History, Distribution, Damage, and Life Cycle of a Pine Shoot Gall Sawfly, *Xyela gallicaulis* (Hymenoptera: Xyelidae)[1]

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Abstract Larvae of *Xyela gallicaulis* Smith cause shoot stem galls in young pines. Loblolly pine, *Pinus taeda* L., is the most seriously damaged, but galls have been observed on slash pine, *P. elliottii* var. *elliottii* Engelm., and shortleaf pine, *P. echinata* Mill. Studies in Virginia and Georgia confirm a 2-year life cycle. Larval development takes 4 - 6 wks. After feeding, larvae bore out of the galls and drop to the ground where they form a papery cocoon in the soil to pupate, and where they remain for 22 - 25 months. Adults emerge from cells constructed in the soil from early-December to mid-January of the second year. Eggs are inserted into the vegetative buds during odd-numbered years. Insect associates found feeding in or on gall tissues are the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Tortricidae), and the weevil *Conotrachelus carolinensis* Schoof (Curculionidae).

Key Words Symphyta, *Pinus*, shoot galls

Larvae of *Xyela gallicaulis* Smith cause shoot galls in pines, an unusual habit in *Xyela* where larvae of most species live and develop in the staminate cones. This seldom-collected species is known only from the southeastern United States and is considered a rare species because few specimens are known in collections. Its damage and occurrence at high population levels are sporadic, occurring only in certain years and unnoticeable for many more. Because of its long life cycle, infrequent occurrence, difficulty to rear, and limited and intermittent economic importance, it is unlikely that past studies will be completed or new studies initiated in the near future. Plans to further define the life history of this insect were curtailed by the senior author. Yet, these observations and records need to be reported and assimilated with other work on the pest. Therefore, we present a review of this species and bring together the mostly unpublished biological observations and research that has been conducted with this sawfly, combining the initial research from Virginia with subsequent observations in Georgia in the 1970s.

The first record of *X. gallicaulis* was in May 1939 when deformed developing shoots of young loblolly pines, *Pinus taeda* L., were noted in Virginia (Hetrick 1939). At that time, damage was attributed to a pine shoot weevil. The locality was not reported, but is presumed to be near West Point, VA (King and Queen Co.) where subsequent

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studies were conducted. Hetrick (1939, 1940, 1941) reported that larvae from these galls were later obtained and identified as a *Xyela* species by R. A. Cushman, who indicated that they may represent a new species. Galls were again discovered in May 1940 from which adults emerged in December 1941 (Hetrick 1940, 1941). Notes prepared on this sawfly in Virginia by Hetrick were presented by R. A. Cushman in the minutes of the 524th meeting of the Entomological Society of Washington (Hetrick 1942). No further observations have been reported from Virginia.

In April 1965, a spindle-shaped gall on a tender shoot of a young 1.8 m tall loblolly pine was discovered by the senior author in Clarke Co., GA. The damage consisted of galls developing on the current year pine shoots. Additional galls were abundant on both shortleaf, *Pinus echinata* Mill., and slash, *Pinus elliottii* var. *elliottii* Engelm., pines. Larval specimens and galls were sent to the Insect Identification and Parasite Introduction Research Branch, Entomology Research Division, U. S. Department of Agriculture (currently the Systematic Entomology Laboratory) and were identified as *Xyela* sp. or *Pleroneura* sp. by B. D. Burks. A preliminary identification based on larvae, possibly as *Pleroneura* sp., was because of the similarity of larval anatomy (Smith 1967) and habits (Webb and Forbes 1951) to species of *Pleroneura* that form galls on *Abies* spp. Accounts from 1965 - 1969 referred to this insect as *Pleroneura* sp. (Anonymous 1965). Reared adults obtained in 1970 were determined by the junior author to be a new species, later described by Smith (1970) as *Xyela gallicaulis*.

Materials and Methods

The earlier study areas in Virginia were in King and Queen Co. near West Point (Hetrick 1942). The study area in Georgia was in loblolly pine plantations in Clarke Co. about 275 m from the University of Georgia Arboretum, Whitehall.

Hetrick (1939, 1940) collected infested shoots and placed them in soil pots in the laboratory. He also noted that plant material was placed in a soil cage so that adults might be obtained (Hetrick 1940). Additional rearing methods are not available, but several adults reportedly emerged in 1941 (Hetrick 1941).

