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Preliminary notes on the three Cecidomyiidae (Diptera) galls on *Machilus thunbergii* Hayata (Lauraceae) in the Guandaushi forest of central Taiwan

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Abstract. Three cecidomyiid galls were found on *Machilus thunbergii* Hayata (Lauraceae) in the Guandaushi forest of central Taiwan. The one on the twigs is the spindle-shaped gall. The two on the leaves are the swan-shaped gall and the club-shaped gall. These galls are all induced by gall midges of the genus *Daphnephila* (Diptera: Cecidomyiidae). Galls, the larvae of the inducers, gall size, and the general structures of the gall were studied and are described in this paper.

Keywords: Cecidomyiidae; Gall; Guandaushi; *Machilus*.

Introduction

Four cecidomyiid galls on *Machilus zuihoensis* Hayata in the Guandaushi forest have been recorded (Yang et al., 1996). They are urn-shaped, mouse-shaped, coniform, and spindle-shaped galls. *Machilus thunbergii* Hayata, an associated species of *Machilus zuihoensis*, grows in broad-leaf forests at the altitude of 200–2,300 m throughout Taiwan. Yukawa (1981) recorded one cecidomyiid gall, barrel-shaped gall of *Daphnephila machilicola*, on the undersurface of leaves of *Machilus thunbergii*. In Guandaushi forest of central Taiwan, there are two cecidomyiid galls on the leaves and one on the twigs of *Machilus thunbergii.* All inducers belong to the genus *Daphnephila*. Although the study area was limited to altitudes of 1,400–1,600 m, the frequency and density of galls differ with the elevation. The properties of the induced parts, larvae of the gall inducers, gall size, and the appearance of gall were studied and described in this paper, but the specific name of each inducer is still unknown. The average number of galls per leaf or twig and the vegetation associations were also investigated.

Materials and Methods

Galls were collected at the altitude of 1,400–1,600 m in the Guandaushi forest between October 1995 and February 1996. A dial caliper was used to measure the size of mature galls. Dissected gall was observed under a stereo microscope. For the identification of gall-inducing larvae to the family level, we followed the key of Peterson (1960). The genus *Daphnephila* was identified by Dr. J. Yukawa.

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Two 10 m line transects were set up at each 50 m elevation interval along a walkway. The density of galls on *Machilus thunbergii* was determined. The frequency and coverage of the vegetation which surrounding galled plants were also investigated.

Results and Discussion

Spindle-Shaped Galls

Fifteen mature spindle-shaped galls were collected at 1,500–1,600 m elevation on February 23, 1996. Both old and new galls were present on node and internode parts of twigs. The gall surface is smooth. The gall is about 5.7 mm wide and 14.7 mm long. The gall length is more variable than the width (Table 1). The gall has a cap at the top (Figure 1A). Gall color ranges from red, red marbled with green, to red only on the top. The induced part is generally enlarged. Galls may appear singly or in numbers. The new galls may grow from center of the induced part. It is a prosoplasmic gall that bears vascular tissue, sclerchyma, and nutritive layer around the larval chamber. The induced part of the host plant appears sclerosed and

Table 1. Measurements of mature spindle-shaped gall on *Machilus thunbergii* (n=15) in the Guandaushi forest.

	Measurements[a]	
	Length (a)	Width (b)
Range (mm)	12.4~17.0	4.8~6.5
Average (M±SD) (mm)	14.7±1.5	5.7±0.5
CV (%)	9.85	8.95

[a]The methods for measurements are shown in Figure 1E.

scaled. When the gall inducer exits from the gall, the cap drops off to reveal an ostiole. The larval chamber is longitudinal (Figure 1B). Each gall contains one white and cylindrical larva, an unidentified species of genus *Daphnephila*. The head is very small and withdrawn into the prothorax (Figure 1C). The sternal spatula, a dermal structure of the prothorax, is trapezoid and has two pointed, free, anterior projections. The sternal spatula expands broadly and laterally (Figure 1D).

