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# Resistance of Ivy Geraniums to the Twospotted Spider Mite<sup>1</sup>

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**Abstract.** Resistance to the twospotted spider mite (*Tetranychus urticae* Koch) of 18 cultivars of ivy geranium [*Pelargonium peltatum* (L.) L'Her ex Ait.] was evaluated under greenhouse conditions by mass screening, by measuring fecundity on isolated leaves, and by paired leaf tests for selected cultivars. 'Sybil Holmes', 'Yale', and 'Cornell' were among the most susceptible, whereas 'Double Lilac White', 'Sunset', and 'Salmon Queen' were relatively mite-free. 'Madeline Crozy' and 'Cornell' were preferred for oviposition over the resistant 'Double Lilac White'. Mite resistance was not related to density of simple or glandular leaf trichomes, but there was an apparent relationship between mite susceptibility and severity of oedema.

Ivy geraniums are common flowering hanging basket plants produced in greenhouses for Mother's Day and general spring sales. Untreated plants are frequently infested by the twospotted spider mite. In certain plant species, morphological or biochemical differences among cultivars are related to mite resistance. Glandular hairs have been reported to entrap or impede spider mites on tomatoes (3) and tobacco (4). Water-soluble extracts and essential oils in strawberry foliage are repellent to mites on strawberry (2, 6) and biochemical differences between cultivars are associated with mite susceptibility in hops (5). Spider mite resistance has also been demonstrated in certain cultivars of zonal geranium, *Pelargonium X hortorum* L. H. Bailey (7), where it is associated with adhesiveness and direct toxicity of exudate from glandular leaf trichomes (8).

Because ivy geraniums require a lengthy production period and generally receive little maintenance, characterization of resistant cultivars would be desirable for integrated pest management. The objectives of this study were to evaluate selected ivy geranium cultivars for resistance to twospotted spider mites and to clarify the nature of that resistance.

## Materials and Methods

In February, 18 ivy geranium cultivars were obtained as rooted cuttings from commercial growers and were grown in the greenhouse as stock plants. For the initial mass screening test, rooted cuttings from the stock plants of each cultivar were transplanted in Pro-Mix BX in 10-cm pots and grown to 4–5 fully expanded leaves in a 24 to 27°C (day) and 17° (night) greenhouse. Initially, 1.0 cm<sup>3</sup> Osmocote 14–6.2–11.6 (N-P-K) was applied to the surface of each pot, and plants were then fertilized at 250 ppm N with a 30–4.4–8.3 soluble fertilizer at 10-day intervals. The pots were arranged on capillary mats in a randomized complete block design with 8 replications. There was no contact among adjacent plants. Each plant was infested with 6 adult female mites taken from a greenhouse colony of *T. urticae* maintained on kidney beans. Mite populations were evaluated on 4 replications at 3 and 5 weeks after infestation by removing one-half of all leaves (1 leaf per node) and counting the number of live adult female spider mites on both leaf surfaces.

To assess mite fecundity on ivy geranium cultivars, egg production by females of known age was measured. Established cuttings (grown as in previous experiment) were trimmed to 2 fully expanded young leaves. Each leaf petiole was banded 7.5 mm below the blade with a thin strip of masking tape, and a ring of Tanglefoot was applied over the tape to prevent the escape of mites. Each leaf was inoculated with 3 newly emerged (< 24 hr) mated females. Four replicates of each cultivar were held on capillary mats for 12 days, after which all eggs and immature mites on each leaf were counted.

A test for nonpreference was conducted based on the mass screening and fecundity test results. Resistant cultivar 'Double Lilac White' (DLW) was compared as a standard against 5 susceptible cultivars, 'Sybil Holmes', 'Yale', 'Madeline Crozy', 'Cornell', and 'Balcon Imperial'. Established cuttings were paired with a leaf of comparable size on DLW. Paper clips held the leaf edges together so that mites could cross freely to either side. Tape and Tanglefoot barriers were placed on the leaf petioles as in the preceding test. Five adult female mites were transferred

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to each leaf. This arrangement was replicated 8 times for each of the 5 test cultivars. After 48 hr, the leaves were separated and the eggs deposited on each cultivar were counted.