In Georgia, unsuccessful attempts were made to rear the adults in 1965 and 1967. These efforts consisted of permitting emerging larvae to construct prepupal cocoons in glass vials of soil and storing them at 5°C. When vials were removed from cold storage and placed at room temperature, larval movement could be seen through the glass, but after about 6 months all larvae had died.

In the spring of 1969, infested pine shoots were gathered, and emerging larvae were collected after they bored out of the galls. Twelve 17-cm clay pots were filled with sandy clay soil to within 5 cm of the top rim. A 2.5-cm layer of sandy loam and a thin layer of pine needles were placed on top of the soil. All soil and pine needles were autoclaved to eliminate any possible predators or pathogens. The drainage hole at the base of the pot was covered with a piece of wire screen to prevent escape of larvae or the invasion by unwanted predators. Twenty larvae were placed in each pot on top of the soil. Larvae immediately began to burrow into the soil until they were not visible. A flexible plastic screen was secured to the top of the pot with an adjustable metal band tightened around the rim. Pots were then sunk to the rim in an outdoor walk-in screened rearing cage. The "floor" of this cage was composed of a 13-cm layer of gravel provided with drainage and covered by about 20 cm of decomposed sawdust. A 73% shade cloth covered this area. No watering or other care was conducted during the rearing period.

This technique was successfully used to rear adults from larvae collected in May 1969 (adults emerged December 1970) and larvae collected in May 1971 (adults emerged December 1972) under laboratory conditions.

Results

Distribution. Confirmed observations of *X. gallicaulis* were made in 9 Georgia counties (Clarke, Oglethorpe, Greene, Morgan, Jasper, Putnam, Jones, Bibb, and Wilkinson). Hetrick (1942) and Kulman (in litt.) reported the species in King and Queen and Pulaski counties in Virginia. It is likely that this sawfly may be found throughout the upper Piedmont Region from central Georgia to northern Virginia. There is one record from Great Smoky Mountains National Park with no further data (Smith 2008).

Hosts. Loblolly pine, *Pinus taeda*, appears to be the favored host and is most seriously injured by *X. gallicaulis*. The shortleaf pine, *P. echinata*, and slash pine, *P. elliottii* var *elliottii*, also have been observed with galls and damage. However, the senior author was unable to confirm any injury on a variety of exotic pines and other conifers growing in the University of Georgia Arboretum at Whitehall. This arboretum is only 275 m from the heavily-infested loblolly-slash pine plantation where most of the sawfly observations were made. Several additional species and 1 pine cross were found to have 1 - 7 galls. These were the table-mountain pine, *P. pungens* Lamb. (1 gall), pitch pine, *P. rigida* Mill. (2 galls), and the cross, *P. rigida* x *P. taeda* (7 galls).

Pine species showing no symptoms of attack were maritime pine, *P. pinaster* Ait; eastern white pine, *P. stobus* L.; Italian stone pine, *P. pinea* L.; Scotch pine, *P. sylvestris* L.; Japanese red pine, *P. densiflora* Sieb. & Zucc.; Masson pine, *P. massoniana* Lamb.; Japanese black pine, *P. thunbergiana* Franco; Taiwan red pine, *P. taiwanensis* Mayata; longleaf pine, *P. palustris* Mill.; Austrian pine, *P. nigra* Arnold; Caribbean pine, *P. caribaea* Morelet; Hartweg pine, *P. hartwegii* Lindl; jack pine, *P. banksiana* Lamb.; Monterey pine, *P. radiata* D. Don; and Virginia pine, *P. virginiana* Mill.

Damage. Developing larvae caused spindle-shaped galls to form as the pine shoots elongated (Fig. 1). No shoot mortality from this sawfly has been noted on any of the infested shoots marked in field plots; however, attack by it and its associates can cause conelet mortality and, therefore, reduce seed production. Feeding of the weevil, *Conotrachelus carolinensis* Schoof, has in many cases removed gall tissue from half or more of the shoot and so weakened it that mechanical breakage and shoot mortality have resulted. This could affect tree form and could reduce seed crop in seed orchards by causing mortality of shoot-bearing cones. When the gall is distal on the shoot to the cones, weevil feeding will not reduce seed yield. However, it is possible that when shoot galls develop proximal to the cones and are attacked by weevils that feeding would cause shoot and cone mortality. Diseases also may be introduced through the lesions created by the sawfly larva.

