickness; Trichome density; Resistance

葡萄是我国果树大树种之一,其栽培面积和产量位居世界前列,在世界葡萄产业中占有重要位置,然而葡萄病虫害却成为制约其发展的关键性因素[1-3]。近年来,随着Bt棉商业化种植后化学杀虫剂用量的减少、葡萄种植面积的大幅度增加、气候条件的变化等因素,致使盲蝽类害虫绿盲蝽(*Apolygus lucorum* Meyer-Dür)的种群数量剧增,危害加重,演变成为我国葡萄上的主要害虫[4-6]。葡萄新梢和嫩叶

被害后呈现黑色小点，随着叶片的伸展形成不规则的穿孔，花蕾受害后停止发育且枯落，幼果被害后布满小黑点，随着果实的增大形成不规则褐色斑痕，出现裂果甚至脱落，严重影响了葡萄的生长发育，降低果实品质和产量，给葡萄生产带来巨大的经济损失[7-8]。目前，绿盲蝽的防治仍以化学防治为主，但化学农药的大量使用存在环境污染、果品农药残留、害虫抗药性等一系列风险问题。因此，建立科学合理、可持续的绿盲蝽综合防治体系势在必行。

植物抗虫性的利用是最经济有效的害虫治理策略，而物理结构抗性是植物抗虫性的主要组成部分，在预防或减轻害虫危害方面发挥着重要作用，已被应用于多种害虫的防治中[9-11]。研究植物的物理形态对于植物抗虫性的研究利用具有重要意义。物理结构抗性是指植物通过叶片韧性、细胞组成成分、体表毛状体或腺体等固有的特殊结构来减少害虫的取食或产卵，以达到抵抗害虫危害的目的，如植物坚韧的叶片中含有一些木质素和纤维素等不易被昆虫消化的物质，使昆虫难以获得蛋白质、糖类等营养物质，取食率降低，从而减少害虫的危害[11-12]。国内外学者在植物物理结构抗性方面的研究已取得较大进展，Bodnaryk[13]对叶片表皮蜡质结构与十字花科兰跳甲（*Phyllotreta cruciferae* Goeze）取食关系的研究发现，具有叶表蜡质层的十字花科可以抵御跳甲的取食危害；芦屹等[14]研究了棉花叶片的形态特性对抗蚜程度的影响，结果也证明叶片蜡质含量高的棉花品种对棉蚜（*Aphis gossypii* Glover）的抗性强；有研究表明，甘蔗对螟虫的抗性与纤维含量有关，纤维含量高的甘蔗品种对螟虫的抗性强[15-17]；林凤敏等[18]研究发现，在一定的生长期，叶片表皮层厚和油点多的棉花品种对绿盲蝽具有抗性；有报道指出，叶片茸毛多的棉花品种可以抵抗蚜虫、叶螨和叶蝉的危害[19-21]。

目前为止，葡萄对绿盲蝽的抗性机制尚不清楚，还没有真正意义上的抗绿盲蝽葡萄品种，利用葡萄抗虫性治理绿盲蝽未取得突破，而且有关葡萄形态结构与其对绿盲蝽抗性关系的相关研究尚未见报道。笔者以9个不同葡萄品种为材料，分别测定其叶片厚度、上表皮层厚度、下表皮层厚度、丝毛密度和刺毛密度，并且比较分析它们与葡萄对绿盲蝽抗性的关系，旨在了解葡萄对绿盲蝽的抗性机制，为抗绿盲蝽葡萄品种的筛选和绿盲蝽的综合治理提供科学依据。

1 材料和方法

1.1 葡萄品种

选择9个供试葡萄品种，分别为‘巨峰’‘玫瑰香’‘红地球’‘红宝石’‘藤稔’‘赤霞珠’‘蛇龙珠’‘霞多丽’和‘品丽珠’。

1.2 葡萄对绿盲蝽的抗性鉴定

试验在山东省烟台市农业科学研究院试验农场葡萄园内进行，试验地管理较粗放，葡萄园及周边杂草较多，绿盲蝽历年发生普遍且严重。

于2012—2014年5月上中旬越冬代绿盲蝽若虫发生后期、葡萄新梢生长期进行调查。每个葡萄品种随机选取20个新梢，记录其顶端5片嫩叶受绿盲蝽危害情况，每5个新梢为1个重复，共4次重复。将葡萄叶片受害级别分为0、1、2、3级，分别对应于被调查葡萄叶片破损面积占叶片总面积的0、0~20%、20%~40%、40%~100%。按照以下公式计算受害指数。

