HRI's Mission:

To direct, fund, promote and communicate horticultural research, which increases the quality and value of ornamental plants, improves the productivity and profitability of the nursery and landscape industry, and protects and enhances the environment.

Species and Cultivar Influences on Infestation by and Parasitism of a Columbine Leafminer (*Phytomyza aquilegivora* Spencer)[1]

S.K. Braman[2], G.D. Buntin[2] and R.D. Oetting[2]
Department of Entomology, University of Georgia
College of Agricultural and Environmental Sciences
1109 Experiment Street, Griffin, GA 30223

Abstract

Columbine, *Aquilegia* spp., are regularly attacked by agromyzid leafminers, *Phytomyza* spp. Effects of columbine species and cultivars on infestation by the leafminer *Phytomyza aquilegivora* Spencer, and subsequent parasitism by hymenopterous parasitoids was evaluated in two-year field trials at four locations in central and north Georgia. Among 20 columbine taxa planted in non-irrigated, wooded sites in central and north Georgia, two selections (*A. flabellata* and *A. caerulea* 'Dwarf Fantasy Mix') were comparable to the moderately resistant native species *A. canadensis*. In irrigated sites in central and north Georgia, all cultivars were equally infested by the leaf miner. The most heavily attacked selections among all sites were *A. alpina*, *A. chrysantha* 'Yellow Star', *A. caerulea*, *A. caerulea* 'McKana mix', *A. caerulea* 'Music hybrid', *A. skinneri*, and *A.* x *hybrida* 'Ruby Port'. The variegated selection, *A. vervaeneana* 'Woodside', sustained intermediate infestation levels as did *A. vulgaris* 'Winkie Blue & White'. Cultivar influences on parasitism of leafminers was quantified at two sites. Eleven species of hymenopteran parasitoids representing three families were recovered. Leafminers infesting *A. chrysantha* 'Yellow Star' were most heavily parasitized at both locations. *Chrysocharis pentheus* Walker was the most abundant parasitoid, representing 41% of all parasitoids collected and 48.4% of the species reared from leafminers in central Georgia. *Seladerma* sp. was the only parasitoid reared from leafminers collected in north Georgia and represented 22.1% of all parasitoids obtained.

Index words: Columbine, *Aquilegia* sp., host plant resistance, biological control, parasitism, Hymenoptera, Agromyzidae.

Species used in this study: *A. alpina*; *A. caerulea*; *A. caerulea* 'Dwarf Fantasy mix'; *A. caerulea* 'McKana mix'; *A. caerulea* 'Music hybrid'; *A. chrysantha* 'Yellow Star'; *A. canadensis*; *A. flabellata*; *A.* x *hybrida* 'Biedermier mix'; *A.* x *hybrida* 'Ruby Port'; *A.* x *hybrida* 'Spring Magic mix'; *A.* x *hybrida* 'Sunlight White'; *A. skinneri*; *A. vervaeneana* 'Woodside'; *A. viridiflora*; *A. vulgaris* 'Magpie'; *A. vulgaris* 'Nora Barlow'; *A. vulgaris* 'Winkie Blue & White'; *A.* sp. 'Danish Dwarf'; *A.* sp. 'Royal Purple'.

Significance to the Nursery Industry

Growing pest-resistant taxa simplifies management and reduces pesticide use. Determining species and cultivars of plants with improved resistance characteristics provides management options, market characteristics and identifies germplasm for breeding programs. Pest-resistant plants may or may not be compatible with natural enemies (parasitoids and predators). Examining cultivar influences on natural enemies determines the potential for enhanced control of key pest species using cultural and biological strategies. Columbine taxa with improved resistance to columbine leafminer were identified. Leafminer parasitoids were collected in appreciable numbers suggesting a potential for enhanced biological control of leafminers through conservation of existing natural enemies and appropriate cultivar selection.

