Nonpreference Among Gerbera Cultivars by the Leafminer *Liriomyza trifolii* (Agromyzidae: Diptera)[1]

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Abstract

The leafminer, *Liriomyza trifolii* (Burgess) is a key pest of gerbera daisies (*Gerbera jamesonii* Bolus), which are among the most preferred cut flowers in the world. While insecticides often fail to control this pest, parasitoids have proven to be effective. To maintain the parasitoids in the system, pesticide applications should be avoided. However, the influx of secondary pests like mites, thrips, whiteflies, and aphids during the growing season necessitates chemical sprays, which are effective in controlling the secondary pests, but are often toxic to the natural enemy and hence disrupt biological control. Since chemicals are not easily avoided in this system, an alternative method to avoid leafminers was sought, using host plant resistance, which can be an important component of integrated pest management (IPM) programs. Sixty gerbera cultivars were evaluated for potential resistance to *L. trifolii*. A range in susceptibility measured as leaf punctures and developing mines was evident for the first five weeks of a six-week exposure period. Gerberas 'Jaguar Pink', 'Jaguar Rose Deep', 'Jaguar Salmon Pastel', and 'Revolution Spring Pastel' were the least damaged, exhibiting less than 20% of the highest damage on at least two observation dates. However, consistent exposure to high numbers of leafminers resulted in similar expression of damage among all cultivars after five weeks. Differences among cultivars in force required to puncture leaves could not be consistently associated with damage due to leafminers

Index words: host plant resistance; Gerbera, leafminers.

Species used in this study: 60 cultivars of *Gerbera jamesonii.*

Significance to the Nursery industry

Gerbera daisies are the third most preferred cut flowers in the world, and increasing in demand in the United States. The lack of cost-effective options to control the complex of primary and secondary pests, however, impedes development of a sustainable production system. Anecdotal evidence indicated variable infestation among gerbera cultivars by the primary pest leafminer, *Liriomyza trifolii*. A range in susceptibility among 60 cultivars was observed, suggesting that early and heavily infested plants could serve as early indicator plants, while those that were initially less preferred may provide some benefit in an IPM program. Gerberas 'Jaguar Pink', 'Jaguar Rose Deep', 'Jaguar Salmon Pastel', and 'Revolution Spring Pastel' were the least damaged initially. All cultivars evaluated, however, eventually became equally damaged when in the presence of high populations of leafminers for five weeks.

Introduction

The primary pests affecting greenhouse gerberas are serpentine leafminers, *Liriomyza trifolii* (Burgess) (Diptera: Agromyzidae), which have a wide distribution and attack more than 400 species (14) of plants including vegetables and ornamentals. The larvae feed on the palisade mesophyll (13) and decrease photosynthesis and yield, directly affecting the marketable produce. Rigorous and extended use of pesticides has rendered leafminers resistant to almost all chemistries (7). Leafminers are also protected from chemicals by being concealed within the leaves in their larval stages. Successful biocontrol has been achieved using augmentative releases of parasitoids. This has, however, been effective in areas only where disruptive use of chemicals have been avoided (8).

The influx of secondary pests like mites, thrips, whiteflies, aphids, and pathogens causing powdery mildew through the season necessitate pesticide sprays, which in turn, kill the leafminer parasitoids. Insecticide toxicology assays demonstrated that many of the commonly used pesticides (against secondary pests) cause high mortality in beneficial arthropods (leafminer parasitoid *Diglyphus isaea* (Walker) and the predatory mite *Neoseiulus californicus* (McGregor)) and hence disrupt effective pest management (1). While pesticides are not effective against leafminers, they certainly are detrimental to the effective buildup of natural enemy populations. Host plant resistance could avoid the pest, reducing the need for chemical intervention.

Host plant resistance studies in vegetables have identified effective mechanisms against leafminers. The narrow leaf architecture in celery (15), trichomes and acyl sugars (within the trichomes) in wild tomatoes (5), and jasmonic acid sprays in celery (3) have all successfully reduced leafminer damage/host feeding. However, similar studies in ornamentals or cut flowers are lacking. Resistance could be an innate function of the plant through the chemical contents within the leaf (3), or a function of the toughness of leaf as found to deter lace bugs (10). Even partial resistance could supplement biological control and work synergistically to control leafminer pests (17).

In this unique system, while pesticides work against secondary pests, they disrupt biological control of the primary pest. IPM can provide an effective solution for gerberas. Finding a successful host plant resistance mechanism would assist in designing an IPM protocol. A successful IPM program would control leafminers, the primary pest, through host plant resistance, natural enemies, or a combination of both,

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and utilize pesticides compatible with biological control to manage the secondary pests and pathogens.

Materials and Methods

Plant material. Seeds of 60 gerbera cultivars (*Gerbera jamesonii*, Ball® horticultural company, West Chicago, IL, see Table 1) were germinated in a commercial facility (Speedling® Inc., Blairsville, GA). Seeds were planted in cell packs (128 cells/tray) filled with Fafard super fine germinating mix (Agawam, MA) and, after being watered lightly, kept in the germination chamber at 23.9C (75F) and 80–100% relative humidity until complete germination was achieved a week later. When plants were well rooted after 7 wks, they were transplanted into larger cell packs (36 cells/tray) and housed in a greenhouse on the UGA-Griffin campus.

Greenhouse choice study. Sixty gerbera cultivars were evaluated for leafminer feeding or oviposition, and subsequent development in a greenhouse choice study. A randomized complete block design with 10 replications for each of the 60 cultivars was employed in the experiment. Each plant was an experimental unit. All the plants were exposed to high leafminer pressure for 72 hr at a commercial greenhouse and then returned to the UGA-Griffin campus facility. High leafminer pressure was maintained by 2 biweekly introductions, each an excess of 500 *L. trifolii* captured from other greenhouses on the UGA-Griffin Campus and grower greenhouses in Thomaston, GA. Data collection began 48 hr after relocation to UGA-Griffin campus. Data included the numbers of stings (puncture marks caused by egg laying or feeding by the leafminer) and the number of mines (silver patterns characterized by the lack of chlorophyll due to the feeding and development of the leafminer larva within the leaf) found in a 15 cm^2 area of each of 3 upper leaves on the plant (non-destructive sampling). Data were collected weekly on each of the 600 experimental units from May 11 to June 15, 2011. Age of larvae was not assessed during the study.

