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Grape Cultivar Feeding Preference of Adult Japanese Beetles

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***Abstract*. The Japanese beetle is a major insect pest of grapes in the eastern United States. An examination of Japanese beetle preference for currently grown grape cultivars would be useful to growers in developing pest control strategies with reduced chemical inputs. The objective of this study was to examine grape cultivar preference of Japanese beetles for commercially available grape cultivars in both cage choice and field experiments. Outdoor cage choice screening studies included 32 grape cultivars from various *Vitis* species and were conducted at the Kentucky State University Research Farm in Frankfort, KY. Feeding preference was determined by examining incidence of damage (percent of leaves damaged per vine) and leaf area loss, which was rated as 0 pt, 0%; 1 pt, 1% to 10%; 2 pt, 11% to 20%; 3 pt, 21% to 30%; 4 pt, 31% to 40%; 5 pt, 41% to 50%; 6 pt, 51% to 60%; and 7 pt, more than 60%, by leaf position from the first (shoot tip) to 10th leaves. Analysis of variance indicated that there were significant differences in Japanese beetle leaf damage for cultivar and leaf position main effects. Leaf damage by Japanese beetles varied by leaf position on the shoot, with the fourth through sixth leaves from the tip with the most severe damage. Generally, cultivars showing an incidence of damage greater than 70% were either European or French hybrid cultivars, and those with less than 70% incidence of damage were either American cultivars or American cultivars with a *V. labrusca* background. The grape cultivars Marquis, Reliance, Catawba, Concord Seedless, Concord, Edelweiss, and Einset showed promise as selections for growers interested in reduced chemical inputs for control of Japanese beetles.**

The Japanese beetle (*Popillia japonica* Newman) is an introduced scarab beetle that was first discovered in New Jersey in 1916 (Fleming, 1976). It is the most widespread and destructive insect pest in the eastern United States, with a direct cost of more than $450 million each year for renovating or replacing damaged turf and ornamental plants (Potter and Held, 2002). Although Japanese beetle grubs damage grass roots from lawns, golf courses, and pastures, adults attack mostly the foliage, flowers, and fruits of more than 300 plant species in 79 families, including grapes (Fleming, 1972).

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When feeding on grape leaves, adult Japanese beetles typically produce irregularly shaped holes that result in various degrees of leaf area loss (LAL). Although grapevines are able to tolerate some defoliation, severe LAL will delay ripening, reduce fruit yield and quality (Boucher and Pfeiffer, 1989), and possibly reduce cold hardiness of buds and canes (Mansfield and Howell, 1981). Langford and Cory (1948) classified grape varieties as preferred, attractive, frequently attacked, and unattractive, and proposed that the physical characteristics of host plant leaves might determine this preference. The preferred and attractive varieties were *Vitis vinifera*, French hybrids, and *V. aestivalis* with thin, glossy, and tender foliage; the frequently attacked varieties were mostly *V. labrusca* with leaves coarse and leathery above and tomentose or woolly below; the unattractive varieties were from *V. champini* × *V. labrusca* that have young shoots and coarse foliage covered with a tomentum. Their results, however, were drawn from nonreplicated vine damage observations of cultivars that were grown in the 1940s; many currently planted cultivars were not examined.

An examination of Japanese beetle preference for currently cultivated grape cultivars would be useful to growers in developing pest control strategies with reduced chemical inputs with nonpreferred cultivars. The objective of this study was to examine grape cultivar preference of Japanese beetles to 32 commercially available grape cultivars in both cage choice and field experiments.

Materials and Methods

Cage choice study. Thirty-one grape cultivars including European, French hybrid, and American cultivars (Table 1), and one rootstock cultivar '3309 Couderc' were chosen for the cage choice study. Propagation of these grapevines was conducted with 1-year-old cuttings collected from the Kentucky State University (KSU) Research Vineyard (Frankfort, KY) and Double-A-Vineyards (Fredonia, NY) in Mar. 2006. Cuttings were 30 to 45 cm in length with four to five buds treated with Hormex no. 8 rooting powder (Brooker Chemical Co., Chatsworth, CA), and were placed vertically in trays filled with Perlite. The trays were then placed on a mist bench with bottom heating set at 25 °C. After 4 weeks, rooted cuttings were transplanted into 1.9-L containers filled with Pro-Mix BX potting medium (Premier Horticulture, Quakertown, PA) supplemented with 5 g Osmocote 14-14-14 (14N–6.1P–11.6K; Scotts Co., Marysville, OH) per pot. Vines were fertilized every 7 to 10 d with 720 ppm of Peters 20-20-20 (20N–8.7P–16.6K) water-soluble fertilizer (Scotts Co.) until they were transferred to an outdoor cage. Bamboo stakes were used to support the propagated grapevines.