受害指数=Σ（受害级别×相应的叶片数量）/（调查总叶数×最大受害级别值）×100

依据受害指数，参照林凤敏等[22]的方法并修改，采用设定抗虫性值的方法综合评价供试葡萄品种对绿盲蝽的抗性指数。每年测定结果的抗性值设为1~5，即受害指数最大的20%至受害指数最小的20%，最后平均每个品种的抗性值，获得该品种的抗性指数。抗性指数≤2为高感，2~3为中感，3~4为中抗，＞4为高抗。

1.3 葡萄叶片厚度测定

于葡萄新梢生长期采摘新梢顶部倒数第3片初展开叶片，室内切取叶片中部制成临时玻片，置于400倍MOTIC显微镜下测量叶片厚度、上表皮层厚度、下表皮层厚度。每品种3个重复，共计观测30枚叶片。

1.4 葡萄叶片茸毛密度测定

葡萄叶片上的茸毛分为2类，直立着生为刺毛，平铺着生为丝毛。刺毛一般沿叶脉分布，在葡萄新梢生长期取新梢顶部倒数第3片叶，用解剖刀切取长约1 cm的中脉，于40倍MOTIC显微镜下观察记录刺毛的数量，每品种3个重复，共计观测15枚叶片。丝毛一般密布整个葡萄叶片背面，杂乱无法计数，可按丝毛稀密程度分为5级：无毛（1级）、稀（2级）、中（3级）、密（4级）、极密（5级），取葡萄新梢顶

部倒数第3片叶，于100倍MOTIC显微镜下观察记录丝毛的稀密级别。

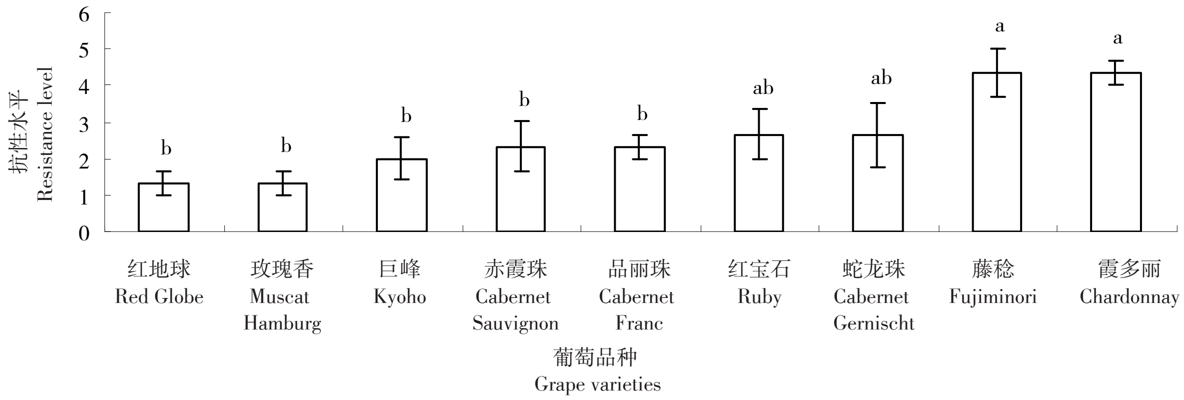
1.5　数据统计分析

不同葡萄品种的受害指数、叶片厚度和茸毛密度均采用DPS 9.50软件的Duncan's新复极差法进行多重比较分析，采用线性回归法进行不同葡萄品种的抗性指数与其叶片厚度、上下表皮层厚度、丝毛密度和刺毛密度的相关性分析。

2　结果与分析

2.1　不同葡萄品种对绿盲蝽的抗性鉴定

综合3 a的田间调查结果对不同葡萄品种进行绿盲蝽抗性鉴定，结果表明不同葡萄品种对绿盲蝽的抗性存在差异(图1)。'红地球''玫瑰香''巨峰''赤霞珠''品丽珠''红宝石''蛇龙珠''藤稔''霞多丽'的综合抗性指数分别为1.33、1.33、2.00、2.33、2.33、2.67、2.67、4.33、4.33。其中，'藤稔''霞多丽'对绿盲蝽表现为高抗(抗性指数>4)，'红地球''玫瑰香''巨峰'对绿盲蝽表现高感(抗性指数≤2)。



图中数据为平均值±标准误，标注不同字母的表示差异显著(Duncan's, $P < 0.05$)。

Data are presented as mean ± SE, and the different letters indicate significant difference (Duncan's, $P < 0.05$).