Penetrometer study. From the results of the greenhouse experiments, 15 cultivars were selected from among 4 categories: high number of stings and mines (cultivar #2, 53, 28, 39), medium number of stings and high number of mines (cultivar #40, 49, 35), high number of stings and low number of mines (cultivar #16, 56), low number of stings and mines (cultivar #5, 7, 30, 50, 55, 57). *L. trifolii* oviposition is exclusively through the dorsal side of the leaf while other leafminer species use a combination of dorsal and ventral side or exclusively one side also (2, 11, 12). Using a penetrometer force gauge (Chatillon DFX-010-NIST Digital Force Gauge), the force required (in newtons) to penetrate the dorsal side of the leaf was assessed. Ten observations each from 3 similarly aged leaves for each cultivar were taken, equaling 30 observations for each cultivar. Each leaf was placed on a stage attached to the force gauge and the pointed portion of the instrument was lowered according to prescribed operating procedures between leaf veins and observations recorded.

Statistical analyses. Data were subjected to analysis of variance (ANOVA) using the general linear model procedure (SAS Institute 2003, Cary, NC). Means in both studies were separated using Tukey's HSD test at α = 0.05. Data from the penetrometer study were further subjected to a correlation analysis using PROC CORR (SAS Institute 2003, Cary, NC) to determine if leaf damage had a correlation with leaf toughness or lack thereof.

Table 1. Gerbera cultivars evaluated for leafminer *L. trifolii* preference.

Cultivar #	Cultivar name
1	Jaguar Fire
2	Jaguar Fire Dark Eye
3	Jaguar Orange Deep
4	Jaguar Orange Picotee
5	Jaguar Pink
6	Jaguar Red
7	Jaguar Rose Deep
8	Jaguar Rose Picotee
9	Jaguar Salmon Pastel
10	Jaguar Scar Shade Dark Eye
11	Jaguar tangerine
12	Jaguar White
13	Jaguar Yellow
14	Jaguar Yellow Dark Eye
15	Royal Mix
16	Royal Semi-Double Pink Dark Eye
17	Royal Semi-Double Vanilla Dark Eye
18	Royal Semi-Double Watermelon Dark Eye
19	Durora Mini-Double Mix
20	Festival Apricot
21	Festival Apricot Dark Eye
22	Festival Cream
23	Festival Mix Dark Eye
24	Festival Peach Dark Eye
25	Festival Pink Shade Dark Eye
26	Festival Red Dark Eye
27	Festival Salmon
28	Festival Salmon Orange Shade
29	Festival Scarlet Dark Eye
30	Festival White Shade
31	Festival Yellow Lemon
32	Festival Mini Orange Shade
33	Festival Mini Pink Soft
34	Festival Mini Pastel Deep Shade
35	Festival Mini Yellow Shade
36	Mini Revolution Mix
37	Festival Semi-Double Orange Shade
38	Festival Semi-Double Rose Shade
39	Festival Semi-Double Yellow
40	Festival Spider Salmon Eye
41	Festival Spider Yellow
42	Kameleo Micro Mix
43	Mega Revolution Champagne
44	Mega Revolution Golden Yellow Dark Eye
45	Mega Revolution Orange Dark Eye
46	Mega Revolution Purple Shade
47	Mega Revolution Scarlet Dark Eye
48	Mega Revolution White
49	Mega Revolution Yellow Shade
50	Revolution Pink
51	Revolution Pink Baby
52	Revolution Pink Pastel Dark Eye
53	Revolution Red Shade Dark Eye
54	Revolution Rose Shade
55	Revolution Pastel Orange Dark Eye
56	Revolution Scarlet Dark Eye
57	Revolution Spring Pastels
58	Revolution White
59	Revolution Yellow
60	Yellow Dark Eye

Results and Discussion

Greenhouse choice study. Even though mines in several plants were absent during the first week, all plants in the study sustained oviposition or feeding punctures at that point (Tables 2 and 3). Numbers of punctures and mines varied by cultivar, but were not always consistent from week to week. Trends were identified indicating differential susceptibility among cultivars. While no cultivars were immune to *L. trifolii*, 'Gerbera Jaguar Pink' (cultivar #5), 'Gerbera

Table 2. Mean ± SE number of *L. trifolii* oviposition and feeding leaf punctures per gerbera plant by cultivar.

