

Additional Records of *Polyrhachis (Myrmatopa) varicolor* Viehmeyer (Formicidae: Formicinae) from Southern Thailand, with Notes on Its Nesting Habits

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ABSTRACT.— *Polyrhachis (Myrmatopa) varicolor* Viehmeyer (Formicidae: Formicinae) is newly recorded from sixteen different sites in Southern Thailand based on material from colonies on low vegetation and specimens from tree fogging samples. The nesting habits, including nesting sites, nest material and the colony composition, of this species were examined. We found no remarkable variation in nest size (height, width and depth), nest location above ground and the number of entrances per nest, whilst the ranges of these values overlapped among nests from different localities. Nests of this species were made of silk sheets, while the carton and other materials, such as plant tissue fragments, are incorporated into their nest wall structures. This species is polydomous with the colony members distributed over several nests, although colonies were generally monogynous.

KEY WORDS: *Polyrhachis varicolor* Viehmeyer, Southern Thailand, nesting habits

INTRODUCTION

Polyrhachis is one of the largest ant genera (Formicidae), with its members being distributed mostly in the tropics and subtropics of the Old World (Bolton, 1995; Dorow, 1995). Currently, the genus contains over 500 described species and is divided into 12 subgenera: *Aulacomyrma*,

Campomyrma, *Chariomyrma*, *Cyrtomyrma*, *Hagiomyrma*, *Hedomyrma*, *Hemioptica*, *Myrma*, *Myrmatopa*, *Myrmhopla*, *Myrmothrinx* and *Polyrhachis* (Bolton, 1995, 2003; Dorow, 1995; Kohout, 2003, 2008).

The nesting habits of *Polyrhachis* ants are highly diverse. Nesting sites range from subterranean to arboreal, with the walls of arboreal nests composed of silk produced by their own larvae, carton, or a combination of both (Dorow et al., 1990; Hung, 1967; Liefke et al., 1998; Noon-anant et al., 2008; Robson and Kohout, 2005, 2007). Moreover, many different strategies occur in this genus, from monodomy to polydomy, and from

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monogyny to polygyny (Dorow, 1995; Dorow and Maschwitz, 1990; Dorow et al., 1990; Liefke et al., 1998; Noon-anant et al., 2008; Robson and Kohout, 2007; Schellerich-Kaaden et al., 1997).

The subgenus *Myrmatopa* comprises arboreal-nesting ants with 41 described species found throughout the tropics of Asia and the Australian region (Dorow, 1995; Kohout, 2008). Their nests are constructed on leaves or by joining together leaves of various trees and shrubs (Kohout, 1999; Noon-anant et al., 2008).

Polyrhachis (Myrmatopa) varicolor Viehmeyer was originally described by Viehmeyer (1916) from Singapore under the name *P. (Campomyrma) fruhstorferi* spp. *varicolor*. It was later placed in the subgenus *Myrmatopa* and the *wallacei* species-group by Emery (1925). However, this species was raised to species level by Kohout (2008) and placed into a new *flavicornis*-group.

Definitive information on the worker-queen association, distribution, nesting habits and socioecological characteristics of *P. varicolor* are still lacking. So, this study aims to provide additional information of *P. varicolor* from Southern Thailand based on the morphological characteristics of the workers, and queens when information on the worker-queen association is available, in order to make a more complete description, and examines the distribution and nesting habits of this species, including nesting sites, nest material and colony composition.

MATERIALS AND METHODS

Study area.— Southern Thailand (Fig. 1) lies between 6° and 12° N latitude and forms a narrow peninsula flanked by the Gulf of Thailand in the east and the Andaman Sea in the west. The climate in Southern Thailand is influenced by both the northeast monsoon, with October to December the wettest months on the east, and the Southwest monsoon, with May to October the wettest months on the west (Geo-Informatics and Space Technology Development Agency, 2003). The LANDSAT 5 mosaic for this region shows many mountain ranges running from the Upper to Lower region. The Upper region is shared by Thailand and Myanmar, with the Tanao Si (Tenasserim) mountain range running in a north-south direction along the border and ending at the Kra Buri river in Ranong Province. On the west of the Peninsula, the Phuket mountain range extends from Ranong to Phuket Province. On the east, the Nakorn Si Thammarat mountain range stretches from Surat Thani southward to Satun Province which lies at the southern end of the country. On the Thai-Malay border the Sankalakhiri mountain range stretches NW-SE along the border and then turns southward into Malaysia (Geo-Informatics and Space Technology Development Agency, 2003).

