Population Dynamics of Thrips (Thysanoptera: Thripidae: Phlaeothripidae) Inhabiting *Vaccinium* (Ericales: Ericaceae) Galls in Georgia

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ABSTRACT Thrips inhabiting leaf galls on noncultivated *Vaccinium* species were surveyed throughout Georgia. *Frankliniella caudiseta* Sakimura & O'Neill was present on *V. tenellum* Aiton and *V. myrsinites* Lam. Blueberry thrips, *Frankliniella vaccinii* Morgan, was only collected from *V. arboreum* Marsh. *Catinathrips similis* Nakahara occurred on *V. tenellum* and *V. myrsinites*. However, *C. vaccinicola* Nakahara was collected only on *V. arboreum*. *Haplothrips rectipennis* Hood, a predaceous species, was found on all *Vaccinium* species. *F. vaccinii* and *C. vaccinicola* were both capable of initiating gall formation on plants in the spring. Both species may coexist in the same gall and are univoltine on mature growth during a season. However, in cutover areas where new plant growth was generated during the summer, 1 additional generation was produced. Adult terebrantians became active during April. Larvae were abundant during May and June. On 2nd-growth plants, larvae were abundant during July and August and adults were collected in October. The predator *H. rectipennis* colonized galls during May. Larvae of this species became abundant during May and June. One generation was produced. Adults remained in the galls until leaves dropped from the plants, usually in October. Thrips significantly reduced shootlength, bud formation, and fruit production of both *V. arboreum* and *V. myrsinites*. These observations have implications for blueberry plant improvement efforts.

KEY WORDS thrips, blueberry, *Vaccinium*, galls, population dynamics

VACCINIUM ARBOREUM MARSH., sparkleberry, is common to dry, sandy, or rocky woods and old fields and ranges from southeast Virginia south to Florida and west to Oklahoma, the Ozarks, and Texas. This upright shrub (2–9 μm tall) has deciduous-persistent leaves and shiny black berries and makes an attractive ornamental. The flowers provide a good nectar source for the rare northern hairstreak butterfly (Payne et al. 1990). The berries are dry and seedy with little flesh and little taste, but are an important food source for many songbird species (scarlet tanagers, robins, cardinals, bluebirds, and brown thrashers) and are also eaten by deer, chipmunks, rabbits, foxes, and raccoons (Payne et al. 1990). *Vaccinium* spp. also are host plants for the striped hairstreak and brown elfin butterflies (Payne et al. 1990). Additional *Vaccinium* species common in central and south Georgia include *Vaccinium myrsinites* Lam, *Vaccinium darrowii* Camp, *Vaccinium corymbosum* L., *Vaccinium staminueum* L., and *Vaccinium tenellum* Aiton. These species are potential sources for traits important in blueberry breeding programs including insect and disease resistance, low chilling requirements, heat, drought, and cold tolerance, and upland soil adaptation (Luby et al. 1990).

More than 300 species of primary and secondary gall-inhabiting Thysanoptera are recognized (Ananthakrishnan 1978). Most species are tropical and are common in Indo-Malaysia and Australia. Wood (1956, 1960) discussed the occurrence of 2 species, blueberry thrips, *Frankliniella vaccinii* Morgan, and *Catinathrips* (=*Taeniothrips*) *vaccinophilus* (Hood), forming leaf galls on cultivated lowbush blueberries in New Brunswick and Nova Scotia. Beshear (1985) made field observations of *Catinathrips beshearae* Nakahara, which induces marginal leaf galls on *Calycanthus* spp. (sweetshrub). This species, originally mistaken for *C. vaccinophilus*, was later described as a new species (Nakahara 1992, 1993).