Ivy geranium cultivars possess varying numbers of simple and/or glandular leaf trichomes, and it was of interest to determine if these were related to mite resistance. Under natural conditions, nearly all mite feeding is on the lower surface of leaves. Simple trichomes on the leaf undersides were counted by examining two 5-mm discs taken from each of 5 fully expanded young leaves for each cultivar. Glandular trichomes were counted on photographs of a typical 3.6-mm<sup>2</sup> area at 50×.

Oedema is a common problem during ivy geranium production and growers have noted a relationship between oedema development and mite infestations (R. Oglevee, personal communication). The corky outgrowths on geranium leaves, termed oedemata, are initiated at stomata and increase under conditions of high soil mixture, high humidity, and warm soil temperature (1). Ivy geranium cultivars were grown under conditions of constant moisture on a capillary mat to accentuate oedema. To test for an association with mite infestation, the severity of oedema was rated visually as low, moderate, or high after 5 weeks on plants in the mass screening test.

## Results and Discussion

The results of the mass screening test, along with the leaf trichome counts and oedema ratings for each cultivar, are summarized in Table 1. Three of the most susceptible cultivars, 'Sybil Holmes', 'Yale', and 'Cornell', are among the most commonly grown ivy geraniums for retail sales. Numbers of adult female mites increased ca. 20 times on 'Sybil Holmes' and 'Yale' during the 5-week screening, and many more eggs and immatures were observed. In contrast, the less common cultivars 'Double Lilac White', 'Sunset', and 'Salmon Queen' were relatively mite-free after 5 weeks.

Results of the fecundity tests on intact leaves were in general agreement with the mass screening trials, and susceptibility rankings of the 18 cultivars were significantly correlated between the 2 tests (Table 2). Mites on cultivars 'Yale', 'Pascal', 'Sybil Holmes', and 'Madeline Crozy' produced the greatest number of progeny. As in the mass screening test, cultivars 'Amethyst', 'Sunset', and 'Double Lilac White' were among the 5 most resistant cultivars. No eggs or immatures were found on 'Double Lilac White'. Very few of the original female mites were alive on any cultivar after the 12-day test.

The apparent mite resistance shown by certain cultivars, such as 'Double Lilac White', could result from antibiosis, nonpreference, or both. In the paired leaf studies (Table 3), 2 of the relatively susceptible cultivars, 'Madeline Crozy' and 'Cornell', were preferred for oviposition over the resistant 'Double Lilac White'. However, differences in oviposition were nonsignificant when 'Double Lilac White' was paired with 'Yale', 'Sybil Holmes', or 'Balcon Imperial'. One possible explanation concerns the preferred sites for mite oviposition. On ivy geraniums, most mite eggs are laid in webs connecting the concavities along the undulate leaf margins. Leaves of 'Sybil Holmes' and 'Balcon Imperial' are generally smaller and flatter than 'Double Lilac White' and, from a physical standpoint, offer fewer oviposition sites. Females mites moved easily between the paired leaves, and it is likely that many of the eggs laid on 'Double Lilac White' were from females that survived and fed on the susceptible cultivar.

There was no relationship between the density of simple or glandular leaf trichomes and mite resistance (Table 1, Fig. 1).

Table 1. Population increase of twospotted spider mites on 18 ivy geranium cultivars. Populations represent mean number of adult females/plant, 3 and 5 weeks after infestation with 6 adult female *T. urticae* each.