Cultivar	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Jaguar Fire	28.5 ± 5.41af	14.8 ± 4.07a	25.3 ± 6.31ac	19.6 ± 4.24ab	20.7 ± 7.23ad	19.4 ± 4.07ab
Jaguar Fire Dark Eye	47.8 ± 8.32a	32.0 ± 3.42a	36.7 ± 9.66ac	46.0 ± 8.29ab	38.5 ± 13.17ad	26.5 ± 3.43ab
Jaguar Orange Deep	13.6 ± 4.08cf	12.5 ± 3.62a	22.2 ± 4.10ac	27.4 ± 5.83ab	29.7 ± 7.61ad	18.9 ± 5.35ab
Jaguar Orange Picotee	24.4 ± 5.46af	24.6 ± 4.22a	15.2 ± 4.53ac	16.7 ± 5.88b	17.5 ± 4.89ad	16.6 ± 6.29ab
Jaguar Pink	13.7 ± 3.58cf	10.4 ± 3.62a	12.5 ± 1.15ac	20.2 ± 4.78ab	22.8 ± 3.46ad	2.9 ± 1.16b
Jaguar Red	38.6 ± 6.64ae	18.0 ± 4.42a	33.7 ± 6.04ac	28.2 ± 6.06ab	37.9 ± 4.60ad	29.1 ± 4.53ab
Jaguar Rose Deep	9.4 ± 2.38ef	7.0 ± 2.96a	9.6 ± 4.37bc	15.8 ± 7.31b	4.9 ± 1.60d	16.8 ± 8.02ab
Jaguar Rose Picotee	6.6 ± 2.34f	9.3 ± 2.69a	13.4 ± 3.19ac	15.8 ± 3.53b	9.0 ± 3.21cd	7.6 ± 3.18ab
Jaguar Salmon Pastel	16.1 ± 3.07bf	12.9 ± 3.76a	13.5 ± 3.61ac	12.3 ± 2.91b	15.8 ± 5.00bd	15.8 ± 3.37ab
Jaguar Scar Shade Dark Eye	15.1 ± 3.70cf	19.0 ± 3.79a	31.3 ± 8.14ac	30.6 ± 8.06ab	33.9 ± 10.51ad	22.1 ± 4.83ab
Jaguar tangerine	29.0 ± 6.15af	16.1 ± 2.76a	31.5 ± 6.53ac	32.6 ± 6.06ab	23.1 ± 4.36ad	15.9 ± 3.54ab
Jaguar White	19.7 ± 7.19af	18.4 ± 6.05a	18.0 ± 5.43ac	28.5 ± 7.73ab	21.6 ± 4.85ad	13.4 ± 3.99ab
Jaguar Yellow	37.7 ± 8.60ae	24.7 ± 4.21a	29.2 ± 3.98ac	26.3 ± 4.77ab	16.5 ± 2.83bd	14.8 ± 2.98ab
Jaguar Yellow Dark Eye	15.5 ± 3.88cf	12.1 ± 3.84a	23.8 ± 5.59ac	14.7 ± 3.96b	17.8 ± 5.34ad	11.8 ± 2.59ab
Royal Mix	18.4 ± 2.13af	18.4 ± 3.59a	21.3 ± 6.27ac	14.5 ± 4.44b	20.6 ± 4.48ad	16.1 ± 3.56ab
Royal Semi-Double Pink Dark Eye	13.0 ± 2.63cf	22.7 ± 3.54a	24.6 ± 3.22ac	41.7 ± 10.03ab	51.1 ± 10.14a	27.3 ± 11.04ab
Royal Semi-Double Vanilla Dark Eye	25.7 ± 5.74af	20.7 ± 3.34a	31.6 ± 6.92ac	29.9 ± 5.63ab	21.4 ± 4.32ad	22.9 ± 7.32ab
Royal Semi-Double Watermelon Dark Eye	27.1 ± 3.41af	29.0 ± 7.39a	19.3 ± 4.20ac	33.8 ± 7.80ab	20.9 ± 3.46ad	31.7 ± 6.88ab
Durora Mini-Double Mix	32.6 ± 10.02af	19.0 ± 4.31a	13.0 ± 2.85ac	22.4 ± 4.56ab	16.4 ± 3.41bd	15.1 ± 4.16ab
Festival Apricot	22.4 ± 5.60af	33.2 ± 10.61a	31.6 ± 4.38ac	27.7 ± 5.75ab	25.6 ± 9.11ad	36.3 ± 11.60a
Festival Apricot Dark Eye	10.7 ± 2.54df	12.2 ± 3.75a	7.8 ± 1.73c	15.4 ± 2.08b	19.9 ± 3.92ad	13.1 ± 3.83ab
Festival Cream	40.3 ± 8.20ad	30.9 ± 5.55a	26.7 ± 8.81ac	42.2 ± 8.59ab	25.2 ± 7.53ad	16.6 ± 3.83ab
Festival Mix Dark Eye	23.5 ± 5.95af	17.2 ± 5.44a	23.2 ± 4.54ac	28.6 ± 6.42ab	26.7 ± 4.23ad	28.8 ± 6.45ab
Festival Peach Dark Eye	12.4 ± 2.81cf	12.7 ± 3.47a	15.8 ± 3.95ac	17.0 ± 3.68b	29.2 ± 5.07ad	14.3 ± 3.44ab
Festival Pink Shade Dark Eye	26.0 ± 6.76af	21.5 ± 4.64a	31.5 ± 8.22ac	49.3 ± 12.01ab	29.1 ± 8.12ad	25.0 ± 5.21ab
Festival Red Dark Eye	14.4 ± 1.75cf	10.2 ± 2.49a	24.3 ± 7.63ac	35.1 ± 6.88ab	26.6 ± 4.54ad	15.0 ± 3.63ab
Festival Salmon	22.0 ± 3.63af	22.4 ± 5.66a	16.9 ± 5.71ac	29.4 ± 6.56ab	26.3 ± 6.46ad	12.5 ± 2.42ab
Festival Salmon Orange Shade	23.5 ± 4.51af	8.8 ± 2.61a	19.7 ± 5.66ac	57.5 ± 16.57a	44.3 ± 9.40ab	16.8 ± 3.21ab
Festival Scarlet Dark Eye	23.7 ± 5.06af	22.5 ± 6.23a	17.3 ± 3.74ac	28.8 ± 7.89ab	17.6 ± 3.83ad	19.2 ± 4.15ab
Festival White Shade	46.5 ± 7.23ab	33.1 ± 2.55a	23.8 ± 2.12ac	24.4 ± 5.00ab	21.2 ± 7.07ad	17.7 ± 4.58ab
Festival Yellow Lemon	31.5 ± 4.81af	18.1 ± 3.77a	27.7 ± 4.64ac	30.5 ± 6.62ab	26.4 ± 6.65ad	30.3 ± 5.40ab
