Research Article

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Impact of insecticide-manipulated defoliation by Japanese beetle (*Popillia japonica*) on grapevines from vineyard establishment through production

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Abstract

BACKGROUND: Japanese beetle (JB), *Popillia japonica* Newman, is a severe pest of grapes in the southeastern USA where viticulture is a growing industry. This study evaluated the impact of foliar injury from JB field populations on growth, fruit ripening, berry composition and yield of young vines of six cultivars from vineyard establishment through the first year of production. Three spray regimes, carbaryl applied every 7 or 14 days, or no insecticide, were used to manipulate levels of defoliation by JB.

RESULTS: Cultivars varied in susceptibility and response to defoliation by JB. Some (e.g. Norton) showed reduced vine growth and delayed post-veraison increase in total soluble sugars and pH, as well as reduced cluster number and weight, berries per cluster and yield. Others (e.g. Concord) showed little or no measurable impact from JB. Notably, the biweekly spray regime was as effective as weekly sprays in mitigating the impacts of defoliation.

CONCLUSION: Foliar loss from JB feeding can set back establishment and productivity of young grapevines. Nevertheless, many growers can reduce spray frequency without compromising the benefits of JB management. Even susceptible cultivars can tolerate low to moderate (<20%) levels of defoliation, and some are resistant enough to be grown without treating for JB.
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Keywords: defoliation; grapevine; Japanese beetle; *Popillia japonica*; carbaryl

1 INTRODUCTION

In the southeastern United States, where the growing season is relatively long and vineyards are surrounded by pasture and other grassy larval habitats, leaf-skeletonizing Japanese beetle (JB), *Popillia japonica* Newman (Scarabaeidae: Rutelinae), often reaches very high densities on grapevines.[1] JB activity peaks in mid- to late July, coincident with the later stages of veraison (berry ripening) for early-ripening grape cultivars.[1,2] Because unprotected vines may be $\geq$50% defoliated, many growers apply weekly cover sprays, typically with carbaryl, during JB flight to prevent such damage.[3] JBs aggregate on grapevines in response to aromatic volatile compounds released from JB-damaged leaves.[4] They tend to feed most heavily on European and French–American hybrid varieties,[5,6] but the basis for such apparent preference has not been studied.

Few studies have examined the impact of JB defoliation on grapevines. Natural beetle populations failed to reduce shoot growth, yield or fruit quality of established 'Seyval Blanc' (*Vitis* sp., interspecific hybrid) grapevines in Virginia; in that study, however, the unprotected vines were only 6.5% defoliated.[7] Feeding by caged JBs on potted non-bearing vines reduced whole-vine carbon assimilation more than did comparable levels of mechanical injury.[8] Similarly, intensive post-veraison foliage feeding by caged beetles on established vines had greater impact on fruit soluble solids and titratable acidity at harvest than did manually removing whole leaves.[7] Natural levels of JB defoliation reduced cold hardiness of young planted grapevines.[9] However, no previous studies have quantified relationships between natural JB defoliation and growth, yield, fruit ripening and berry composition of young field-grown vines from planting to first harvest, or compared such impact among cultivars.

In Kentucky, where viticulture is an alternative to the declining tobacco industry, new vineyards are being planted at increasing pace.[10,11] Cultivar selection and pest control are crucial to new growers because vineyard establishment is costly, and new vines typically do not yield a crop for 3 years.[12,13] A poor start can set back productivity, and costs for re-establishing a failed planting could be devastating for growers. Defoliation by insects is particularly

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stressful for young vines, which, because of their smaller size and lower levels of storage carbohydrates, are less able than mature vines to compensate for the stress of leaf area loss.[14]

Integrated pest management guidelines, especially action thresholds for new growers, will benefit from better understanding of how varying levels of vine defoliation from JB affect growth, yield and fruit quality of young grapevines from vineyard establishment through the first year of production. This study examined such responses for six cultivars differing in susceptibility to JB. Defoliation levels were manipulated by cover spray frequency, so the data also provide insight into the extent to which insecticide inputs can be reduced without compromising production.