From late June to mid July 2006, vines from each cultivar were randomly separated into three groups. Vines from each group were pruned to a single shoot with 10 leaves before they were placed in a cage at 20 to 30 cm apart. They were then hardened for at least 10 d before adult Japanese beetles were released in the cage for feeding. All cages were 11 × 2.7 × 1.8 m in size and were covered with Econet B fine mesh (Hummert International, St. Louis, MO), which allows 95% air flow and 85% light transmission.

The Japanese beetles were captured using a Safer pheromone trap (Safer, Lititz, PA) and released into the cages within 1 h of capture at a level of 15 beetles per vine. Japanese beetles were allowed to feed on grapes in the cages continuously for 48 h before data were taken for feeding incidence and severity. The experiment was replicated three times in July 2006 and each cage was treated as a replicated block (three replicate blocks). In each cage, vines were arranged in a completely randomized design of three replications; there were three individual vines for each cultivar per replication. Japanese beetle damage data were collected for each vine and included feeding incidence (percent of damaged leaves) and severity, which was visually rated as 0 pt, 0%; 1 pt, 1% to 10%; 2 pt, 11% to 20%; 3 pt, 21% to 30%; 4 pt, 31% to 40%; 5 pt, 41% to 50%; 6 pt, 51% to 60%; and 7 pt, more than 60% of estimated LAL (Boucher and Pfeiffer, 1989). Leaves with more than 60% LAL by Japanese beetles desiccate and die after a period of time. Damage on each leaf on a shoot was evaluated to determine whether Japanese beetle feeding preference varied by shoot position. Damage by Japanese beetles to young and mature leaves was also evaluated by examining the average LAL of the first (shoot tip) to 10th leaves.

Field choice study. In a limited field study, 'Chambourcin' (French hybrid background), 'Edelweiss' (American hybrid), and 'Norton' (American cultivar of *V. aestivalis*) grapevines were purchased from Double-A-Vineyards (Fredonia, NY) and planted in May 2005 at the KSU Research Farm (Frankfort, KY). The vines were pruned back to two buds on Apr. 2006 and allowed to establish trunks with the aid of bamboo stakes. Standard vineyard practices in Kentucky, such as fertilization, disease and weed management, and vine management were conducted as needed (Bordelon et al., 2006; Brown et al., 2004).

In June and July 2006, an experiment was conducted to examine field preference for the grape cultivars Chambourcin, Edelweiss, and Norton by Japanese beetles. The cultivars were planted in a completely randomized block design with four replications. There were 15 individual vines per cultivar in each replication. The average number of Japanese beetles on each grapevine was determined by counting Japanese beetles every other day from 10:00 AM to 12:00 PM from June 21, when Japanese beetles were first noticed, until 21 July 2006. The LAL from each vine resulting from damage by Japanese beetles was also visually estimated on 21 July 2006.

Data analysis. All data were analyzed with relevant SAS 9.1 procedures (SAS Institute, Cary, NC) unless specified. Data of damage incidence (measured as a percentage) were transformed with the arcsine square root function. Analysis of variance was completed using the Mixed Model. Mean separation was conducted by LSD at a $P \leq 0.05$ level of significance. General Linear Model regression analysis was conducted with the statistical program Costat 6.3 (CoHort Software, Monterey, CA) to determine the relationship between incidence of damage and LAL. Both linear and polynomial regression models were fit to the data, and the significance of the models was determined.

Results

Cage choice study. Analysis of variance indicated that there were significant differences in Japanese beetle leaf damage for cultivar ($P < 0.01$) and leaf position ($P < 0.01$) main effects, there was not a significant interaction between the main effects ($P = 0.07$), and there was not a significant difference between blocks ($P = 0.71$). Leaf damage by Japanese beetles varied by leaf position on the shoot (Fig. 1). The fourth, fifth, and sixth leaves from a shoot tip showed the most severe damage. Mature leaves (7th–10th), which have developed the typical physical characteristics of the cultivar, had less LAL. The youngest leaves (the first to

Table 1. Foliage feeding incidence and severity[z] of Japanese beetles to grapes in cages.

