ADAINA PRIMULACEA MEYRICK, 1929: A GALL-INDUCING PLUME MOTH OF SIAM WEED FROM SOUTH FLORIDA AND THE NEOTROPICS (LEPIDOPTERA: PTEROPHORIDAE)

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Abstract- The life history of *Adaina primulacea* Meyrick is described and illustrated. Larvae induce formation of stem galls on Siam Weed, *Chromolaena odorata* (L.) R.M.King & H. Rob., and feed and pupate within these galls. This neotropical species was discovered in South Florida in 1993 and has since been exported for biological control studies. The identity of the species is established in this paper by comparison of reared specimens with images of the holotype from Panama. The female genitalia are described and illustrated for the first time.

Key Words: cecidogenous, *Chromolaena odorata*, *Eupatorium cannabinum*, Siam Weed, Asteraceae, stem galls, *Adaina primulacea, A. microdactyla*, *A. simplicius*, *A. bipunctata*, biological control, larvae, pupae, Pterophoroidea, Pterophorinae

The genus *Adaina* Tutt, 1905 includes 28 species worldwide (Gielis 2003), 20 of which occur in the Neotropical Region. The type species, *Adaina microdactyla* (Hübner) is widespread in the Palearctic Region, and also extends into the Oriental and Australian Regions. It is well known, because it is one of the few stem-gall-producing pterophorids. It feeds on hemp agrimony, *Eupatorium cannabinum* L. Known hostplants of *Adaina* are restricted to composites (Asteraceae) (Matthews & Lott 2005). The genus includes species with internal feeding larvae, such as flower borers, as well as external feeding species which skeletonize leaves. Species with endophagous larvae, such as the type species, have adults ranging from white to yellowish with few markings, while adults of the external feeders are more mottled with darker wing patterns.

As in the type species, larval feeding damage of a species previously reported as *Adaina* sp. (Walton & Waterhouse 1998, Zacharides *et al*. 1998, Muniappan & Bamba 2000, Matthews & Lott 2005, Matthews 2006) results in the production of stem galls in which the mature larvae feed and pupate. This species was recently determined by the first author as *Adaina primulacea* Meyrick, 1929, by comparison of reared specimens with photographs of the holotype in the Natural History Museum, London, including images of the male genitalia slide provided courtesy of Cees Gielis. Larvae discovered in 1993 by the second author were infesting the shoots and stems of Siam Weed, *Chromolaena odorata* (L.) R.M.King & H. Rob. growing on the grounds of the Fort Lauderdale Research and Education Center (FLREC) of the University of Florida. The species has since been investigated as a potential biological control agent for Siam Weed, a rapidly spreading invasive plant of tropical and subtropical areas worldwide.

Siam Weed is a native of the West Indies, Central and South America but has become a serious pest throughout the Old World tropics, including central and western Africa, India, Sri Lanka, south-west China, the Philippines, Malaysia, Indonesia, Northern Australia, and Papua New Guinea (Crutwell 1968, 1974, Muniappan & Bamba 2000, Walton & Waterhouse 1998, Zachariades *et al.* 1998). Siam Weed is quickly established and competes with crops as well as native vegetation in enviromentally sensitive areas. It is a fire hazard in grasslands and a problem weed in pastures as it is toxic to cattle.

Cultures of *A. primulacea* derived from Florida material in 1995 and 1996 have been maintained and studied in South Africa where oviposition and gall formation were successful on both local and west African forms of *Chromolaena* (Zacharides *et al.* 1998). This species was discovered in Florida subsequent to previous accounts of the fauna (Kimball 1965, Matthews 1989, Matthews *et al.* 1990). Along with establishing the identity of this species and providing an account of the life history and distribution, we describe and illustrate the larvae and pupae and include a redescription of the adult. The adult, and male and female genitalia, are also illustrated, the latter published for the first time.

Adaina primulacea Meyrick, 1929

(Figs. 1-3, 7, 12-14, 15c-f)

Diagnosis. This species is distinguished from other *Adaina* by the uniform pale lemon yellow color of the forewings, marked by a small grayish brown spot at the forewing cleft base and by characters of the genitalia. Male genitalia are distinguished based on the relative length, shape, and curvature of the saccular process of the left valve and a small dentate saccular process on the right valve. Female genitalia are recognized by the thorn-like shape of the anterior apophysis.

Redescription – adults (male, female). HEAD with labial palpi slender, erect, length less than eye diameter, uniform light buff. Front and vertex with scales appressed, light ochraceous buff to light buff yellow, cream to light buff yellow between antennae. Occiput with tuft of linear light buff yellow to ochraceous buff scales, lengths reaching eye diameter. Antenna with sparse cream scaling above, minutely ciliated below, base cream or cream mixed with light buff scales. THORAX including tegulae uniform light buff yellow to pale lemon yellow. Foreleg coxa light buff. Femur medially with pair of chestnut-brown stripes flanked by thin cream stripes, laterally light buff with single chestnut-brown stripe. Tibia medially with central chestnut-brown stripe, laterally cream, distally with tuft of cream scales. Tarsomeres cream, first (proximal) tarsomere with chestnut-brown stripe medially, extending to proximal 0.75× of length. Midleg coxa light buff, femur and tibia as on foreleg but chestnut-brown stripe on tibia distally flaired at scale tuft. Tibial spurs cream above, with chestnut-brown stripe below, medial spur longest. Tarsomeres cream, with ventrolateral stripe on proximal 0.75× of first tarsomere. Hindleg cream to light buff yellow, with two pair of tibial spurs. Medial spurs