Braman et al. (1993) noted the occurrence of *F. vaccinii*, *Catinathrips vaccinicola* Nakahara, and *Haplothrips rectipennis* Hood within leaf galls of sparkleberry in Georgia. Affected plants exhibit a tight curling of the leaves about the stems (Fig. 1) usually accompanied by a reddening of the typically green or golden-green foliage. Infested leaves of *V. tenellum* turn black instead of the more typical reddish-purple of the other species. Sampling

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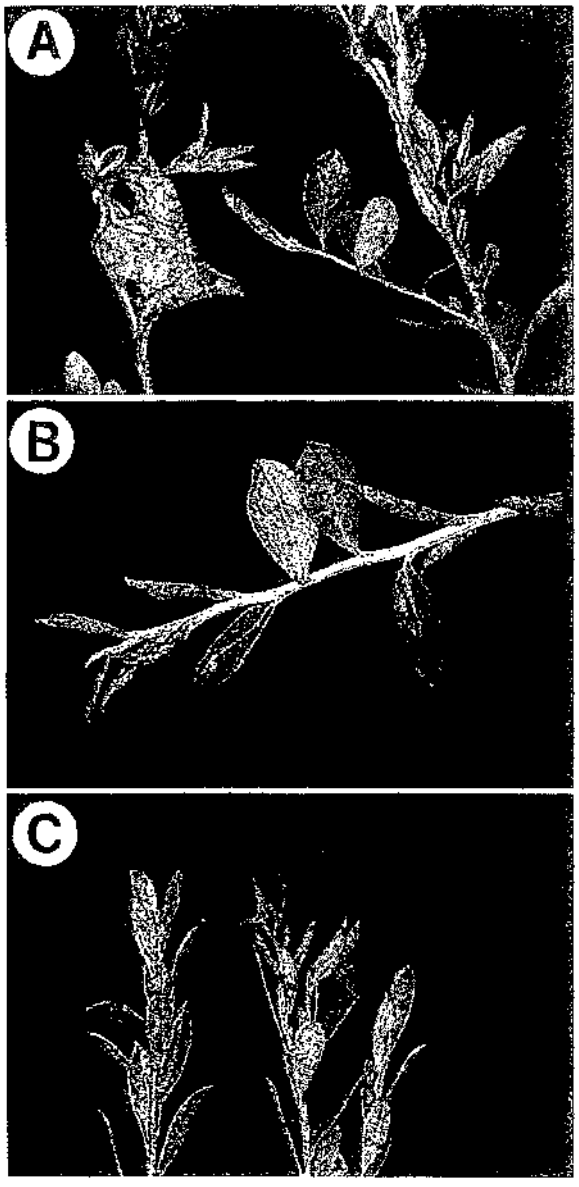

Fig. 1. Thrips induced damage to *V. arboreum* (A) *V. tenellum* (B), and *V. myrsinites* (C).

within the state was undertaken to better understand the interactions of thrips species within the galls, to determine their seasonal distribution, and to assess their influence on growth and fruit production.

Materials and Methods

Thrips Extraction and Identification. Terminals collected from *Vaccinium* spp. were placed in Berlese funnels for 5 d and the thrips were recovered in vials containing 70% ethanol attached immediately beneath the funnels. Thrips were identified by microscopic examination of prepared slide mounts of adults. Larvae of *F. vaccinii* and *Catinathrips* spp. cannot be distinguished from each other and were thus counted as a single category, larval Terebrantia. Immature *H. rectipennis* was readily distinguishable as a tubuliferan from the other immature thrips.

Study Sites and Thrips Collection. Periodic collections of at least 10 terminals were made from *V. arboreum*, *V. tenellum*, and *V. myrsinites* on each of 24 dates during 1988 and 1989 throughout Georgia (Table 1). Ten terminals from *V. arboreum* in Henry, Harris, and Peach counties (north central, central, and south central Georgia) were collected at random approximately once per month during 1992 from May through September for thrips extraction. Each collection was made in the same location to examine progression of the local population through time. Terminals were placed inside self-sealing plastic bags and kept in a cooler on crushed ice, returned to the Georgia Station, and placed in Berlese funnels.