2 EXPERIMENTAL METHODS

2.1 Site and plant material

A research vineyard with six cultivars of grapes was established on a Maury silt loam (a fine, mixed, semi-active, mesic, typic Paleudalfs; 314 m elevation) at the University of Kentucky Horticulture Research Farm in Lexington, Kentucky. The site was cultivated, and a cover crop of perennial ryegrass (*Lolium perenne* L.) and KY 31 fescue [*Schedonorus phoenix* (Scop.) Holub] was established in 2005. Vines were planted in early May 2006 in a 6 × 3 factorial, randomized, complete block design with eight replications for each cultivar/insecticide spray combination, and two vines per experimental unit. The six cultivars included two American cultivars, 'Concord/own rooted' (*Vitis labruscana* L.) and 'Norton/own rooted' (*V. aestavalis* Michx.), two European *V. vinifera* L., 'Cabernet Franc/C 3309' and 'Cabernet Sauvignon/C3309', and two French–American hybrids, 'Chambourcin/own rooted' (*V. vinifera* × *V. riparia)* and 'Frontenac MN 1047/own rooted' (*Vitis* sp., interspecific hybrid). Vines were trained to a 1.8 m high, single high-wire bilateral cordon system with 2.4 × 3.0 m (vine × row) spacing, and managed according to University of Kentucky recommendations.[12,13] Defoliation levels were manipulated with insecticides (Section 2.3) that provided three intensities of JB management for three consecutive years.

2.2 Leaf characteristics

In mid-June 2006, at the start of JB flight in the first growing season, eight fully expanded leaves were collected from vines of all cultivars in each replicate and evaluated for several parameters (leaf thickness, relative toughness, nitrogen and water content) that can affect suitability of woody plant foliage for leaf-chewing insects.[15] Four leaves per replicate were placed in paper bags, frozen on dry ice and stored at −80 °C. Those leaves were lyophilized and ground in a Wiley mill (Thompson Scientific, Philadelphia, PA) using a 40-mesh screen. Nitrogen content was determined by modified Kjeldahl analysis.[16]

Two leaves of each cultivar per replicate were randomly selected for evaluation of leaf thickness and toughness. Thickness was measured between veins by a Mitutoyo Digimatic thickness indicator IDC series 504 (Mitutoyo, Tokyo, Japan). Relative toughness was measured with an electronic digital force gauge with a pointed punch (Mark-10; Hicksville, NY) pushed through the adaxial leaf surface. Four measurements were recorded per leaf, with two leaves per experimental unit for each parameter, with values averaged to a single value per replicate. Two leaves per replicate were weighed fresh, oven dried and reweighed for determination of water content.

2.3 Insecticide treatment regimes and defoliation evaluations

Two insecticide treatments, carbaryl 480 g L^{-1} SC (Sevin XLR Plus; Bayer, Research Triangle Park, NC) applied at 5 mL L^{-1} (2.4 g AI L^{-1}) by backpack sprayer until drip every 7 or 14 days during the JB flight period, and no insecticide treatment, were used during the 2006, 2007 and 2008 growing seasons to provide varying levels of protection from JB defoliation. Vines treated every 7 or 14 days received seven or three applications, respectively, between 23 June and 4 August 2006, and between 21 June and 1 August 2007. In 2008, those vines were sprayed 5 or 3 times, respectively, between 3 July and 1 August 2008, at which point all vines were sprayed to protect the fruit from insect damage. Standard JB traps and lures (Trécé, Adair, OK) placed in two locations near vineyards and orchards at the research farm were used to monitor JB flight and determine spray timing.

The extent of overall JB defoliation on individual vines was visually estimated to the nearest 5% by two independent observers in late July, just after JB peak flight. Defoliation estimates (two ratings per vine, two vines per experimental unit) were averaged to provide a single value per replicate.

2.4 Vine growth, internode length and dormant pruning weight

During the first (2006) and second (2007) growing seasons, vines were defruited and not cropped. The young vines were trained to two primary shoots in 2006 to establish trunks. Impact of JB defoliation on current season shoot extension and internode length of first-year vines was evaluated on 19 October 2006, 3 days after the occurrence of killing frost. The dominant primary shoot (one per vine, two vines per replication) was evaluated for total length and internode length (= total shoot length/total number of buds per shoot). Following the second growing season, the canes were trained to cordons and the shoots on cordons were spur pruned (pruned to ≤4 buds every 10 cm along the cordon) during dormancy in mid-February 2008 to retain 36 buds per vine, and not balance pruned. Plant material removed from the vines during dormant pruning was bundled and weighed.