longest. Lateral spurs with faint brownish gray stripe ventrally. FOREWING length - males 6.0 mm -7.0 mm, mean 6.7 mm (n= 9); females 7.0 mm - 8.0 mm, mean 7.8 mm (n= 9). Cleft origin at about 0.6× wing length from base. Dorsal ground color light buff yellow to pale lemon yellow (the latter in fresh specimens). Cleft base marked by small diffuse light grayish brown crescent-shaped spot. Radius and basal portion of veins 1A with trace of ochraceous-buff scales. Fringes concolorous, light buff yellow to pale lemon yellow. Forewing venter light sulphine yellow or grayish yellow except light buff yellow to pale lemon yellow along costa. Fringes as on dorsum. HINDWING dorsum light sulphine yellow or grayish yellow. Hindwing venter with anterior and posterior lobes weakly overscaled with light buff yellow. Middle lobe grayish yellow. Venous scales ochraceous-orange. Dorsal and ventral fringes as on forewing. ABDOMEN cream to light buff yellow.

Male genitalia. Uncus slender, length about equal to that of tegumen. Tegumen tapered laterally, dorsal connection with vinculum narrow. Valvae asymmetrical. Right valve shorter and more slender than left valve, with small dentate saccular process at about one-third from base, and with variably sclerotized ridge extending anteriad of process and distad along saccular margin. Scale brush pocket on right and left valvae reaching about two-thirds length of valve. Left valve broadly rounded, with slender curved saccular spine about one-half valve length. Spine extending laterally from thickened base, then strongly curved posteriad. Apex of spine curved toward dorsum. Vinculum narrow, terminating dorsally as curved notch on dorsal margin of valve, adjacent to lateral margin of tegumen. Juxta with arms asymmetrical, right arm broader and slightly longer than left, with rounded apex. Aedeagus curved, about one-half length of right valve, apex acute, vesica with minute blade-like cornutus. Coecum penis about one-fifth length of aedeagus.

Female genitalia. Papilla analis short, weakly sclerotized except for moderately sclerotized narrow band laterally at base of posterior apophysis, tapering medially on ventral surface. Setation minute to long, covering entire surface posteriad of sclerotized band; with a few short setae radiating from a minute ventral median lobe. Posterior apophysis slender, straight or slightly curved, about 3.5× length of papilla analis, extending anteriad beyond segment VIII. Anterior apophysis a minute tapered thorn-like process laterad on anterior margin of segment VIII dorsum. Segment VII about 2× length of segment VIII, with ventral margin extending posteriad over membranous area of segment VIII, forming a convex rim. Ostium to left of middle. Antrum tapered anteriad, without sclerites. Ductus bursae as wide as ostium, length slightly less than corpus bursae. Corpus bursae ovoid, without signa. Inception of ductus seminalis near base of ductus bursae. Ductus seminalis wide, with distinct bend curving dorsad around corpus bursae, anterior half inflated, apically constricted as filamentous extension.

Fig. 1. *Adaina primulacea*, reared adult ♂, em. 25.ix.1993 (data in text).

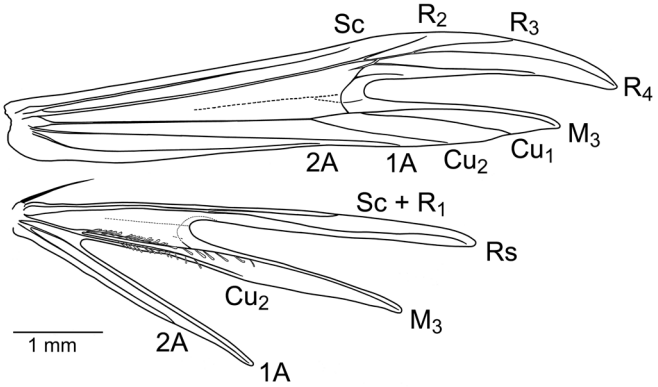

Fig. 2. Wing venation of *A. primulacea* and placement of venous scales along the underside of hindwing veins M_3 and Cu_2.

