Defoliation and Infestation of *Cucurbita pepo* Genotypes by Diabroticite Beetles

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Abstract. Seventy-six *Cucurbita pepo* L. cultivars and breeding lines were evaluated under field conditions for infestation levels and defoliation (leaf area consumed by beetles) by adult diabroticite beetles in 1992 and 1994. Striped and spotted cucumber beetles, *Acalymma vittatum* (F.) and *Diabrotica undecimpunctata howardi* Barber, respectively, were most common, but some western and northern corn rootworms, *D. virgifera virgifera* LeConte and *D. barberi* Smith and Lawrence, respectively, also were present. In general, pumpkin, delicata, acorn winter squash, scallop, and yellow straightneck summer squash types were the least infested and defoliated. Caserta/yellow, zucchini, caserta/zucchini, caserta, and precocious yellow straightneck types were the most infested and defoliated. The number of beetles per plant was correlated ($r \geq 0.72$) with leaf defoliation and proportion of plants infested, indicating that beetle infestation is a good predictor of damage. The cultivars and breeding lines that were the least infested and defoliated can be used in breeding programs to develop desirable genotypes with reduced beetle preference. Conversely, those genotypes that were highly preferred have potential as trap crops for these beetle pests.

The striped and spotted cucumber beetles are important worldwide pests of many species of the Cucurbitaceae (Metcalf and Metcalf, 1992). Infestations of adult cucumber beetles can destroy young plants and vector bacterial wilt and other diseases (Gergerich et al., 1986; Rand, 1916). Two related species, the adult western corn rootworm and the northern corn rootworm, also infest cucurbits. Howe et al. (1976) and Bach (1977) reported the western corn rootworm to be the dominant species on cucurbits in the midwestern United States, and in some years it is the dominant species in New York (Hoffmann, 1993).

Because of the potential losses associated with feeding damage to emerging plants and the transmission of diseases, cucumber beetle

control typically relies on scheduled applications of insecticides, starting when beetles first appear (Cornell Cooperative Extension, 1995). The use of cultivars with reduced beetle preference could help reduce the need for insecticides.

Cucumber beetles are stimulated to feed on cucurbits by the presence of cucurbitacins, and cultivars with low levels of cucurbitacins show less beetle damage (Chambliss and Jones, 1966; Metcalf and Rhodes, 1990). However, genotypes with lower cucurbitacin content are more susceptible to spider mite infestations (Da Costa and Jones, 1971). Cucumber beetle preference studies have been summarized by Robinson (1992). Cucurbitacin levels of all cucurbits could be reduced through breeding and selection (Ferguson et al., 1983) and the development of cucurbit cultivars less preferred by beetles is a potential tool for improved management of these pests. Therefore, we evaluated 76 breeding lines and cultivars of *C. pepo* possessing desirable horticultural or disease-resistant traits for leaf defoliation and beetle infestation to identify potentially useful germplasm.

Although a highly sensitive analytical method for detecting cucurbitacins is available for laboratory screening of beetle preference (Ferguson et al., 1983; Gorski et al.,

1986), we used field evaluations of beetle damage and leaf defoliation because it was the simplest and most economical screening method available.

Materials and Methods

The genotypes used in 1992 and 1994 were selected to represent the major *C. pepo* market classes in summer squash: yellow straightneck, precocious yellow straightneck, striped (caserta type), green (zucchini type), scallop, and cocozelle; and in winter squash: acorn, jack o' lantern pumpkin, and delicata. Also included was a breeding line (G-92-730) that segregates for striped and yellow fruit (caserta/yellow type), and one (G-92-622) that segregates for striped and green fruit (caserta/zucchini type). Cornell Univ. squash breeding lines were included from the Geneva (R. Robinson) and Ithaca (M. Kyle) breeding programs, selected to represent a broad range of fruit types (Tables 1 and 2). Much of the breeding work at both locations has involved interspecific crosses to bring in virus resistance [*C. moschata* (Duchesne) Poir., *C. ecuadorensis* Cutler & Whitaker, and *C. martinii* Bailey] and powdery mildew resistance (*C. martinii*), thus the pedigrees of these lines are complex. The progenitor species are provided for each breeding line, but in most cases, considerable selection through generations of inbreeding and backcrossing has occurred so the lines generally resemble *C. pepo* types and are predominantly derived from this species.