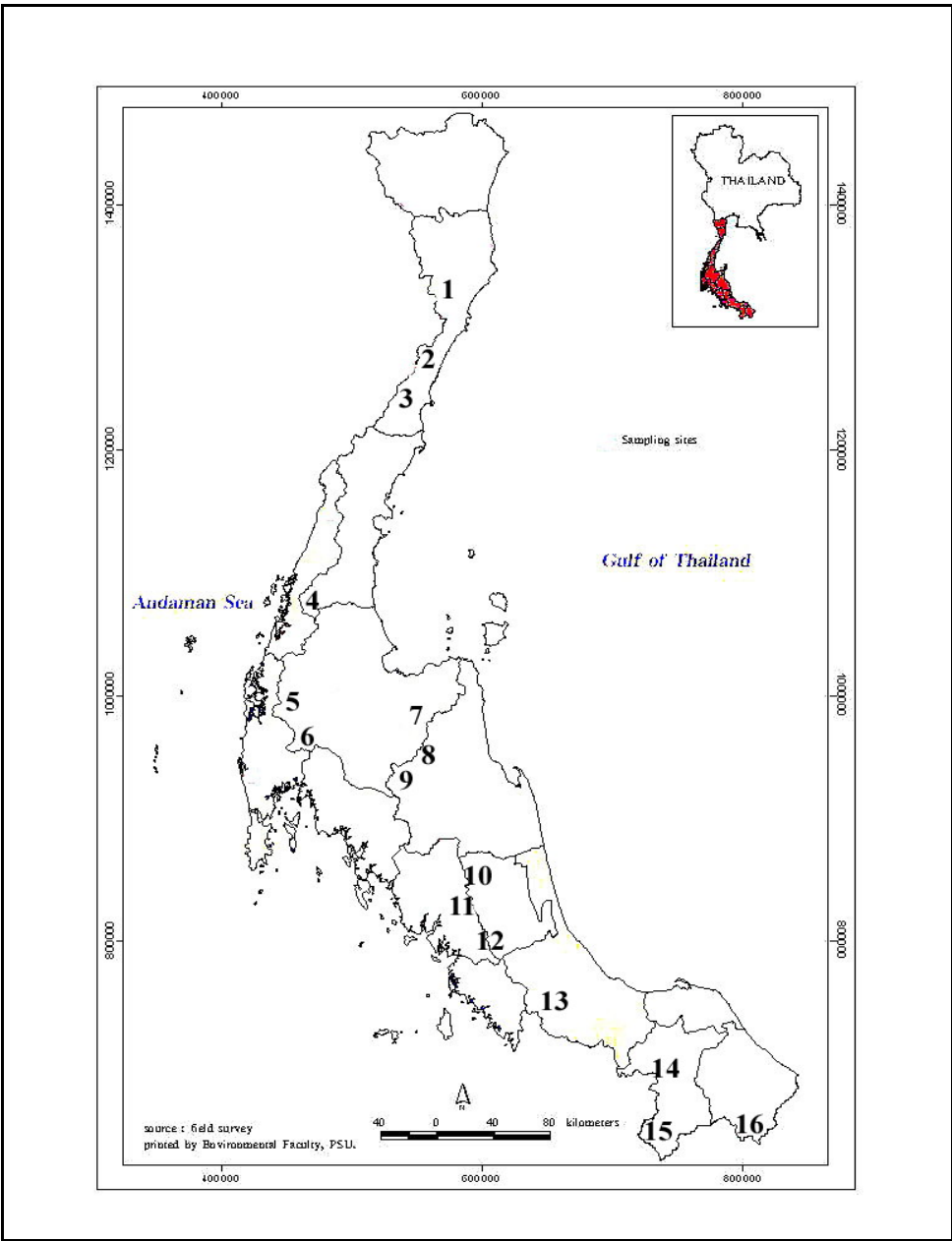


FIGURE 1. Map of Southern Thailand and its sixteen sampling sites: 1-3 in the Tenasserim mountain range; 4-6 in the Phuket mountain range; 7-9 in the Khao Luang mountain range; 10-13 in the Khao Banthat mountain range and 14-16 in the Sankalakhiri mountain range (modified from the Southern Remote Sensing GIS Center, Prince of Songkla University 2008).

Sources and sampling of ant specimens.—

Specimens examined were loaned from the following museums, institutions and private collections (abbreviations followed Brandão (2000)).

AMK	Ant Museum, Kasetsart University, Bangkok, Thailand.
MCSN	Museo Civico di Storia Naturale “Giacomo Doria”, Genova, Italy.
MNHU	Museum für Naturkunde der Humboldt Universität, Berlin, Germany.
OXUM	Hope Entomological Collections, Oxford University Museum of Natural History, Oxford, U.K.
PSNH	Princess Maha Chakri Sirindhorn Natural History Museum, Prince of Songkla University, Songkhla, Thailand.
SKYC	Seiki Yamane Collection, Kagoshima University, Kagoshima, Japan.
TNHM	Thailand Natural History Museum, Pathum Thani, Thailand.

Specimens were also obtained from field collections in Southern Thailand during September 2004 to December 2007. Collecting from low vegetation less than 4 m above the ground including colonies was conducted by hand while some specimens were obtained from canopy knockdown.

Nests of *P. varicolor* were collected along four mountain ranges: Tenasserim, Phuket, Nakorn Si Thammarat (consisting of Khao Luang and Khao Banthat) and Sankalakhiri ranges (Fig. 1). At least three sampling sites were established in representative areas of the lowland rainforest ranging in elevation from 0 to 600 m above mean sea level (msl) for each of the four mountain ranges. Ant nests on low vegetation at less than 4 m above the ground were collected during March 2004 to March 2008. The frequency of sampling at each site throughout the year was specifically designed

to cover both dry and wet seasons on each side of Southern Thailand.