Introduction

Columbine, *Aquilegia* spp., are valuable additions to perennial shade gardens for their aesthetic attributes and as nectar sources for butterflies. Agromyzid flies, *Phytomyza* spp., commonly infest cultivated columbine (6, 7, 8, 9) resulting in unsightly mines on the leaves. Host plant resistance has been demonstrated as a valuable integrated pest management strategy in the landscape (5). Insect and disease problems and associated economic and environmental costs in the nursery and landscape can be minimized by selecting relatively pest-resistant species or varieties that are well suited to local growing conditions. Resistance among ornamental species to some key landscape and production pests has been identified (for example, 2, 3, 4, 10, 11, 13, 14). However, resistance properties of available plant taxa are not well characterized. Armitage (1) observed that native columbine, *A. canadensis* is less susceptible to leafminers. The objectives of this study were threefold. We sought to 1) determine how many and which leaf miners were prevalent on columbine in Georgia, 2) characterize and quantify parasitism on leafminers, and 3) determine and document potential resistance to leafminers among columbine species and cultivars.

Methods and Materials

Leafminer activity. Aquilegia species and cultivars (20 taxa, Tables 1–3) were evaluated at four sites in central and north Georgia during 2002 and 2003 for differences in susceptibility to leafminers. Leafminer parasitism was also quantified at two locations in Spalding Co. in central Georgia. Additional specimens were collected from Fannin Co. in north Georgia to assess parasitism. Site 1: A completely randomized design with six replications of 20 columbine taxa (three plants per replication) were installed in a non-irrigated, wooded (primarily Quercus spp.) location during April 2002

[1]Received for publication July 13, 2004; in revised form September 20, 2004. We appreciate the taxonomic services of S.J. Scheffer (Diptera: Agromyzidae) and M.W. Gates (Hymenoptera: Eulophidae, Pteromalidae, Eucoilidae), Systematic Entomology Laboratory, Agriculture Research Service, US Department of Agriculture. A.F. Pendley, R. Slaughter, and M. Mead provided valuable technical assistance.

[2]Professor of Entomology.

Table 1. Mean ± s.e. number of leaves with mines (LWM) and total mines per plant (TM) among columbine, *Aquilegia* spp., cultivars in a non-irrigated, wooded location, (Site 1) Griffin, GA, 2002.

