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降雨强度对棉花上棉花粉蚧掉落的影响

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摘要: 为了解降雨对棉花粉蚧 *Phenacoccus solenopsis* Tinsley 的影响, 本文应用人工模拟降雨器方法研究了不同降雨强度条件下棉花粉蚧各个虫期的掉落比例。结果表明随着降雨强度的增加, 棉花粉蚧掉落率逐渐增大; 同一降雨强度下龄期越高、虫体越大掉落率越低。15 mm/h 时棉花粉蚧各个虫期掉落率均较低, 为 0.7%–3.3%; 45–75 mm/h 时掉落率增大, 为 7.0%–17.7%; 105 mm/h、135 mm/h、165 mm/h、195 mm/h 时掉落率变化范围分别是 10.0%–23.7%、12.3%–32.3%、13.3%–38.7%、16.0%–45.7%。掉落率 (Y) 与降雨强度 (X) 之间关系方程为 $Y = 0.2587X^{0.9850}$ (1 龄若虫)、 $Y = 0.2549X^{0.9845}$ (2 龄若虫)、 $Y = 0.0266X^{1.4014}$ (3 龄若虫)、 $Y = 0.0507X^{1.1307}$ (雌成虫)。

关键词: 扶桑绵粉蚧; 棉花; 降雨强度; 掉落率

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Falling rates of *Phenacoccus solenopsis* Tinsley on cotton plant under different rainfall intensity

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Abstract: In order to understand the impact of the rainfall on the cotton mealybug *Phenacoccus solenopsis* Tinsley, the artificial rainfall simulator method was used in studying the falling rates of the cotton mealybug at different rainfall intensity in this paper. The results indicated that the falling rates went up while rainfall intensity rose. At the same rainfall intensity, the higher the mealybug age, the lower the falling rates. Falling rates were little as 0.7%–3.3% when the rainfall intensity with 15 mm/h. The falling rates increased as 7.0%–17.7% when the rainfall intensity were 45–75 mm/h. The falling rates varied with 10.0%–23.7%, 12.3%–32.3%, 13.3%–38.7% and 16.0%–45.7% as the rainfall intensity were 105 mm/h, 135 mm/h, 165 mm/h and 195 mm/h. The formulations to simulate the relationship between the rainfall intensity and falling rates of *P. solenopsis* were $Y = 0.2587X^{0.9850}$ (1st nymph), $Y = 0.2549X^{0.9845}$ (2nd nymph), $Y = 0.0266X^{1.4014}$ (3rd nymph) and $Y = 0.0507X^{1.1307}$ (female adult).

Key words: *Phenacoccus solenopsis* Tinsley; cotton plant; rainfall intensity; falling rate

棉花粉蚧 *Phenacoccus solenopsis* Tinsley 是 2008 年入侵我国的一种对园林观赏植物、蔬菜和大田作物等安全生产潜在威胁严重的有害生物 (Tinsley, 1898; 陆永跃等, 2008; 武三安和张润

志, 2009; Wang *et al.*, 2010; 孙峰和陆永跃, 2011)。该虫繁殖力强、危害严重、适生区广、传播扩散迅速, 分布范围不断扩大 (徐卫等, 2009; 王艳平等, 2009; 马骏等, 2011; 关鑫等, 2009b;

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徐家文等, 2015)。2014 年已在广东、海南、湖南等 12 个省市 120 个县(市、区)发现该虫发生为害。棉花粉蚧取食行为可塑性强, 寄主范围宽, 已记录到 57 科 207 种, 而且随着侵入区域扩大、调查深入, 其寄主范围将不断增大; 同时, 棉花粉蚧若虫、雌成虫体表均覆盖有白色蜡粉层, 对其抵抗杀虫剂和其他致死因素威胁起到了一定保护作用, 因此, 该粉蚧自身具备的各种生物学优势为其入侵、定殖和短时间内暴发成灾奠定了基础 (Aheer *et al.*, 2009; 朱艺勇等, 2011; 周湾等, 2012; 崔志富等, 2015)。