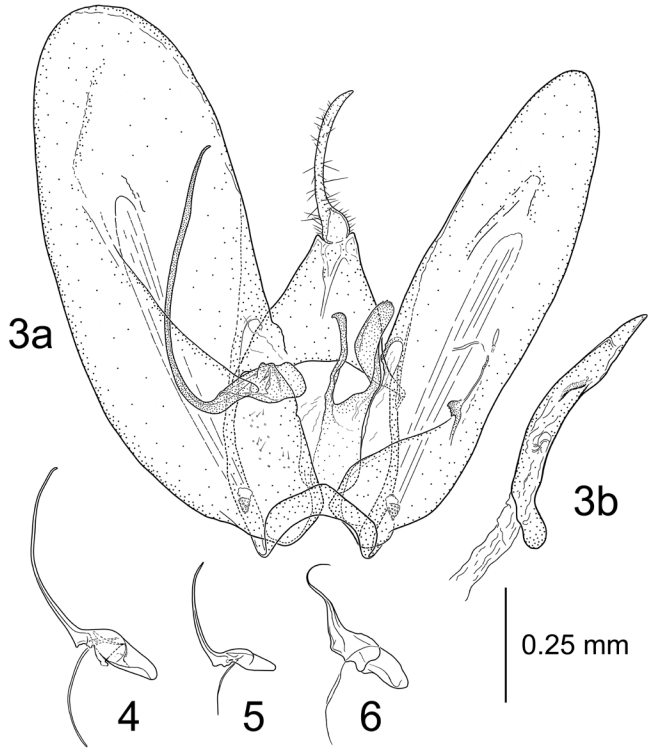

Fig. 3–6. Male genitalia of *Adaina*: **3a)** *A. primulacea* male genitalia with aedeagus removed, slide DM 659; **3b)** aedeagus of same individual; **4)** saccular process of left valve of *A. microdactyla*, slide DM 1466; **5)** same, *A. bipunctata*, slide DM 1448; **6)** same, *A. simplicius*, slide DM 238.

Material examined – adults. PC= pupal case or exumium, LS = larval skin with pinned adult. USA: FLORIDA: Broward Co.: Davie, Tree Tops Co. Park 11 Sep 1993 T. Lott, D. Matthews & B. Maharajh, ex. larva in stem gall on *Chromolaena odorata* (1 ♀, 1 LS, 1 PC) [DMC - D. Matthews Collection]; Davie, Univ. Fla., FLREC 6 Aug 1993 B. Maharajh, ex. larva in stem gall on *C. odorata* (3 ♀, slides DM 661, DM 1457) [DMC]; same location, 23 Aug 1993 B. Maharajh, ex. larva in stem gall on *C. odorata* (1 PC, pinned) [DMC]; Davie, University Dr. S of Rolling Hills Golf Course 11 Sep 1993, em. 17 Sep 1993 T.A. Lott, D. Matthews & B. Maharajh, ex. larva in stem gall on *C. odorata* (1 ♂, 2 ♀, w/ PC) [DMC]; same data, em. 18 Sep 1993 (1 ♂, slide DM 1456, 1 PC) [DMC]; same data, em. 19 Sep 1993 (1 ♂, 1 ♀, 2 LS, 2 PC) [DMC]; same data, em. 20 Sep 1993 (6 ♂, slide DM 659, 4 ♀, slide DM 1458, 5 LS, 7 PC) [DMC]; same data, em. 21 Sep 1993 (1 ♀) [DMC]; same data, em. 25 Sep 1993 (3 ♂, **Fig. 1**, 2 LS, 3 PC) [DMC]; same data, em. 28 Sep 1993 (1 ♂, slide DM 1459, 1 ♀, 2 LS, 2 PC) [DMC]; Davie, Nob Hill Road 21 Nov 2001 D. Matthews & T.A. Lott, in stem galls on *C. odorata* (2 ♀, 2 PC, 2 LS) [DMC]. All specimens are currently held in the first author's collection [DMC]. Voucher specimens will be deposited at the McGuire Center for Lepidoptera and Biodiversity, Florida Museum of Natural History, Gainesville, FL [MGCL] and the National Museum of Natural History, Washington, D.C. [USNM].

LIFE HISTORY AND IMMATURES

First instar larvae mine young stems and shoots of *Chromolaena odorata* (=*Eupatorium odoratum* L.) causing the plant to produce a gall. The later instars are stem borers, primarily within the galls.