Measurements and terminology.—

Abbreviations and definitions of measurements and indices follow Hung (1967, 1970), Kohout (1988) and Ward (1999, 2001) with some modification as follows:

HW	Head width: maximum width of head, excluding eyes, measured in full-face view (Fig. 2A).
HL	Head length: maximum length of head from posterior margin of head to anterior extremity (including teeth) of clypeus, measured in full-face view (Fig. 2A).
SL	Scape length: length of first antennal segment, excluding radicle (condyle) (Fig. 2A).
CI	Cephalic index: $HW \times 100/HL$.
SI	Scape index: $SL \times 100/HW$.
PrW	Pronotal width: maximum width of pronotum, between bases of pronotal spines, or across humeri, measured in dorsal view (Fig. 2B).
MPL	Mesonoto-propodeal length: diagonal distance from anterior mesonotal margin to maximum extension of posterolateral propodeal lobe, measured in lateral view (Fig. 2C).
MTL	Metatibial length: maximum length of metatibia, excluding basal condyle (Fig. 2D).
MTI	Metatibial index: $MTL \times 100/HW$.
PL	Petiolar length: horizontal distance from anterior margin (excluding short peduncle) to posterior margin of petiole, measured in lateral view (Fig. 2C).
PH	Petiolar height: maximum height of petiole, viewed posteriorly, excluding any spines and denticles (Fig. 2E).
PW	Petiolar width: maximum width of petiole, viewed posteriorly, excluding any spines and denticles (Fig. 2E).
PI	Petiolar index: $PH \times 100/PW$.
PLI	Petiolar length index: $PL \times 100/PH$.

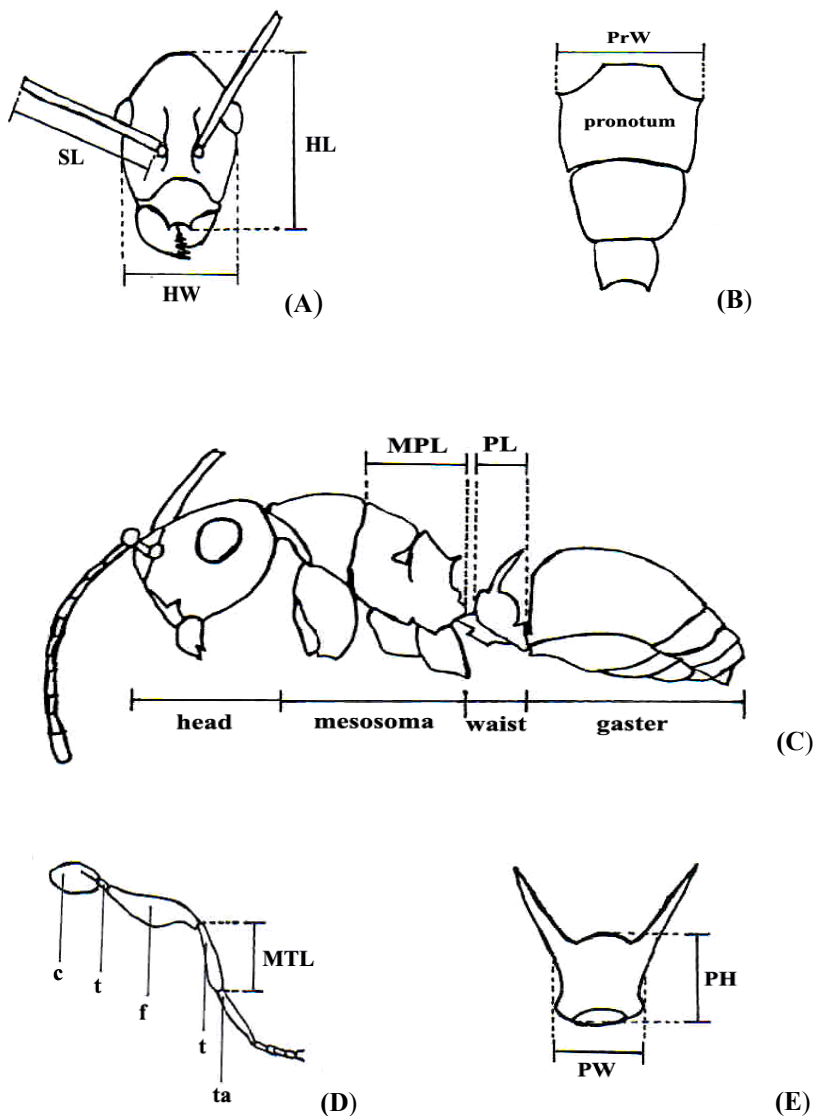


FIGURE 2 (A-E). Measuring points and some morphological terms of the worker. (A) Head in full-face view. (B) Mesosoma in dorsal view. (C) Whole body in lateral view. (D) Leg in full-face view, c = coxa, t = trochanter, f = femur, t = tibia, ta = tarsus. (E) Petiole in back view.

All linear measurements are in millimetres and were made using a Nikon SMZ 800 stereomicroscope with an eyepiece graticule calibrated against a stage micrometer.

All images were taken with a Nikon Coolpix 990 digital camera attached to a Nikon SMZ 1000 stereomicroscope and multi-focused montage images were produced using Helicon Focus 4.47 Pro (MP)

from a series of photographs. Artifacts and unnecessary parts surrounding the objects were erased and cleaned up using the retouching function of Helicon Focus. The sharpness, brightness and contrast of images were adjusted using Adobe Photoshop 7.0.