Observations have thus far shown that loblolly pine is the most heavily-injured pine species with as many as 38 of 144 shoots of one tree infested. Overall infestation averaged about 10% of the tree shoots in the study plantation near Athens, GA, in 1969.

Life cycle. Hetrick (in litt.) observed in his studies conducted in Virginia that galls appeared each spring on pine shoots, and larval development was completed in 4 - 6 wks. After larval emergence, larvae dropped and burrowed into the soil where they remained for 22 - 23 months. This indicates a 2-yr life cycle. Our finding in Georgia corroborates additional observations (Hetrick, in litt.) on the life cycle of the sawfly in Virginia.

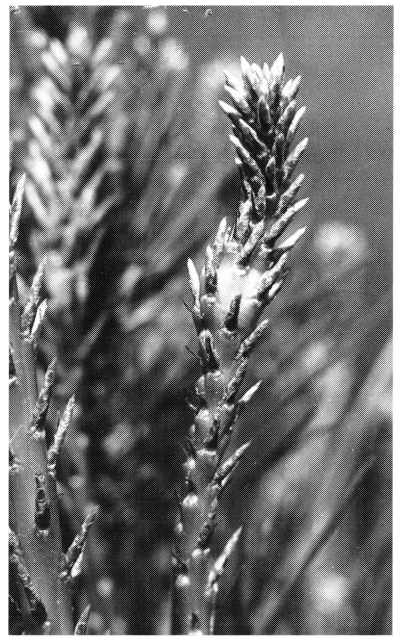

Fig. 1. Loblolly pine shoot with *Xyela gallicaulis* gall.

The known occurrence of this insect in northeastern Georgia was first observed in the spring of 1965 when galls developing on loblolly pine shoots (Fig. 1) were reported. The earliest indication of shoot attack occurs during the second week of April. The young, developing shoots show a slight swelling approx. 2 - 4 cm from the tip. Unhatched eggs are found in the center of this swollen shoot. Efforts to locate similar damage during the following spring of 1966 were unsuccessful. During the spring of 1967, the insects and its characteristic damage were again common in plantations. Rearing efforts were again a failure, and, as was experienced before, the insect did not appear the following spring (1968). This pattern also suggests a 2-yr life cycle. Reappearance of the insect and damage in 1969 confirmed this suspicion. Adult emergence was successful in December 1970 from the 1969 rearings, 38% of the adults ($n = 212$) emerged with a male to female sex ratio of 1:1.7 (Table 1). Adult emergence occurred for 1 month, 7 December – 6 January. However, 100% of the males had emerged by 22 December, whereas, only 83% of females had emerged by the same date. Damage again appeared in the spring of 1971, and a second successful rearing of 1971-collected larvae occurred in December 1972. However, for the next 4 "attack years," (1973 - 1979), the insect and its damage were not found in northeastern Georgia.

When the infestation was first noted on 20 April 1965, the larvae within the galls were nearly full grown. Only one larva was found within each gall. By 3 May, the larvae began boring out of the galls and dropping to the ground to construct pupal cells. Collected larvae placed in soil-filled dishes burrowed to the bottom of the rearing jars and spun a thin transparent cocoon (Fig. 2) within earthen cells. By 17 May, 60% of the larvae had emerged from the galls. Only one generation occurred.

Table 1. Rearing percentages and sex ratios for *Xyela gallicaulis*, 1970

Rearing Number	Number of Larvae in Rearing May 1969	Number of Adults Emerged Dec. 1970	% Emergence	Sex		Sex Ratio
				m	f	
1	20	6	30	2	4	1:2
2	20	10	50	2	8	1:4
3	20	14	70	8	6	1.7:1
4	12	2	17	1	1	1:1
5	4	1	25	0	1	0:1
6	14	5	36	1	4	1:4
7	26	1	4	0	1	0:1
8	20	8	40	5	3	1.6:1
9	20	12	60	6	6	1:1
10	20	11	55	3	8	1.2:7
11	16	4	25	1	3	1:3
12	20	9	45	2	7	1:3.5
Totals	212	83	38	31	52	1:1.7
			Avg. %			