2.5 Berry ripening and composition at harvest

Post-veraison (point after which berries change color) ripening was evaluated weekly from 12 August 2008 until each cultivar's respective harvest date (Section 2.6). For each weekly sample, 100 berries per replicate of each spray treatment/cultivar combination were collected into plastic bags, placed in a cooler in the field and evaluated the same day. Berries were crushed by hand, and the juice was placed in 100 mL beakers. A sample (5 mL) was used to determine the percentage total soluble solids (TSS), which are mostly sugars,[17,18] measuring them as degrees brix using a handheld PAL-1 digital refractometer (ATAGO, Bellevue, WA). Juice pH was measured with a glass electrode and pH meter (model AR15; Fisher Scientific, Pittsburgh, PA).

At harvest, a 100-berry sample was collected from each replicate pair of vines, crushed by hand, and the juice was placed in 100 mL beakers to determine berry composition. Harvest dates were based on commercial ripeness standards. TSS and pH were measured as previously described. Total acidity (TA), expressed as grams of tartaric acid per liter of juice, was also determined at harvest by titrating the juice to pH 8.2 with 0.1 M sodium hydroxide.[19]

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Table 1. Characteristics of grape foliage just before *Popillia japonica* flight in June 2006, and subsequent *P. japonica* defoliation of non-treated vines by late July in 2006 and 2007

		Leaf characteristics[b] (± SEM)				Percentage defoliation[c] (± SEM)	
Cultivar	Type[a]	Relative toughness (g)	Thickness (μm)	H_2O (%)	N (%)	2006	2007
Concord	A	105 (±2)	109 (±3)	64 (±2)	2.2 (±0.1)	7 (±1)	5 (±1)
Norton	A	84 (±14)	86 (±10)	70 (±7)	2.4 (±0.1)	44 (±6)	44 (±3)
Cabernet Franc	E	83 (±3)	58 (±2)	65 (±7)	2.7 (±0.1)	39 (±10)	35 (±7)
Cabernet Sauvignon	E	97 (±5)	68 (±3)	65 (±7)	2.6 (±0.1)	48 (±5)	38 (±7)
Chambourcin	H	69 (±6)	84 (±3)	69 (±3)	2.6 (±0.1)	46 (±8)	43 (±6)
Frontenac	H	46 (±2)	81 (±4)	69 (±5)	2.3 (±0.1)	38 (±3)	37 (±4)
ANOVA[b]							
$F_{5,35}$ =		9.4**	11.9**	24.8**	9.8**	11.2**	11.0**
Contrasts *t*:							
Concord vs rest		3.9**	6.1**	6.4**	4.7**	7.3**	7.2**
Norton vs E		0.8	3.7**	7.9**	3.0**	0.1	1.5
Norton vs H		3.2**	0.5	2.0*	0.2	0.3	0.6
E vs H		4.7**	3.9**	7.3**	3.5**	0.3	1.2

[a] A = American, E = European, H = hHybrid (French–American) cultivars.
[b] For test statistics from ANOVA (*F*) and single-degree-of-freedom linear contrasts (*t*), * and ** denote $P \leq 0.05$ and 0.01, respectively.
[c] Relative defoliation of the different cultivars was similar in 2008 (data not shown).

2.6 Yield components

Bird netting was installed over all vines on 28 July 2008. Harvest dates were 28 August (Concord), 5 September (Chambourcin), 12 September (Norton) and 17 September (Cabernet Franc, Cabernet Sauvignon). Treatments within each cultivar were harvested on the same date. Number of clusters, yield (kg) and average cluster weight (g) per vine were recorded. A random 100-berry sample was weighed from each treatment/cultivar combination for each replicate, and average berry weight from those samples was used to estimate the number of berries per cluster per vine.

2.7 Statistical analyses

Percentage defoliation and foliage characteristics were compared among non-treated vines of the different cultivars by analysis of variance (ANOVA) for a randomized complete block design, and means were separated by preplanned single-degree-of-freedom linear contrasts. Percentage defoliation, vegetative growth, yield and berry composition were similarly compared between spray regimes within cultivar, as described above, to examine consequences of different intensities of JB management. Spray regime effects on post-veraison brix and pH levels of ripening berries were analyzed within cultivar by ANOVA for repeated measures, and within cultivars and dates as described above. Percentages were arcsine square-root transformed; botanical parameters were not transformed because they met requirements for normality and homogeneity of variances. All data are presented as original means ± standard error (SE). Statistix 9 (Analytical Software, Tallahassee, FL) was used for all analyses.