Swan-Shaped Galls

On February 14, 1996, fifteen mature swan-shaped galls were collected at between 1,425 and 1,550 m altitude. The gall has irregular carinae like a swan's wings, a long neck like a swan's neck, and a short stalk connecting to the host leaf on the abaxial surface (Figure 2A–B). The outer surface of mature galls is smooth and covered by a thin layer of white wax. The gall is about 3. 6 mm wide and 8.5 mm long. The neck part is about 3.4 mm long and 0.9 mm wide. Length varies less than the other measurements (Table 2). Gall color ranges from pink to red with green interblended. One to twenty galls at different stages of development can be found on one leaf. The ostiole is located on the connection between the gall body and neck. The larval chamber is longitudinal but does not reach the neck (Figure 2C). Each gall contains one yellow, flat larva. The inducer belongs to the genus *Daphnephila*. Vascular tissue, sclerenchyma, and a nutritive layer surround the larval chamber. The abdomen becomes narrower from the midlength to the end (Figure 2D). The head is very small and retracts into the prothorax. The posterior and anterior margins of the oblong sternal spatula are straight. The two free projections on the anterior margin are curved slightly downward (Figure 2E).

Club-Shaped Galls

Fifteen mature club-shaped galls were collected at 1,525–1,600 m elevation on February 14, 1996. The gall is long and tapering from distal to proximal end and connects to the host leaf (Figure 3A). The smooth gall averages 15.7 mm long, 1.6 mm wide, and 8.6 mm long in the expanded head (Table 3). The length is more variable than the width. The gall has a cap at the top (Figure 3A). Galls always arise near leaf edges, and the tops of galls are often toward leaf edges. Each gall has a long stalk to

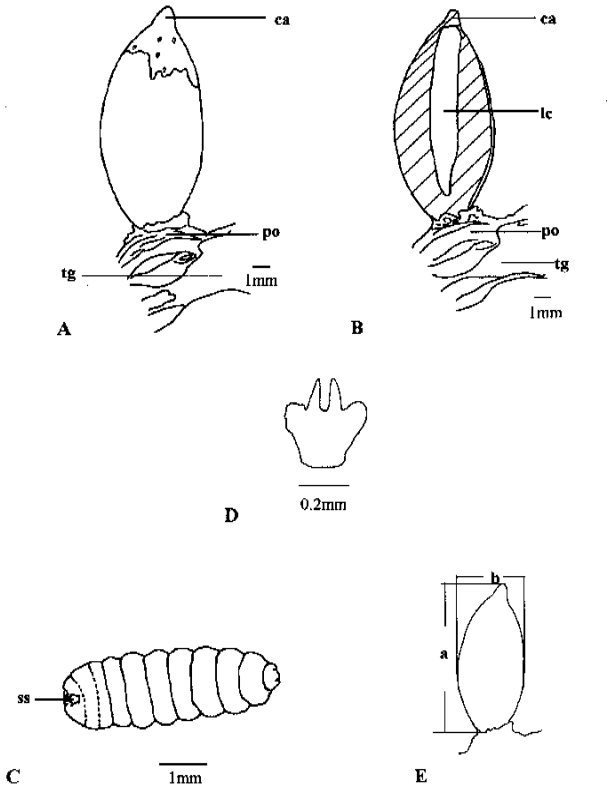

Figure 1. Spindle-shaped gall induced by *Daphnephila* sp. 1 on the twig of *Machilus thunbergii*. A, lateral view; B, longitudinal section; C, larva of inducer; D, sternal spatula of larva; E, methods for measurements of the gall. Legends of abbreviation: a: length; b: width; ca: cap; lc: larval chamber; po: position; ss: sternal spatula; tg: twig.