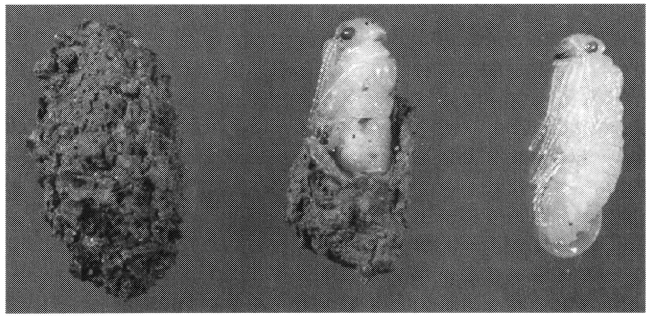

Fig. 2. Cocoon and pupae of *Xyela gallicaulis*. Cocoon on left, partially exposed pupa at center, pupa at right.

The pupa is active, capable of locomotion, and has heavily-sclerotized, functional mandibles. It burrows its way to the surface of the soil where adult emergence occurs (Figs. 3 - 5). In 1970, adult emergence was first noted on 7 December and continued to 12 January. However, 100% of the males (n = 31) emerged by 22 December whereas 90% of the females (n = 47) emerged by 26 December. The remaining 4 female adults

emerged during the next 17 d. Male emergence generally preceded that of females, and overall sex ratio was 1:1.7 (M:F). Of the 12 rearing lots established, percentage emergence ranged from 4 - 70% with an average of 38% (Table 1).

Mating is common soon after adult emergence. The male from the rear, twists his abdomen around and sets his claspers around the female abdomen, then they assume the tail-to-tail position (Fig. 6). Mating continues for up to 5 min, and multiple matings between the individuals occur. During this mating period the male claspers palpate the female abdomen. Female activity is not necessarily restricted, and she is able to move about and drag the male without interruption of copulation. Disturbance

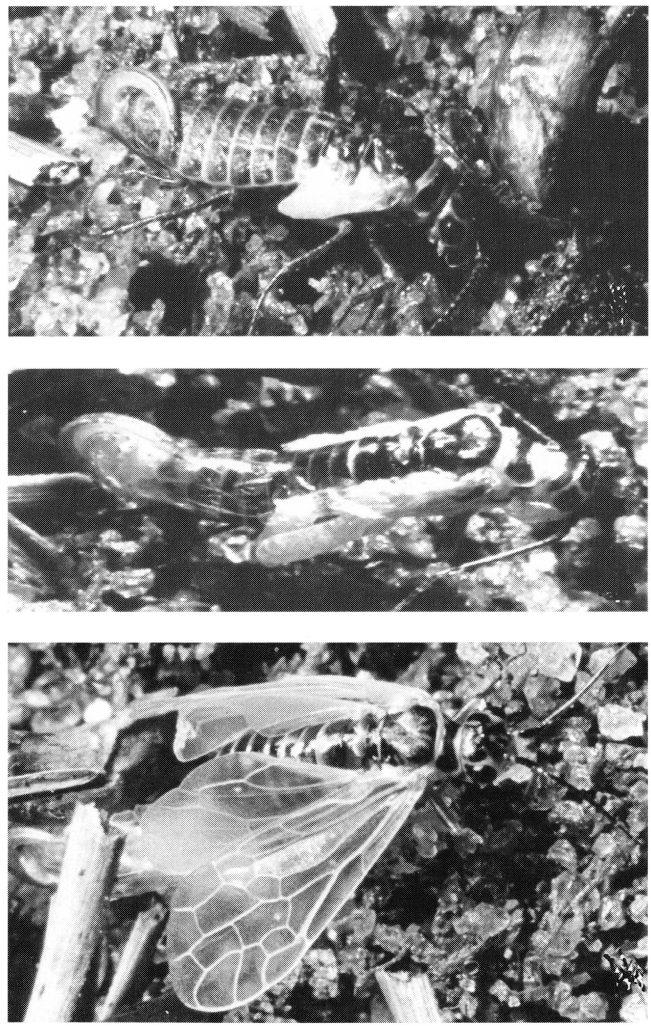

Fig. 3 - 5. Adult eclosion of *Xyela gallicaulis*. 3, Beginning. 4, Partial adult. 5, Adult.