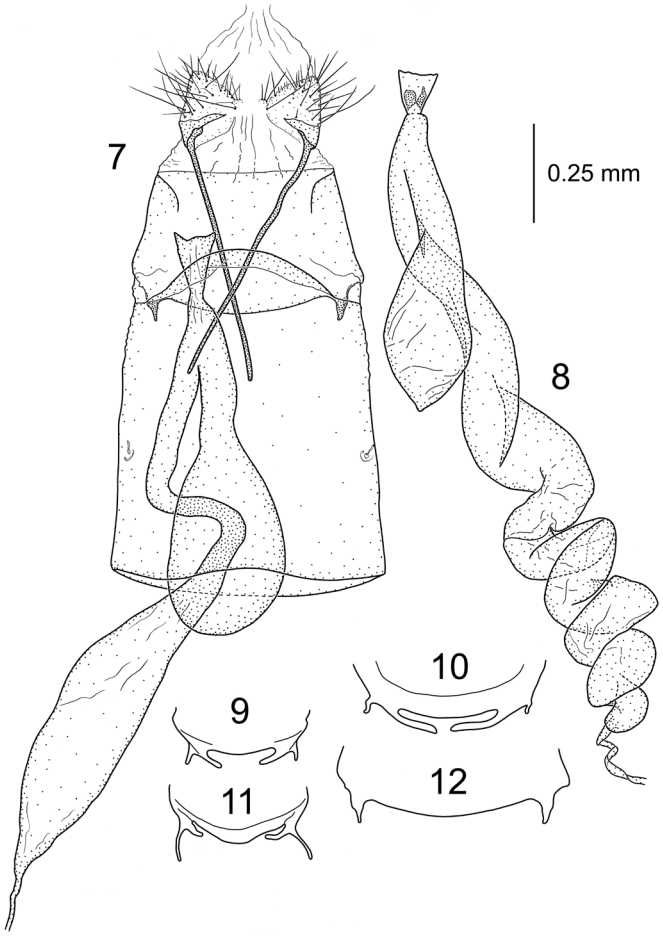

Fig. 7–12. Female genitalia of *Adaina*: **7)** *A. primulacea*, composite drawing of slides DM 661 and DM 1458; **8)** antrum, ductus bursae, corpus bursae, and ductus seminalis of *A. microdactyla*, slide DM 1460; **9)** outline of dorsal anterior margin of segment VIII showing anterior apophyses of *A. bipunctata*, slide DM 236; **10)** same, *A. microdactyla*, slide DM 1460; **11)** same, *A. simplicius*, slide DM 237; **12)** same, *A. primulacea*, slide DM 1458.

Head capsule measurements indicate five larval instars (Matthews 2006). Rows of closely spaced galls are seen on stems of heavily infested plants (Fig. 15b). Pupation occurs within the hollowed-out gall chamber formed by larval feeding on gall tissue. While larvae move freely within the gall, the pupa (Fig. 15e,f) is positioned head-up, toward the small operculum, through which the larva expels frass. These openings are also used by colonies of small ants that inhabit abandoned gall chambers. The host grows in hammocks and thickets in its native range of South Florida and the Florida Keys, the West Indies, Central and South America, and southern Texas (Cronquist 1980).

Final instar larva. Figures 13a-h and 15c, d. Maximum length 9 mm. Body cream colored. Dorsum of each segment covered with band of small ferrugineous, dentate scobinations, most conspicuous on T1 and A7-A10. Cuticle bearing lightly sclerotized scobinations on T1 and A7-A10. Prolegs absent on A3-A6 and vestigial on A10 with 0-3 crochets present (minute prolegs without crochets are present on A3-A6 of early instars but lost before the 4th instar). Setae minute to medium length, longest seta not exceeding head width. Localized secondary setae present, some forming short anterior fringe along dorso-anterior margin of each segment. Spiracles, T1, A1-A7 round, slightly exserted, with sclerotized peritremes. Spiracle on A8 (Fig. 13e) conspicuously enlarged, conical, directed posteriad, arising from near segment posterior margin. Setal nomenclature for both larva and pupa descriptions follows Stehr (1987).

Head: Width 0.67-0.84 mm. Light brown to brownish yellow. Adfrontal sclerite reaching anteclypeus. Mandibles reddish brown, broad, 5-toothed. Dorsal tooth very small. Distal seta replaced by pore. Labrum with 4 setae. Labral notch obtuse, shallow. Lateral flange of labrum with 3-4 points distad.

Thorax: Prothorax with anterior setal fringe. Fringe continued along lateral and part of posterior margin of scobinate cervical shield area. Seta D2 at least 2× length of D1. XD and SD setae difficult to distinguish from secondary fringe setae. About 4 L setae present, 2 apparently primary, with distinct peritremes. Three SV setae present, posterior seta 0.5× length of the other 2. Setae numerous on thoracic legs. Dorsum of segments T2-T3 with slight transverse indentation so that segment dorsum appears bilobed in lateral aspect. Dorsal primary and secondary setae present on anterior half (lobe) only. About 6 minute to short setae forming anterior fringe, D1 within fringe, D2 posteriad, distinct. A group of about 6 SD setae adjacent to scobinate area. Five or 6 L setae present: 1 longer seta surrounded by 3-4 shorter setae and 1 isolated short seta directly posteriad of the others. Three - 5 SV setae present, 2 distinctly longer than the others.

Abdomen: Segments A1-A7 with dorsal area subdivided as on T2-T3 but with seta D2 on posterior lobe. Seta D1 about 0.67× length of D2, usually distinct and posteriad of anterior fringe. Setae D1 and D2 erect, anterior fringe setae projecting more anteriad. One SD seta dorsad of spiracle and about 4 secondary setae anteriad of SD seta, continuing anterior fringe. Lateral setae arranged with L1 and L2 close together, L3 ventroposteriad. Several minute secondary setae (about 6) also ventrad of L1-L2. One - 2 SV setae present. Proleg scar sometimes visible on A3-A6. Segment A8 with scobinations along anterior margin prominent, distinctly dentate. Fringe setae minute. Spiracle enlarged, conical, positioned more posteriodorsad than on A7. Seta D1 directly dorsad of A8 spiracle, primary SD seta, 2 secondary setae, and L1 and L2 directly anteriad. Two additional L setae ventrad of spiracle. Venter of A8 with 1 SV seta and 1 V seta. Dorsum of A9 and A10 with scobinations and sclerotized area forming a contiguous anal plate. Posterior extent of A9 distinguished by row of dentate scobinations. Anterior fringe setae lacking on A9 but D and SD setae lateral, forming contiguous fringe with A10 anal plate setae. Venter of A9 with 1 SV and 1V seta. Venter of A10 with about 15 setae surrounding vestigial proleg. Area laterad of proleg lightly sclerotized.