Cultivar	Trichome density		Oedema rating <sup>x</sup>	Mean no. mites <sup>w</sup>	
	Simple <sup>z</sup>	Glandular <sup>y</sup>		3 wk	5 wk
Sybil Holmes	—	++	++	59 ab	127 a
Yale	++	—	++	47 abc	115 ab
Madeline Crozy	++	—	+	72 a	92 abc
Pascal	++	+	++	42 abc	74 abcd
Cornell	+	—	+	20 cd	70 bcd
Balcon Royale	+	+	++	27 cd	67 bcd
Anita	—	—	+	24 cd	53 cde
Balcon Imperial	—	+	+	46 abc	53 cde
Rouletta	+	—	++	39 cd	47 cde
Sugar Baby	—	++	+	4 d	43 cde
Spain	—	—	+	18 cd	40 cde
Madame la Crousse	—	—	+	22 cd	31 de
Rigi	+	—	—	13 cd	27 de
Amethyst	—	—	+	12 cd	26 de
Madame Margot	+	++	—	17 cd	17 de
Sunset	+	+	—	4 d	16 de
Salmon Queen	++	—	—	13 cd	9 de
Double Lilac White	—	+	—	12 cd	4 e

<sup>z</sup>For simple trichomes, density was classed as 0–10(—), 11–60(+), or 61–210(+++) leaf hairs per cm<sup>2</sup>.

<sup>y</sup>For glandular trichomes, density was classed as 0–4(—), 5–10(+), or 11–29(+++) trichomes per 3.6 cm<sup>2</sup>.

<sup>x</sup>Oedema ratings: low oedema (—), moderate oedema (+), high oedema (++) at 5 wk of plant growth. In these experiments, oedema was probably accentuated by plant growth on capillary mat.

<sup>w</sup>Mean separation by Duncan's multiple range test, 5% level. Cultivar rankings at 3 and 5 weeks were significantly correlated by Spearman's coefficient of rank correlation, 1% level.

Table 2. Mean number of eggs and immature twospotted spider mites on ivy geranium foliage, 12 days after individual leaves were inoculated with 3 young adult mated females each.

Cultivar	Mean no. progeny/leaf	Susceptibility ranking from Table 1 <sup>z</sup>
Yale	73 a <sup>y</sup>	2
Pascal	69 a	4
Sybil Holmes	53 ab	1
Madeline Crozy	51 ab	3
Balcon Imperial	45 bc	8
Sugar Baby	41 bc	10
Spain	39 bc	11
Balcon Royale	30 bcd	6
Cornell	29 bcd	5
Rigi	28 bcde	13
Madame la Crousse	25 cdef	12
Salmon Queen	20 cdef	17
Madame Margot	12 def	15
Rouletta	8 def	9
Anita	8 def	7
Sunset	8 def	16
Amethyst	2 ef	14
Double Lilac White	0 f	18

<sup>z</sup>Cultivar susceptibility rankings from mass screening and fecundity tests were significantly correlated by Spearman's coefficient of rank correlation, 1% level.

<sup>y</sup>Mean separation by Duncan's multiple range test, 5% level.

Table 3. Relative preferences of adult female *T. urticae* for susceptible ivy geranium cultivars vs. Double Lilac White (DLW), as measured by oviposition on paired leaves after 48 hr.

Test cultivar	Mean no. eggs on test cultivar	Mean no. eggs on DLW	% of total eggs laid on test cultivar	<i>t</i> -value for paired comparisons vs. DLW
Madeline Crozy	27.0	5.4	83.4	3.2*
Cornell	27.6	10.4	71.8	3.0*
Yale	14.3	12.4	53.5	0.2
Sybil Holmes	15.0	12.4	54.8	0.4
Balcon Imperial	11.6	15.5	42.9	0.5

\*Significant at 5% level; 8 replications.