Festival Mini Orange Shade	28.0 ± 4.50af	30.2 ± 6.25a	31.3 ± 10.09ac	44.5 ± 7.45ab	33.4 ± 5.26ad	15.5 ± 4.09ab
Festival Mini Pink Soft	22.8 ± 3.70af	20.1 ± 3.70a	24.0 ± 5.80ac	22.6 ± 4.97ab	31.0 ± 6.20ad	20.1 ± 2.70ab
Festival Mini Pastel Deep Shade	35.2 ± 6.48af	23.6 ± 5.41a	24.2 ± 5.31ac	29.7 ± 6.05ab	16.6 ± 3.90bd	11.7 ± 2.61ab
Festival Mini Yellow Shade	42.7 ± 8.57ac	19.2 ± 4.79a	16.7 ± 2.66ac	19.0 ± 3.07ab	23.6 ± 7.37ad	10.6 ± 2.13ab
Mini Revolution Mix	23.6 ± 5.41af	23.3 ± 5.11a	30.5 ± 6.16ac	26.4 ± 5.32ab	28.8 ± 7.99ad	23.0 ± 5.21ab
Festival Semi-Double Orange Shade	38.5 ± 6.68ae	28.5 ± 4.17a	43.2 ± 4.77a	37.1 ± 8.16ab	27.0 ± 4.67ad	22.1 ± 2.57ab
Festival Semi-Double Rose Shade	26.9 ± 5.60af	21.4 ± 4.19a	41.0 ± 9.56ab	35.2 ± 6.70ab	33.4 ± 3.97ad	30.3 ± 5.31ab
Festival Semi-Double Yellow	35.1 ± 5.83af	26.0 ± 5.10a	40.8 ± 8.79ab	50.4 ± 8.74ab	41.8 ± 7.29ac	30.9 ± 6.05ab
Festival Spider Salmon Eye	29.8 ± 5.01af	24.0 ± 4.63a	25.0 ± 5.63ac	25.9 ± 6.61ab	26.2 ± 5.26ad	7.1 ± 2.03ab
Festival Spider Yellow	38.8 ± 5.34ae	20.1 ± 6.56a	31.3 ± 5.93ac	45.6 ± 11.30ab	31.5 ± 5.67ad	26.2 ± 5.31ab
Kameleo Micro Mix	21.2 ± 4.08af	15.6 ± 5.22a	16.1 ± 5.14ac	19.4 ± 4.06ab	9.9 ± 1.29cd	19.0 ± 4.50ab
Mega Revolution Champagne	30.0 ± 6.28af	31.3 ± 6.51a	27.7 ± 5.75ac	26.2 ± 3.89ab	29.0 ± 5.69ad	30.3 ± 8.41ab
Mega Revolution Golden Yellow Dark Eye	12.4 ± 3.66cf	13.3 ± 3.66a	19.5 ± 5.48ac	25.1 ± 5.35ab	17.5 ± 2.42ad	14.6 ± 5.14ab
Mega Revolution Orange Dark Eye	22.5 ± 6.65af	14.2 ± 2.68a	15.8 ± 3.58ac	27.4 ± 4.37ab	28.5 ± 4.97ad	18.1 ± 4.66ab
Mega Revolution Purple Shade	26.9 ± 8.42af	16.6 ± 4.44a	20.4 ± 4.78ac	19.2 ± 5.74ab	17.9 ± 6.62ad	22.7 ± 7.90ab
Mega Revolution Scarlet Dark Eye	35.2 ± 10.86af	27.2 ± 9.27a	17.5 ± 4.87ac	25.4 ± 10.00ab	25.0 ± 5.41ad	13.7 ± 4.18ab
Mega Revolution White	11.0 ± 3.77df	10.0 ± 1.42a	13.1 ± 4.52ac	14.8 ± 4.42b	17.8 ± 5.06ad	16.8 ± 5.20ab
Mega Revolution Yellow Shade	27.0 ± 4.57af	23.5 ± 4.39a	22.1 ± 7.26ac	26.2 ± 5.56ab	25.0 ± 7.20ad	25.9 ± 5.35ab
Revolution Pink	15.6 ± 4.19cf	13.8 ± 2.45a	21.3 ± 3.83ac	26.0 ± 4.83ab	13.7 ± 4.66bd	14.1 ± 5.41ab
Revolution Pink Baby	23.1 ± 5.81af	26.3 ± 4.75a	22.9 ± 6.10ac	41.8 ± 12.37ab	26.0 ± 7.99ad	24.4 ± 5.98ab
Revolution Pink Pastel Dark Eye	38.2 ± 5.77ae	31.2 ± 4.69a	32.8 ± 5.87ac	37.4 ± 10.05ab	25.1 ± 5.53ad	19.1 ± 4.27ab
Revolution Red Shade Dark Eye	14.2 ± 1.67cf	21.7 ± 5.34a	16.7 ± 3.53ac	40.7 ± 10.70ab	37.8 ± 7.93ad	14.7 ± 4.05ab
Revolution Rose Shade	42.7 ± 6.46ac	25.7 ± 3.02a	25.1 ± 4.26ac	29.6 ± 6.22ab	33.0 ± 7.36ad	24.6 ± 8.54ab
Revolution Pastel Orange Dark Eye	8.4 ± 3.41ef	10.0 ± 2.10a	10.2 ± 3.05bc	16.6 ± 3.32b	11.9 ± 2.64bd	18.2 ± 5.07ab
Revolution Scarlet Dark Eye	29.7 ± 6.16af	28.1 ± 6.44a	34.5 ± 6.34abc	47.2 ± 6.09ab	38.1 ± 7.38ad	17.9 ± 6.13ab
Revolution Spring Pastels	13.5 ± 3.13cf	13.2 ± 3.10a	12.6 ± 1.79ac	17.1 ± 3.69b	27.3 ± 4.95ad	13.4 ± 8.62ab
Revolution White	23.8 ± 6.83af	32.3 ± 4.90a	27.8 ± 6.16ac	27.4 ± 6.38ab	23.6 ± 6.30ad	23.3 ± 7.42ab
Revolution Yellow	27.5 ± 3.55af	26.2 ± 4.94a	28.0 ± 4.56ac	29.6 ± 6.08ab	20.5 ± 4.32ad	25.6 ± 5.84ab
Yellow Dark Eye	16.3 ± 3.76bf	14.1 ± 4.09a	12.6 ± 3.34ac	33.3 ± 9.28ab	23.5 ± 7.04ad	23.1 ± 5.79ab
F	3.75	2.35	2.32	2.35	2.18	1.52
df	59, 599	59, 599	59, 599	59, 599	59, 599	59, 599
P	< 0.0001	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0102