	May 1		May 15		May 29		June 12	
Species, cultivar	**LWM**	**TM**	**LWM**	**TM**	**LWM**	**TM**	**LWM**	**TM**
A. alpina	0.8 ± 0.4fg [z]	2.0 ± 1.0de	2.7 ± 0.5cd	6.2 ± 1.1cf	12.5 ± 1.3ab	25.5 ± 1.8a	18.5 ± 3.7a	86.5 ± 32.1a
A. caerulea	4.3 ± 1.2ae	7.2 ± 1.6be	6.7 ± 1.2ab	16.7 ± 2.0ab	9.3 ± 1.0ae	24.2 ± 3.2a	13.2 ± 1.7ac	45.2 ± 14.5b
A. caerulea 'Dwarf Fantasy mix'	1.2 ± 0.6fg	2.0 ± 0.9de	1.5 ± 1.5cd	2.5 ± 2.5bf	3.2 ± 1.4f	3.8 ± 1.8c	3.0 ± 1.2gh	4.5 ± 1.5c
A. caerulea 'McKana mix'	3.3 ± 1.1af	6.7 ± 2.2be	4.7 ± 1.7bc	9.0 ± 2.6bf	9.0 ± 1.3ae	22.6 ± 3.9ab	9.0 ± 1.0bf	19.2 ± 4.4bc
A. caerulea 'Music hybrid'	5.5 ± 0.9a	16.2 ± 2.6a	9.4 ± 3.7a	26.2 ± 9.8a	9.7 ± 1.5ad	21.8 ± 5.0ab	14.0 ± 1.8ab	23.8 ± 5.7bc
A. chrysantha 'Yellow Star'	1.7 ± 0.6cf	2.8 ± 1.0de	4.0 ± 1.2bd	9.0 ± 3.3bf	11.0 ± 4.3ac	25.0 ± 9.0a	9.2 ± 2.7bf	23.0 ± 9.0bc
A. canadensis	0.2 ± 0.2g	0.2 ± 0.2e	0.2 ± 0.2d	0.3 ± 0.3f	1.0 ± 0.5f	1.3 ± 0.7c	2.3 ± 1.0h	4.2 ± 2.3c
A. flabellata	1.7 ± 0.5cf	3.3 ± 1.6de	1.8 ± 0.6cd	5.2 ± 2.1cf	3.2 ± 0.8f	9.3 ± 4.3ac	4.0 ± 1.6fh	13.8 ± 7.2bc
A. x *hybrida* 'Biedermier mix'	3.5 ± 0.8af	6.3 ± 1.8be	1.7 ± 0.6cd	3.7 ± 1.4ef	2.3 ± 0.6f	4.5 ± 0.9bc	2.3 ± 1.0h	3.7 ± 1.9c
A. x *hybrida* 'Ruby Port'	4.7 ± 0.9ad	12.7 ± 2.1ab	5.0 ± 1.1bc	14.2 ± 4.1bd	9.0 ± 1.0ae	28.3 ± 1.0a	7.5 ± 2.4ch	29.7 ± 9.9bc
A. x *hybrida* 'Spring Magic mix'	3.7 ± 0.7af	8.2 ± 3.1bd	5.0 ± 1.7bc	15.2 ± 7.1bc	13.2 ± 3.1a	24.8 ± 7.6a	4.7 ± 1.5fh	15.2 ± 4.9bc
A. x *hybrida* 'Sunlight White'	4.2 ± 1.1ae	8.8 ± 3.0ad	2.5 ± 0.4cd	5.2 ± 1.2cf	3.8 ± 1.1df	12.7 ± 5.7ac	5.2 ± 1.2eh	15.3 ± 3.4bc
A. skinneri	4.0 ± 1.5 af	7.0 ± 3.1be	4.8 ± 1.0bc	9.2 ± 2.3bf	12.4 ± 2.3ab	25.8 ± 7.0a	11.3 ± 4.9bd	20.0 ± 2.6bc
A. vervaeneana 'Woodside'	1.5 ± 0.7dg	3.0 ± 1.6de	2.5 ± 0.7cd	5.0 ± 1.2cf	6.5 ± 1.7bf	19.8 ± 7.2ac	10.7 ± 3.8be	17.7 ± 4.9bc
A. viridiflora	4.8 ± 1.2ac	8.0 ± 2.7be	5.2 ± 0.9bc	10.0 ± 2.1bf	7.2 ± 1.7af	14.3 ± 2.4ac	4.3 ± 1.2fh	9.8 ± 3.8c
A. vulgaris 'Magpie'	5.2 ± 0.7ab	11.5 ± 2.7ac	5.2 ± 0.8bc	13.3 ± 3.5be	4.3 ± 0.8df	13.2 ± 3.6ac	3.0 ± 1.5gh	5.0 ± 1.7c
A. vulgaris 'Nora Barlow'	5.0 ± 1.3ab	9.7 ± 3.2ad	3.8 ± 1.4cd	8.8 ± 3.1bf	5.0 ± 1.3cf	14.5 ± 4.8ac	4.5 ± 1.2fh	15.0 ± 6.0bc
A. vulgaris 'Winkie Blue & White'	2.5 ± 0.7ag	3.8 ± 0.9ce	2.6 ± 0.4cd	4.4 ± 0.7df	5.2 ± 1.6cf	11.8 ± 5.1ac	7.3 ± 1.7dh	14.5 ± 4.8bc
A. 'Danish Dwarf'	2.0 ± 1.1bg	4.0 ± 2.3ce	2.5 ± 1.0cd	4.0 ± 2.1df	7.2 ± 1.2af	12.3 ± 1.0ac	8.3 ± 1.8bh	13.3 ± 5.3bc
A. 'Royal Purple'	3.3 ± 1.5ag	9.3 ± 5.0ad	4.7 ± 0.9bc	13.3 ± 7.8be	5.7 ± 1.4cf	16.2 ± 5.6ac	3.0 ± 0.9gh	8.5 ± 2.4c

[z]Means followed by the same letter within a column are not (P > 0.05) significantly different.