Cultivar	Vitis[y] group	Incidence (% leaves damaged)	Leaf area loss[x] (1–10)
Mars	AL	42 d[w]	0.5
Marquis	HL	61 cd	1.1
Reliance	AL	64 bcd	1.1
Catawba (At[v])	AL	64 bcd	1.1
Concord Seedless	AL	64 bcd	1.2
Concord	AL	66 bcd	1.2
Edelweiss	A	66 bcd	1.6
3309 Couderc	A	67 bcd	1.7
Einset	HL	69 bcd	1.6
Cabernet Sauvignon (Pr)	E	72 bc	1.6
Cabernet Franc	E	72 bc	1.8
Vanessa	A	74 bc	1.7
Jupiter	H	74 bc	2.0
Rougeon	AM	75 abc	1.7
St. Croix	H	77 abc	1.5
St. Vincent	H	78 abc	2.5
Vignoles	H	79 abc	1.5
Lemberger	E	79 abc	2.0
Chambourcin	H	80 abc	2.3
Glenora	HL	81 abc	2.6
DeChaunac	H	84 abc	1.9
Marshal Foch	H	84 abc	2.0
Himrod	AL	84 abc	2.7
Chardonel	H	84 abc	3.0
Delaware (Pr)	H	85 abc	2.3
Cayuga White	H	87 abc	2.4
Chardonnay (Pr)	E	87 abc	2.9
Chancellor	H	87 abc	2.9
Frantenac	H	87 abc	2.5
Lacrosse	H	89 abc	2.9
Seyval	H	91 ab	2.5
Vidal Blanc	H	94 a	3.4

[z]Incidence data are reported as percent leaves damaged; however, mean separation was performed on data that was subjected to arcsine square root transformation. Severity of leaf damage was rated as 0 pt, 0%; 1 pt, 1% to 10%; 2 pt, 11% to 20%; 3 pt, 21% to 30%; 4 pt, 31% to 40%; 5 pt , 41% to 50%; 6 pt, 51% to 60%; and 7 pt, more than 60% of estimated leaf area loss (Boucher and Pfeiffer, 1989).

[y]A, American cultivar; AL, American cultivar with *Vitus labrusca* background; AM, American cultivar with Muscadine background; E, European cultivar; H, French hybrid cultivar; HL; French hybrid with *V. labrusca* background.

[x]Denotation of 1 to 10 refers to the leaf number on a shoot, with 1 being the youngest and 10 being the oldest.

[w]Any two means of incidence not followed by a same letter are significantly different at $P \leq 0.05$.

[v]Pr, classified as preferred by Langford and Cory (1948); At, classified as attractive by Langford and Cory (1948).