非生物因子包括温度、光照、气流、气压、湿度等与昆虫个体发育和种群动态密切相关。其中环境湿度的变化会直接导致昆虫体内含水量变化, 打破昆虫体内的水分平衡, 影响昆虫抗寒性、越冬存活, 进而对其个体发育、繁殖、群体发生等产生影响。作为调节环境湿度的重要方式之一, 降雨除了通过影响空气湿度、土壤含水量作用于昆虫的取食行为、生长发育、存活和生殖生命活动外, 其机械冲刷作用对昆虫也具有直接致死效应, 从而影响昆虫种群发生改变 (Fitt, 2003; 常晓娜等, 2008; 党志浩和陈法军, 2011)。例如, 春夏的降雨尤其暴雨导致湿地松粉蚧 *Oracella acuta* Lobdell 初孵若虫大量死亡是其种群迅速凋落的重要因素 (汤才和黄德超, 2003)。目前, 关于环境因素影响棉花粉蚧的研究主要集中在温度 (关鑫等, 2009a; Patil *et al.*, 2011; Lu *et al.*, 2011; Yayla *et al.*, 2012; Guan *et al.*, 2012; Prasad *et al.*, 2012; Qin *et al.*, 2013; 丁吉同等, 2013; Wang *et al.*, 2014; 王飞飞等, 2014)、寄主植物转换 (Dhawan *et al.*, 2011; 黄芳等, 2011; Guan *et al.*, 2012; 王前进等, 2013)、食物胁迫 (郑婷等, 2011)、光周期 (王超等, 2014) 等几个方面, 关于降雨对棉花粉蚧的影响研究尚未见报道。本文应用室内人工模拟降雨方法研究了不同降雨强度条件下棉花植株上棉花粉蚧各个虫期的掉落规律, 为全面掌握环境因子对该虫影响提供了依据。

1 材料与方法

1.1 试验材料

供试昆虫: 在华南农业大学检疫与入侵害虫实验室人工气候箱中 (温度 26℃–28℃, RH 60%–75%, 周期 (L:D=14 h:10 h), 以棉花 *Gossypium hirsutum* L. 为寄主饲养建立棉花粉蚧种

群, 取其中健康的各虫态供试。

供试植物: 种植在温室内塑料花盆 (直径 25 cm, 高 35 cm) 中的棉花幼苗, 选取高约 35 cm 健壮植株备用。

试验仪器: PXJY-B 型人工模拟降雨器 (南京璞晓电子科技有限公司)、细毛笔、秒表、计数器、凡士林、隔离网罩等。

1.2 试验方法

取 5 株棉花, 每株每个虫期接 20 头 (1 龄若虫、2 龄若虫、3 龄若虫、雌成虫) 棉花粉蚧, 共计 100 头。待粉蚧稳定取食后, 将带虫棉花植株均匀放置于降雨器降雨区位置。按 0 mm/h、15 mm/h、45 mm/h、75 mm/h、105 mm/h、135 mm/h、165 mm/h、195 mm/h 设 8 个降雨强度, 每个雨量重复 3 次。按照降雨强度梯度打开降雨器开关降雨 30 min 后停止, 搬出棉花, 待植株上雨水晾干后检查记录各虫期棉花粉蚧活虫数量, 计算掉落的粉蚧数量。

掉落率(%) = (降雨前接入虫期粉蚧数量 - 降雨后该虫期存活粉蚧数量) / 降雨前接入虫期粉蚧数量 × 100

1.3 数据分析

用 SPSS 统计软件分析数据差异性和关系, 显著性检验水平为 $P < 0.05$ 。

2 结果与分析

对试验结果分析表明无论是降雨量间还是虫期间棉花粉蚧的掉落率均有变化 ($F = 30.57$, $df = 27$, $P = 0.0001$) (表 1)。随着降雨强度增加, 在棉花植株上同一虫期棉花粉蚧的掉落率呈逐渐增大趋势。例如, 对于 1 龄若虫没有降雨处理 (对照) 掉落率最低, 为 1.7%; 15 mm/h 时掉落率稍增大, 为 3.3%; 45 mm/h、75 mm/h 降雨时掉落率分别增长到 14.3%、17.7%; 当降雨强度大于 100 mm/h 时, 棉花粉蚧 1 龄若虫的掉落率显著增大, 雨强为 105 mm/h、135 mm/h、165 mm/h、195 mm/h 时掉落率分别为 23.7%、32.3%、38.7%、45.7%。在同一降雨强度下不同虫期掉落率也有所不同, 总体上表现为龄期越高、虫体越大掉落率越低的趋势。所有降雨强度下 1 龄若虫、2 龄若虫间掉落率差异不显著, 45 mm/h、105 mm/h 时 3 龄若虫、雌成虫掉落率显著降低, 75 mm/h、135 mm/h、165 mm/h、195 mm/h 时仅雌成虫掉落率显著降低。