In 1992, 36 *C. pepo* genotypes were evaluated for preference (as reflected by beetle infestation per plant and leaf defoliation) by striped cucumber beetle. Genotypes were seeded on 17 June into 50-cell flats containing Promix BX (Premier Brands, Yonkers, N.Y.) in a greenhouse maintained at $\approx 28^{\circ}\text{C}$, except as noted below. Flats were transferred to a cold frame 10 days later where they remained until transplanting. On 1 July, when plants had one or two true leaves, they were transplanted to field plots. The soil type was fine, illitic, mesic, Aeric, Epiaqualf [U.S. Dept. of Agriculture (USDA), 1994]. A complete commercial fertilizer, 13N–13P–13K, was banded in the field row on 30 June at a rate of 337 kg·ha⁻¹. No pesticides were applied at any time during the study.

Because cucurbitacin content can change rapidly with seedling development (Jaworski et al., 1985), evaluations of preference by cucumber beetles were conducted as early as possible. Since emergence rates vary among field-grown genotypes, those emerging earlier can incur more beetle damage than those emerging later. To minimize this potential bias, transplant size was standardized by placing the more rapidly developing seedlings under slightly cooler greenhouse conditions (20°C) to retard growth.

A randomized complete-block design was used with five replications per genotype. Each replication consisted of a single row of five hills spaced 0.91 m apart. Rows were spaced 1.83 m apart. The hills were thinned to one

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plant each 4 days after transplanting, resulting in a total of 25 plants for each genotype.

On 15–16 and 22–23 July, when plants had two to three and four to five true leaves, respectively, all plants in every plot were inspected and the number of striped and spotted cucumber beetles per plant were recorded separately. In addition, the extent of defoliation (leaf area consumed by beetles) of each leaf of every plant was rated on a scale of 0 to 5 (0 = 0%, 1 = greater than or equal to 1% ≤ 20%, 2 = greater than or equal to 20% ≤ 40%, 3 = greater than or equal to 40% ≤ 60%, 4 = greater than or equal to 60% ≤ 80%, 5 = greater than or equal to 80% ≤ 100% defoliation). Average leaf defoliation ratings were calculated for each plant and averaged across replications.

In 1994, 40 *C. pepo* genotypes were evaluated. Seeding was conducted as in 1992, but delayed until 28 July to improve chances for increased beetle populations in the field. Transplants were handled and fertilized as described for 1992. On 11 Aug., seedlings at the first true-leaf stage were transplanted to field plots. The soil type was loamy-skeletal, mixed, mesic, Glossoboric, Hapludalf (USDA, 1994). No pesticides were applied following transplanting. The experimental design was as in 1992. All plants were inspected on 22–23 Aug. and 2 Sept., when plants had one to two and four to five true leaves, respectively, and the number of corn rootworm and cucumber beetles per plant and extent of defoliation of each plant were recorded as in 1992.

Genotypes were divided into groups according to fruit types, for purposes of statistical analyses. Analysis of variance (ANOVA) was conducted to determine if differences existed in number of beetles/plant, proportion of infested plants, and defoliation ratings between and within fruit types. Means were separated using LSD at $P \leq 0.05$. In 1992, a repeated-measure ANOVA was used to analyze differences among fruit types in beetle infestation and defoliation and for interaction with date. In 1994, only data from 22 to 23 Aug. were analyzed because beetle counts were extremely low on 2 Sept. To determine if defoliation ratings, proportion of infested plants, and number of beetles/plant were correlated, we conducted linear correlation analysis.

Table 1. Infestation and defoliation of *Cucurbita pepo* cultivars and breeding lines by striped cucumber beetle (Freeville, N.Y., 1992).