Pupa. Figures 14a-c and 15e, f. Maximum length 7.5 mm. Dorsum with T2-A4 width nearly uniform. Lower abdominal segments tapered to a rounded tip at A10. Cephalic end with front, antenna base, pronotum, and anterior 0.33× of mesonotum flattened in the same plane to form near circular crown fringed with setae. Setae simple. Primary setae short to medium length, longest seta about 0.5× of maximum body width. Secondary setae present, two types. One type minute, without distinct peritremes, forming dense pubescence on cephalic crown. The other type similar to primary setae, short to medium length, with dark peritremes, and grouped with primary setae. All setae on abdomen directed posteriad. Setal pinacula on cephalic crown slightly elevated. No protuberances or dorsal ridges present on thorax and abdomen. Body color light yellow, head and cephalic crown light brown, crown moderately sclerotized. Abdomen with ventroposterior margin of A8 fused to A9 and immobile, dorsum partly movable. Anterior hamuli absent, posterior hamuli consisting of a uniform fringe of medium length, ventrally curved setae lacking hooked tips.

Head: Front with cephalic ridge dividing dorsoanterior and ventral surfaces. Cephalic ridge continued as ridge on antenna base. Dorsum of front with thick covering of minute setae, setae ending at cephalic ridge and forming marginal fringe. Two short primary setae on dorsum of front, anterolaterad near antenna. Setae straight, directed anteriad. Vertex present as tiny triangular posterolateral sclerite. Ventral face of front with minute sclerotized thorn-like process near cephalic margin. A longitudinal row of about 3 minute setae between median process and lateral margin with antenna, venter of front otherwise smooth. Frontoclypeal suture absent. One ventrally projecting clypeal seta present, seta about 0.5× length of frontal setae. Clypeolabral suture lacking, lateral margins of clypeus barely indicated by a small furrow. Labrum small, with u-shaped margin, seta lacking. Pilifers minute, touching at meson or not. Gena rounded, completely smooth and glossy, seta minute. Suture with glazed eye barely discernible. Sculptured eye obscure, setae lacking. Maxilla extending to 0.46× of T2 leg length. Distal tip of maxilla not exposed. Antenna extending to about 0.65× of T2 leg length. Antenna base mesad of foreleg with fringe of about 15 minute setae. No setae or ridge laterad of T1 leg.

Thorax: Pronotum indented at anterior margin near midline. Setae D1 and D2 in transverse alignment at about 0.67× from anterior segment margin. Setae short, about 0.5× length of frontal setae. Lateral margin forming rounded flange with 10-15 variable length setae, 1-2 setae nearly as long as frontal setae. Midline suture visible. Foreleg extending to about 0.95× length of T2 leg. Anterior half of foreleg noticeably broad, swollen at position of adult epiphysis but lacking longitudinal ridge. Coxal sclerite exposed. Anterior margin of mesonotum straight (not convex). Spiracle along anterior margin

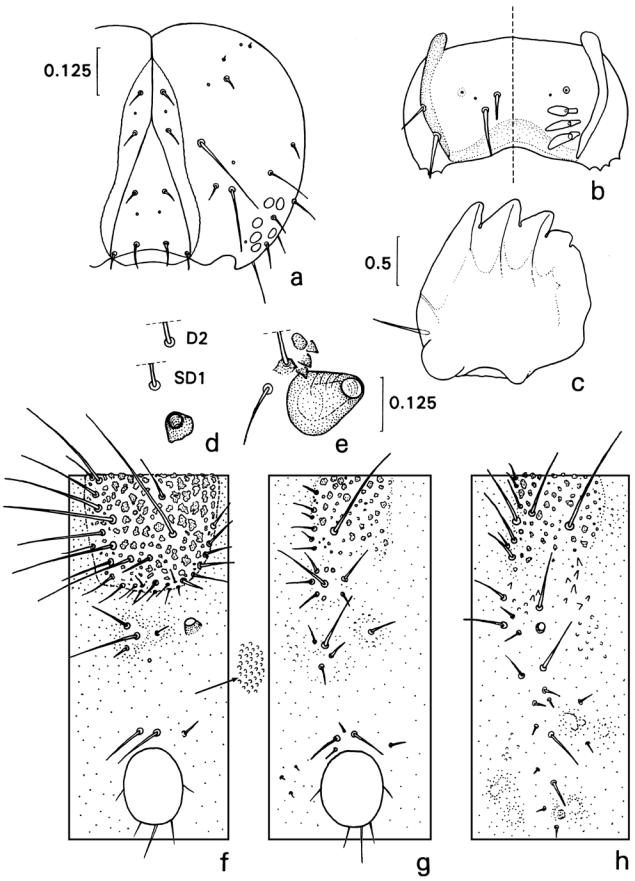

Fig. 13. Larval morphology of final instar *A. primulacea*: **a)** head, frontal view; **b)** labrum epipharyngeal surface on right; **c)** right mandible; **d)** seta D2, SD1, and A7 spiracle; **e)** seta D2, SD1, and A8 spiracle; **f)** chaetotaxic map of segment T1; **g)** segment T2; **h)** segment A3.