Cultivars with high simple trichome density such as ‘Yale’ and ‘Salmon Queen’ were relatively susceptible and resistant, respectively. Conversely, cultivars ‘Sybil Holmes’ (susceptible) and ‘Double Lilac White’ (resistant) had almost no simple trichomes. ‘Sybil Holmes’ (susceptible) had the highest density of

glandular trichomes (ca. 800/cm<sup>2</sup>) while ‘Madame Margot’ a relatively resistant cultivar, had the next highest number (ca. 450/cm<sup>2</sup>). Susceptible cultivar ‘Yale’ and resistant cultivar ‘Salmon Queen’ had almost no glandular trichomes. These findings were surprising in that adhesiveness and toxicity of glandular trichome

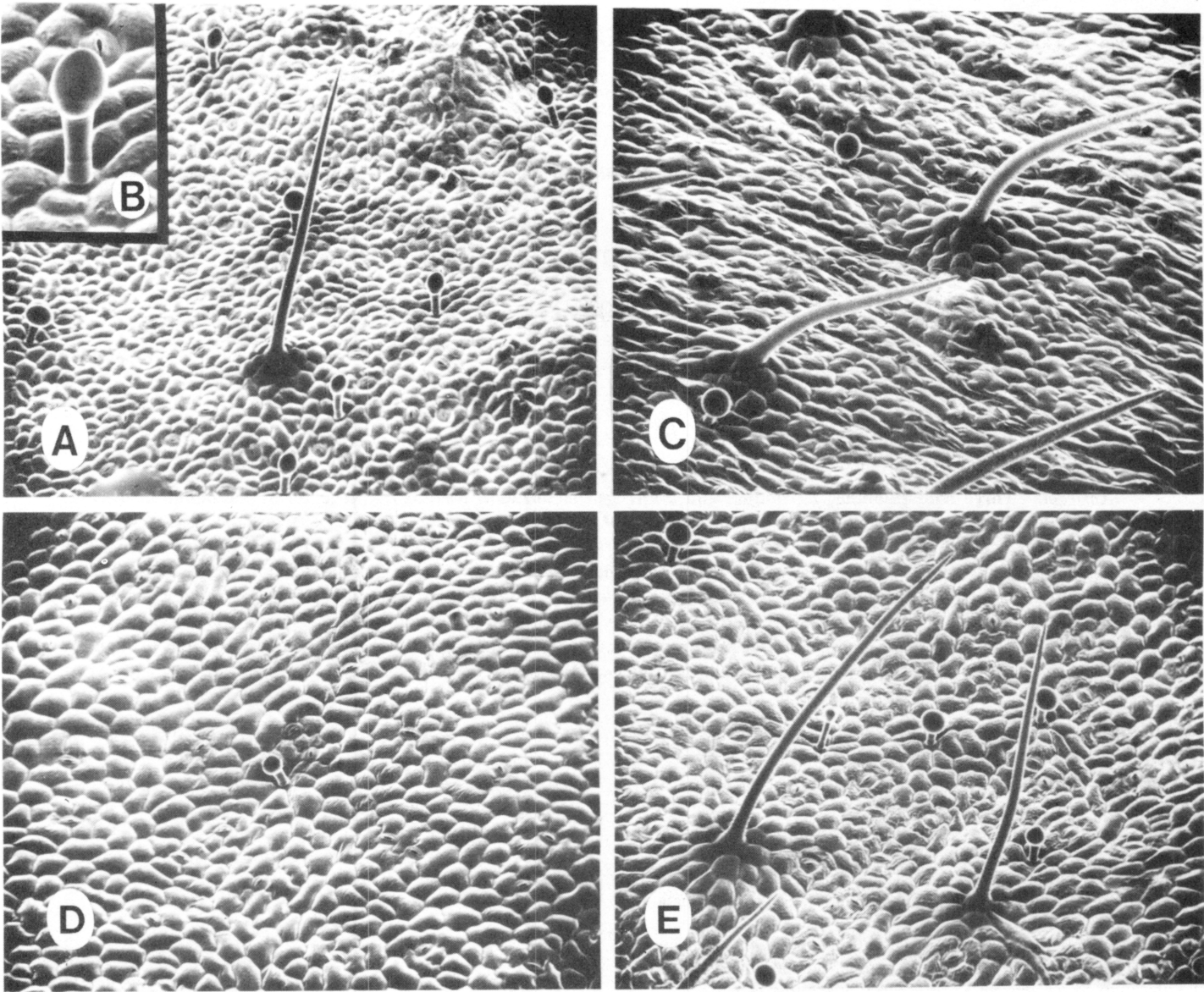


Fig. 1. Topography of leaf undersides of ivy geranium cultivars. A) ‘Sybil Holmes’ (susceptible). B) glandular trichome of ‘Sybil Holmes’. C) ‘Yale’ (susceptible). D) ‘Double Lilac White’ (resistant). E) ‘Salmon Queen’ (resistant).

exudate were reported to be important in mite resistance of *P. X hortorum* (7). On some ivy geranium cultivars, we observed some trichomes with excess exudate completely coating the trichome head and stalk, but on no cultivar did the simple or glandular trichomes appear to hinder mite movement. On most cultivars, density of both trichome types was higher on the adaxial than on the abaxial surface of the leaves.

There was an apparent relationship between mite susceptibility and severity of oedema (Table 1). The 4 most resistant cultivars developed only a low number of oedemata, while most of the susceptible cultivars were more severely affected. Although this concurs with general observations, reasons for the association are unclear. Oedema is usually associated with overwatering and high soil moisture, high humidity, and cool temperatures—just the opposite of conditions conducive to mite population growth. Possibly, oedema is linked to physiological or nutritional changes in the leaves which favor mite survival.

The possibility that the exudate from glandular trichomes of some cultivars is directly toxic to mites has not been eliminated, but it seems likely that biochemical differences in leaf quality are responsible for the varying levels of susceptibility. The combination of mite and oedema resistance in the less-common cultivars, such as 'Double Lilac White', 'Sunset', 'Madame Margot', 'Amethyst', and 'Salmon Queen', may encourage increased production of these cultivars over the common, mite-susceptible ivy geraniums.

