Redescription of the Drywood Termite *Incisitermes inamurae* (Isoptera: Kalotermitidae) From Southern Taiwan

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**ABSTRACT** *Kalotermes inamurae* Oshima 1912 (Isoptera: Kalotermitidae) is reassigned to *Incisitermes* (Krishna, 1961) based on the winged imago that is described herein for the first time. The two size morphs of the soldier caste are redescribed, as is the distinctly different morphology of the soldier of incipient colonies. The distribution of *I. inamurae* is restricted to the tropical zone of Taiwan. Another tropical species, *Incisitermes meggregori* (Light), from Luzon, Philippines, has similar soldier morphology and may be a junior synonym of *I. inamurae*. The five *Incisitermes* species reported in Japan, China, Taiwan, and the Philippines were compared morphologically.

**KEY WORDS** *Incisitermes*, winged imago, soldier, taxonomy, Taiwan

*Kalotermes inamurae* Oshima 1912 (Isoptera: Kalotermitidae) was described in brief based on specimens collected by Tokie Inamura at Kuraur in Heng-Chun Peninsula, Taiwan. In 1913, the original description was translated into English (Oshima 1913), but no additional details were provided. Due to the lack of winged imagoes, Oshima did not assign this species to a subgenus. In 1961, Krishna reorganized the genus *Kalotermes* and assigned most of the species to other genera. Although Krishna (1961) questioned the genus of this species, he did not propose a new combination, probably due to unavailability of winged imagoes. In light of a recent collection of *K. inamurae* from southern Taiwan, including the type locality, we describe the large and small soldiers, and we also describe the incipient soldier and the winged imago for the first time. According to the current Kalotermitidae taxonomic system (Krishna 1961), a new combination for this species is herein proposed as *Incisitermes inamurae* (Oshima).

*Incisitermes* species, commonly referred to as drywood termites, are mostly found in dead trees or dead portions of living trees in their native habitats. Due to their low moisture requirement, some species are able to survive in artificial structures. The highest species diversity of *Incisitermes* (20 species) is found in the Neartic and Neotropical Americas (Constantino 1998). A few species are known from Australia (Gay 1975), India (Roonwal and Chhotani 1989), and Oceania (Krishna 1961). In East Asia, five named *Incisitermes* species including *I. inamurae* have been recorded. *Incisitermes meggregori* (Light) and *Incisitermes taylori* (Light) are found in the Philippines (Light 1921, 1930). Both *Incisitermes minor* (Hagen), found in the central east coast of China (Huang and He 2000) and southern Japan (Indrayani et al. 2004, Mori 1976), and *Incisitermes immigrans* (Snyder), found at Iwojima Island and South Daito Island, Japan (Ohkuma et al. 2004, Takematsu 1997, Yasuda et al. 2000), were introduced from the New World. The five Asian species are compared here.

**Materials and Methods**

Redescriptions and descriptions are based on examination of 53 colony samples collected from 28 localities, including the type locality in Heng-Chun Peninsula (Fig. 1). Termites were preserved in 85% ethanol. Morphometric data were obtained by using a stereomicroscope (model SZX12, Olympus Optical Co., Ltd., Tokyo, Japan) fitted with a calibrated ocular micrometer. The color pictures of each caste taken with a digital camera (DP70, Olympus Optical Co., Ltd.) can be viewed at http://flrec.ifas.ufl.edu/su/hou-feng-li.shtml. The terms “large” and “small” soldiers (Oshima 1913, Krishna 1961, Scheffrahn et al. 2000) are equal to the terms “long-headed” and “short-headed” soldiers (Banks and Snyder 1920). Measurements were adopted from Roonwal (1969), and the color scheme of Sands (1965) was used. Specimens for scanning electron micrographs (SEMs) were dehydrated in 95%, 100% ethanol and 1,1,1,3,3,3-hexamethyldisilazane for 24 h each consecutively (Nation 1983). Dehydrated specimens were sputter-coated with platinum, and their images were taken with a scanning electron microscope (SEM-5510LV, JEOL, Tokyo, Japan) at 10 kV. Contrast of SEMs was enhanced by using the software GIMP, version 2.6 (Free Software Foundation, Inc., Boston, MA), and backgrounds were converted into black. Scale bars were

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redrawn. Collection localities were mapped by using the software Google Earth, version 4.3 (Google Inc., Mountain View, CA).

**Incisitermes inamurae** (Oshima)

*Calotermes* (subg. ?) *inamurae* Oshima: Oshima 1912: 61–63. [female dealate, large soldier, small soldier]. *Kalotermes inamurae*: Snyder 1949: 16. 

*Kalotermes inamurae*: Krishna 1961: 336.