Fruit type	Line/cultivar	Rating date					
		15–16 July			22–23 July		
		Beetles/plant (no.)	Infested plants (%)	Defoliation rating ^z	Beetles/plant (no.)	Infested plants (%)	Defoliation rating ^z
Scallop	Scallop	0.48 ^{ns}	28 ^{ns}	0.51 ^{ns}	0.32 ^{ns}	20 ^{ns}	0.49 ^{ns}
	Peter Pan	0.88	40	0.46 a	0.36	28	0.39
	Type mean ^y	0.68 a ^x	34 a	0.48 a	0.34 a	24 ab	0.44 a
Acorn	Royal Acorn	0.76 a	28 a	0.53 a	0.20 a	20 a	0.35 a
Yellow straightneck	Slender Gold	0.21 ^{ns}	21 a ^w	0.43 a	0.38 a	16 a	0.41 a
	Gold Bar	0.48	24 ab	0.50 a	0.48 a	24 ab	0.48 ab
	Yellow crookneck	0.64	24 ab	0.46 a	0.48 a	32 ab	0.53 ab
	I-91-575-1 ^v	0.80	40 ab	0.83 b–d	0.88 a	36 ab	0.73 b
	Early Prolific straightneck	1.48	32 ab	0.67 a–c	0.60 a	24 ab	0.57 ab
	Sundance						
	crookneck	1.64	48 a–c	0.60 ab	1.36 a	40 ab	0.62 ab
	G-92-341 ^u	2.28	76 c	1.06 d	3.24 b	76 c	1.45 c
	I-91-511-1R	2.56	52 bc	0.89 cd	1.36 a	48 bc	0.77 b
	Type mean	1.26 ab	40 a	0.68 a	1.10 ab	37 a–c	0.70 a
	G-92-730 ^u	3.01 a–c	68 b	1.16 b	1.46 a–c	48 b–d	1.47 b
Caserta/yellow	G-92-622	3.04 a–c	76 b	1.50 c	2.68 b–d	76 e	1.62 bc
Zucchini	I-91-504-2L	1.00 ^{ns}	32 ^{ns}	0.81 ab	1.92 ^{ns}	48 ^{ns}	1.02 ab
	I-91-576-1	1.68	48	0.76 a	0.84	40	0.84 a
	G-92-330 ^u	2.12	48	1.31 cd	1.44	48	1.22 a–c
	Black Jack	2.52	72	1.10 b–d	2.84	44	1.38 b–d
	G-92-309	2.56	64	1.28 cd	3.16	44	1.51 b–d
	I-91-513	2.65	70	1.12 b–d	3.92	60	1.44 b–d
	G-92-563	2.68	60	1.15 cd	2.76	48	1.89 d
	G-92-327 ^u	3.00	68	1.04 a–c	1.92	40	1.45 b–d
	Ambassador	3.08	60	1.01 a–c	1.40	32	1.41 b–d
	G-92-627	3.24	76	1.40 de	3.92	64	1.77 d
	Senator	3.64	64	1.18 cd	2.36	60	1.64 cd
	President	4.28	82	1.27 cd	0.82	36	1.56 cd
	Dark Green	4.40	72	1.32 cd	2.88	56	1.67 cd
	Embassy Green	5.32	72	1.07 a–c	2.92	52	1.23 a–c
	G-92-306	5.56	64	1.24 cd	1.76	52	1.45 b–d
	G-92-322	5.82	88	1.68 e	4.04	79	2.58 e
	Type mean	3.32 bc	65 b	1.17 b	2.43 b–d	50 cd	1.50 b
	G-92-562	2.52 ^{ns}	64 ^{ns}	0.99 a	3.68 ab	48 ^{ns}	1.02 a
	Cocozelle	3.32	60	1.16 ab	1.88 a	64	1.26 a
	G-92-572	3.60	72	1.55 c	2.12 a	64	2.69 c
	I-91-507	3.60	76	1.33 bc	1.28 a	40	1.59 ab
	Caserta	5.20	76	1.37 bc	5.68 b	80	2.63 c
	G-92-624	6.52	83	1.54 c	5.94 b	84	2.05 b
	Type mean	4.12 c	72 b	1.33 bc	3.43 d	63 de	1.87 c
Precocious yellow straightneck	Gold Rush	7.44 d	88 b	1.34 bc	3.00 cd	76 e	1.79 bc

^zBased on leaf area consumed by beetles, rated on a scale of 0–5 (0 = 0%, 1 = greater than or equal to 1% ≤ 20%, 2 = greater than or equal to 20% ≤ 40%, 3 = greater than or equal to 40% ≤ 60%, 4 = greater than or equal to 60% ≤ 80%, 5 = greater than or equal to 80% ≤ 100% defoliation).

^yMean of all breeding lines, cultivars, or both within a fruit type.

^xMean separation of fruit types by LSD test, $P \leq 0.05$, shown in italics.

^wMean separation of cultivars and breeding lines within a fruit type by LSD test, $P \leq 0.05$, not italicized.