Nesting sites.— The distance of nests above the ground was measured and the number of nest entrances was counted in the field. All the nests were brought back to the laboratory at the Department of Biology, Faculty of Science, Prince of Songkla University, for examination of nest size and material and colony composition. The maximum height, width and depth of each nest were measured in centimetres.

Nest material.— Nests were examined using a scanning electron microscope (JSM-5800LV, JEOL) at the Scientific Equipment Center, Prince of Songkla University, Songkhla, Thailand. The nest material was classified according to Robson and Kohout (2005, 2007) into silk (typically flat sheets thought to arise from larval silk), carton (fine and coarse particulate plant material) and other material (silk from unknown sources).

Colony composition.— Colony composition was determined by counting the numbers of workers, dealate queens, winged queens and males. Colonies of most *Polyrhachis* species are polydomous, where a single colony has more than one nest (Dorow and Maschwitz, 1990; Liefke et al., 1998; Schellerich-Kaaden et al., 1997; Schultz and Alonso, 2000). In this study it was difficult to precisely delimit colony boundaries in the field. Consequently, multiple nests found on the same tree or that were located close to each other were inferred to belong to the one colony. In addition, if workers were observed moving between nests or the transfer of workers between nests did not express

aggressive interactions these nests were thought to belong to the same colony.

Data analysis.— One-way ANOVA was used to compare mean values for nest size (height, width and depth) and nest location (height above ground), among the four mountain ranges, when the variances were homogeneous. In addition, the non-parametric Kruskal-Wallis test was used when variances were heterogeneous. In all cases, the Tukey HSD was used for post hoc multiple comparisons, and the Mann-Whitney U-test for comparisons of heterogenic subsets (Zar, 1996). The independent-Sample T-Test was used to compare mean values for nest size (height, width and depth) and nest location above ground, between the nests from two mountain ranges from which sufficient nests were collected. Analyses were performed using the SPSS version 14.0 for Windows software. In all cases, a P-value of 0.05 or less was considered statistically significant.

RESULTS

Systematics

Genus *Polyrhachis* F. Smith, 1857

Myrma Billberg, 1820: 104. Type species: *Formica militaris* Fabricius, 1781: 493, worker; by subsequent designation of Wheeler, 1911: 860. Although *Myrma* is an older name, the historically frequently used name *Polyrhachis* is applied.

Polyrhachis F. Smith, 1857: 58. Type species: *Formica bihamata* Drury, 1773: 73, pl. 38, Figs. 7 and 8, worker; by original designation.

Subgenus *Myrmatopa* Forel, 1915

Myrmatopa Forel, 1915: 107 (as subgenus of *Polyrhachis* F. Smith). Type

species: *Polyrhachis schang* Forel, 1879: 123, queen; by original designation.

Myrmatopa Forel; Emery, 1925: 180; Dorow, 1995: 42; Bolton, 1995: 36; Bolton, 2003: 124; Kohout, 2008: 282. As subgenus of *Polyrhachis* F. Smith.

Ireneae Donisthorpe, 1938: 502; Chapman and Capco, 1951: 186. Type species: *Dolichoderus omyrmex* Donisthorpe, 1938: 502, worker; by original designation (synonymy by Brown, 1973: 181 with *Polyrhachis*).

***Polyrhachis (Myrmatopa) varicolor*
Viehmeyer (Figs. 3-8)**

Polyrhachis fruhstorferi subsp. *varicolor* Viehmeyer, 1916: 163. Type locality: Singapore (H. Overbeck) [MNHU]; Emery, 1925: 180 (combination in *P. (Myrmatopa)*).

Polyrhachis varicolor Viehmeyer: Kohout, 2008: 259. Raised to species level.

Non-type material examined.— S. Thailand: Songkhla Prov., Kuan Mod Dang, Prince of Songkla University 0 - 100 m, 17.vii.2007, nesting on lower vegetation, 1.85 m above ground, Colony A (NAW) (workers, queens); Songkhla Prov., Ton Nga Chang W.S. 100 - 300 m, 25.vii.2002, canopy fogging (S. Tongjerm) (workers); same loc., 16.xi.2002, canopy fogging (S. Tongjerm) (workers); Phatthalung Prov., Khao Pu-Khao Ya N.P. 0 - 300 m, 4.iv.2006, nesting on lower vegetation, 2.00 m above ground, Colony B (NAW) (workers, queen); Nakhon Si Thammarat Prov., Khiriwong Village 100 - 400 m, 21.iii.2008, nesting on lower vegetation, 1.37 m above ground, Colony C (NAW) (workers); Surat Thani Prov., inner mainland, Klong Sang W.S. 100 - 300 m, 1.v.1994, canopy fogging (L. Lebel) (workers); Surat Thani Prov., Island edge, Klong Sang W.S. 100 - 300 m, 1994, canopy fogging (L. Lebel) (workers); Prajuab Khiri

Khan Prov., Ka Oon Waterfall 100 - 200 m, 28.xii.2005, nesting on lower vegetation, 1.38 m above ground, Colony D (NAW) (workers); same loc., 8.iii.2006, nesting on lower vegetation, 2.55 m above ground, Colony E (NAW) (workers, queen); same loc., 9.ii.2007, nesting on lower vegetation, 2.30 m above ground, Colony F (NAW) (workers, queen); same loc., 9.ii.2007, nesting on lower vegetation, 2.73 m above ground, Colony G (NAW) (workers, queen). same loc., 9.ii.2007, nesting on lower vegetation, 2.60 m above ground, Colony H (NAW) (workers).