3 RESULTS

3.1 Leaf characteristics and defoliation evaluations

JBs were the only insect defoliators observed damaging the vines. Concord, characterized by tough, thick leaves with relatively low nitrogen and water content, sustained relatively little defoliation compared with the other cultivars (Table 1). That damage was mainly scraping of the adaxial leaf surface as opposed to skeletonization. Although the hybrid cultivars, as a group, had the least tough leaves, and European cultivars had the thinnest leaves with highest nitrogen content, untreated vines of all cultivars other than Concord sustained similar levels of defoliation (Table 1).

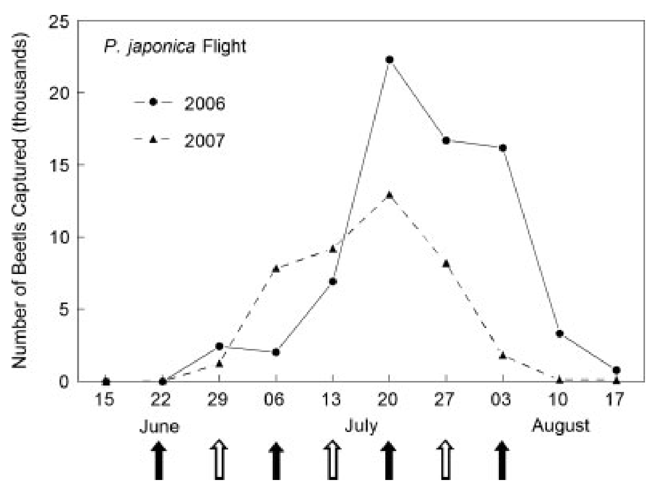

Figure 1. *Popillia japonica* flight in 2006 and 2007, showing the dates of weekly (all arrows) and biweekly (open arrows) carbaryl sprays.

Weekly insecticide treatments for JB began 20–22 June in all three years, shortly after first flight (Fig. 1). Biweekly spray regimes began the following week, and both treatment regimes were discontinued in early August, after which beetle densities declined and no longer warranted application (Fig. 1). The carbaryl spray regimes provided distinct levels of JB defoliation within all cultivars in each year, with a significant linear effect of treatment (ANOVA, polynomial contrasts, $P < 0.01$) (Fig. 2). Although non-sprayed Concord vines had little defoliation, the main treatment effect for that cultivar was still significant

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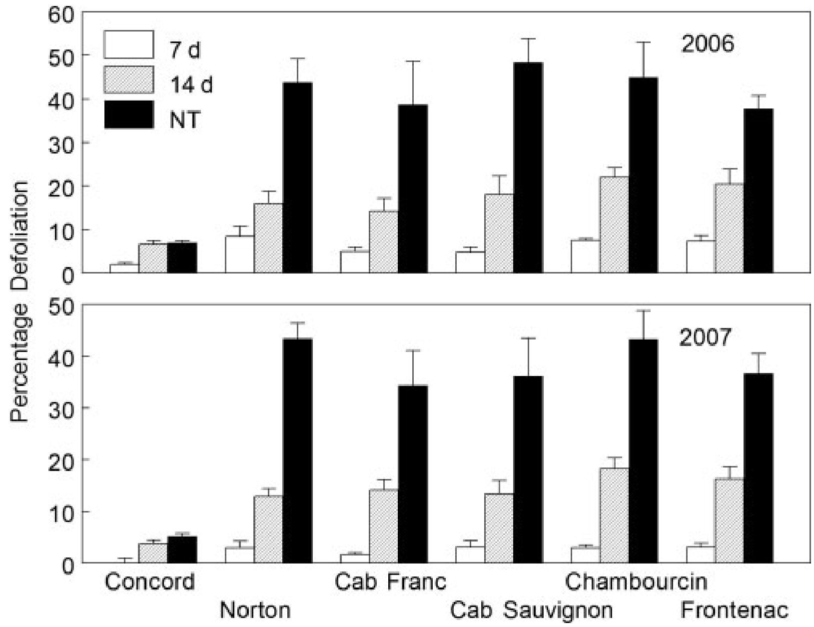

Figure 2. Levels of *Popillia japonica* defoliation on six grape cultivars under carbaryl cover sprays applied every 7 or 14 days, or without insecticide treatments (NT). Similar defoliation levels and differences between cultivars and spray regimes also occurred in 2008 (data not shown).