表 1 不同降雨强度下棉花植株上棉花粉蚧各虫期的掉落率 (%)

Table 1 Falling rates for different stages of *Phenacoccus solenopsis* on cotton plants when treated by different rainfall intensity

降雨强度 (mm/h) Rainfall intensity	掉落率 Falling rate (%)			
	雌成虫 Female adult	1 龄若虫 1 st nymph	2 龄若虫 2 nd nymph	3 龄若虫 3 rd nymph
15	3.3 ± 0.58 eA	3.3 ± 1.53 cA	1.0 ± 1.73 dA	0.7 ± 1.16 dA
45	14.3 ± 1.53 dA	13.7 ± 1.53 bcA	7.3 ± 2.31 cB	7.0 ± 1.00 cB
75	17.7 ± 1.53 cdA	16.7 ± 2.08 bA	12.3 ± 2.08 bcAB	8.7 ± 1.53 bcB
105	23.7 ± 1.53 cA	22.3 ± 3.22 bA	14.7 ± 1.53 bB	10.0 ± 2.00 bcB
135	32.3 ± 2.08 bA	38.0 ± 1.73 aA	31.7 ± 2.89 aA	12.3 ± 2.08 abB
165	38.7 ± 3.51 bA	37.0 ± 6.00 aA	33.7 ± 1.53 aA	13.3 ± 0.58 abB
195	45.7 ± 3.06 aA	42.3 ± 6.11 aA	36.0 ± 1.00 aA	16.0 ± 1.00 aB
CK	1.7 ± 0.003 fA	1.0 ± 0.006 dA	0 eB	0 eB

注: 表中掉落率为平均值 ± 标准误, 同一列数据后具相同小写字母者、同一行数据后具相同大写字母者表示经 Duncan 氏多重比较差异不显著 ($P < 0.05$)。Note: The falling rates in the table were mean ± SE, and same small letter in the same column and same capital letter in the same row indicated no significant difference at the 0.05 level (Duncan's multiple range test).