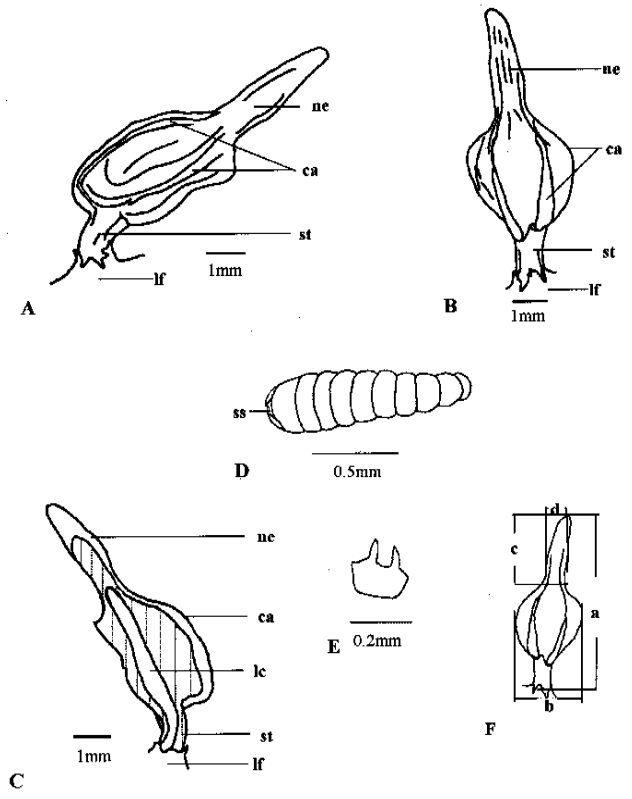

Figure 2. Swan-shaped gall induced by *Daphnephila* sp. 2 on the leaves of *Machilus thunbergii*. A, lateral view; B, lateral view; C, longitudinal section; D, larva of inducer; E, sternal spatula of larva; F, methods for measurements of the gall. Legends of abbreviation: a: length; b: width; c: length of neck; ca: carinae; d: width of neck; lc: larval chamber; lf: leaf; ne: neck; ss: sternal spatula; st: stalk.

Table 2. Measurements of mature swan-shaped gall on *Machilus thunbergii* (n=15) in Guandaushi forest.

	Measurements[a]			
	Length (a)	Width (b)	Length of neck (c)	Width of neck (d)
Range (mm)	7.3~10.8	2.8~4.4	2.5~4.2	0.7~1.1
Average (M±SD) (mm)	8.5±0.8	3.6±0.5	3.4±0.5	0.9±0.1
CV (%)	9.88	13.90	13.89	11.29

[a]The methods for measurements are shown in Figure 2F.

Table 3. Measurements of mature club-shaped gall on *Machilus thunbergii* (n=15) in the Guandaushi forest.

	Measurements[a]		
	Length (a)	Width (b)	Length of club body (c)
Range (mm)	9.7~17.9	1.3~2.0	5.4~10.0
Average (M±SD) (mm)	15.7±2.2	1.6±0.2	8.6±1.2
CV (%)	13.81	11.20	13.67

[a]The methods for measurements are shown in Figure 3E.

connect with the leaf (Figure 3A). Galls are mostly green, but the portion which grows parallel to the leaf is commonly red or deeply green. There are commonly 1–4 galls of the same size per leaf. Growth angle ranges from 0° to 50° but rarely 90°. After the inducer exits, the cap drops off to reveal the ostiole. The larval chamber is longitudinal (Figure 3B) and contains one larva at the base. The inducer belongs to the genus *Daphnephila*. The larva is yellow and flat and semicircular in cross section. The head is small and somewhat withdrawn into the prothorax. The abdomen becomes narrower from about midlength to end (Figure 3C). The posterior straight margin of the oblong sternal spatula is narrower than the anterior one (Figure 3D). The middle of the anterior margin is concave. The anterior margin has two parallel and slender projections (Figure 3D).