minute, peritreme sclerotized. Anterior 0.67× of mesonotum covered with minute secondary setae. A transverse band of about 15 short to medium length primary and secondary setae at 0.33× from anterior margin. Setae of band all with dark peritremes. Setae D1 and D2 difficult to distinguish from secondary setae of band, SD1 and SD2 usually distinct, with SD1 longest. Forewing nearly extending to tip of midleg, smooth (veins unmarked), a small cluster of about 10 minute setae near base. Midlegs not touching at meson, separated by fore and hindlegs. Midleg reaching middle of A5. Midline suture apparent on mesonotum but spliting only to about 0.67× at emergence. Metanotum with v-shaped mark at midline instead of suture line. Metanotum with 3-4 short setae anteriad in D position and 3-4 setae in SD position within anterolateral angle. Hindwing extending to about 0.33× of A2, even with spiracle. Tips of hindlegs exposed posteriad of forelegs, between midleg tips, slightly exceeding T2 leg.

Abdomen: Setae lengths variable, very short to medium length, all directed posteriad, with dark pertremes. Primary setae usually longer but difficult to distinguish from secondary setae (especially D setae). Dorsal setae shorter on lower abdominal segments. Segment A1-A2 with 4 D setae and 4 SD setae, A2 also with L1-L2 setae near forewing margin. Segment A3 with 5 D, 3-4 SD setae present, and L1 and L2 between spiracle and forewing margin; A4 with 5-6 D, 4 SD setae, and L1 and L2 present (no L3 or SV setae); A5 with 6-7 D, 3 SD, 3 L (close together), and 1-2 SV setae; A6 with 7-9 D, 5 SD, 2-3 L, 1-2 SV setae; A7 with 5 D, 5-8 SD, 2 L, and 1 SV seta. Spiracles on A2-A7 round with dark peritremes, very slightly exserted and with dark traces of tracheae visible from beneath cuticle. Segment A8 fused to posterior margin of A7 in both males and females except for a slightly movable part on dorsum. Segments A8-A10 completely fused, segment margins obscure. Segment A8 with 3-4 short D setae, 3-4 short SD setae, L1 short, L2 medium length and no SV setae. Genital slit conspicuous on females. Spiracular scar present on A8. Segment A9 with about 8 setae on dorsum (groups indistinct), no setae on venter. Segment A10 with 2 setae slightly anteriad of hamuli fringe but difficult to distinguish. Hamuli consisting of dense fringe along tip and sides of A10, hamuli medium length, curving ventrad but lacking hooked tips. Tip of A10 rounded. Anterior hamuli absent but a small, flat circular mark present. Venter of A8-A10 rounded, no lateral ridges or ventral plate present.

Immature material examined. L = larva, LS = larval skin/exuvium, P = pupa, PC = pupa case/exuvium. USA: FLORIDA: Broward Co.: Davie, University Drive, south of Rolling Hills Golf Course 11 Sep 1993 D. Matthews, T.A. Lott, & B. Maharajh, in stem gall on *Chromolaena odorata* (199 L, 19 LS, 8 P, 14 PC) [DMC]; same, preserved 24 Sep 1993 (29 L, 5 LS, 4 P, 5 PC); same, preserved 1 Nov 1993 reared on artificial diet (1 P); Davie, University of Florida, FLREC 23 Aug 1993 B. Maharajh, in stem gall on *C. odorata* (1 L); 11 Sep 1993 D. Matthews, T.A. Lott, & B. Maharajh, in stem gall on *C. odorata* (1 L); Davie, Treetops County Park 11 Sep 1993 D. Matthews, T.A. Lott, & B. Maharajh, in stem galls on *C. odorata* (8 L, 1 LS, 1 1st instar head capsule); Davie, Nob Hill Road 21 Nov 2001 D. Matthews & T.A. Lott, in stem galls on *C. odorata* (38 L, 1 LS, 1 P). All specimens currently held in DMC with vouchers to be deposited at MGCL and USNM.

Distribution and phenology. This species was originally described from one male from Toboga Island, Gulf of Panama, (500 ft.) collected in September (Meyrick 1929). Gielis (1992) also listed one male from Costa Rica (Punt. Monteverde) collected in December 1987. The Florida specimens are all from Broward County. As the host is widespread thoughout the Neotropics, including the West Indies, and Central and South America, it is likely this species will be found in these areas and possibly in Old World tropical regions where the host is an invasive weed. The Florida specimens were reared from larvae collected from stems of *C. odorata* in August and September before the plants were in bloom. The seasonal habits and number of generations per year are unknown. It is possible that flowers are also used as reported for *A. microdactyla*, which has two broods, one which bores in stems and produces galls, the other feeding in flowers, although Gielis (pers. comm.) indicates flower feeding has not been recently confirmed. In the northern hemisphere, flowering of Siam Weed occurs in late December and is brought on by short day lengths (Walton & Waterhouse 1998).