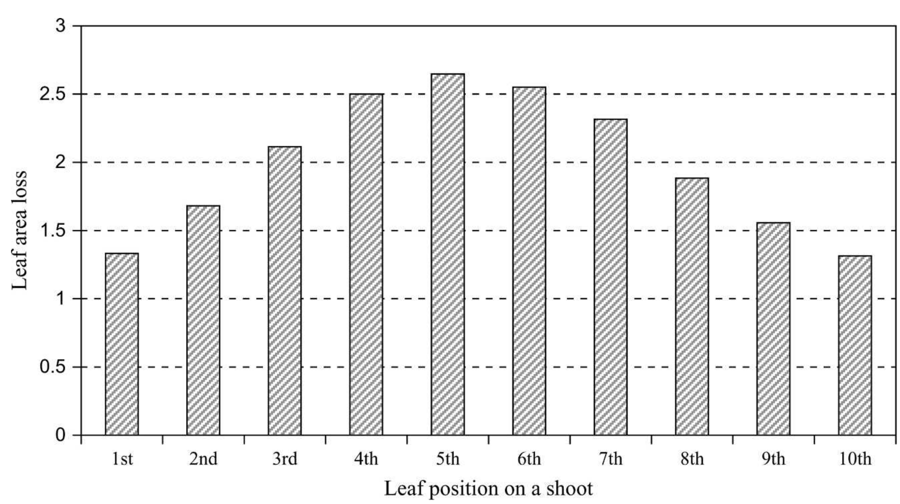

Fig. 1. Leaf area loss as a result of feeding by Japanese beetles by leaf position on individual grape shoots in cages. Leaf damage was rated as 0 pt, 0%; 1 pt, 1% to 10%; 2 pt, 11% to 20%; 3 pt, 21% to 30%; 4 pt, 31% to 40%; 5 pt, 41% to 50%; 6 pt, 51% to 60%; and 7 pt, more than 60% of estimated leaf area loss (Boucher and Pfeiffer, 1989). The youngest unfurled leaf on a shoot was named as the first leaf.

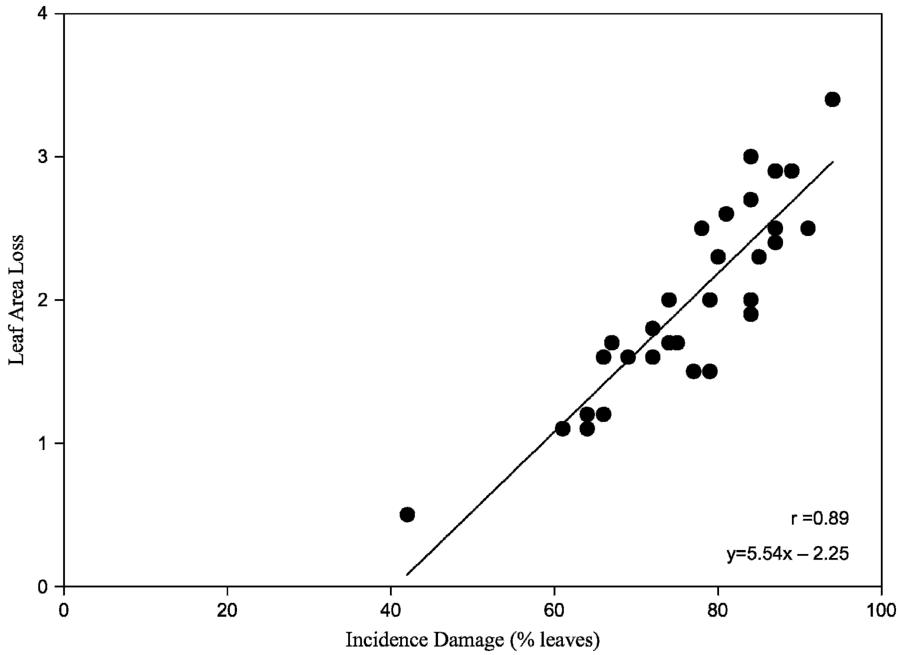

Fig. 2. The relationship between the incidence of damage and leaf area loss for 32 grape cultivars. The leaf area loss from leaves 1 (youngest) to 10 (oldest) was rated as 0 pt, 0%; 1 pt, 1% to 10%; 2 pt, 11% to 20%; 3 pt, 21% to 30%; 4 pt, 31% to 40%; 5 pt, 41% to 50%; 6 pt, 51% to 60%; and 7 pt, more than 60% of estimated leaf area loss (Boucher and Pfeiffer, 1989). Incidence damage was the percent of leaves (1–10) that had any observable damage.

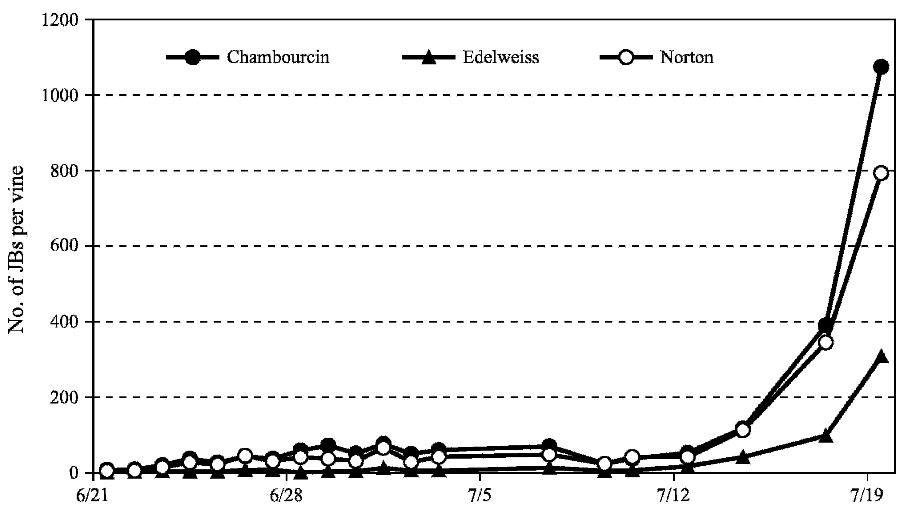

Fig. 3. Number of Japanese beetles (JBs) counted during the field choice study.