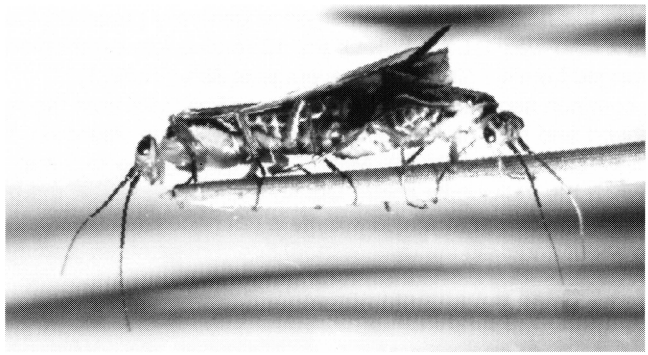

Fig. 6. Adults of *Xyela gallicaulis* mating.

of a mating pair with a small brush did not cause them to refrain from mating. Following mating, the female flexes her ovipositor and removes it from the sheath.

Adult flight was never observed in the field. In the laboratory where the temperature was approx. 24°C, adult flight was stimulated on one occasion when a vial of commercial turpentine was uncapped and waved over a group of ten adults. Almost immediately all of the adults flew about in the laboratory. This same flight response to turpentine fumes was never demonstrated in the field.

Actual oviposition was not observed, but location of the eggs indicates that they are deposited into the central area of the vegetative bud during the adult flight and mating period in December. As early as 12 April, there is a slight swelling of the developing shoots adjacent of the egg. Because egg eclosion had not yet occurred, larval activity is not necessary to cause initial gall development.

Two eggs were found in early spring (first week in April) during dissection of young developing shoots or vegetative buds. These teardrop-shaped eggs are 0.34 X 0.76 mm. Within the chorion, the head and mandibles of the developing larva can be seen moving even when the remainder of the body is not yet formed. Head capsule width is 0.1 mm. As development continues, the folded body develops in the large end of the egg. The larvae go through 5 instars.

Insect associates. Two insect associates were observed. Tip moth larvae, *Rhyacionia* spp., which ordinarily bore into and kill the shoots of pines, predictably were found feeding on the tips of galled shoots. During the first 3 instars, larvae of the Nantucket pine tip moth, *Rhyacionia frustrana* (Comstock) (Tortricidae), migrate on the surface of pine shoots and feed on the needles and external shoot tissue (Yates 1967). During the fourth instar, larvae begin to bore into the shoot, sever the conductive tissue, and thus cause shoot mortality. On a number of occasions, tip moth larvae were found inside *X. gallicaulis*-caused galls. This was after the sawfly larva had bored out of the gall and dropped to the ground to pupate. Because there was no evidence of other external damage to the shoot, it appears that the tip moth larvae entered the galls through sawfly emergence holes. Interestingly, no shoot killing was observed when tip moth larvae entered these galls. Larvae were apparently able to satisfy their appetites within this gall without destroying the conductive tissue.

A second associated insect found, also reported by Hetrick (1939), is the weevil *C. carolinensis* Schoof (Curculionidae). During shoot observations, adult weevils were often seen feeding on the external gall tissue. As many as 4 adult weevils were found feeding on a single gall. In most cases, this feeding exposed the excavation found within the gall. Samples later revealed that weevil larvae could be found maturing inside. This indicates that weevil egg laying occurs in or on galled shoots.

Galls collected during the winter have been found containing as many as 8 overwintering weevil larvae, and it is presumed these are the same weevil species. *Conotrachelus carolinensis* has been found on pine shoots having galls of *Xyela* and have been reared from these same galls (Warner, in litt.).

Hymenopteran parasites recorded from *X. gallicaulis* infested galls during the spring of 1967, 1969, and 1971 were *Habrocytus* sp. (Pteromalidae); *Tetrastichus* sp. (Eulophidae), and *Eurytoma levo* Bugbee (Eurytomidae). Records were not kept regarding percentage parasitism; however, from the number of parasites emerging from the shoots collected, parasitism was greater than 25%. Hetrick (1942) listed 2 parasitoids, *Eurytoma tylodermatis* Ashmead and *Habrocytus thyridoptrigis* Howard as reared from *Xyela* galls. He noted that both species are known to attack larva of the "pine shoot moth."

Acknowledgments

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