^vBreeding line progenitor species are *C. martinii* × *C. pepo*, unless otherwise indicated. “G” and “I” prefixes indicate breeding programs at Geneva and Ithaca.

^uBreeding line progenitor species are *C. ecuadorensis* × *C. pepo*.

^{ns}Nonsignificant.

Table 2. Infestation and defoliation of *Cucurbita pepo* cultivars and breeding lines by cucumber and corn rootworm beetles (Freeville, N.Y., 1994).

Fruit type	Line/cultivar	Beetles/plant (no.)	Infested plants (%)	Defoliation rating ^z
Acorn	Royal Acorn	0.04 a ^y	4 a	0.20 a
Pumpkin	I-93-2028 ^x	0.00 ^{ns}	0 ^{ns}	0.06 ^{ns}
	I-93-2024	0.08	8	0.16
	Type mean ^w	0.04 a	4 a	0.11 a
Delicata	I-92-581-4	0.12 a	12 a	0.12 a
Yellow straightneck	I-93-238	0.04 a ^v	4 ^{ns}	0.26 a
	I-93-239-R	0.04 a	4	0.04 a
	G-94-186 ^u	0.08 a	8	0.24 a
	G-94-31 ^u	0.76 b	29	1.22 b
	Type mean	0.23 ab	11 a	0.44 a
Zucchini	G-94-113 ^u	0.12 ^{ns}	12 ^{ns}	0.22 a
	G-94-40 ^u	0.20	20	0.14 a
	G-94-53 ^u	0.20	20	0.34 ab
	G-94-25 ^u	0.28	28	1.26 c-e
	G-94-85 ^u	0.36	20	1.18 cd
	Black Jack	0.44	27	1.60 c-f
	G-94-434	0.44	16	1.12 bc
	G-94-177 ^u	0.44	32	1.72 c-f
	G-94-23 ^u	0.48	40	2.02 ef
	G-94-117 ^u	0.50	31	1.78 c-f
	G-94-114 ^u	0.50	35	1.16 bc
	G-94-12 ^u	0.52	34	1.86 c-f
	G-94-430	0.52	43	2.04 ef
	G-94-484	0.60	56	2.28 f
	G-94-164 ^u	0.68	32	1.82 c-f
	G-94-10 ^u	0.72	30	2.02 ef
	G-94-481	0.80	64	1.76 c-f
	G-94-91 ^u	0.80	40	1.56 c-f
	G-94-29 ^u	0.86	53	1.22 c-e
	G-94-21 ^u	0.88	40	1.86 c-f
Caserta	I-93-2005	1.06	35	1.38 c-e
	I-93-2006	1.14	34	1.80 c-f
	G-94-80 ^u	1.24	52	1.16 bc
	G-94-146 ^u	1.38	92	2.00 d-f
	Type mean	0.62 ab	37 b	1.47 bc
	G-94-431	0.04 a	4 a	0.34 a
	G-94-424	0.52 ab	29 b	0.90 ab
	G-94-466	0.56 ab	32 b	1.24 a-c
	G-94-446	0.56 ab	44 bc	1.44 bc
	I-93-2009	1.06 a-c	40 bc	1.28 a-c
Precocious yellow straightneck	I-93-2007	1.54 bc	75 d	1.92 c
	I-93-2008	1.80 c	56 cd	1.84 bc
	Type mean	0.87 b	40 b	1.28 b
	G-94-77 ^u	0.54 a	27 a	1.34 a
	G-93-633	2.68 b	57 b	2.78 b
	Type mean	1.61 c	42 b	2.06 c

^zBased on leaf area consumed by beetles, rated on a scale of 0–5 (0 = 0%, 1 = greater than or equal to 1% ≤ 20%, 2 = greater than or equal to 20% ≤ 40%, 3 = greater than or equal to 40% ≤ 60%, 4 = greater than or equal to 60% ≤ 80%, 5 = greater than or equal to 80% ≤ 100% defoliation).

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^wMean of all breeding lines, cultivars, or both within a fruit type.

^vMean separation of cultivars and breeding lines within a fruit type by LSD test, $P \leq 0.05$, not italicized.

^uBreeding line progenitor species are *C. ecuadorensis* × *C. pepo*.

^{ns}Nonsignificant.

ses using the mean values of five replications of each genotype.