Worker measurements.— HW 1.03 - 1.30; HL 0.93 - 1.50; SL 1.63 - 1.93; CI 79.49 - 123.21; SI 148.65 - 158.06; PrW 0.83 - 1.03; MPL 1.20 - 1.47; MTL 1.47 - 1.87; MTI 135.14 - 152.78; PL 0.35 - 0.47; PH 0.23 - 0.33; PW 0.43 - 1.30; PI 20.51 - 69.23; PLI 116.67 - 171.43 (14 non-type workers measured).

Worker description.— Medium-sized species, with slightly elongated head. Clypeus weakly convex in lateral view; anterior extremity of clypeus with a pair of short teeth that are slightly broad and separated. Frontal carina well elevated and weakly sinuate in full-face view. Antennal scape long, extending beyond posterior margin of head by at least half of its length. Eye convex, slightly protruding beyond lateral outline of head. Pronotum in dorsal view, convex laterally and slightly narrowed posteriorly, armed with anterolateral teeth. Mesosoma is distinctly laterally marginate throughout. Mesonotum only slightly higher than propodeum. Propodeal dorsum slightly sloping; propodeal spines small directed upward. Petiolar spines backing posterior view slightly diverging, in lateral view distinctly curved backward, longer than height of petiole. Petiole in lateral view with anterodorsal margin rounded, anterior slope

distinctly convex and posterior slope slightly convex. Subpetiolar process low, with posteroventral corner more or less angulate.

Mandible with very fine and superficially microsculpture scattered over surface shining. Head including clypeus and frontal lobes, dorsa of mesosoma and petiole with superficial sparse punctures; dorsum of pronotum punctate to puncto-striate. Antenna densely microsculptured and shining. Sides of mesosoma closely puncto-reticulate and shining. Gaster densely microsculptured and shining. Legs densely microsculptured and dull.

Antennal flagellum with very fine sparse pubescence. Head, clypeus, frontal lobe, mandible, coxae, trochanters, ventral femora, petiolar pedicel above and below, subpetiolar process posteriorly with a few yellow, standing hairs. Gaster ventrally with many yellow standing hairs and sparse pubescence. Pubescence on clypeus, frontal lobe, mandible and gastral tergites minute and sparse.

Head including mandible, antennal scape and flagellum, mesosoma, petiole and legs reddish-brown to dark reddish-brown. Gaster reddish-brown to black.

Queen measurements.— HW 1.25 - 1.35; HL 1.70; SL 2.10 - 2.20; CI 73.53 - 79.41; SI 161.54 - 162.96; PrW 1.40 - 1.55; MPL 1.80 - 1.95; MTL 2.07 - 2.17; MTI 158.02 - 166.67; PL 0.45 - 0.50; PH 0.30 - 0.40; PW 0.60 - 0.65; PI 50.00 - 61.54; PLI 125.00 - 150.00 (three non-type queens measured).

Queen description.— Similar to the worker in structure, but pronotum in dorsal view with reduced anterolateral teeth. Propodeal dorsum in lateral view distinctly shorter than declivity, propodeal spines much reduced. Petiolar spines in lateral view stout. Body sculpture similar to that in the worker, but dorsum of pronotum lacking striation. Pilosity similar to worker, but dorsa of mesoscutum and mesoscutellum with a few yellow standing hairs. Coloration similar to worker but head, mesosoma, and petiole reddish-brown to black.

Remarks.— This species is very similar to *P. flavicornis* F. Smith but can be diagnosed by a suite of worker characters: viz the pronotum is slightly marginate laterally (Fig. 5); and the head, mesosoma, legs, petiole and petiolar spines are more reddish (Fig. 3). In addition, in the queen the frontal lobes (Fig. 7), mesoscutum and parapsides (Fig. 8) are reddish, partly with black stains. On the other hand, *P. flavicornis* workers can be recognised by the combination of the following conditions: the pronotum is weakly marginate laterally; the mandible, legs and antennal flagellum are reddish-brown; and the scape and first flagellar segment reddish-brown to black. Moreover, the *P. flavicornis* queens differs from those of *P. varicolor* in their entirely black head and mesosoma, except appendages.



FIGURE 3. *P. varicolor* Viehmeyer worker in lateral view of whole body.



FIGURE 4. *P. varicolor* Viehmeyer worker, head in full face view.

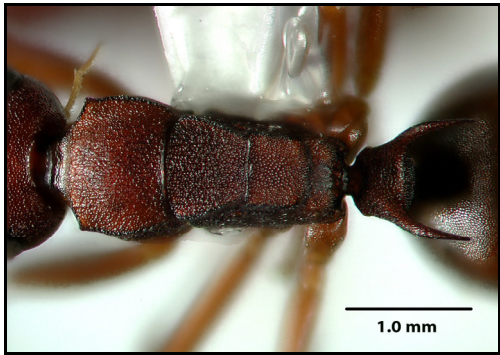


FIGURE 5. *P. varicolor* Viehmeyer worker in dorsal view of mesosoma and petiole.



FIGURE 6. *P. varicolor* Viehmeyer queen in lateral view of whole body.