Table 2. Impact of *Popillia japonica* defoliation, manipulated by spray regime for two consecutive years, on vegetative growth of young grapevines during the first and second growing seasons

		Cultivar[a]					
Growth measure[b]	Spray regime	Concord	Norton	Cabernet Franc	Cabernet Sauvignon	Chambourcin	Frontenac
Shoot length (± SEM) (cm)	7 day	210 (±25)	230 (±24)	222 (±26)	263(±22)	229(±24)	245(±27)
	14 day	243 (±16)	201 (±18)	225 (±27)	258(±21)	220(±19)	211(±14)
	NT	248 (±21)	187 (±19)	179 (±24)	184(±20)†	199(±16)	222(±15)
	$F_{2,14}$ =	1.2	2.5	2.0	16.7**	0.8	0.8
Internode length[c] (± SEM) (cm)	7 day	6.6(±0.4)	5.5 (±0.3)	4.3 (±0.3)	4.7(±0.3)	5.7(±0.4)	5.7(±0.3)
	14 day	7.0 (±0.3)	5.8 (±0.2)	4.6 (±0.3)	4.6(±0.3)	5.3(±0.2)	5.5(±0.4)
	NT	6.6 (±0.3)	5.2 (±0.3)	3.8 (±0.2)	4.1(±0.2)	4.9(±0.2)†	5.3(±0.2)
	$F_{2,14}$ =	0.9	1.4	3.6*	2.1	3.3‡	0.6
Pruning weight (± SEM) (g)	7 day	240 (±42)	383 (±41)	482 (±53)	455(±55)	533(±32)	566(±60)
	14 day	241 (±51)	360 (±44)	544 (±65)	506(±41)	518(±85)	466(±86)
	NT	382 (±85)	231 (±23)†	297 (±37)†	285(±54)†	285(±43)†	432(±22)
	$F_{2,14}$ =	2.2	5.6*	5.1*	7.9**	5.3*	1.0

[a] All statistical analyses are within cultivar. For *F*-statistics (ANOVA), **, * and ‡ signify that the main effect of the spray regime is significant at $P \leq 0.01$, 0.05 and 0.07 respectively. † signifies that the mean for NT (non-treated) vines differs significantly from the mean for treated vines (single-degree-of-freedom linear contrasts, $P < 0.05$). There were no significant differences between 7 and 14 day spray regimes for any parameter of any cultivar.
[b] Length measurements and pruning weight taken after 2006 and 2007 growing seasons respectively.
[c] Calculated as total shoot length (cm)/total number of buds on the primary dormant shoot.

($F = 22.0$, 40.4 in 2006 and 2007 respectively; df = 2, 14; $P < 0.001$).

3.2 Impact of *Popillia japonica* defoliation on vine growth

Spraying the relatively resistant Concord for JB provided no benefit to vine growth. Frontenac, a fast-growing early-season cultivar, also showed no benefit from either cover spray regime, in spite of 37–38% defoliation of non-treated vines. In contrast, JB defoliation significantly reduced one or more measures of vine growth of four of the five susceptible cultivars (Table 2). Notably, for those cultivars, the biweekly cover sprays were as effective as weekly sprays in mitigating adverse impacts of JB defoliation on vine growth.

3.3 Impact of *Popillia japonica* defoliation on berry ripening and fruit composition

For Concord there were no significant effects of spray regime or spray × date interaction on post-veraison accumulation of TSS or increase in pH levels (ANOVA for repeated measures, all *P*-values ≥0.26). Fruit clusters of Frontenac, an early ripening cultivar, were heavily attacked by birds prior to netting, and by the