**Imagoes** (Fig. 2; Table 1). In dorsal view, head capsule, antennae, notum, and dorsum orange or orange yellow except for ferruginous compound eyes; costal veins including costal margin, subcosta, radius, and radial sector ferruginous orange; generally giving the winged imago a uniform orange appearance.

Head capsule subcircular. Frons broadly concave with faint rugosity. Labrum wide linguiform, orange yellow, semitransparent; clypeus narrow, yellow white. Compound eye chestnut brown, subcircular, protruding and large, contacting antennaal socket; ocellus elliptical, yellowish contrasting with orange head capsule, right above compound eye and contacting ocular sclerite. Epicranial suture faint, Y-shaped toward posterior margin, several branches close to ocellus on each side. Antennae composed of 17–19 segments, usually 17 or 18, first segment longest, second segment shortest, in general, the segment length gradually increasing from proximal segments to distal segments, proximal segments orange and grading to yellow at distal segments. Mandibular dentition as in Fig. 2C. The posterior margin of the first plus second marginal tooth in left mandible shorter than the anterior margin of the third marginal tooth, which is the character of the genus *Incisitermes* and not of the genus *Kalotermes* described by Krishna (1961). Pronotum wider than long and wider than head; anterior margin smoothly incised, anterior corner rounded, posterior margin faintly concave, sides slightly convex with scattered short and long setae up to 0.2-mm-long, posterior corner broadly rounded. Wing membrane translucent and faintly tuberculate; costal veins including costal margin, subcosta, radius, and radial sector sclerotized. Costal margin in forewing with scattered short setae ≈0.1 mm, subcosta and radius terminating at costal margin at proximal half of wing from suture, radial sector with about eight branches in distal half of wing; media unsclerotized, in some specimens, slightly sclerotized beyond distal one-fourth length of wing; cubitus with >11 branches toward posterior margin, several branches close to wing scale slightly sclerotized. In ventral view, postmentum oval, anterior quarter pale yellowish, noticeably different from orange yellow posterior part; gena and palps orange yellow. Abdominal sternites and femora pale yellow. Tibia, tarsus, and claws orange yellow. Arolia present.

Comparison. The noticeably orange head and pronotum and brownish wing and body of *I. minor* imago gives it a much darker appearance than *I. inamurae* and *I. immigrans* in general. The winged imago of *I. inamurae* resembles that of *I. immigrans*, but the former is larger. Total length with wings of the *I. inamurae* alate is ≥13.2 mm compared with =12.0 mm in *I. immigrans*. Head width at eyes in *I. inamurae* is ≥1.5 mm, whereas in *I. immigrans* is =1.1 mm, and pronotum maximum width is ≥1.65 mm and =1.2 mm for *I. inamurae* and *I. immigrans*, respectively. Arolia present in *I. inamurae* and *I. immigrans* but not in *I. minor*. The winged imagoes of *I. meggregori* and *I. taylori* are unknown.

**Soldier** (Figs. 3 and 4; Table 2). Three distinct morphs of soldier caste, large and small forms from mature colonies, and the incipient soldier from young colonies were found. Material from four mature colonies is represented in our collection, including 10, 11, 28, and 29 soldiers, respectively, consisting of 21–50% large soldiers and 50–79% small soldiers. In incipient colonies, the first several soldiers produced were significantly smaller than soldiers found in mature colonies, a difference also observed by the H.-F.L. in *I. snyderi* and *I. schwarzi*, and reported previously in *Neotermes papua* (Desneux) (Roisin and Pasteels 1991), and *Mastotermes darwiniensis* Froggatt (Watson 1974). In general, large soldiers are the most sclerotized and incipient soldiers the least sclerotized. Morphometrics of large, small, and incipient soldiers are given in Table 2.

**Large Soldier** (Figs. 3A and B and 4A and B; Table 2). Head capsule in dorsal view, rectangular, ferruginous orange anteriorly grading to yellow posteriorly,
sides parallel with >50 lateral setae of variable length to 0.2 mm, anterior corners nearly square at mandibular articulations, posterior margin evenly rounded, median posterior margin slightly concave. Epicranial suture faint. Surface of head capsule when viewed ventrally, pale yellow except for reddish anterior corners at mandibular articulations. Head capsule when viewed laterally, covered with dense setae of variable length to 0.2 mm on both dorsal and ventral discs. Frons slopes smoothly from vertex, surface weakly rugose and slightly concave, with five to eight long setae at frontal carinae. Clypeus narrow, white, trapezoid. Labrum orange yellow, linguiform, pilose in distal half with around five long setae up to 0.3 mm. In lateral view, eyespot yellow, elliptical, and situated a short distance behind, and at same height as antennal fossae; a faded yellowish circular spot right above eyespot, 0.1 mm in diameter, situated close to vertex. Mandibles pitch black distally and grading to chestnut brown at base, robust with a moderate basal hump; left mandible with short distal blade and three marginal teeth, first two prominent, third less prominent; right mandible with distal blade in distal half, and two triangular teeth in basal half; dentition as in Fig. 4B; in lateral view, mandibles angling upward from plane of head. Antennae with 13–16 segments, rarely 13, the proximal three segments ferruginous orange and grading to yellow at apical segment; first segment longest; third antennal segment subclavate with long setae on distal end; relative length formula usually 2+3+4=5. Antennal carinae ferruginous orange, markedly protruding. Postmentum orange-yellow anteriorly grading to pale yellow posteriorly, bearing setae laterally. Pronotum wide and squarely incised at anterior margin to form an angle 130°; anterior corners sharply rounded; posterior margin with slight concavity; posterior corners broadly rounded. All large soldiers with wing pads on meso- and metanotum. Femora yellow-white, noticeably inflated, slightly longer than tibia. The enlarged third antennal segment, swollen femur, and incised pronotum are the characters separating the genus Incisitermes from the genus Kalotermes.