图1　不同葡萄品种的抗性水平

Fig. 1 Resistance levels of the different grape varieties

2.2　不同葡萄品种叶片厚度及上、下表皮层厚度的测定

结果表明，不同葡萄品种的叶片厚度及上、下表皮层厚度均存在显著差异($P<0.05$)，'巨峰'叶片厚度及上、下表皮层厚度均为最大，分别为435.26、65.60、39.87 μm，而最小值出现在3个葡萄品种上，分别为'玫瑰香'叶片厚度358.44 μm、'赤霞珠'上表皮层厚度49.37 μm、'藤稔'下表皮层厚度31.24 μm(表1)。

表1　不同葡萄品种叶片厚度及上、下表皮层厚度

Table 1 Leaf thickness and leaf epidermis thickness of the different grape varieties

品种 Varieties	叶片厚度 Leaf thickness/μm	上表皮厚度 Leaf upper epidermis thickness/μm	下表皮厚度 Leaf abaxial epidermis thickness/μm
巨峰 Kyoho	435.26±7.31 a	65.60±1.12 a	39.87±1.46 a
玫瑰香 Muscat Hamburg	358.44±5.21 c	54.63±0.80 b	33.72±1.43 bcde
红地球 Red Globe	375.00±3.85 bc	50.13±0.67 b	34.81±0.64 bcd
红宝石 Ruby	366.15±2.70 bc	55.64±1.71 b	32.13±0.53 de
藤稔 Fujiminori	420.19±6.59 a	65.00±1.01 a	31.24±1.26 e
赤霞珠 Cabernet Sauvignon	382.05±10.79 b	49.37±6.52 b	36.34±1.41 b
蛇龙珠 Cabernet Gernischt	363.34±9.66 bc	56.49±1.18 b	35.56±0.78 bc
霞多丽 Chardonnay	377.84±1.89 bc	54.25±0.51 b	32.69±1.51 cde
品丽珠 Cabernet Franc	372.50±13.71 bc	54.69±1.74 b	32.63±0.24 cde

注：表中数据为平均值±标准误，每列数据后不同字母表示差异显著(Duncan's, $P < 0.05$)。下同。

Note: The data in the table are mean ± SE, and those in the same column followed by different letters are significantly different (Duncan's, $P < 0.05$). The same below.

2.3 不同葡萄品种叶片茸毛密度的测定

由表2可以看出，不同葡萄品种叶片丝毛及刺毛密度存在显著差异($P < 0.05$)。'红地球''红宝石'叶片光滑无毛为1级，'霞多丽'为2级，'品丽珠'为3级，'藤稔'和'蛇龙珠'为4级，'巨峰''玫瑰香''赤霞珠'丝毛密度最大，为5级。'玫瑰香'刺毛密度显著高于其他葡萄品种($P < 0.05$)，为每cm 252.67根，其次为'蛇龙珠'(每cm137.73根)，而'巨峰'的刺毛密度最小，为每cm 6.60根。

表2 不同葡萄品种叶片丝毛及刺毛密度

Table 2 The density of filamentous and spinous trichomes on leaves of the different grape varieties

品种 Varieties	丝毛密度 Filamentous trichomes density	刺毛密度 Spinous trichomes density (number per cm)
巨峰 Kyoho	5	6.60±3.56 c
玫瑰香 Muscat Hamburg	5	252.67±87.64 a
红地球 Red Globe	1	18.87±1.16 c
红宝石 Ruby	1	37.33±6.77 bc
藤稔 Fujiminori	4	10.87±2.60 c
赤霞珠 Cabernet Sauvignon	5	32.13±5.95 bc
蛇龙珠 Cabernet Gernischt	4	137.73±49.34 b
霞多丽 Chardonnay	2	16.20±1.64 c
品丽珠 Cabernet Franc	3	40.07±7.13 bc

2.4 葡萄叶片厚度、上下表皮层厚度、丝毛密度和刺毛密度与其对绿盲蝽抗性的关系

通过线性回归分析了葡萄不同品种叶片性状与其对绿盲蝽抗性指数之间的关系(表3)。结果表明，葡萄叶片厚度、上表皮层厚度、下表皮层厚度与其对绿盲蝽的抗性指数不存在显著关系($P > 0.05$)；葡萄叶片丝毛密度、刺毛密度与其对绿盲蝽的抗性之间也不存在显著相关性($P > 0.05$)。

表3 葡萄对绿盲蝽抗性(y)与叶片厚度、上下表皮层厚度、丝毛密度和刺毛密度(x)的关系

Table 3 The relationship between the grape resistances to *A. lucorum* (y) and their leaf characteristics (x)