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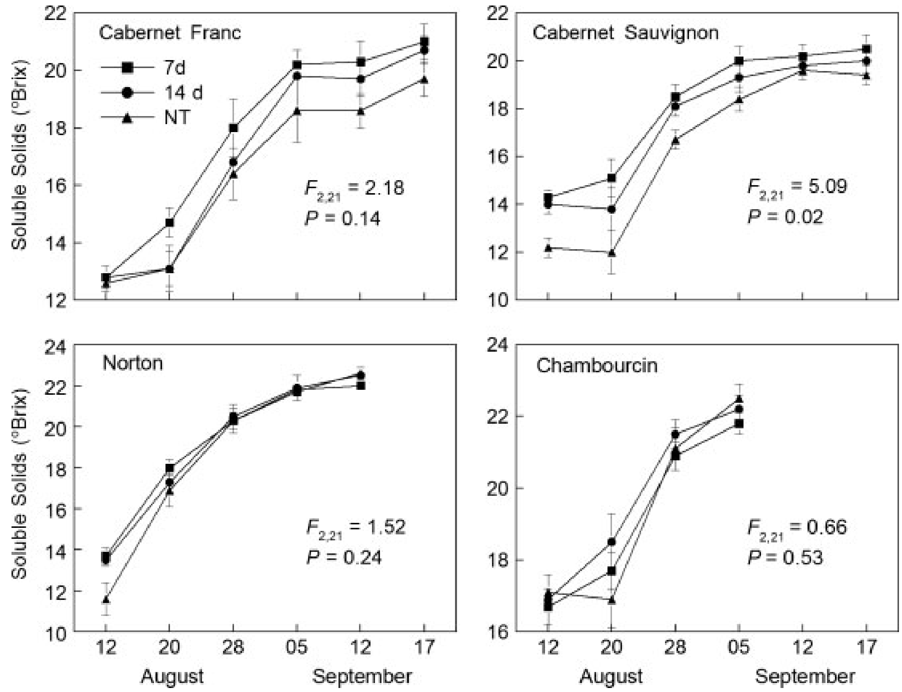

Figure 3. Impact of *Popillia japonica* defoliation on percentage soluble solids (brix) accumulation during the later stages of berry ripening. The main effect for treatment (ANOVA for repeated measures) is shown in each graph. The main effect for date is significant ($P < 0.001$) for all cultivars with no significant treatment by date interaction.

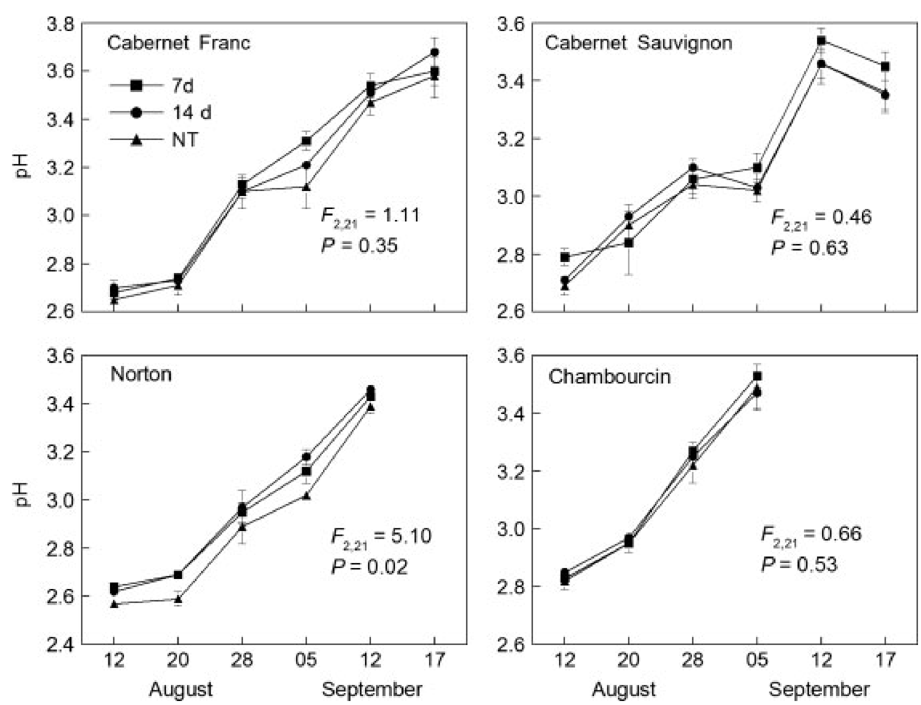

Figure 4. Impact of *Popillia japonica* defoliation on pH levels during the later stages of berry ripening. The main effect for treatment (ANOVA for repeated measures) is shown in each graph. The main effect for date is significant ($P < 0.001$) for all cultivars with no significant treatment by date interaction.

green June beetle, *Cotinis nitida* L. Therefore, its berry composition and yield were not evaluated.