Coy (1995) pointed out that the term vegetation associations implies that invertebrates distinguish suitable habitat on the basis of which plants or plant associations are present. The plants accompanying *Machilus*

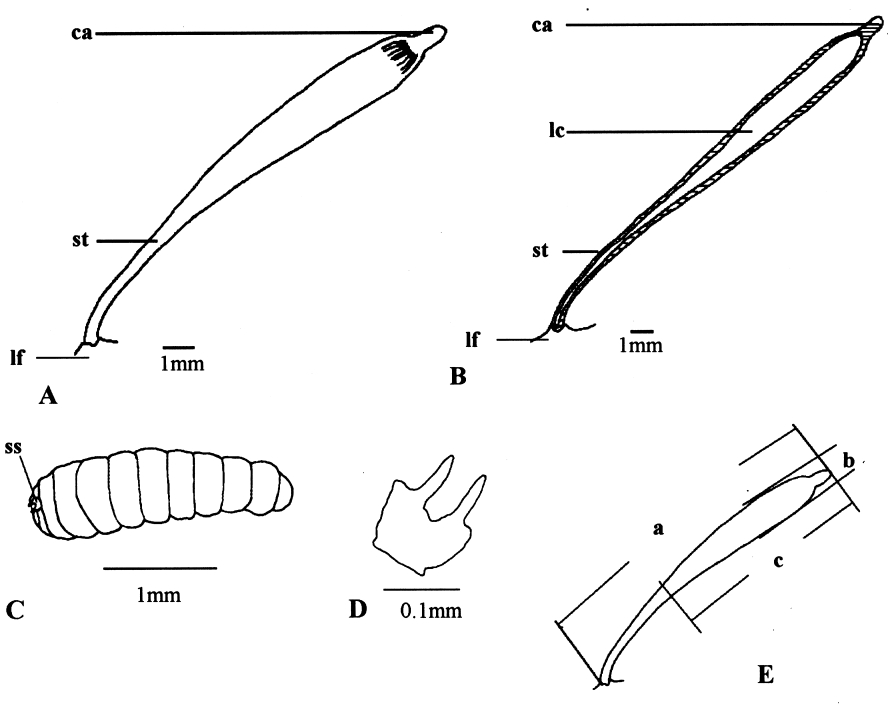

Figure 3. Club-shaped gall induced by *Daphnephila* sp. 3 on the leaves of *Machilus thunbergii*. A, lateral view; B, longitudinal section; C, larva of inducer; D, sternal spatula of larva; E, methods for measurements of the gall. Legends of abbreviation: a: length; b: width; c: length of club head; ca: cap; lc: larval chamber; lf: leaf; ss: sternal spatula; st: stalk.

thunbergii and their important value indices (IVI) were, from one to three, 22.4 for *Plagiogyria dunnii*, 20.6 for *Dicranopteris lineauis* var. *tetraphylla* and 17.8 for *Cinnamomum subavenium* (Table 4).

All three gall inducers belong to the genus *Daphnephila*. These are known to induce structurally complex and highly differentiated gall on *Machilus* in Taiwan and Japan (Yukawa, 1981; 1996), and on *Machilus* and *Lindera* in India (Gagné, 1973). These three gall types are all covering galls. When the gall is mature, the inducer is completely enclosed and the ostiole is minute (Dreger-Jauffret and Shorthouse, 1992). They are all prosoplasmic galls because they have highly differentiative tissue (Küster, 1911). All three gall types have red pigment and a special scent, which may be related to the scent of the host plant. This may signify that the inducer solicits some silence gene and still keeps some active gene of the host plant. Interestingly, most spindle-shaped galls become green when the inducers pupate inside.

Table 4. The important value index (IVI) of companion plants of *Machilus thunbergii* in the Guandaushi forest.