Small Soldier (Figs. 3C and 4C and D; Table 2).
Head capsule orange yellow in dorsal view, antennal carinae and frontal carinae protruding and darker, ferruginous orange. Mandibles pitch black; base

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Table 1. Measurements of *I. inamurae* imagoes, *n* = 10 from three colonies including five males and five females

| Measurement (mm)       | Range        | Mean ± SD |
|------------------------|--------------|-----------|
| No. antennal segments  | 17–19        | 17.5 ± 0.6|
| Head length to labrum tip | 1.70–2.05   | 1.80 ± 0.12|
| Head length to medium base of clypeus | 1.30–1.60 | 1.42 ± 0.09|
| Head width, max at eyes | 1.50–1.65   | 1.56 ± 0.04|
| Head ht without postmentum | 0.55–1.10  | 1.00 ± 0.06|
| Labrum width, max | 0.58–0.70   | 0.63 ± 0.04|
| Eye max diam with sclerite | 0.40–0.47   | 0.44 ± 0.03|
| Distance from eye to lower margin of head, min | 0.15–0.30 | 0.26 ± 0.04|

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Fig. 2. Scanning electron micrographs of *I. inamurae* winged imago. Dorsal (A) and oblique (B) views of head and pronotum; mandibles (C); right forewing (D). 1+2, the fused first and second marginal teeth; 3, the third marginal tooth. Scale bars = 500 μm.
lighter, dark chestnut brown. Thoracic dorsum orange-yellow or yellow; abdominal dorsum lighter, yellow or pale yellow. Tibiae yellow; femora and sternum yellow-white. Yellow postmentum contrasting with yellow-white genae. In general, small soldier comparatively less scleritized than large morph. Almost every structure is paler than those of the large soldier by one scale in Sands’ color scheme (Sands 1965).

In dorsal view, head capsule subsquare, shorter than that of large soldier; sides slightly convex with >50 lateral setae of variable length to 0.2 mm, anterior corners nearly square, posterior corner and posterior margin usually covered by pronotum. Epicranial suture faint. Clypeus a narrow, white, trapezoid. Labrum orange yellow, linguiform, pilose in distal half with more than ten long setae over 0.2 mm and less than 5 up to 0.3 mm. Mandibles, much more slender than that of large soldier, with slight basal hump; dentition as in Fig. 4D. Pronotum wide and incised at anterior margin; anterior corners sharply rounded; posterior margin with slight concavity. All small soldiers with wing pads on meso- and metanotum.

In lateral view, head capsule, both dorsal and ventral discs covered with setae of variable length to 0.2 mm of same density. Frons sloping smoothly from vertex, surface smooth, faintly concave, with five to eight long setae at frontal carinae. Mandible angled upward ≈30° from plane of head. Antennae with 14–17 segments, rarely 17, the proximal three segments darker, ferruginous orange, third segment sub-clavate; antennal formula 2<3>4=5. Eyespot yellow, elliptical, and situated a short distance behind antennal fossae; a subcircular patch <0.1 mm with the same color with eyespot situated above eyespot, close to vertex. Femora inflated, as long as tibia.

**Incipient Soldier** (Figs. 3D and 4E and F; Table 2). Head capsule pale yellow or yellow white with orange yellow antennal carinae and frontal carinae. Mandibles dark chestnut brown in distal half; base lighter, ferruginous orange. Thoracic dorsum yellow-white and semitransparent; abdominal dorsum white. Tibiae, femora and sternum white. Postmentum yellow-white. In general, incipient soldiers are much smaller than either small or large soldiers in size, and only mandibles and anterior part of head are strongly sclerotized.