Jaguar Rose Deep' (cultivar #7), 'Gerbera Jaguar Salmon Pastel' (cultivar #9) and 'Gerbera Revolution Spring Pastels' (cultivar #57), consistently showed less damage (Table 4). Sustained exposure to high populations of leafminers rendered plants equally damaged by the sixth week when there were no more significant differences in cultivar damage (F values range= 1.33–3.75, df = 59, 599, p values range = < 0.0001–0.059, Tables 2, 3).

Table 3. Mean ± SE number of *L. trifolii* mines per gerbera plant by cultivar (n = 10)

Cultivar	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Jaguar Fire	2.1 ± 0.58ad	4.3 ± 2.30ab	3.8 ± 0.79bc	8.6 ± 0.54ab	7.3 ± 0.80ab	11.4 ± 1.53a
Jaguar Fire Dark Eye	3.3 ± 1.06ad	4.8 ± 1.30ab	6.6 ± 1.14ac	17.3 ± 1.46a	16.2 ± 1.51ab	19.8 ± 1.92a
Jaguar Orange Deep	2.1 ± 0.42ad	2.5 ± 0.72ab	4.3 ± 0.68bc	6.3 ± 0.97ab	8.9 ± 1.48ab	9.0 ± 2.45a
Jaguar Orange Picotee	1.7 ± 0.55ad	3.3 ± 0.53ab	4.7 ± 0.96bc	7.3 ± 0.97ab	9.6 ± 1.10ab	12.4 ± 1.64a
Jaguar Pink	1.7 ± 0.40ad	2.2 ± 0.62ab	1.9 ± 0.50c	3.2 ± 1.07b	6.2 ± 1.23ab	8.7 ± 2.15a
Jaguar Red	3.4 ± 0.74ad	4.4 ± 1.27ab	3.3 ± 0.41bc	8.3 ± 1.48ab	13.9 ± 0.97ab	15.9 ± 1.58a
Jaguar Rose Deep	0.6 ± 0.21d	1.4 ± 0.30ab	2.1 ± 0.65c	3.3 ± 0.94b	3.7 ± 0.49b	10.4 ± 1.02a
Jaguar Rose Picotee	2.9 ± 0.80ad	3.5 ± 1.96ab	4.3 ± 0.73bc	5.8 ± 0.80b	8.0 ± 1.03ab	8.3 ± 2.14a
Jaguar Salmon Pastel	1.3 ± 0.36bd	2.2 ± 0.43ab	2.0 ± 0.37c	3.3 ± 0.64b	6.2 ± 1.14ab	7.2 ± 1.33a
Jaguar Scar Shade Dark Eye	2.6 ± 0.94ad	2.3 ± 0.53ab	3.5 ± 1.07bc	11.4 ± 0.83ab	8.3 ± 1.49ab	7.3 ± 1.28a
Jaguar tangerine	3.5 ± 0.84ad	5.6 ± 1.13ab	3.0 ± 0.58c	4.5 ± 0.80b	6.6 ± 0.84ab	9.2 ± 1.64a
Jaguar White	2.1 ± 0.60ad	3.2 ± 0.91ab	5.0 ± 1.57bc	7.7 ± 0.76ab	8.4 ± 1.26ab	8.1 ± 1.47a
Jaguar Yellow	4.6 ± 0.91a	6.1 ± 1.07a	6.0 ± 0.64ac	7.8 ± 1.02ab	10.3 ± 1.55ab	16.8 ± 3.36a
Jaguar Yellow Dark Eye	1.2 ± 0.20bd	2.8 ± 0.73ab	3.5 ± 0.59bc	6.6 ± 1.32ab	8.2 ± 1.29ab	11.4 ± 1.57a
Royal Mix	1.8 ± 0.48ad	2.8 ± 0.76ab	4.1 ± 0.84bc	6.7 ± 1.25ab	10.2 ± 2.20ab	11.1 ± 1.22a
Royal Semi-Double Pink Dark Eye	1.7 ± 0.42ad	1.6 ± 0.32ab	4.9 ± 0.84bc	6.4 ± 0.89ab	5.0 ± 0.55b	7.6 ± 1.15a
Royal Semi-Double Vanilla Dark Eye	2.1 ± 0.54ad	2.9 ± 0.66ab	3.7 ± 0.41bc	6.0 ± 0.75b	5.7 ± 0.95ab	7.3 ± 0.60a
Royal Semi-Double Watermelon Dark Eye	3.3 ± 0.76ad	5.5 ± 0.97ab	9.3 ± 1.11ab	7.9 ± 1.30ab	5.3 ± 0.50b	9.8 ± 2.16a
Durora Mini-Double Mix	1.7 ± 0.29ad	2.5 ± 1.02ab	3.5 ± 1.01bc	3.7 ± 1.02b	5.8 ± 0.94ab	5.7 ± 0.96a
Festival Apricot	1.2 ± 0.31bd	2.4 ± 0.44ab	3.2 ± 0.64bc	5.1 ± 0.53b	8.2 ± 0.98ab	7.9 ± 1.59a
Festival Apricot Dark Eye	2.1 ± 0.50ad	3.1 ± 0.81ab	5.3 ± 0.95ac	6.5 ± 1.31ab	8.3 ± 2.47ab	9.6 ± 3.48a
Festival Cream	4.4 ± 0.77ab	4.8 ± 1.34ab	6.7 ± 0.91ac	7.0 ± 1.13ab	7.1 ± 1.33ab	7.1 ± 1.48a
Festival Mix Dark Eye	2.9 ± 0.86ad	2.6 ± 0.59ab	4.6 ± 0.56bc	6.6 ± 1.27ab	7.5 ± 1.37ab	9.3 ± 2.18a
Festival Peach Dark Eye	4.2 ± 0.69ac	6.0 ± 1.24ab	3.3 ± 0.68bc	8.9 ± 0.74ab	9.1 ± 0.86ab	9.0 ± 1.57a
Festival Pink Shade Dark Eye	2.5 ± 0.93ad	2.5 ± 0.72ab	4.5 ± 1.04bc	6.9 ± 0.57ab	7.0 ± 0.80ab	9.4 ± 1.31a
Festival Red Dark Eye	3.3 ± 0.81ad	4.4 ± 1.21ab	5.0 ± 1.37bc	6.1 ± 0.56b	6.5 ± 0.82ab	12.3 ± 2.02a
Festival Salmon	2.1 ± 0.39ad	2.3 ± 0.46ab	4.0 ± 0.52bc	5.4 ± 0.91b	9.7 ± 0.75ab	14.1 ± 2.21a
Festival Salmon Orange Shade	2.8 ± 0.63ad	5.8 ± 0.90ab	4.8 ± 0.80bc	5.6 ± 0.92b	9.0 ± 0.64ab	9.2 ± 1.93a