Ten terminals from plants in each county were collected on 20 dates during 1993 from April through October and processed in the same manner. Additional samples were obtained from secondary growth during mid-to-late summer 1993, in an area where many *V. arboreum* had been mowed along a powerline. Sparkleberry leaves senesced in September and October.

Collection sites were all rural. In Henry County, sparkleberry occurred as roadside vegetation surrounded by agricultural land and a piece of commercial property. Leaf samples were collected in the Franklin D. Roosevelt State Park in Harris County along the entrance to camping areas in a primarily wooded location. Peach County collections were made along an entranceway to a private rural residence.

Thrips Effect on Shoot Length, Buds, and Fruit Number in *V. myrsinites* and *V. arboreum*. A comparison of shoot length and number of buds on uninfested versus infested shoots of *V. myrsinites* was made on 18 January 1989 in Columbia County, Florida. Paired counts were made on 50 randomly selected plants. The experimental area was mowed before a similar comparison of fruit number could be made. The effect of thrips on shoot length and fruit number per shoot was observed on *V. arboreum* in Peach County, Georgia on 2 July 1989 using paired comparisons of healthy versus infested shoots on 50 randomly selected plants. Paired *t*-tests were used to determine significant differences in growth parameters as affected by thrips infestation. The relationship of fruit or bud number and shoot length was examined using the general linear models procedure (SAS Institute 1985).

Results

Thrips Species Composition 1988–1989. Species found in *Vaccinium* galls during 1988 and 1989 included *Frankliniella caudiseta* Sakimura & O'Neill, *F. vaccinii*, flower thrips, *F. tritici* (Fitch), western flower thrips, *F. occidentalis* (Pergande), *F. bispinosa* (Morgan), *Pseudothrips beckhami* Be-

Table 1. Thrips species collected in leaf galls on *Vaccinium* spp., 1988–1989

Date	Thrips species presence (+) or absence (–)								
	F. vaccinii	*F. occidentalis*	*F. bispinosa*	*F. tritici*	*F. caudiseta*	*H. rectipennis*	*C. similis*	*C. vaccinicola*	*P. beckhami*
					V. arboreum				
26 May 1988	+	–	–	–	–	+	–	–	–
9 July 1988	+	–	–	–	–	+	–	–	–
13 July 1988	+	–			–	+	–	–	
12 Nov. 1988	–	+		–				–	–
11 Jan. 1989	+	–	–	–	–	+	–	–	
3 Apr. 1989	+	–	–	–	–	+	–	+	–
16 Apr. 1989	+	–	–	–	–	–	–	+	–
28 Apr. 1989	+	–	+	+	–	–	–	+	–
5 May 1989	+	–	–	+	–	+	–	+	
12 May 1989	+	+	–	+		–	–	–	–
26 May 1989	+	–	–	–	–	+	–	–	–
1 June 1989	+	–	–	–	–	–	–	–	–
15 June 1989	+	–	–	–	–	+	–	–	–
28 June 1989	+	–		–	–	–	–	–	–
7 July 1989	+	–	–	–	–	+	–	–	–
16 July 1989	+	–	–	–	–	+	–	–	–
21 July 1989	–	–	–	–	–	+	–	–	–
15 Aug. 1989	–	–	–	–	–	+	–	–	–
21 Aug. 1989	–	–	–	–	–	+	–	–	–
28 Aug. 1989	–	–	–	–	–	+	–	+	–
4 Sept. 1989	+	–	–	–	–	+	–	+	–
16 Sept. 1989	–	–	–	–	–	+	–	–	
27 Sept. 1989	+	–	+	+	–	+	–	–	
3 Oct. 1989	+	–	–	–	–	+	–	–	–
					V. tenellum				
5 July 1988	–	–	–	–	+	+	–	–	–
11 July 1988	–	–	–	–	+	+	–	–	–
9 Nov. 1988	–	–	–	–	–	+	–	–	–
14 Apr. 1989	–	–	–	+	–	+	+	–	–
14 Sept. 1989	–	–		–	–	+	+		
					V. myrsinites				
6 July 1988		–	–	–	+	–	–	–	–
18 Aug. 1988	–	–		–	+	–	–	–	–
20 Sept. 1988	–	–	–	–	+	+	–	–	–
7 Oct. 1988	–	–	–	–	+	–	–	–	–
14 Nov. 1988	–	–	–	–	+	+	–	–	
4 Apr. 1989	–	–	+		+	+	+		+
15 Aug. 1989		–	–	–	–	+	–	–	–
21 Aug. 1989	–	–	–	–	–	+	–	–	–