Table 2. Mean ± s.e. number of leaves with mines (LWM) and total mines per plant (TM) among columbine, *Aquilegia* spp., cultivars in an irrigated, wooded location, (Site 2) Griffin, GA, 2002 and 2003

	May 15, 2002		May 29, 2002		June 12, 2002		April 1, 2003	April 30, 2003	
Species, cultivar	**LWM**	**TM**	**LWM**	**TM**	**LWM**	**TM**	**LWM**	**LWM**	**TM**
A. alpina	0.6 ± 0.4	1.5 ± 1.2	0	0	0.3 ± 0.2	0.9 ± 0.6	0.2 ± 0.2	4.2 ± 2.3	20.8 ± 10.6
A. caerulea 'McKana mix'	0.1 ± 0.1	0.4 ± 0.4	1.2 ± 0.8	2.7 ± 1.8	0.1 ± 0.1	0.2 ± 0.2	1.6 ± 1.6	4.2 ± 2.4	15.0 ± 8.3
A. chrysantha 'Yellow Star'	0.3 ± 0.3	1.9 ± 1.9	0.2 ± 0.2	0.3 ± 0.3	1.3 ± 0.7	2.8 ± 1.8	2.4 ± 1.5	5.8 ± 1.6	31.0 ± 12.2
A. canadensis	0.2 ± 0.2	0.4 ± 0.4	0.4 ± 0.4	0.5 ± 0.5	0	0	3.5 ± 3.2	2.0 ± 1.2	7.0 ± 4.4
A. flabellata	0	0	0	0	0.1 ± 0.1	0.1 ± 0.1	0.5 ± 0.5	0.4 ± 0.4	1.2 ± 1.2
A. x *hybrida* 'Biedermier mix'	0.2 ± 0.2	0.2 ± 0.2	0.7 ± 0.3	1.1 ± 0.6	0.7 ± 0.7	1.8 ± 1.8	1.0 ± 0.8	3.4 ± 1.9	13.4 ± 8.2
A. skinneri	2.0 ± 1.3	4.2 ± 2.8	1.3 ± 0.8	1.9 ± 0.9	1.4 ± 1.2	1.9 ± 1.6	1.4 ± 1.4	3.8 ± 3.3	13.0 ± 12.3
A. vervaeneana Woodside	0.2 ± 0.2	0.2 ± 0.2	0.3 ± 0.3	0.7 ± 0.7	0.6 ± 0.6	5.2 ± 5.2	2.0 ± 2.0	0	0
A. viridiflora	0.1 ± 0.1	0.4 ± 0.4	0	0	0.1 ± 0.1	0.1 ± 0.1	0	2.8 ± 2.5	10.6 ± 7.3
A. vulgaris 'Winkie Blue & White'	0.1 ± 0.1	0.1 ± 0.1	0.2 ± 0.2	0.2 ± 0.2	0.4 ± 0.4	0.7 ± 0.7	0	5.4 ± 4.0	17.8 ± 12.6

in Spalding Co., GA [33.267°N, 84.283°W, elevation 285 m (935 ft)]. Plants were watered until establishment and not irrigated thereafter. Site 2: A randomized complete block design with five replications of ten columbine taxa (four plants per replication) were planted in May 2002, in an irrigated setting under Quercus spp. in the Research and Education Garden of the UGA Griffin Campus in Spalding Co., GA [33.267°N, 84.283°W, elevation 285 m (935 ft)]. Site 3. A randomized complete block design with six replications of nine plant taxa were installed in June 2002 at the Mountain Station in irrigated plots in a corner foundation, partially shaded, plot in Blairsville, GA [34.850°N, 83.95°W, elevation 594 m (1948 ft)]. Site 4: A completely randomized design with five replications of 12 columbine taxa were planted in June 2002 in a non-irrigated setting in Fannin Co., GA [34.500°N, 84.467°W, elevation 447 m (1466 ft)] under a maple (Acer), oak (Quercus), hemlock (Tsuga) canopy.

At intervals during 2002 and 2003, plants at all locations were sampled for leafminers by counting the total number of leaves per plant, number of leaves per plant with mines and the number of mines per plant. Plants at site 1 were evaluated on four dates during 2002 and 2003 (Table 1). Plants at site 2 were evaluated three times during 2002 and twice during 2003 (Table 2). Plants at Blairsville (site 3) and Fannin Co. (site 4) were observed for leafminer activity during 2002 and evaluated on six dates during 2003 (Blairsville, Table 3) and on three dates during 2003 for the plants at site 4 in Fannin Co. (Table 4).