JB defoliation on non-treated vines resulted in delayed increase in post-veraison TSS of Cabernet Sauvignon (Fig. 3) and delayed increase in pH levels of Norton (Fig. 4). Increase in TSS was also initially delayed for non-treated Norton vines (Fig. 4, August 12, linear contrasts; $t = 3.3$, $P < 0.05$). For the other cultivars, however, the spray regime did not significantly affect those indicators of ripening phenology (Figs 3 and 4). TSS and pH increased significantly over time for all cultivars ($P < 0.001$), reflecting natural berry ripening.

The spray regimes did not affect TSS or juice pH at harvest for any susceptible cultivar (note final dates in Figs 3 and 4). For

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Table 3. Impact of *Popillia japonica* defoliation, manipulated by spray regime for three consecutive years, on total yield and numbers and size of clusters and berries in the first season of harvest (mean ± SEM)

Cultivar[a]	Spray regime[b]	Yield per vine (kg)	Clusters per vine	Cluster weight (g)	Berry weight (g)	Berries per cluster
Concord	7 day	5.4 (±0.4)	57 (±3)	96 (±6)	2.72 (±0.15)	35 (±2)
	14 day	5.3 (±0.8)	55 (±6)	93 (±7)	2.80 (±0.12)	33 (±3)
	NT	6.7 (±0.7)	65 (±5)	103 (±5)	2.73 (±0.15)	38 (±2)
	$F_{2,14}$ =	1.8	1.0	1.1	0.2	1.6
Norton	7 day	2.5 (±0.3)	33 (±4)	75 (±4)	1.07 (±0.05)	69 (±4)
	14 day	2.2 (±0.3)	34 (±4)	64 (±4)	1.00 (±0.02)	64 (±4)
	NT	0.6 (±0.2)†	9 (±3)†	53 (±6)†	0.78 (±0.05)†	61 (±8)
	$F_{2,12}$ =	14.7**	15.5**	6.25*	14.9**	0.7
Cabernet Franc	7 day	6.9 (±0.7)	60 (±6)	117 (±7)	1.20 (±0.03)	97 (±3)
	14 day	7.2 (±1.1)	63 (±8)	113 (±5)	1.19 (±0.03)	96 (±5)
	NT	4.8 (±1.1)†	48 (±13)	107 (±8)	1.17 (±0.05)	92 (±6)
	$F_{2,13}$ =	2.4	0.9	0.7	0.5	0.4
Cabernet Sauvignon	7 day	8.5 (±0.9)	59 (±6)	150 (±8)	1.24 (±0.05)	121 (±6)
	14 day	8.0 (±0.8)	59 (±6)	136 (±4)	1.19 (±0.07)	117 (±7)
	NT	5.5 (±1.3)†	39 (±8)†	136 (±11)	1.21 (±0.05)	113 (±10)
	$F_{2,14}$ =	3.7*	3.6*	1.1	0.3	0.5
Chambourcin	7 day	8.5 (±1.1)	70 (±6)	122 (±11)	2.08 (±0.04)	59 (±5)
	14 day	8.3 (±0.7)	71 (±6)	118 (±6)	1.95 (±0.08)	61 (±3)
	NT	5.8 (±0.4)†	57 (±3)†	101 (±5)‡	1.92 (±0.12)	54 (±5)‡
	$F_{2,11}$ =	4.0*	4.1*	2.0	1.2	2.4

[a] All statistical analyses are within cultivar. For *F*-statistics (ANOVA), ** and * signify that the main effect of the spray regime is significant at $P \leq 0.01$ and ≤ 0.05 respectively. For mean separation, † and ‡ signify that the mean for NT (non-treated) vines differs significantly from the mean for treated vines at $P \leq 0.05$ and ≤ 0.08 respectively (single-degree-of-freedom linear contrasts).
[b] There were no significant differences between 7 and 14 day spray regimes for any parameter of any cultivar.

Concord, TSS averaged 17.8±0.4, 17.7±0.4 and 17.2±0.4, and pH averaged 3.59±0.04, 3.56±0.03 and 3.55±0.03 for 7 day, 14 day and no-spray regimes respectively ($P > 0.39$). Titratable acidity at harvest also did not differ between the 7 day, 14 day and no-spray treatments (Concord: 5.6 ± 0.8, 4.9 ± 0.4, 5.1 ± 0.5; Norton: 10.7±0.3, 11.0±0.4, 11.4±0.6; Cabernet Franc: 5.3±0.1, 5.4±0.2, 5.2 ± 0.5; Cabernet Sauvignon: 8.3 ± 0.3, 8.0 ± 0.3, 8.4 ± 0.5; Chambourcin: 9.6 ± 0.2, 9.4 ± 0.4, 10.0 ± 0.4 respectively; all *P*-values ≥0.46).