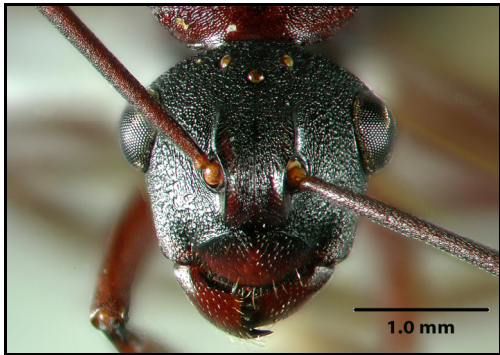


FIGURE 7. *P. varicolor* Viehmeyer queen, head in full face view.

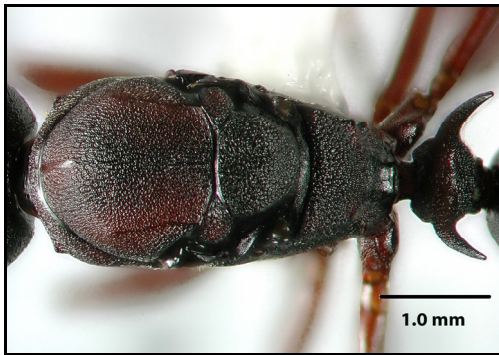


FIGURE 8. *P. varicolor* Viehmeyer queen in dorsal view of mesosoma and petiole.

Distribution.— This species has been detected in Singapore, Southern Thailand and Cambodia (Fig. 9). It has mostly been recorded from undisturbed and disturbed lowland rain forest, but one nest was

collected from an orchard near a forest edge. Most examined specimens were from colonies located on understory vegetation or from fogging samples.

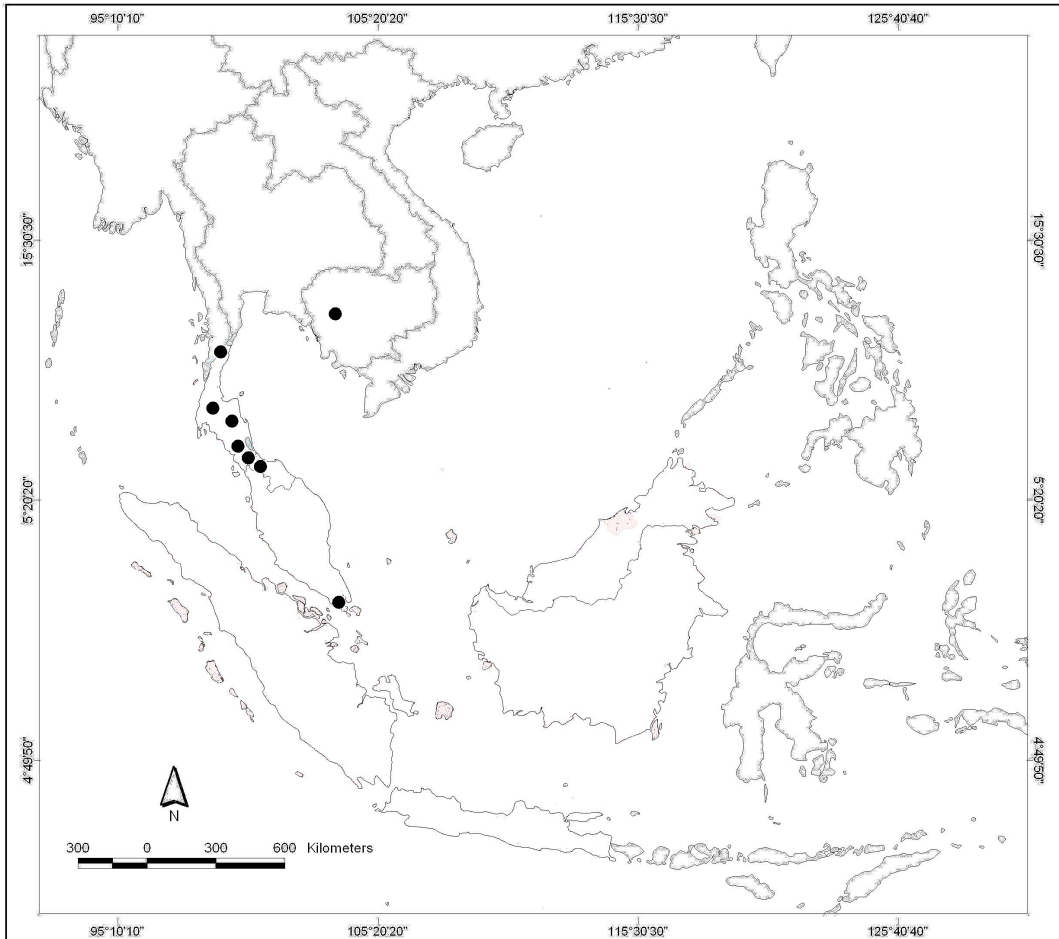


FIGURE 9. Distribution of *P. varicolor* Viehmeier (modified from the Southern Remote Sensing GIS Center, Prince of Songkla University, 2008).

TABLE 1. Size, location of the nests, and the number of entrances per nest for *P. varicolor* in Southern Thailand (Note: n = total number of nests).