Parasitism. Parasitism of leafminers was evaluated by collecting leaves from each cultivar at site 1 during 2002 and site 2 during 2003 at each sampling date. Six leaves per plant were returned to the laboratory, confined in plastic bags for emergence of fly pupae or parasitoids. Fly pupae were held for emergence of leafminers or parasitoids in 32 ml plastic cups with paper lids at room temperature [25C (76F)]. Leaves from infested plants in Fannin Co. were randomly collected and held for leafminer/parasitoid emergence to confirm species identities for leafminers and parasitoids. Flies and hymenopteran parasitoids that emerged were submitted to the

Table 3. Mean ± s.e. number of leaves with mines (LWM) and total mines per plant (TM) among columbine, Aquilegia spp., cultivars in an irrigated, partial shade location, Site 3 Blairsville, GA, 2003

Species, cultivar	June 11		June 25		July 9		July 13		July 23		August 26	
	LWM	TM	LWM	TM	LWM	TM	LWM	TM	LWM	TM	LWM	TM
A. alpina	6.4 ± 4.2	13.0 ± 8.5	11.8 ± 7.3	36.6 ± 27.5	15.8 ± 9.7	52.4 ± 39.0	21.2 ± 13.0	139.8 ± 119.9	23.6 ± 14.4	144.2 ± 119.5	24.4 ± 15.0	141.8 ± 119.7
A. caerulea 'McKana mix'	28.6 ± 28.6	69.6 ± 69.6	32.6 ± 32.1	84.4 ± 83.6	45.6 ± 41.4	127.2 ± 122.0	62.4 ± 55.0	246.0 ± 150.6	64.0 ± 55.7	132.8 ± 121.0	65.8 ± 56.5	134.2 ± 120.7
A. chrysantha 'Yellow Star'	7.8 ± 4.8	20.2 ± 13.8	11.0 ± 7.2	26.4 ± 17.1	13.8 ± 9.2	34.2 ± 22.2	19.2 ± 12.3	41.0 ± 25.8	21.0 ± 13.2	45.8 ± 29.2	23.8 ± 14.8	49.8 ± 31.8
A. canadensis	0	0	1.2 ± 1.2	3.2 ± 3.2	2.7 ± 2.7	6.7 ± 6.7	5.0 ± 5.0	7.5 ± 7.5	5.0 ± 5.0	7.5 ± 7.5	5.5 ± 5.5	8.5 ± 8.5
A. flabellata	0	0	0.2 ± 0.2	0.2 ± 0.2	1.0 ± 1.0	1.6 ± 1.6	4.5 ± 4.5	6.0 ± 6.0	5.2 ± 5.2	7.5 ± 7.5	6.0 ± 6.0	9.5 ± 9.5
A. x *hybrida* 'Biedermier mix'	21.4 ± 17.7	39.4 ± 33.1	7.6 ± 5.1	15.6 ± 9.6	10.0 ± 6.5	19.4 ± 12.0	15.0 ± 10.1	26.8 ± 16.5	16.8 ± 11.3	28.6 ± 17.6	18.6 ± 12.4	30.6 ± 18.8
A. skinneri	18.0 ± 11.1	69.4 ± 50.3	13.4 ± 11.9	62.0 ± 57.4	17.4 ± 14.2	67.2 ± 60.9	26.6 ± 21.5	131.2 ± 121.2	30.0 ± 23.4	132.4 ± 121.0	35.6 ± 27.3	134.2 ± 120.7
A. vulgaris 'Winkie Blue & White'	2.6 ± 2.6	3.4 ± 3.4	2.8 ± 2.8	7.4 ± 7.4	3.8 ± 3.8	8.2 ± 8.2	4.4 ± 4.4	10.6 ± 10.6	5.4 ± 5.4	11.6 ± 11.6	6.4 ± 6.4	13.8 ± 13.8

Systematic Entomology Laboratory, Agriculture Research Service, US Department of Agriculture in Beltsville, MD, for identification.

Data were subjected to ANOVA using the GLM procedure of SAS (12). Mean separation following a significant ANOVA was accomplished using a Waller-Duncan test with a K-ratio of 100.