Scientific name	F	Do (cm^2)	RF (%)	RD (%)	IVI
Plagiogyria dunnii	1	752	10.30	12.11	22.41
Dicranopteris linearis var. *tetraphylla*	0.5	956	5.15	15.40	20.55
Cinnamomum subavenium	0.63	705	6.49	11.35	17.84
Lasianthus fordii	0.88	349	9.07	5.62	14.69
Neolitsea variabillima	0.5	371	5.15	5.98	11.13
Syzygium buxifolium	0.5	299	5.15	4.82	9.97
Blastus cochinchinensis	0.25	420	2.57	6.76	9.33
Eurya acuminata var. *acuminata*	0.5	254	5.15	4.09	9.24
Embelia oblongifolia	0.63	149	6.49	2.40	8.89
Ardisia sieboldii	0.25	363	2.57	5.85	8.42
Asplenium normale	0.63	101	6.49	1.63	8.12
Smilax china	0.63	72	6.49	1.16	7.65
Illicium arborescens	0.25	311	2.57	5.01	7.58
Woodwardia unigemmata	0.13	218	1.34	3.51	4.85
Euonymus laxiflorus	0.25	91	2.57	1.47	4.04
Michelia compressa	0.13	150	1.34	2.42	3.76
Meliosma squamulata	0.25	72	2.57	1.16	3.73
Castanopsis kawakamii	0.25	43	2.57	0.69	3.26
Engelhardtia roxburghiana	0.25	40	2.57	0.64	3.21
Angiopteris lygodiifolia	0.13	112	1.34	1.80	3.14
Daphne odora var. *atrocaulis*	0.13	70	1.34	1.13	2.47
Cyathea podophylla	0.13	39	1.34	0.63	1.97
Elaeocarpus japonicus	0.13	37	1.34	0.60	1.94
Pasania hancei	0.13	35	1.34	0.56	1.90
Dendropanax dentigerus	0.13	28	1.34	0.45	1.79
Ardisia cornudentata	0.13	26	1.34	0.42	1.76
Archniodes spp.	0.13	17	1.34	0.27	1.61
Selaginella doederleinii	0.13	9	1.34	0.14	1.48
Unknown 1	0.13	120	1.34	1.93	3.27
Total			100.00	100.00	200.00

F: frequency; Do: dominance; RF: relative frequency; RD: relative dominance.

Table 5. The gall frequency and the average number of galls per leaf or twig on *Machilus thunbergii* between 1,400–1,600 m elevation in the Guandaushi forest in February, 1996.

Point	Elevation (m)	Number of sample	Number of gall		
			Spindle-shaped	Swan-shaped	Club-shaped
H24	1425	3	0	106	0
H28	1450	2	0	141	0
H32	1475	1	0	10	0
H36	1500	1	23	3	0
H43	1525	1	25	0	18
H49	1550	1	0	23	3
H56	1575	2	5	0	7
H60	1600	3	1	0	70
	Average		1.5	3.9	1.4
	Range		1–4	1–20	1–4

Within our study area at 1,400–1,600 m elevation, the swan-shaped galls occur at lower, the club-shaped galls at higher, and the spindle-shaped galls at intermediate elevations (Table 5). This may be related to the complete use of a common resource and also to the reduction of competitive pressure. Swan-shaped and club-shaped galls are induced under the leaf, so they have the distinct pressure of competing for a common resource. Gagné (1986) indicated that plant-feeding gall midges appear to have followed an ecological path rather than a phylogenetic one. Perhaps the pattern of altitude distribution of these three cecidomyiid galls of *Machilus thunbergii* is related to environmental differences.

The genus *Daphnephila* has only been recorded in Japan (Yukawa and Masuda, 1996) and India (Gagné, 1973). The host plant *Machilus thunbergii* is distributed in the tropics and subtropics in Asia (Liu et al., 1994). The family Cecidomyiidae is ancient, but plant feeding probably evolved during the period of green plant radiation in the late Cretaceous. Cecidomyiidae presumably were preadapted for plant feeding and gall-inducing in an early period of angiosperm radiation (Roskam, 1992). Maybe the three cecidomyiid galls on *Machilus thunbergii* have already spent a long time adapting to host plant of this local region.

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臺灣關刀溪森林豬腳楠癭蚋蟲癭之初步探討

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於臺灣中部關刀溪森林之豬腳楠上發現 3 種不同形態的蟲癭。枝條上的 1 種爲紡綞狀蟲癭；葉部的 2 種爲天鵝狀蟲癭與球棒狀蟲癭。此 3 種蟲癭的造癭者皆爲雙翅目癭蚋科 *Daphnephila* 屬的昆蟲。本文分別就其發生部位、造癭幼蟲、蟲癭大小及一般特徵加以描述。

關鍵詞：癭蚋科；蟲癭；楨楠屬；關刀溪。