DISCUSSION

Miller (2005) reported 179 identified species of lepidopteran gallers worldwide representing 20 families. Of these, the family Pterophoridae included two palearctic species, *A. microdactyla* and *Platyptilia nemoralis* Zeller, the later on *Senecio cacliaster* Lam. A third palearctic species, *Gillmeria ochrodactyla* (Denis & Schiffermüller) is known to feed within stem galls on *Tanacetum vulgare* L. (Cees Gielis, pers. comm.) but pupate externally on the stems. *Adaina primulacea* adds another identified species to the list of cecidophylous Lepidoptera, a fourth species to the known cecidogenous pterophorids, and is the first cecidogenous pterophorid identified from the Neotropics. As hosts and life histories are known for only 8 of the 28 species of *Adaina*, and descriptions of several new neotropical species are anticipated, the discovery of additional gallicolous species is likely. A recent experimental study by Diamond *et al.* (2008) demonstrated that larvae of the stem boring pterophorid *Hellinsia glenni* (Cashatt) attained greater mass when transferred and reared on *Solidago* galls induced by a tephritid fly compared to larvae reared in stems, thus supporting the nutrition hypothesis for the adaptive nature of insect galls with an empirical test using a non-adapted species. While it is not known whether or not *Adaina primulacea* has continuous broods or also feeds on flowers and shoots as reported for *A. microdactyla*, both of these species present unique opportunities for further studies on the evolutionary significance of gall induction.

Although Gielis (1992) revised the genus *Adaina*, as the life history of more species of these moths becomes known,

additional insight into relationships within the genus as well as the family may be gained from morphological studies of the immatures and from reared series of adults with definitively associated males and females. The genus is presently defined by characters of the wing venation and of male and female genitalia. *Adaina* and *Hellinsia* Tutt are similar in some general features of the genitalia such as asymmetry in the male valvae and lateral placement of the antrum in females. The forewing venation of *Adaina*, however, is distinguished from that of *Hellinsia* having veins R_3 and R_4 stalked vs. free (Fig. 2).

Larval morphology of internally feeding *Hellinsia* species such as the type species *H. osteodactylus* (Zeller) vs. internal feeders in *Adaina* is very similar. In both genera, setae of the internal feeders are unmodified and arise individually instead of on tubercles or verrucae and the dorsum of the thoracic and abdominal segments is covered with numerous tiny sclerites. External feeders of both genera tend to have modified and clustered setae and have one or more extra teeth added to the basic 5-toothed mandible, and in many species, the adfrontal sclerite on the larval head does extend all the way to the anteclypeus (Matthews 2006). The A4-A6 prolegs of *Adaina* flower and stem/gall borers examined are reduced, without crochets, and with either the length not exceeding the width, or absent as in *A. primulacea.* In *Hellinisa* flower and stem borers, the prolegs are shorter than in the external feeders but crochets are present. In *Adaina,* the A8 spiracle is noticeably enlarged in certain species, such as *A. primulacea* (Fig. 13e) and external feeders, such as *A. ambrosiae* (Murtfeldt) (Matthews 2006), although not in the flower borer *A. simplicius* (Grossbeck). The pupal chaetotaxy in these genera is generally a reduced version of the larva. In both *Hellinsia* and *Adaina* internal feeders, the anterior hamuli of segment A10 in pupae are absent or reduced in number. Pupae of *Adaina* borers (*A. microdactyla*, *primulacea*, and *simplicius*) are unique however, in having a minute hooked process near the anterior margin of the head (Mellini 1954, Matthews 2006).

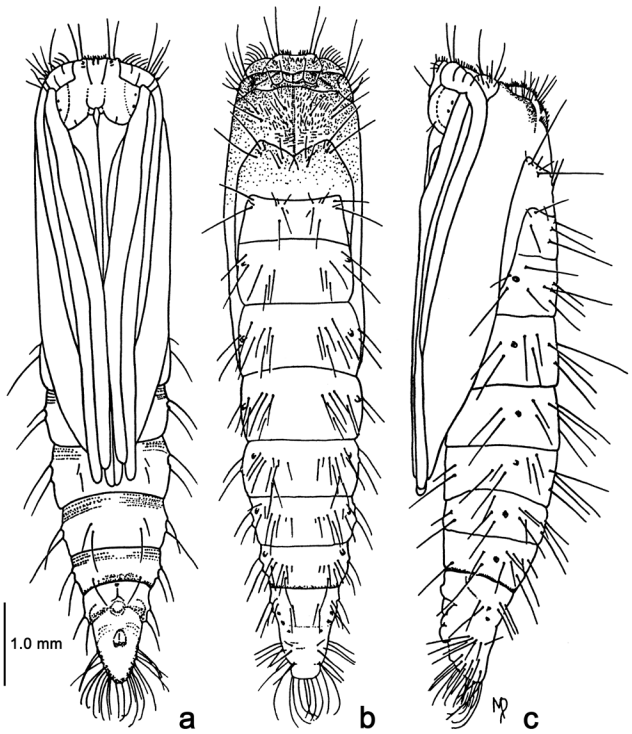

Fig. 14. Pupa of *A. primulacea*: **a)** ventral view; **b)** dorsal view; **c)** lateral view.