shear & Howell, *C. vaccinicola*, *C. similis* Nakahara, and *H. rectipennis* (Table 1). *F. tritici*, *F. bispinosa*, and *F. occidentalis* occur on a wide variety of plants in Georgia (Beshear 1973, 1979, 1983) primarily in the flowers. *Pseudothrips beckhami* was previously known only from bloodroot flowers, *Lachnanthes tinctoria* (Walt.) Ell. (Beshear and Howell 1976). The last 4 species were collected in low numbers and were probably incidental visitors to the galls.

Frankliniella vaccinii and *C. vaccinicola* were found only on *V. arboreum*. *F. caudiseta* and *C. similis* were collected on *V. tenellum* and *V. myrsinites*, but were not found on *V. arboreum*. *H. rectipennis* was present on all *Vaccinium* species.

Adult *F. caudiseta* were collected from *V. myrsinites* in Echols County, Georgia, and Columbia County, Florida, from July 1988 through January 1989 and again during April–June 1989. Larvae were present in low numbers in July 1988, became abundant in August through October, then decreased during November 1988. Larvae were again detected in the June 1989 samples. *F. caudiseta* was described as a new species from berlese funnel samples of pine needles and oak leaves in Florida (Sakimura and O'Neill 1979). No host association was made at that time.

Seasonal Trends. Specimens of *F. vaccinii*, *C. vaccinicola*, and *H. rectipennis* were present in 1992 and 1993 collections from all locations (Table 2). Adults of *F. vaccinii* and *C. vaccinicola* emerge from the soil in the spring and initiate the galls on new leaves. Either species appears capable of initiating the gall. For example, during 1993 *C. vaccinicola* adults were present before *F. vaccinii* in Peach County and were predominant in samples collected early in the season in Henry County (Table 2). Conversely, *F. vaccinii* was predominant in the first collections in Harris County that yielded thrips after Berlese extraction.

Adult terebrantians became active in early April in Peach County and late April in Henry and Har-

Table 2. Seasonal occurrence of thrips inhabiting *Vaccinium* galls in Georgia, 1992 and 1993