Festival Scarlet Dark Eye	1.6 ± 0.33ad	1.6 ± 0.42ab	4.0 ± 1.05bc	9.2 ± 0.82ab	6.9 ± 1.07ab	6.1 ± 1.22a
Festival White Shade	2.5 ± 0.48ad	1.8 ± 0.55ab	2.5 ± 0.71c	4.5 ± 0.81b	4.9 ± 1.21b	14.9 ± 2.30a
Festival Yellow Lemon	2.7 ± 0.35ad	2.4 ± 0.39ab	5.2 ± 1.00ac	12.6 ± 0.93ab	14.4 ± 1.62ab	14.0 ± 1.13a
Festival Mini Orange Shade	1.7 ± 0.67ad	1.5 ± 0.46ab	4.2 ± 0.90bc	5.6 ± 0.75b	5.5 ± 0.82ab	7.0 ± 1.29a
Festival Mini Pink Soft	0.7 ± 0.28d	1.7 ± 0.56ab	2.5 ± 0.61c	5.1 ± 0.70b	18.6 ± 0.43a	18.2 ± 0.79a
Festival Mini Pastel Deep Shade	1.8 ± 0.47ad	1.3 ± 0.70ab	2.4 ± 0.54c	4.4 ± 1.02b	6.3 ± 0.67ab	12.9 ± 1.42a
Festival Mini Yellow Shade	3.7 ± 1.05ad	5.9 ± 1.04ab	7.0 ± 1.41ac	8.5 ± 1.53ab	7.0 ± 1.15ab	11.6 ± 2.53a
Mini Revolution Mix	1.0 ± 0.35d	1.4 ± 0.70ab	2.2 ± 0.39c	5.5 ± 0.82b	6.0 ± 1.15ab	7.1 ± 1.52a
Festival Semi-Double Orange Shade	2.8 ± 0.81ad	5.5 ± 1.83ab	4.0 ± 0.52bc	9.1 ± 1.18ab	7.7 ± 0.88ab	9.7 ± 1.22a
Festival Semi-Double Rose Shade	3.6 ± 0.78ad	4.1 ± 1.00ab	6.0 ± 1.20ac	8.6 ± 1.48ab	7.7 ± 0.87ab	8.0 ± 0.74a
Festival Semi-Double Yellow	2.9 ± 0.66ad	2.7 ± 0.54ab	4.5 ± 0.62bc	7.4 ± 1.09ab	7.2 ± 0.73ab	9.5 ± 1.61a
Festival Spider Salmon Eye	1.9 ± 0.30ad	2.4 ± 0.57ab	4.9 ± 0.75bc	8.4 ± 0.62ab	11.0 ± 1.48ab	11.5 ± 1.81a
Festival Spider Yellow	2.9 ± 0.65ad	4.4 ± 1.11ab	5.5 ± 1.51ac	9.0 ± 1.56ab	8.2 ± 1.05ab	8.3 ± 1.37a
Kameleo Micro Mix	1.7 ± 0.41ad	2.5 ± 0.71ab	6.2 ± 0.82ac	7.5 ± 0.55ab	7.8 ± 0.94ab	12.1 ± 0.58a
Mega Revolution Champagne	1.1 ± 0.29cd	2.8 ± 0.37ab	3.3 ± 0.72bc	5.9 ± 0.83b	9.8 ± 2.93ab	10.1 ± 1.67a
Mega Revolution Golden Yellow Dark Eye	2.1 ± 0.34ad	3.5 ± 0.78ab	4.0 ± 0.54bc	11.9 ± 1.23ab	9.1 ± 1.72ab	10.8 ± 2.09a
Mega Revolution Orange Dark Eye	2.7 ± 0.63ad	5.3 ± 1.33ab	5.2 ± 0.91ac	8.4 ± 0.53ab	9.5 ± 1.02ab	9.8 ± 1.07a
Mega Revolution Purple Shade	1.2 ± 0.24bd	2.7 ± 0.52ab	2.8 ± 0.56c	4.0 ± 0.45b	6.1 ± 0.93ab	6.0 ± 1.63a
Mega Revolution Scarlet Dark Eye	1.4 ± 0.30bd	4.5 ± 1.01ab	6.1 ± 1.31ac	6.0 ± 1.34b	6.1 ± 0.66ab	8.6 ± 1.31a
Mega Revolution White	0.7 ± 0.25d	2.0 ± 0.43ab	4.1 ± 1.03bc	4.7 ± 0.79b	5.4 ± 0.82ab	8.2 ± 1.74a
Mega Revolution Yellow Shade	1.7 ± 0.36ad	4.6 ± 0.94ab	11.3 ± 1.16a	8.1 ± 1.91ab	13.7 ± 0.66ab	16.3 ± 1.07a
Revolution Pink	1.9 ± 0.43ad	0.9 ± 0.36b	3.6 ± 0.89bc	4.6 ± 0.67b	7.2 ± 1.49ab	5.5 ± 1.29a
Revolution Pink Baby	1.6 ± 0.39ad	3.5 ± 0.99ab	3.0 ± 0.58c	5.3 ± 0.64b	6.7 ± 1.29ab	6.7 ± 1.44a
Revolution Pink Pastel Dark Eye	3.6 ± 0.64ad	2.6 ± 0.64ab	1.9 ± 0.38c	4.1 ± 0.36b	5.9 ± 1.09ab	5.3 ± 1.31a
Revolution Red Shade Dark Eye	1.5 ± 0.23ad	2.4 ± 0.97ab	3.6 ± 0.83bc	9.7 ± 0.89ab	10.4 ± 1.28ab	9.9 ± 0.88a
Revolution Rose Shade	1.7 ± 0.41ad	4.1 ± 0.95ab	3.6 ± 0.79bc	5.0 ± 0.71b	7.6 ± 0.76ab	8.1 ± 0.95a
Revolution Pastel Orange Dark Eye	0.8 ± 0.22d	1.3 ± 0.33ab	2.3 ± 0.48c	3.7 ± 0.36b	6.7 ± 0.98ab	7.9 ± 1.24a
Revolution Scarlet Dark Eye	1.9 ± 0.50ad	3.5 ± 0.47ab	3.4 ± 0.55bc	3.7 ± 0.50b	5.8 ± 0.76ab	7.3 ± 2.31a
Revolution Spring Pastels	0.7 ± 0.20d	1.5 ± 0.47ab	2.8 ± 0.92c	3.7 ± 0.73b	3.7 ± 0.45b	5.4 ± 0.65a
Revolution White	1.3 ± 0.26bd	1.5 ± 0.30ab	3.4 ± 0.54bc	4.5 ± 0.81b	7.5 ± 1.33ab	6.2 ± 1.34a
Revolution Yellow	3.7 ± 0.60ad	5.3 ± 1.01ab	6.1 ± 1.02ac	9.1 ± 1.31ab	9.4 ± 1.87ab	10.7 ± 1.81a
Yellow Dark Eye	1.0 ± 0.43d	2.2 ± 0.60ab	3.0 ± 0.45c	4.9 ± 0.72b	8.6 ± 1.39ab	11.3 ± 1.48a
F	3.27	2.61	2.54	1.84	1.52	1.33
df	59, 599	59, 599	59, 599	59, 599	59, 599	59, 599
P	< 0.0001	< 0.0001	< 0.0001	0.0003	0.0103	0.0590