In dorsal view, head capsule slightly rounded or subsquare; sides slightly convex with <50 lateral setae of variable length to 0.2 mm, anterior corners curved inward; posterior corner and posterior margin rounded. Epicranial suture obsolete. Clypeus a narrow, white, trapezoid. Labrum orange yellow, linguiform, pilose in distal half with more than 10 setae >0.2 mm pointing upward and forward. Mandibles, more slender than that of small soldier, with faintly basal hump, dentition as in Fig. 4F. Pronotum wide and smoothly incised at anterior margin; anterior corners sharply rounded; posterior margin with slight concavity. Some incipient soldiers with wing pads on meso- and metanotum.

In lateral view, head capsule, both dorsal and ventral disc, covered with scattered setae. Frons sloping
smoothly from vertex, slightly concave, with less than five long setae up to 0.2 mm at frontal carinae. Mandible angled upward ≈ 30° from plane of head. Antennae with 11–14 segments, usually 11 or 12, the proximal three segments darker, orange yellow, third segment slightly clavate; antennal formula 2<3>4=5. Eyespot pale yellow, elliptic; in lateral view, a subcircular spot with the same color of eyespot situated above eyespot close to vertex. Femora inflated, as long as tibia.

Comparison. The body size and color of *I. inamurae* soldiers are similar to those of *I. immigrans*, and both are smaller and much lighter than *I. minor*. The pronotum of *I. inamurae* is wider than the head and the anterior margin is smoothly incised, whereas the pronotum of *I. immigrans* and *I. minor* are as wide as head and the anterior margin is sharply incised. The meso- and metathorax of *I. inamurae* are also wider than the head giving *I. inamurae* a noticeably wider thorax compared with most *Incisitermes* spp. The third
Based on the description by Light (1921), *Incisitermes mcgregori* collected at Luzon Island, the Philippines, resembles *I. inamurae*, especially the mandible dentition, pilosity of head, the wing pads on meso- and metanotum, and the uncommonly wide pronotum. Due to these two species being close in geographic distribution and having similar soldier morphology, we propose that *I. mcgregori* may be a junior synonym of *I. inamurae*. However, collection of *I. mcgregori* winged imago and further comparisons are necessary to confirm their systematic position.

Based on the description by Light (1930), the *I. taylori* collected at Mindanao Island, the Philippines, is much smaller than the four *Incisitermes* spp. discussed above. The body length and head width of *I. taylori* are only $<5.00 \text{ mm}$ and $\approx 1.17 \text{ mm}$, respectively, compared with $>7.0 \text{ mm}$ and $>1.67 \text{ mm}$ for the others.

### Material Measured

**TAIWAN, Pingtung Co., Hengchung Township:** All samples collected by N. Kanzaki, Y.-C. Lan, H.-F. Li, and J.-F. Tsai. Longluantan: 21.93°N, 120.83°E; 19-X-2008; 1 incipient soldiers, 1 for SEM (TW789). Eulanbi Park: 21.90°N, 120.85°E; 19-X-2008; 4 large soldiers, 1 for SEM, 4 small soldiers, 2 for SEM (TW794). Longkeng Ecological Reserve Area: 21.90°N, 120.86°E; 19-X-2008; 2 incipient soldiers, 1 for SEM (TW798).

**Material Examined.** *Incisitermes immigrans*, soldiers and alates: USA. Hawaii, Oahu. Kaena Point State Park: 21.55°N, 158.23°W, 6-XII-96, J. Chase and J. Mangold (HI24 and HI26); Kaneana Cave area: 21.51°N, 158.23°W, 6-XII-96, J. Chase and J. Mangold (HI34). *Incisitermes minor*, soldiers and alates: USA. Arizona, Hwy 82 riparian: 31.51°N, 110.80°W, 3-XI-05, J. Chase, J. Mangold, and R.H. Scheffrahn (US605 and US606). California, Santa Cruz Co., Scotts Valley: 37.04°N, 122.02°W, 15-X-03, M. Folkins (US552). *I. immigrans* and *I. minor* used for comparison are deposited in the University of Florida termite collection, Fort Lauderdale Research and Education Center, Florida (FLREC).

### Type Material.

All known type specimens collected by Tokie Inamura at Kuraru (now, Heng-Chun Research Center, Taiwan Forestry Research Institute), Pingtung Co., Taiwan were initially deposited at Institute of Science, Government of Formosa (Oshima 1913). The Institute of Science was later divided into the Agriculture Research Institute, Forestry Research Institute, Industry Research Institute, and Tropical Medicine Research Institute in 1939. No type specimens were found by H.-F.L. in 2008 from the Insect Collection of Taiwan Forestry Research Institute, Taipei (TFRI) and Taiwan Agriculture Research Institute, Wufeng, Taichung, and other four major insectariums in Taiwan under National Museum of Natural Science, Taichung (NMNS), National Taiwan University, Entomology Department, Taipei (NTU), National Chung-Hsing University, Entomology Depart-
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