Results and Discussion

Leafminer activity. All plant cultivars sustained at least moderate leafminer damage at all locations during at least one of two years. Statistically significant ($P < 0.05$) gradients in severity of infestation and damage were evident among cultivars at two of four locations, Site 1 and Site 4 (Tables 1–4). A heavy leafminer population was present in 2002 at Site 1; no leafminers were present during 2003 at this site (Table 1). Leafminers at this site were heavily parasitized during 2002. Leafminer populations were low at Site 2 during 2002 and moderate during 2003 (Table 2). Too few leafminers were present on plants in Blairsville (site 3) and Fannin Co. (site 4) during 2002 to evaluate. Populations increased, however, during 2003 (Tables 3 and 4).

Leafminers present at all sites were identified as *Phytomyza aquilegivora* Spencer, part of the columbine leafminer complex of three species known to attack columbine in North America. *P. aquilegivora* produces linear mines on columbine, while *Phytomyza aquilegiana* Frost, also known to occur in the southeastern United States, produces blotch mines. *Phytomyza columbinae* Sehgal, also known to produce linear mines, occurs in the western United States.

While all species and cultivars sustained damage, some were less heavily infested than others. At site 1, where 20 plant taxa were compared under heavy leafminer populations in 2002, the least affected plant taxa were *A. caerulea* 'Dwarf Fantasy Mix', *A. canadensis*, and *A. flabellata*. Although *A. alpina* was not initially heavily infested (Table 1, May 1–15 fewer than 3 leaves with mines), by the middle of June, it was severely damaged (>18 leaves with mines and >86 total mines per plant). *A. chrysantha* 'Yellow Star' and the variegated A. *vervaeneana* 'Woodside' were initially less heavily attacked, but eventually sustained moderate infestation levels. No selections were leafminer-free, and no plant taxa were less heavily infested than the native *A. canadensis*. No significant differences ($P > 0.05$) in leafminer densities were noted among the plant taxa monitored at the irrigated site 2 and Blairsville plots, although the same general trend was apparent (Tables 2 and 3) with *A. canadensis* and *A. flabellata* being slower to become infested. At the non-irrigated site 4 in Fannin Co. in north Georgia, differences in leafminer densities were only significant ($P < 0.05$) on the last sampling date in 2003 (Table 4). Again, *A. canadensis*, *A. flabellata*, and *A. caerulea* 'Dwarf Fantasy Mix' were the least heavily infested.

Parasitism. A total of 122 parasitoids were reared from leafminers collected in the field. Eleven species of hymenopteran parasitoids representing three families were recovered (Table 5). Parasitoid emergence on the final collection date at each of the two locations where parasitism was monitored was sufficient to enable comparison of total parasitism among plant taxa tested. Leafminers infesting *A. chrysantha* 'Yellow Star' were the most heavily parasitized at both locations (Table 6). *Chrysocharis pentheus* Walker

Table 4. Mean ± s.e. number of leaves with mines (LWM) and total mines per leaf (TM) among cultivars of columbine, *Aquilegia* spp., cultivars in a non-irrigated, wooded location, Site 4 Blue Ridge, GA, 2003.

	April 23		May 15		May 29	
Species, cultivar	**LWM**	**TM**	**LWM**	**TM**	**LWM**	**TM**
A. caerulea	0	0	0	0	6.0 ± 0.0a [z]	50.0 ± 0.0a
A. caerulea 'Dwarf Fantasy mix'	0	0	0	0	0d	0f
A. caerulea 'McKana mix'	0	0	0	0	5.0 ± 1.5ac	30.3 ± 6.9b
A. canadensis	0.3 ± 0.3	1.7 ± 1.7	0	0	0d	0f
A. flabellata	0.2 ± 0.2	0.4 ± 0.4	0	0	0.8 ± 0.6dc	2.8 ± 2.0ef
A. x *hybrida* 'Ruby Port'	0.2 ± 0.2	0.2 ± 0.2	0	0	3.0 ± 0.6ad	18.0 ± 6.1bd
A. skinneri	0.5 ± 0.5	3.0 ± 3.0	0.5 ± 0.5	2.5 ± 2.5	2.8 ± 1.7ad	8.2 ± 6.4df
A. vervaeneana 'Woodside'	0	0	0	0	1.3 ± 0.7bd	4.3 ± 2.3df
A. vulgaris 'Nora Barlow'	1.0 ± 1.0	4.3 ± 4.3	1.0 ± 1.0	3.7 ± 3.7	5.5 ± 0.5ab	28.0 ± 7.0bc
A. vulgaris 'Winkie Blue & White'	0.8 ± 0.6	3.2 ± 2.0	0.7 ± 0.3	2.3 ± 1.4	3.0 ± 1.6ad	14.7 ± 5.5ce
Aquilegia sp. 'Danish Dwarf'	0.4 ± 0.4	1.2 ± 1.2	0.6 ± 0.4	1.6 ± 1.0	2.0 ± 0.6ad	12.3 ± 6.3df
Aquilegia sp. 'Royal Purple'	1.0 ± 0.6	3.7 ± 3.2	0.7 ± 0.5	1.5 ± 1.2	1.0 ± 0.7cd	4.2 ± 2.6df