Table 4. **Gerbera cultivars highly preferred by the leafminer *L. trifolii* with > 80% of highest damage on at least 2 observation dates.**

Cultivar #	Cultivar name
2	Gerbera Jaguar Fire Dark Eye
13	Gerbera Jaguar Yellow
18	Gerbera Royal Semi-Double Watermelon Dark Eye
22	Gerbera Festival Cream
24	Gerbera Festival Peach Dark Eye
33	Gerbera Festival Mini Pink Soft
35	Gerbera Festival Mini Yellow Shade
49	Gerbera Mega Revolution Yellow Shade
59	Gerbera Revolution Yellow

While cultivar groups of 'Gerbera Jaguar' and 'Gerbera Revolution' showed potential for lower leafminer preferences, the non-preference did not extend to all color variants in the group. 'Gerbera Jaguar Rose Deep' (cultivar #7) was among cultivars that had least damage while 'Gerbera Jaguar Fire Dark Eye' (cultivar #2) sustained consistently high damage. While 'Gerbera Revolution Spring Pastel' (cultivar #57) showed lower damage, 'Gerbera Revolution Yellow' (cultivar #59) and 'Gerbera Mega Revolution Yellow' (cultivar #49) sustained heavier leafminer damage.

The mine damage values for the cultivar lines averaged across the six observation dates (Table 5) ($f = 4.21$; $df = 5, 169$; p value $= 0.0010$) identified the cultivar lines 'Gerbera Revolution' and 'Gerbera Festival Mini' as having significantly less mine damage overall. Cultivar lines 'Gerbera Jaguar', 'Gerbera Royal', 'Gerbera Festival', and 'Gerbera Mega Revolution' had significantly higher damages and were not significantly different among them.

Penetrometer study. Cultivars showed significant differences in the force required to penetrate the dorsal surface of the leaves ($f = 13.68$; $df = 14, 449$; p value < 0.0001) (Fig. 1). However, the force required to penetrate the surface was not consistent with the preference or non-preference of leafminer damage from the correlation analysis ($R = 0.0032$; $P = 0.4948$). Data from leafminer non-preferred cultivars like 'Gerbera Revolution Scarlet Dark Eye' (cultivar #56), 'Gerbera Festival White Shade' (cultivar #30), and leafminer preferred 'Gerbera Festival Spider Salmon Eye' (cultivar #40) corresponded with the force required to penetrate the surface. A higher force to penetrate the surface in non-preferred cultivars and, less force required to penetrate the surface in highly preferred ones.