Results and Discussion

In 1992, >99% of all beetles recorded were striped cucumber beetles; the balance were spotted cucumber beetles. Repeated-measures ANOVA indicated a significant date × fruit type interaction for beetles/plant and defoliation ratings ($F = 3.21$, $df = 7,32$, $P = 0.011$ and $F = 3.90$, $df = 7,32$, $P = 0.004$, respectively) in 1992 (data not presented). Therefore, results

for the two dates are reported separately. The date × fruit type interaction for beetles/plant was probably due to an unequal decrease in beetles/plant among types on 15–16 July compared to 22–23 July. The date × fruit type interaction for defoliation ratings likely is due to an increase in damage from 15 to 16 to 22 to 23 July in fruit types most defoliated on 15–16 July, compared to little or no change in damage in fruit types least defoliated on 15–16 July. Ranking of fruit types was similar for both 1992 dates (Table 1).

On 15–16 July 1992, the precocious yellow

low straightneck fruit type, represented by ‘Gold Rush’, had the most striped cucumber beetles (Table 1). On 22–23 July, differences among fruit types were less distinct, with caserta/zucchini, zucchini, caserta, and precocious yellow straightneck having more beetles than other types. Scallop and acorn fruit types generally had fewer beetles on both dates. Caserta/yellow, caserta/zucchini, zucchini, caserta, and precocious yellow straightneck fruit types were the most defoliated on 15–16 and 22–23 July, while scallop, acorn, and yellow straightneck types were the least defoliated.

In 1994, beetle counts taken from all *Cucurbita* were pooled for analyses because there were few of some species. Of 580 beetles recorded, 75% were spotted cucumber beetle, 13% were western corn rootworm, 7% were striped cucumber beetle, and 5% were northern corn rootworm. The presence of spotted cucumber beetles and corn rootworms in 1994 was due to the later planting date (Hoffmann, 1993). The precocious yellow straightneck type had the most beetles and the most defoliation (Table 2); however, this type was represented by only two breeding lines (G-94-77 and G-93-633). The least defoliated types were pumpkin, delicata, acorn, and yellow straightneck.

In 1992 and 1994, significant differences in defoliation by beetles existed within yellow straightneck, zucchini, and caserta fruit types, indicating that genetic variation for cucumber beetle preference within these fruit types exists (Tables 1 and 2). In general, beetle defoliation and infestation of fruit types was similar between years even though the dominant beetle species was striped cucumber beetle in 1992 and spotted cucumber beetle in 1994.

For each of the three dates plants were sampled, there were significant positive linear correlations between percentage of infested plants and beetles/plant ($r \geq 0.77$), percentage of infested plants and defoliation ratings ($r \geq 0.78$), and defoliation ratings and beetles/plant ($r \geq 0.72$) ($df = 34$ in 1992, 38 in 1994, $P < 0.001$). The positive correlation between these three variables indicates that beetle populations are a good predictor of defoliation and proportion of plants infested.

Our data indicate that precocious yellow, caserta, zucchini, caserta/zucchini, and caserta/yellow fruit types were the most infested and defoliated fruit types. In general, zucchini has higher cucurbitacin levels than other fruit types (Ferguson et al., 1983), and our results indicate that the caserta and precocious yellow fruit type also may possess high cucurbitacin levels. However, fruit type is not necessarily associated with cucurbitacin levels or beetle preference, since genes that determine fruit type have been bred into various genetic backgrounds showing wide variation in beetle preference.

Some genotypes were highly preferred by cucumber beetles in both years and have the potential to be used as trap crops. This tactic, which has been recommended for many years (Headlee, 1908), holds great potential because aggregation is greatest on preferred genotypes

(Metcalf et al., 1982) and beetles are unlikely to disperse once established on plants (Bach 1989). Radin and Drummond (1994) reported promising results when a squash trap crop was used to manage striped cucumber beetles in cucumber. An additional advantage may be achieved by planting the trap crop earlier than the main crop. Our data indicate that early plantings of cucumbers have higher levels of infestation than ones emerging only a few days later.

The germplasm identified in this study may be used for reducing pesticide use in cucurbits through the development of cultivars with disease and insect resistance. A range of preferences by diabroticite beetle pests in squash has been quantified that can be used to minimize crop damage through reduced preference or through manipulation of beetle infestations (trap crops).

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