[z]Means followed by the same letter within a column are not (P > 0.05) significantly different

Table 5. Hymenopteran parasitoids reared from columbine leafminers, *P. aquilegivora* on columbine cultivars.

Family	Genus species	% of samples
Eucolilidae	unidentified	1.0
Eulophidae	*Chrysocharis* sp.	2.0
	*Chrysocharis oscinidis*Ashmead	2.0
	Chrysocharis pentheus Walker	41.0
	Closterocerus cinctipennis Ashmead	5.7
	Clostocerus trifasciatus Westwood	1.0
	Neochrysocharis formosa Westwood	5.7
	Pediobius testaceipes Crawford	1.0
	Pnigalio minio Walker	14.8
Pteromalidae	*Halticoptera* sp.	3.3
	Seladerma sp.	22.1

Table 6. Mean total number of parasitoids reared from *P. aquilegivora* collected from each columbine cultivar at two sites in Spalding Co., GA.

Species, cultivar	Site 1/ 2002	Site 2/ 2003
A. alpina	4.0 ± 0.6b	2.8 ± 2.1b
A. caerulea	2.0 ± 0.0bd	—
A. caerulea 'Dwarf Fantasy mix'	1.5 ± 0.5cd	—
A. caerulea 'McKana mix'	2.0 ± 1.0bd	0.2 ± 0.2b
A. caerulea 'Music hybrid'	0.0d	—
A. chrysantha 'Yellow Star'	9.0 ± 0.0a	6.6 ± 1.7a
A. canadensis	1.3 ± 0.3d	0.2 ± 0.2b
A. flabellata	1.0 ± 0.6d	0.0b
A. x *hybrida* 'Biedermier mix'	0.0d	0.6 ± 0.6b
A. x *hybrida* 'Ruby Port'	3.8 ± 1.0bc	—
A. x *hybrida* 'Spring Magic mix'	1.0 ± 0.0d	—
A. x *hybrida* 'Sunlight White'	1.2 ± 0.2d	—
A. skinneri	1.0 ± 0.0d	1.0 ± 1.0b
A. vervaeneana 'Woodside'	1.5 ± 0.3cd	0.0b
A. viridiflora	2.0 ± 1.0bd	0.0b
A. vulgaris 'Magpie'	1.5 ± 0.5cd	—
A. vulgaris 'Nora Barlow'	1.5 ± 0.5cd	—
A. vulgaris 'Winkie Blue & White'	1.7 ± 0.3bd	1.8 ± 1.3b
Aquilegia sp. 'Danish Dwarf'	1.0 ± 0.0d	—
Aquilegia sp. 'Royal Purple'	1.4 ± 0.7cd	—

*Means followed by the same letter within a column are not (P > 0.05) significantly different

was the most abundant parasitoid, representing 41% of all parasitoids collected and 48.4% of the species reared from leafminers in central Georgia. *Seladerma* sp. was the only parasitoid reared from leafminers collected in north Georgia and represented 22.1% of all parasitoids obtained.