Date	County	No. per 10 terminals				
		Adult *F. vaccinii*	Adult *C. vaccinicola*	Larvae *Terebrantia*	Adult *H. rectipennis*	Larvae *H. rectipennis*
				1992		
12 May	Henry	10	13	77	12	87
2 June		11	0	64	186	31
9 June		3	0	0	50	0
1 July		0	0	0	189	1
17 July		0	0	0	120	2
28 July		0	0	0	88	2
6 Aug.		0	0	0	272	3
25 Aug.		0	0	1	32	0
11 May	Harris	19	5	230	0	0
22 July		120	0	6	0	0
12 Aug.		8	0	0	0	0
2 Sept.		3	2	2	0	0
11 Sept.		0	0	0	0	0
23 Apr.	Peach	4	22	28	0	4
26 May		26	1	22	45	7
28 July		8	0	0	76	2
25 Aug.		0	0	0	60	0
				1993		
7 Apr.	Henry	0	0	0	0	0
14 Apr.		0	0	0	0	0
21 Apr.		2	47	0	7	0
28 Apr.		0	5	0	1	0
4 May		4	39	6	5	0
12 May		10	17	235	3	26
20 May		8	7	392	7	85
26 May		10	0	542	8	47
2 June		53	0	113	65	64
9 June		11	0	0	37	0
16 June		17	0	0	189	0
24 June		11	0	0	39	0
1 July		2	0	0	39	0
14 July		1	0	0	49	0
29 July		0	0	0	76	1
17 Aug.		0	0	0	58	0
31 Aug.		0	0	0	124	0
5 Oct.		0	0	0	31	0
7 Apr.	Harris (old growth)	0	0	0	0	0
14 Apr.		0	0	0	0	0
20 Apr.		11	4	0	0	0
28 Apr.		8	4	6	0	0
4 May		0	8	1	0	0
12 May		10	9	128	6	3
20 May		8	4	634	2	0
26 May		5	3	275	7	0
2 June		23	5	210	0	0
16 June		10	0	0	51	0
24 June		12	1	0	7	0
1 July		2	0	0	145	1
17 July		1	0	0	256	0
29 July		0	0	0	325	0
17 Aug.		1	0	0	196	0
31 Aug.		0	0	0	99	0
15 Sept.		0	0	0	167	0
5 Oct.		0	0	0	346	0
18 Oct.		0	0	0	86	0
24 June	Harris (new growth)	13	6	14	0	0
1 July		17	2	156	1	2
17 July		29	0	36	0	0
29 July		39	0	0	0	0
17 Aug.		5	1	0	0	0
31 Aug.		1	2	29	0	0
15 Sept.		8	0	7	1	0
5 Oct.		0	0	0	1	0
18 Oct.		2	0	0	1	0
7 Apr.	Peach	0	15	0	0	0
14 Apr.		1	30	0	2	0
21 Apr.		4	17	0	2	0
28 Apr.		2	25	7	7	0
4 May		14	28	39	3	10

Table 2. Continued

Date	County	No. per 10 terminals				
		Adult *F. vaccinii*	Adult *C. vaccinicola*	Larvae *Terebrantia*	Adult *H. rectipennis*	Larvae *H. rectipennis*
		1992				
12 May	Peach	17	2	566	0	46
20 May		8	2	392	7	85
26 May		20	0	176	93	48
2 June		25	0	10	162	0
17 June		7	0	0	110	0
24 June		4	0	0	71	0
1 July		16	0	16	0	2
17 July		0	0	6	31	1
29 July		0	0	0	0	0
31 Aug.		0	0	0	191	0
15 Sept.		0	0	0	432	0
15 Oct.		0	0	0	269	0
18 Oct.		0	0	0	29	0

ris counties. Larval terebrantians were represented abundantly in samples collected from early-to-late May in Peach and Harris counties and from early May to early June in Henry County. Adults of the 1st generation were present in June. Samples obtained from cutover areas in Harris County, where regrowth of *Vaccinium* was prevalent, revealed that in the absence of the *H. rectipennis*, adults of both *F. vaccinii* and *C. vaccinicola* from the old growth colonized and completed another generation on the later season growth (Table 2).

Haplothrips rectipennis adults appeared in the galls soon after their formation in Peach and Henry counties, and somewhat later in the season in Harris County. Larvae of this species were abundant during late May and early June. Inhabitants of the galls at most locations were primarily adult *H. rectipennis* from June through October. This species appears to be predaceous on the terebrantians present in leaf galls. They also were observed to be cannibalistic when leaf galls were opened in the laboratory under a microscope-mounted camera.

Thrips Effect on Shoot Length, Buds, and Fruit Number in *V. myrsinites* and *V. arboreum*. Thrips significantly reduced shoot length by 28.1% ($t = 11.4$, df = 49, $P < 0.0001$) and fruit number by 76.3% ($t = 11.7$, df = 49, $P < 0.0001$) in *V. arboreum* (Table 3). Damaged shoots had a greater chance of producing fewer buds and fruits ($R^2 = 0.84$). *V. myrsinites* was affected similarly by thrips infestation (Table 3). Shoot length was reduced 23.3% ($t = 8.1$, df = 49, $P < 0.0001$), whereas number of buds on infested shoots was reduced 66.7% ($t = 13.8$, df = 49, $P < 0.0001$). Damaged shoots again produced fewer buds ($R^2 = 0.93$).