Nest structure and location	Mountain range			Total
	Tenasserim	Khao Luang	Khao Banthat	
Height (cm.)	(n=5)	(n=1)	(n=2)	(n=8)
Range	2.6 - 12.1	-	3.4 - 6.3	2.6 - 12.1
Mean \pm SE	6.16 \pm 1.81	4.92	5.12 \pm 1.18	5.74 \pm 1.12
Width (cm.)	(n=5)	(n=1)	(n=2)	(n=8)
Range	1.7 - 3.1	-	1.9 - 2.7	1.7 - 3.1
Mean \pm SE	2.40 \pm 0.23	2.54	2.31 \pm 0.37	2.40 \pm 0.16
Depth (cm.)	(n=5)	(n=1)	(n=2)	(n=8)
Range	0.3 - 1.5	-	0.4 - 0.7	0.3 - 1.5
Mean \pm SE	0.76 \pm 0.25	1.28	0.55 \pm 0.19	0.77 \pm 0.17
Location above ground (cm.)	(n=9)	(n=1)	(n=3)	(n=13)
Range	138 - 280	-	164 - 200	137 - 280
Mean \pm SE	219.3 \pm 15.4	137.0	183.0 \pm 10.4	204.6 \pm 12.8
No. of nest entrance (hole)	(n=5)	(n=1)	(n=2)	(n=8)
Range	2-5	-	1-2	1-5
Mean \pm SE	3.20 \pm 0.58	1	1.50 \pm 0.50	2.50 \pm 0.50

Nesting sites (nest size, height above ground, number of entrances per nest)

In all the three mountain range localities the nests of *P. varicolor* were found on the underside of plant leaves or between leaves (Figs. 10, 11). The mean values for nest size (height, width and depth) and nest distance above ground among the mountain ranges were compared and the results of an Independent-Sample T-Test showed that no significant differences were detected between the Tenasserim and Khao Banthat mountain ranges for nest height ($F = 3.55$, $t = 0.34$, $df = 5$, $P = 0.75$), width ($F = 0.01$, $t = 0.21$, $df = 5$, $P = 0.840$), depth ($F = 5.41$, $t = 0.50$, $df = 5$, $P = 0.64$), and nest location

above the ground ($F = 3.02$ (3.022), $t = 1.30$ (1.298), $df = 10$, $P = 0.22$). The Khao Luang mountain range was not included in the comparison because only one nest was found there (Table 1).

Nest material

Three nests of *P. varicolor* were randomly sampled from different colonies and localities in each mountain range, so as to include nests from each mountain range of Southern Thailand. In all samples, the nest material walls were comprised of silk, carton and other material (Fig. 12). Silk sheets were composed of thin layers of similarly sized silk strands and these were covered with

carton and other material. The carton material was made up from coarse and fine particulate plant material, while the other material was silk from unknown sources. In

general there were no distinct differences observed in the structures of the nest wall among nests from different colonies and localities.



FIGURE 10. Nest of *P. varicolor* Viehmeyer from Ka Oon Waterfall, Southern Thailand.



FIGURE 11. Nest of *P. varicolor* Viehmeyer from Khiriwong Village, Southern Thailand.

TABLE 2. Colony composition of *P. varicolor* in Southern Thailand (Note: n = total number of colonies).

Nests and adults of different castes	Numbers per colony			
	Tenasserim (n =6)	Khao Luang (n=2)	Khao Banthat (n=3)	Total range (n=11)
Nests	1-3	1	1	1-3
Dealate queens	0-1	0-1	0-1	0-1
Winged queens	0	0	0-6	0-6
Males	0	0	0-8	0-8
Workers	31-251	1-146	39-151	1-251