third) also displayed less damage than leaves at the fourth through sixth positions.

The Japanese beetles fed on all 32 cultivars, with an incidence of leaf damage ranging from 42% in 'Mars' to 94% in 'Vidal Blanc' (Table 1). Significant differences for the incidence of damage were found among cultivars ($P < 0.01$). The severity of Japanese beetle feeding, which was measured as LAL_{1-10}, was also different among cultivars (Table 1). The LAL_{1-10} ($P < 0.01$) ranged from 0.5 for 'Mars' to 3.4 for 'Vidal Blanc'. Genetic background of cultivars did appear to influence feeding preference of Japanese beetle. There was a high correlation between the incidence of damage and LAL for the 32 grape cultivars (Fig. 2). Generally, cultivars with an incidence of damage greater than 70% were either European or French hybrid cultivars; those with less than 70% incidence of damage were either American or American cultivars with a *V. labrusca* background.

Field choice study. Japanese beetles emerged in late June and the population gradually increased until late July (Fig. 3). From 21 June to 19 July 2006, the number of Japanese beetles per vine was always highest for 'Chambourcin' (a French hybrid cultivar) and lowest for 'Edelweiss' (an American hybrid cultivar), with 'Norton' (an American cultivar from *V. aestivalis*) in between. Statistical analysis with SAS mixed procedure for repeated measures indicated the significant main effects of time ($P < 0.01$) and cultivar ($P < 0.01$) without interaction ($P = 0.71$). The overall average number of Japanese beetles on a vine throughout the period, which was used to estimate the damage by Japanese beetles, was different among cultivars (Fig. 4). 'Chambourcin' (46 Japanese beetles/vine) had the greatest whereas 'Edelweiss' (18 Japanese beetles/vine) had the lowest number of Japanese beetles during the counting period. The average LAL for each cultivar also showed the most severe damage by Japanese beetles on 'Chambourcin' and the least damage to 'Edelweiss' (data not shown).

Discussion

The identification of commercially available grape cultivars that are not preferred by Japanese beetles would be useful to growers in developing pest control strategies that involve decreased chemical inputs. Japanese beetles fed on all the grape cultivars examined in both cage and field studies. A number of cultivars (Marquis, Reliance, Catawba, Concord Seedless, Concord, Edelweiss, 3309 Couderc, and Einset) had less than a 70% incidence of damage, can be considered as not preferred by Japanese beetles, and showed promise as selections for growers interested in reduced chemical inputs for pest management.

Langford and Cory's field observations in 1948 reported that cultivars grown at that time showed differing levels of preference by Japanese beetles. They suggested that the physical characteristics of host plant leaves could determine Japanese beetle preference. They suggested that the preferred and most attractive grape varieties were *V. vinifera*, French hybrids, and *V. aestivalis* with foliage that is thin, glossy, and tender; the frequently attacked varieties were mostly *V. labrusca* with leaves that are coarse and leathery above and tomentose or woolly below; the unattractive varieties were from *V. champini* × *V. labrusca* that have young shoots and coarse foliage covered with a tomentum. The leaf characteristics appear to be related to the genetic background of the varieties.