While general characters and wing venation distinctly place *A. primulacea* within the genus, it is not necessarily more closely related to *A. microdactyla* than other *Adaina* based on the common pattern of gall induction in the host. The left valve saccular process of male genitalia of *A. microdactyla* (Fig. 4), and two other species occuring in Florida, *A. bipunctata* (Möshler) (Fig. 5), and *A. simplicius* (Fig. 6) are similar in having a curved thin sclerotized sulcus extending basad of the main process which is absent in *A. primulacea*. The saccular process of *A. primulacea* also differs from the previous species in having the spine portion extending laterad from the base before curving posteriad, as opposed to extending directly anteriad from the thickened base. The anterior apophysis in the female genitalia of *A. primulacea* (Fig. 12) also differs from *A. bipunctata* (Fig. 9), *A microdactyla* (Fig. 10), and *A. simplicius* (Fig. 11) in that it is a simple thorn-like process as opposed to an ornate bifurcate structure. The antrum in females also lacks the paired sclerites found in *A. microdactyla* (Fig. 8), and the others. Another interesting but variable character is the ductus seminalis, which is straight in *A. simplicius*, bent and distally swollen in *A. primulacea*, and spiraled in both *A. microdactyla* (Fig. 8) and *A. bipunctata.* These last two species seem closest overall in genital characters but are easily distinguished by wing maculation, the first being yellowish with scattered dark scaling, the later white with localized dark spots.

In addition to differences in the morphology of *A. microdactyla* and *A. primulacea*, these two galler species differ somewhat in the reported larval feeding habits. Mellini (1954) illustrates multiple openings in a single large gall for *A. microdactyla*. Larvae of *A. primulacea* inhabit individual galls with only a single opening. Gielis (pers. comm.) indicates identical habits for *A. microdactyla.* Larvae of *A. primulacea* bore within the stems beyond gall tissue, but not to the extent described by Mellini (1954) for *A. microdactyla.* Although seasonal habits of *A. primulacea* are not completely known, *A. microdactyla* is limited to two distinct broods. While phytochemistry, linked with closely related hostplant genera, in this case *Eupatorium* and *Chromolaena*, is the most probable determinant in host selection, host physiology is most likely the significant factor in the evolution of larval habits in this group. Galler species have probably evolved in separate lineages within the genus *Adaina* as they have throughout the order Lepidoptera (Miller 2005).

Crutwell (1974) listed an *Adaina* sp. in hollow stems of *E. odoratum* from Veracruz, Mexico which most likely refers to *Adaina primulacea*. Cruttwell (1968, 1974) also reported *A. bipunctata* from flowers of *E. odoratum* and *E. iresinoides* from Trinidad. These records have not been confirmed with museum specimens and could refer to *A. primulacea*, *A. simplicius*, or *A. bipunctata*. The latter two species are easily distinguished from *A. primulacea* by the white as opposed to yellowish ground color of the wings. The true identity of *A. bipunctata* is problematic, however, as the holotype is not available and was reported as probably lost from the Zoological Museum of Berlin (Gielis 1992). In Florida, *A. simplicius* is more common than what

Fig. 15. Life history of *Adaina primulacea*: **a)** terminal shoot on hostplant, *Chromolaena odorata*, showing frass extruding from developing stem galls; **b)** mature stem galls; **c)** cross-section of stem exposing dorsal view of larva feeding within the developing gall; **d)** lateral view of final instar larva; **e)** lateral view of pupa within gall chamber; **f)** ventral view of pupa.

is generally known as *A. bipunctata*. Larvae of *A. simplicius* are flower borers on several species of composites, especially *Carphephorus odoratissimus* (J.F.Gmel.) Herb. (Matthews 2006). *Adaina simplicius*, or a close relative has also been collected in Argentina and exported to South Africa for study as a biological control agent for Pompom Weed, *Campuloclinium macrocephalum* (Less.) DC. (ARC/LNR 2007).

The status of populations of *A. primulacea* in South Florida should be monitored as this area is under heavy pressure from development. As of 2001 the stand of hostplants supporting the population along University Drive (County Road 817) in Davie was completely eliminated by development. Although the host is a weedy species, growing in dense tangled stands reaching 3 meters, it is native to the area. While *A. primulacea* is considered a species of low priority for the biological control of Siam Weed because of difficulties in inducing sufficient oviposition in captivity and in handling these small moths (Zacharides *et al.* 1998), as the spread and severity of this invasive weed

continues in tropical and subtropical regions of the world, the candidate status of this moth may need to be reassessed. Despite the fact that *Chromolaena odorata* is widespread in the Neotropics, along with preserving species diversity, it is important to maintain local reservoirs of the associated insect fauna for future biological control studies since these isolated populations may include unique genotypes, variably suited for different host strains and environments.

ACKNOWLEDGMENTS

We thank Cees Gielis for his critical review of the manuscript, for providing images of type material for study and comparison with our specimens, and for sharing personal observations. Ernst Arenberger supplied comparative material of *Adaina microdactyla*. Line illustrations of the pupa are by Margo Duncan. Terry A. Lott assisted in fieldwork. Dale H. Habeck provided logistic support to the first author for travel to collecting sites and funding during graduate sudies. We also gratefully acknowledge the support of staff and colleagues at the Fort Lauderdale Research and Education Center. Thanks are also due to Charles V. Covell, Jr., Vitor O. Becker, Reed A. Watkins and anonymous peers for their careful reviews and helpful comments.

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