Thirteen species of parasitoids were reared from a leafminer species on columbine in Maryland (7). Parasitoids reared in greatest abundance in Maryland were *Closterocerus* spp., especially *C. tricinctus* Ashmead. The final generation was the most heavily parasitized. It was observed that parasitoids 'exerted a decided influence' at certain times of the year, but were not numerous in early season samples. We obtained similar results in this study. Parasitoids appeared to play a prominent role in determining whether leafminers would reinfest plants in a particular location during any subsequent year.

Because the leafminers spend the winter as pupae, removal and destruction of infested plant parts and cultivation around infested plants should reduce the likelihood of reinfestation (7). Our data indicate that the columbines *A. flabellata*, *A. caerulea* 'Dwarf Fantasy Mix', and *A. canadensis* were less prone to leafminer infestation than several other columbine taxa. Parasitoids may, as occurred in this study, parasitize leafminers to a greater extent on certain columbine taxa. Although *A. chrysantha* 'Yellow Star' experienced at least moderate infestation by columbine leafminer at most locations in our study, it was the cultivar where the greatest parasitism was observed. Factors responsible for the higher level of parasitism were not determined. Microclimatic conditions, more suitable plant architecture, characteristics of the flowers, or greater suitability of leafminer hosts on that particular cultivar may have played a role. Unfortunately, parasitized larvae still mine their host leaves to a damaging extent prior to their death due to parasitism. Subsequent population numbers presumably are reduced following a season of heavy parasitism. During the duration of our study, *A. aquilegivora* was the only leafminer observed attacking columbine. The leafminer was heavily parasitized by numerous hymenopteran parasitoids. No high level of resistance to the leafminer was observed. However gradients in severity of infestation offer consumers options for reducing the damage potential of this pest.

Literature Cited

1. Armitage, A.M. 1989. Herbaceous Perennial Plants. Varsity Press, Inc. Athens, GA.

2. Braman, S.K. and J.G. Latimer. 2002. Effects of cultivar and insecticide choice on oleander aphid management and arthropod dynamics on *Asclepias* species. J. Environ. Hort. 20:11–15.

3. Braman, S.K. and A.F. Pendley. 1992. Evidence for resistance of deciduous azaleas to azalea lace bug. J. Environ. Hort. 10:41–43.

4. Braman, S.K. and J.M. Ruter. 1997. Preference for twolined spittlebug for *Ilex* species, hybrids and cultivars. J. Environ. Hort. 15:211–214.

5. Braman. S.K., J.G. Latimer, R.D. Oetting, R.D. McQueen, T.B. Eckberg, and M. Prinster. 2000. Management strategy, shade, and landscape composition effects on urban landscape plant quality and arthropod abundance. J. Econ. Entomol. 93:1464–1472.

6. Briton, W.E. 1894. Notes on some leaf miners. Conn. Agric. Exp. Stn. Rep. 18:143–146.

7. Cory, E.N. 1916. The columbine leafminer. J. Econ. Entomol. 9:419–424.

8. Frost, S.W. 1924. A study of the leaf-mining Diptera of North America. Cornell Univ. Agric. Exp. Stn. Memoir 78. 228 pp.

9. Frost, S.W. 1930. The leaf-miners of *Aquilegia*, with a description of a new species. Annals Entomol. Soc. Am. 23:457–460.

10. Gillman, J.H., M.A. Dirr, and S.K. Braman. 1999. Gradients in susceptibility and resistance mechanisms of *Buddleia* L. taxa to the two spotted spider mite (*Tetranychus urtichae* Kocch). J. Amer. Soc. Hort. Sci. 124:114–121.

11. Hodges G., J.M. Ruter, and S.K. Braman. 2001. Susceptibility of *Ilex* species, hybrids and cultivars to Florida wax scale (*Ceroplastes floridensis* Comstock). J. Environ. Hort. 19:32–36.

12. SAS Institute. 2003. SAS/STAT User's Guide. 8.02 ed. SAS Institute, Inc. Cary, NC.

13. Townsend, M.L., R.D. Oetting, and S.K. Braman. 1999. Whitefly and lacebug performance on *Lantana* spp. cultivars in the greenhouse. J. Environ. Hort. 17:99–102.

14. Wang, Y, C.D. Robacker, and S.K. Braman. 1998. Identification of resistance to azalea lace bug among deciduous azalea taxa. J. Amer. Soc. Hort. Sci. 123:502–597.