Generally, cultivated grapes are classified as European (*V. vinifera*), French hybrid (crosses from *V. vinifera* and one or more North American species), and American (all American species and their hybrids) cultivars. Almost every grape cultivar has a complicated *Vitis* background, which determines the combination of leaf surface characteristics. For instance, American grape cultivars could be from *V. aestivalis, V. labrusca, V. rotundifolia, V. riparia, V. rupestris*, etc., or their hybrids; whereas French hybrids could be *V. vinifera* crossed with any North American species. It is difficult to determine accurately the genetic background of a grape cultivar. There are more than 60 species in the genus *Vitis*. Both natural and artificial crossing between these species has resulted in most currently grown cultivars, which differ from one another in

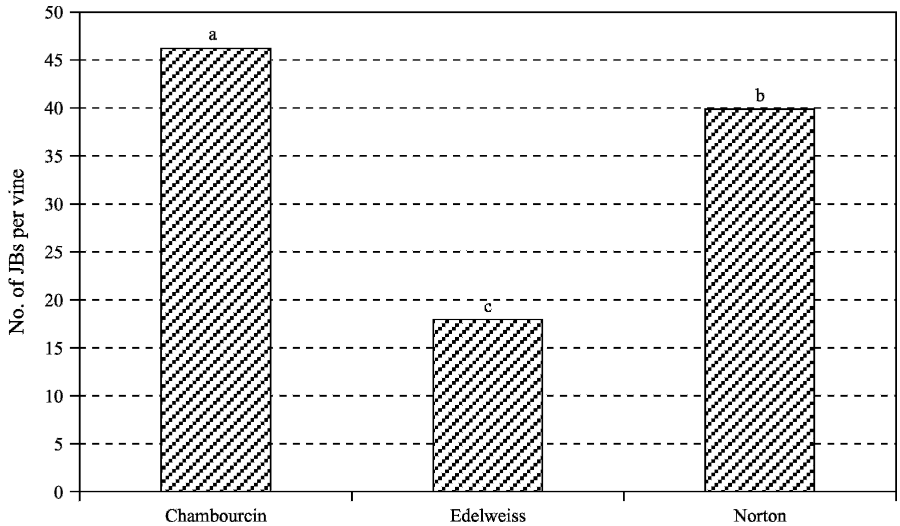

Fig. 4. Cultivar feeding preference by Japanese beetles (JBs) in the vineyard. A different letter over the column indicates mean separation by LSD at a level of significance of $P \leq 0.05$.

foliage appearance and characteristics (Galet, 1998).

Similar to the report of Langford and Cory (1948), cage and field studies in the current study indicate that the genetic background of cultivars influences the feeding preference of Japanese beetles. However, although our study supports the suggestion that grape cultivar feeding preference by Japanese beetles is determined by genetic background, leaf morphology traits (such as thin, glossy, and tender foliage for the frequently attacked cultivars and unattractive cultivars that have young shoots and coarse foliage covered with a tomentum) may be the important factors in determining Japanese beetle cultivar feeding preference (Langford and Cory, 1948; Rowe and Potter, 1996). In addition, leaves damaged by Japanese beetles release damage-induced volatiles that may possibly attract additional Japanese beetles (Loughrin et al., 1997a, b). The cultivars Delaware, Chardonnay, Norton, Cabernet Sauvignon, all classified as preferred cultivars by Langford and Cory (1948), and 'Catawba', classified as an attractive cultivar, were included in both the 1948 study and the current study. These cultivars showed a similar preference, with 'Delaware', 'Chardonnay', 'Norton', and 'Cabernet Sauvignon' all displaying more than 70% incidence of damage, and 'Catawba' with 64% incidence of damage in this study. The cultivars Marquis, Reliance, Catawba, Concord Seedless, Concord, Edelweiss, and Einset displayed less than a 70% incidence of damage in this study. The nonpreferred cultivars Mars and Edelweiss appeared to have young shoots and coarse foliage covered with a tomentum (pers. obs.), supporting the idea that this leaf morphology discourages feeding by Japanese beetles. A thorough screening of leaf characteristics was not completed in this study and should be pursued to determine whether physical leaf characteristics are actually responsible for Japanese beetle feeding preference and that preference is not based on an unobserved physiological reason (e.g., leaf volatile production). Similar feeding preferences by Japanese beetles from both cage and field choice studies for 'Edelweiss' and 'Chambourcin' suggested that Japanese beetle feeding preference in cages can be used as a basis for screening for grape cultivars that are not preferred by Japanese beetles.

In conclusion, Japanese beetles fed on all the grape cultivars examined in both cage and field studies. However, a number of table grape cultivars—Marquis, Reliance, Catawba, Concord Seedless, Concord, Edelweiss, and Einset—had less than a 70% incidence of damage, can be considered as not preferred by Japanese beetles, and show promise as selections for growers interested in reduced chemical inputs for pest management.

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