However, leafminer preferred cultivars like 'Gerbera Festival Semi DB Yellow' (cultivar #39), 'Gerbera Festival Mini Yellow' (cultivar #35), and non-preferred cultivars like 'Gerbera Royal Semi DB Pink Dark Eye' (cultivar #16) and

Table 5. **Mean ± SE of *L. trifolii* mines on cultivar lines across six observation dates.**

Cultivar lines	Damage ± SE
Gerbera Jaguar	5.2895 ± 0.19ab
Gerbera Royal	5.3535 ± 0.28ab
Gerbera Festival	5.4614 ± 0.14a
Gerbera Festival Mini	3.9872 ± 0.32c
Gerbera Mega Revolution	5.1286 ± 0.23ab
Gerbera Revolution	4.4353 ± 0.18bc

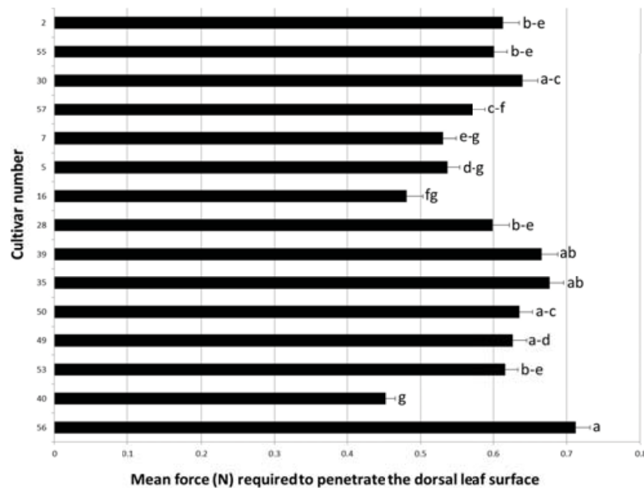

Fig. 1. **Force (means ± SE) in newtons required to penetrate the dorsal surface of gerbera cultivars (cultivar names appear in Table 1). N = 30 for each cultivar number shown. Bars with same case letters are not significantly different (Tukey's HSD, α = 0.05, p value < 0.0001).**

'Gerbera Jaguar Rose Deep' (cultivar #7) inversely corresponded with the force required to penetrate the leaf surface. Preferred cultivars in this situation required higher force to penetrate, while non-preferred cultivars required less force to penetrate. Hence in general, the preference or non-preference of leafminer attack did not align with the force required to penetrate the dorsal surface of leaf.

Anecdotal evidence that yellow cultivars attract more leafminers than other colors is consistent with the fact that yellow sticky cards are best in attracting leafminers (16) and an effective tool in sampling (6, 9). Our experiment was conducted on plants without flowers to assess foliar-based potential for avoidance or antibiosis. Observations of the different cultivars in our study showed very little variation within the spectrum of being pubescent or glabrous, though the texture seemed to have some difference, and hence the investigation into leaf toughness as a factor to deter leafminer oviposition and resultant damage.

Punctures and mines did not correspond in this study. Punctures are a function of either feeding behavior or oviposition, and feeding frequency has been shown to 'not predict' leafminer preference or damage (4). Punctures can hence only be an indicator of leafminer preference while the best measure of resistance is a lower number of mines. There was no consistent preference by leafminers for yellow cultivars. While there were some yellow cultivars that were among the most damaged, all yellow cultivars were not heavily damaged. There were pink and orange cultivars that sustained heavier damage than certain yellow cultivars, but no yellow cultivars ranked very low in number of punctures and mines (Tables 5, 6). Also, innate mechanisms might be expected to be a trait of a certain cultivar group. With 10–12 cultivars coming under the same general cultivar group, we expected that they would be armed with the same defense mechanism and hence remain together in being preferred by leafminers or sustaining damage. The results however didn't agree with that. For example, while 'Gerbera Jaguar Rose Deep' (cultivar #7) and 'Gerbera Jaguar Pink' (cultivar #5) showed low levels of damage, 'Gerbera Jaguar Fire Dark Eye' (cultivar

Table 6. Gerbera cultivars least preferred by the leafminer *L. trifolii* with < 20% of highest damage on at least 2 observation dates.

Cultivar #	Cultivar name
5	Gerbera Jaguar Pink
7	Gerbera Jaguar Rose Deep
9	Gerbera Jaguar Salmon Pastel
57	Gerbera Revolution Spring Pastel

#2) sustained heavy leafminer damage. 'Gerbera Jaguar' (cultivars #5, 7, and 9) and 'Gerbera Revolution' (cultivar #57) were two cultivar groups where at least a few of them showed reduced leafminer damage (Table 6).

While more cultivars in the Gerbera Jaguar line consistently showed low mine damage on individual observation dates (Table 6), cultivar lines (including all cultivars in the cultivar group) 'Gerbera Revolution' and 'Gerbera Festival Mini' showed less mine damage across the duration of the experiment (Table 5). There might be some innate quality in these lines that could help in resistance breeding in gerberas.

Leaf toughness was not a predictor of leafminer preference. Color variants of the cultivar group 'Gerbera Revolution' varied in the force required to penetrate the dorsal leaf surface and did not correspond with leafminer preferences from the greenhouse choice study. 'Gerbera Revolution Scarlet Dark Eye' (cultivar #56) required high force to penetrate the surface, and was one of the cultivars with lower number of mines developing in spite of high number of stings. 'Gerbera Revolution Red Shade Dark Eye' (cultivar #53) was among the cultivars that sustained high leafminer damage, but the force required to penetrate the surface was intermediate but higher than that required to penetrate 'Gerbera Revolution Pastel range Dark Eye' (cultivar #55), which sustained low leafminer damage.

Related species like *G. ambigua* (Cass.) Schultz. Bip., *G. crocea* (L.) Kuntze, *G. linnaei* Cass., *G. serrata* (Thunb.) Druce, *G. tomentosa* DC, *G. viridifolia* (DC.) Sch. Bip., and *G. wrightii* Harv. might provide sources of resistant germplasm. Alternatively jasmonic acid sprays that were successful in celery (3) could be explored. The search for an effective host plant resistance mechanism will have to continue for the reason that it can tremendously help the IPM program that will then result. The leafminer *L. trifolii* has been a successful cosmopolitan pest and will continue to drive pest management in gerbera production for years to come. Our answer to that would depend on finding successful components that could be weaved into an integrated program to control the suite of pests in this system.

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