3.4 Impact of *Popillia japonica* defoliation on the components of crop yield

Popillia japonica defoliation of non-sprayed vines significantly reduced cluster number and yield, compared with protected vines, for all cultivars except Concord (Table 3). Yields for non-treated vines of Norton, Cabernet Franc, Cabernet Sauvignon and Chambourcin were reduced by 76, 30, 35 and 32%, respectively, compared with vines sprayed weekly, and by 73, 32, 31 and 30% compared with vines sprayed biweekly. Non-sprayed vines of Norton and Chambourcin also showed a significant or near-significant reduction in cluster weight, berry weight or berries per cluster compared with 7 day treated vines. There were no significant differences between 7 and 14 day spray regimes for any cultivar (Table 3).

4 DISCUSSION

This study, which quantified the cumulative effects of JB herbivory on young grapevines from planting through the first year of production, indicates that different cultivars vary in both susceptibility and response to JB defoliation. Levels of JB defoliation typical of what occurs on non-sprayed susceptible cultivars in Kentucky significantly reduced vine growth and crop yield. Because defoliation was manipulated by cover spray frequency, this study also provides insight into the extent to which JB management can be reduced without compromising vine growth and first-year production. Notably, even for susceptible cultivars, a biweekly (14 day) cover spray regime was as effective as weekly carbaryl sprays in mitigating the adverse effects of JB defoliation.

Tough leaves with low nitrogen and water content likely contribute to Concord's resistance to JB defoliation, as those characteristics are indicative of poor food quality for leaf-chewing insects.[15] Others, too, have suggested that leaf physical characteristics may determine JB preference among grape cultivars.[5,6] Although not statistically significant, non-treated Concord vines outperformed sprayed vines in a number of parameters, suggesting that adverse effects (e.g. impaired photosynthesis) from the residues may have outweighed the minor leaf area loss from JB. Importantly, there was no evident production advantage from managing JB herbivory on Concord vines.

Non-sprayed vines of Frontenac, a French–American hybrid, were susceptible to JB defoliation. In spite of alleviating leaf area loss, however, neither of the carbaryl spray regimes significantly increased Frontenac shoot growth or dormant pruning weights. The vigorous vegetative growth of Frontenac in Kentucky's warm climate likely allowed the vines to maintain enough leaf area to withstand the heavy defoliation. Phenological differences in vine growth can affect how grapevines respond to defoliation.[8,14]

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Frontenac is a relatively early mid-season ripening cultivar[13] that was ready for harvest on 12 August, about 1 month before the other susceptible cultivars. Therefore, it may also have been less impacted by JB herbivory because of more advanced development of its vines.

Effects of JB defoliation in the first two summers were visually obvious during the training and pruning of the non-sprayed Norton, Cabernet Franc, Cabernet Sauvignon and Chambourcin vines and confirmed by quantitative measures of vegetative growth. The cumulative impact of that stress led to a reduction in the number of fruiting canes capable of sustaining a crop level, followed by significant reductions in clusters and yield per vine in the first year of production.

Viticulture has a long history in the southeastern United States.[11] The present study supports the view that JB has become arguably the most destructive insect pest of grapes in the region. Defoliation of non-protected vines by JB often is severe enough to reduce whole-vine carbon assimilation,[8] winter hardiness of the primary dormant bud[9] and vine growth and crop production (this study). In addition, JB facilitates injury by the obligate fruit-eating green June beetle, a near-harvest pest that can destroy an entire crop,[20] by biting into grape berries and eliciting yeast-mediated fermentation volatiles that attract the latter species.[1,2] JB is now established throughout most of the eastern United States, and is expanding its range into the Great Plains and south central states. It is an ever-present threat to become established in the grape-growing regions of the western United States and in continental Europe.[21]

In Kentucky, many growers apply weekly cover sprays with carbaryl from mid-June until August to protect vines from JB. The present data indicate that the frequency of such sprays could be reduced by half without compromising the benefits of JB management, because low to moderate ($<20\%$) levels of defoliation by JB are unlikely to significantly reduce growth or yield of young vines. Furthermore, relatively resistant cultivars could be successfully grown without insecticidal applications for JB management. This information should allow growers to manage JB more efficiently, with reduced chemical inputs.

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