Discussion

Phipps (1930) mentioned *F. vaccinii* as a pest of low-sweet blueberries in Maine. Injury, which consisted of malformed discolored leaves, was most noticeable on the new burn fields where the most vigorous new growth occurred. Plants were weakened by thrips injury and became prone to winter injury.

Wood (1960) presented the taxonomy, life history, damage, and distribution of *F. vaccinii* and *C. vaccinophilus* on low-bush blueberry in New Brunswick and Nova Scotia. Samples collected in New Brunswick between 1947 and 1951 were all *F. vaccinii*. Those collected in 1951 were ≈25% *C. vaccinophilus*, those after 1951 were nearly all *C. vaccinophilus*. In a survey conducted in 1959 to determine the distribution of the 2 species in New Brunswick and adjacent areas of Nova Scotia, *F. vaccinii* was the predominant species in Cumberland County, Nova Scotia, whereas *C. vaccinophilus* was predominant in all fields in Charlotte County, New Brunswick. In the eastern and northern counties of New Brunswick these 2 species were approximately equal in abundance.

Life histories of *F. vaccinii* and *C. vaccinophilus* were similar. Overwintered females emerged from the ground in late May or early June and attacked the plants (Wood 1960). Galls of both species are similar. All stages are passed within the gall and adults emerge from the galls in the fall to over-

Table 3. Effects of thrips on shoot length, buds, and fruit number in *V. arboreum* and *V. myrsinites*

Plant species	Mean ± SEM ($n = 50$)			
	Healthy shoot length, cm	Damaged shoot length, cm	Healthy buds or fruit	Damaged buds or fruit
V. arboreum	47.3 ± 1.1	34.0 ± 1.2	3.8 ± 0.2	0.9 ± 0.2
V. myrsinites	59.6 ± 3.2	45.6 ± 2.9	2.8 ± 0.2	0.4 ± 0.1

winter in the soil. Langille and Forsythe (1972) determined that the peak of larval abundance of *C. kainos* O'Neill and *F. vaccinii* occurred in mid-July in Maine on lowbush blueberry.

In Georgia, either *F. vaccinii* or *C. vaccinicola* may predominate depending on the location and year of study. Adult terebrantians are actively initiating galls as early as April. Larval thrips are numerous in May and June. The predator *H. rectipennis*, which was not mentioned by Phipps (1930), Wood (1960), or by Langille and Forsythe (1972), was common in all sites in Georgia. This species was also found in the marginal leaf galls produced by *Catinathrips besheareae* on sweet shrub, *Calycanthus fertilis* Walt., and on *C. floridus* L. (Beshear 1985).

Observed effects on shoot length, bud formation and fruit number illustrate a need to consider pest susceptibility in plant improvement programs. Several arthropod pests can currently limit blueberry production either directly or indirectly as vectors including the blueberry maggot, *Rhagoletis mendax* Curran, the leafhopper *Staphytopius magdalensis* Prov., the aphid *Illinoia pepperi* Mac. G., cranberry fruitworm, *Acrobasis vaccinii* Riley, cherry fruitworm, *Grapholita packardi* Zeller, and the plum curculio, *Conotrachelus nenuphar* Herbst (Luby et al. 1990). *Vaccinium* breeders make substantial efforts to evaluate and use wild germplasm in their plant improvement programs.

Available germplasm, including those species that were the focus of our investigation, may provide solutions to currently serious diseases such as stem blight, blueberry shoestring virus, and blueberry stunt as well as important horticultural characteristics mentioned previously. Gall-forming thrips are not currently an important factor in southeastern blueberry production. However, results of our work with plant species presently used in blueberry breeding efforts suggest a potential for inadvertently increasing susceptibility to these insect pests.

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