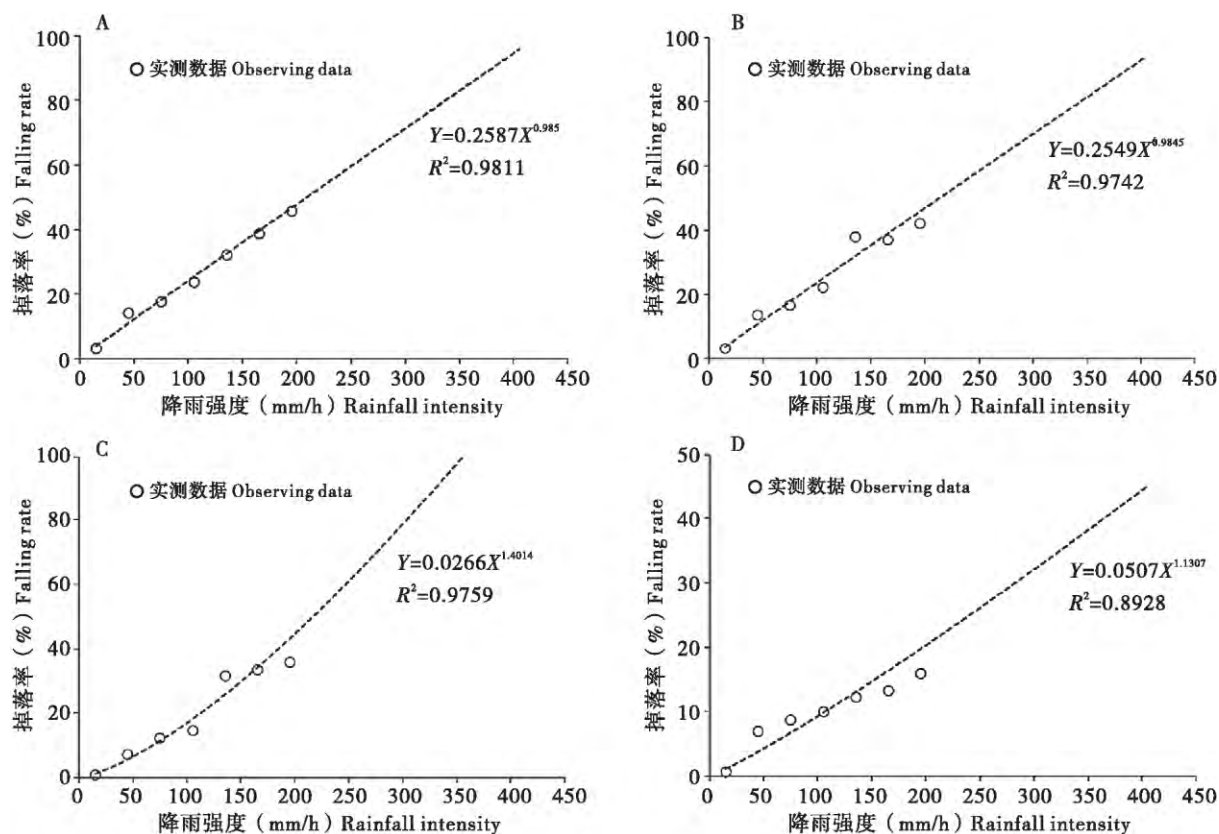


图 1 不同降雨强度下棉花植株上棉花粉蚧各虫期掉落率动态及模拟方程

Fig. 1 Formulations between the rainfall intensity and falling rates for different stages of *Phenacoccus solenopsis* on cotton plants

注: A, 1 龄若虫; B, 2 龄若虫; C, 3 龄若虫; D, 雌成虫。Note: A, 1st nymph; B, 2nd nymph; C, 3rd nymph; D, female adult.

根据表 1 数据, 分析建立了 1 龄若虫、2 龄若虫、3 龄若虫、雌成虫掉落率 (Y) 与降雨强度 (X) 之间的关系方程, 如下: $Y = 0.2587X^{0.9850}$ (1 龄若虫, $n = 7$, $R^2 = 0.9811$)、 $Y = 0.2549X^{0.9845}$ (2 龄若虫, $n = 7$, $R^2 = 0.9742$)、 $Y = 0.0266X^{1.4014}$ (3 龄若虫, $n = 7$, $R^2 = 0.9759$)、 $Y = 0.0507X^{1.1307}$ (雌成虫, $n = 7$, $R^2 = 0.8928$) (图 1)。由所建拟合方程计算出当降雨强度达到 423.3 mm/h 时 1 龄若虫掉落率可达到 100%, 430.0 mm/h 时 2 龄若虫掉落率 100%, 355.7 mm/h 时 3 龄若虫掉落率 100%, 820.6 mm/h 时雌成虫掉落率 100%。

3 结论与讨论

降雨对昆虫的直接影响主要表现为直接的冲刷作用, 降雨量的大小对不同类型和体型大小的昆虫的物理冲刷作用不同, 对小型昆虫影响更大。日降雨量大于 20 mm, 对湿地松粉蚧、粘虫 *Leucania separata* 若虫有很强冲杀作用, 当日降雨量达到 100 mm 以上时, 对棉蚜 *Aphis gossypii* Glover 有明显致死作用, 当日降雨量达到 500 mm 以上时能有效防止棉铃虫 *Helicoverpa armigera* Hübner 猖獗发生 (熊映清, 1981; 李登友等, 1996; 汤才和黄德超, 2003)。本研究发现降雨强度为 195 mm/h 时对棉花粉蚧 1 龄和 2 龄若虫均有较强冲刷作用, 掉落率分别为 45.7%、42.3%, 表明强降雨可能对棉花粉蚧发生为害有抑制作用。

降雨量对同一种昆虫不同虫期影响不同, 25 mm–50 mm 降雨对粘虫 1 龄幼虫致死率最高, 对 3 龄幼虫致死率最低 (樊焕碧, 1992)。本研究同样发现同样降雨条件下棉花粉蚧低龄虫态掉落率高于高龄, 1 龄若虫掉落率比雌成虫高出 20%, 原因可能是低龄若虫虫体微小, 足等力量小, 附着能力较弱, 所以很容易被雨水冲刷掉。

广东地区属于东亚季风区, 降雨量充沛, 年平均降水量在 1300 mm–2500 mm, 大雨或暴雨可能直接造成棉花粉蚧大量死亡, 但是也可能为其随水流作短距离传播扩散提供了有利条件。所以进一步研究明确雨水在棉花粉蚧传播扩散中的作用, 注意雨后及时调查监测虫情, 并合理做好大田肥水管理等就显得有意义了。

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