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## Effects of Fruiting, Pruning, and Nitrogen Fertilization on Shoot Growth of 'Empire' Apple Trees<sup>1</sup>

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Additional index words. fruit size, fruit thinning, *Malus domestica*.

**Abstract.** Three fruit thinning, 2 pruning, and 2 nitrogen fertilization treatments, in factorial combination, were established in a 7-year-old orchard of 'Empire' apple (*Malus domestica* Borkh.)/Malling Merton 106. The pruning and N fertilization treatments were continued over a 4-year period; the initial fruit-thinning treatments induced significantly different bearing patterns that persisted through the 4 years and no additional thinning was done. The thinning treatments resulted in significant differences in yield, but pruning and N had little effect. Total shoot growth/tree was unaffected the first year, but large differences developed in the succeeding years. Crop load and N had major effects on shoot growth while the effect of pruning was minor. Total shoot growth was more closely related to shoot numbers than to mean shoot length and was negatively correlated with the previous year's crop.

In higher density apple orchards, precise control of vegetative growth is essential for consistent yields of high quality fruit. While there have been some detailed studies of apple tree shoot growth, many of these were conducted in an era of larger trees, wider spacings, lower productivity, different cultural practices,

and much less concern about vegetative growth control (1, 9, 24). Other such studies were confined to relatively young trees or to cultivars not commonly grown in this country (2, 3, 4, 5, 19, 21). This study was conducted in an effort to measure the effects of differential cropping, pruning, and N fertilization, singly and in combination, on shoot growth in a modern, medium-density apple orchard.

### Materials and Methods

In late winter of 1977, a 4-year experiment was established in a commercial orchard near Milton, N.Y. It was a 7-year-old planting of 'Empire'/MM 106, at a 4 × 6m spacing (417 trees/ha) on Cossayuna silt loam, one of the better orchard soils of the region. The orchard had produced 2 commercial crops and

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