叶片性状 Leaf characteristics	回归方程 Regression equation	R^2	P
叶片厚度 Leaf thickness	y=−1.935 8+0.011 8x	0.080 1	0.460 6
上表皮层厚度 Leaf upper epidermis thickness	y=−1.358+0.070 3x	0.131 1	0.338 3
下表皮层厚度 Leaf abaxial epidermis thickness	y=9.536 3−0.202 3x	0.239 0	0.181 7
丝毛密度 Filamentous trichomes density	y=2.861 3−0.081 1x	0.014 9	0.754 7
刺毛密度 Spinous trichomes density	y=2.938 9−0.005 7x	0.177 3	0.259 1

3 讨 论

笔者选用9个葡萄品种，通过田间调查及室内测定表明，不同葡萄品种对绿盲蝽的抗性存在差异；不同葡萄品种叶片厚度、上表皮层厚度、下表皮层厚度、丝毛密度和刺毛密度差异显著。曹春玲等[23]研究表明，不同葡萄品种的叶片厚度和茸毛数量存在差异，且烟蓟马(*Thrips tabaci* Lindeman)对不同葡萄品种的选择性均随着它们的变化而呈现出相应的变化；雒珺瑜等[24]和林凤敏等[18,22]通过对棉花叶片性状与绿盲蝽抗性关系的研究发现，不同棉花品种对绿盲蝽的抗性存在差异，且不同棉花品种的叶片厚度、表皮层厚度及茸毛密度差异显著。这与本研究结果相似，说明植物不同品种叶片的物理性状及其对害虫的抗性存在差异。

植物叶片厚度、表皮层厚度是植物的重要抗虫因子，不同寄主植物叶片厚度与抗不同害虫的相关性不同。本研究结果表明，葡萄叶片厚度、表皮层厚度与其对绿盲蝽的抗性没有显著关系，这一结果与一些研究人员的报道一致。林凤敏等[18]研究了棉花叶片性状对绿盲蝽抗性的关系，结果显示叶片厚度与绿盲蝽抗性之间没有显著关系；Eittipibool等[25]研究表明，棉花的叶片厚度与叶蝉发生数量没有明显关系；Arif等[26-27]对棉花叶片厚度与蓟马发生数量关系的研究发现，叶片厚度与其对烟蓟马的抗性也没有显著关系。但也有报道指出叶片厚度与其对昆虫的抗性存在显著关系，Butter等[28]研究发现棉花叶片厚度与其对烟粉虱的抗性呈显著负相关，林凤敏等[18]研究表明棉花铃期叶片表皮层厚度与其对绿盲蝽的抗性存在显著正相关。由此可说明，同一植物对不同害虫、不同植物对同一害虫的抗性机制均不同。

茸毛是植物叶片表面影响害虫取食危害的重要因子，与植物抗虫性存在着密切的关系[22,29]。邢光南等[30]研究指出大豆叶片茸毛密度越大，大豆卷叶螟(*Lamprosema indicata* Fabricius)引起的虫包数和卷叶率越少；Zarpas等[31]研究表明，棉花叶片茸毛密度与其对棉蚜的抗性呈显著负相关；李绍勤等[32]研究

了美洲斑潜蝇(*Liriomyza sativae* Blanchard)取食产卵与菜豆叶片茸毛的关系,结果发现菜豆叶片茸毛密度与其对美洲斑潜蝇的抗性呈显著正相关。但也有研究表明植物叶片茸毛密度与其对昆虫的抗性没有相关关系,曹宇等[33]研究发现西花蓟马对寄主的选择性与寄主植物叶片茸毛密度无关;庞保平等[34]对南美斑潜蝇(*Liriomyza huidobrensis* Blanchard)与寄主植物叶片茸毛关系的研究表明,茸毛密度与其对美洲斑潜蝇的抗性不存在相关关系。本研究表明,葡萄叶片刺毛密度和丝毛密度与其对绿盲蝽的抗性之间没有显著关系。研究结果不完全一致,可能与寄主植物种类差异有关,也可能与害虫种类的不同有关,这进一步说明不同植物品种对不同种类害虫的抗性机制有所不同。

植物对害虫的抗性与植物的物理性状和生化性状密切相关,笔者只研究了葡萄叶片厚度和茸毛密度与其对绿盲蝽抗性的关系,其他一些与植物抗虫性有关的物理性状如葡萄叶片硬度、形状、表面蜡质含量等,生化性状如葡萄叶片酚类化合物包括单宁、黄酮、醌类、木质素等以及营养物质可溶性糖、蛋白质、氨基酸、脂肪酸等的含量,还有待进一步研究。

4 结　论

通过3 a的连续调查,确定了不同葡萄品种对绿盲蝽的抗性水平不同。不同葡萄品种的叶片厚度及茸毛密度差异显著。叶片厚度和茸毛密度与葡萄对绿盲蝽的抗性没有显著关系。

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