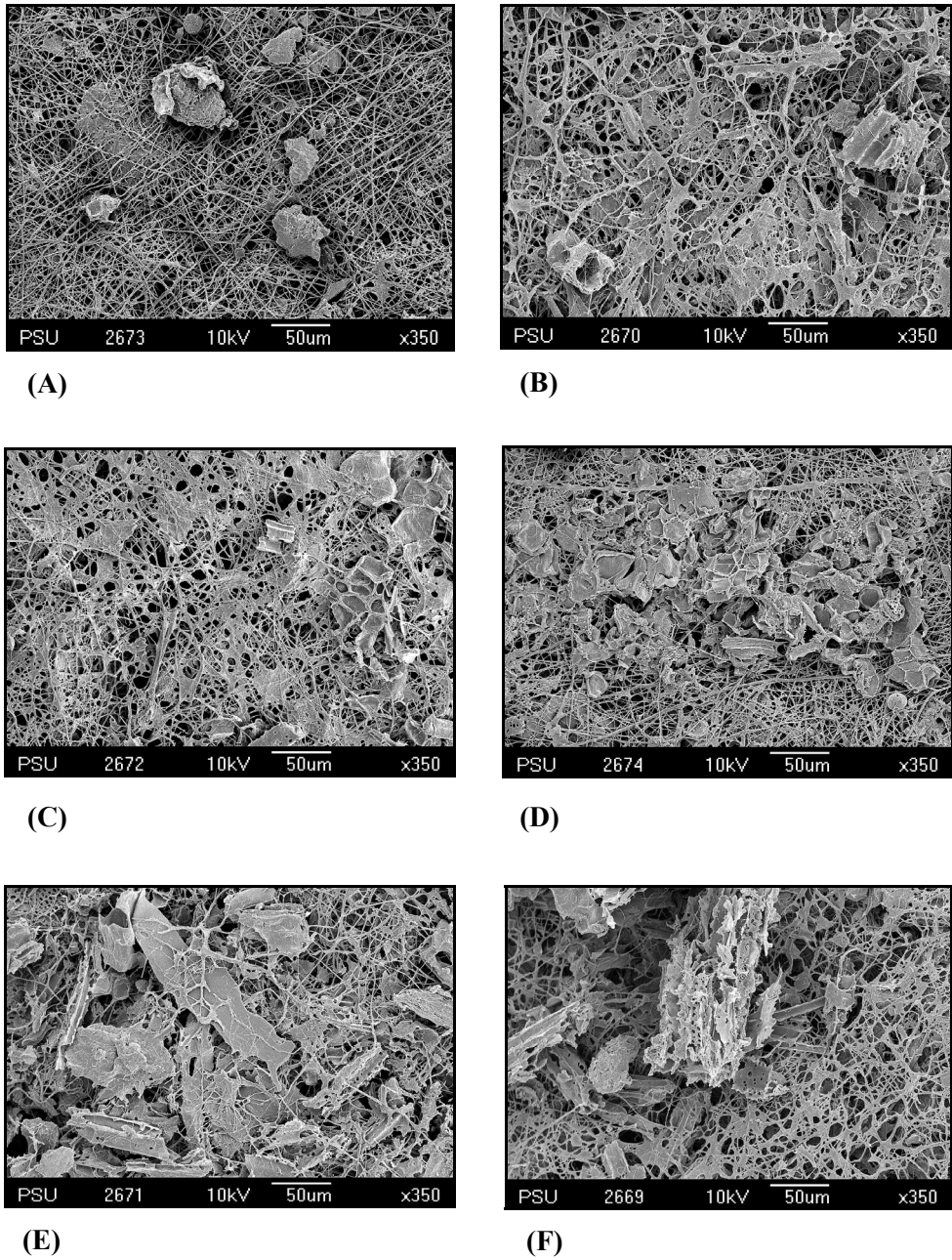


FIGURE 12. The nest wall structure of *P. varicolor* Viehmeyer (A)-(F) Silk sheets (thin layers of similarly sized silk strands), carton (coarse and fine particulate plant material), and other material (silk from an unknown sources) covering the silk sheet.

Colony composition

The colony composition of *P. varicolor* from each mountain range of Southern Thailand is shown in Table 2. Observations on the 14 nests (11 colonies) showed that each colony consisted of 1 - 3 nests and that numbers of different castes were distributed over several nests of a colony. The number of dealate queens per colony was 0 - 1, thus indicating that the colony of this species is generally monogynous. However, the 0 values indicate that in several instances the not all of the nests that make up a single polydome colony were discovered. The colonies were relatively small and the number of workers present ranged from 1 to 251. Both winged queens and males were only found in one colony, with six and eight individuals, respectively.

DISCUSSION

This study indicated that *P. varicolor* was widely distributed in the lowland tropical rainforest of Southern Thailand, nesting on understorey vegetation. However, this species might utilize more than one vertical stratum of the forest for nesting and foraging sites, *P. gracilis cnemidata* Emery, *P. flavicornis*, *P. wallacei wartburgi* Forel, were all collected from canopy using fogging and included the lower vegetation in Southern Thailand (Noon-anant, 2009; Noon-anant and Watanasit, 2003; Noon-anant et al., 2008).

This species was similar to four other *Myrmatopa* species (*P. gracilis cnemidata*, *P. constructor* Smith, *P. flavicornis* and *P. wallacei wartburgi*) collected from the lowland tropical rainforest of Southern Thailand, that also nested on low vegetation using plant leaves (Noon-anant, 2009).

However, these species, with the exception *P. constructor*, have also been collected by canopy fogging in Southern Thailand (Noon-anant, 2009; Noon-anant and Watanasit, 2003).

In this study there were no remarkable or significant differences in the nest size (height, width and depth), the distance of the nest above ground and the number of entrances per nest among nests from the different mountain ranges. Rather, a broad overlap was observed in the ranges of these dimensions from the different localities. This indicates that *P. varicolor* might prefer a broad vertical distribution range for its nesting sites, from the lower vegetation to the canopy, in order to be distributed widely throughout the lowland tropical rainforest of Southern Thailand. At the same time, the nest size (height, width and depth), and the number of entrances per nest, as well as colony size and structure, might also depend on the stage of the colony life cycle and habitat preferences, such as the vertical forest structure, level of disturbance and microclimate.

Nests of *P. varicolor* in the lowland tropical rainforest of Southern Thailand were made of silk sheets composed of thin layers of similarly sized silk strands. Carton and other material, such as plant tissue fragments, were incorporated into the nest wall structure. Many species of *Myrmatopa* have been reported to include silk in their nests, including *P. constructor*, *P. flavicornis* (Noon-anant, 2009; Noon-anant et al., 2008), *P. lombokensis* Emery, *P. solmsi* Emery and *P. subtridens* Emery (Robson and Kohout, 2007). However, one species, *P. schang* Forel, did not incorporate silk into the nests walls (Robson and Kohout, 2007).

Like most other species of *Myrmatopa* for which the nests have been examined, *P. varicolor* incorporates flay sheets of larval

silk into the nest walls. This trait is found in species of *Myrmatopa* found outside continental Asia, such as *P. lombokensis* and *P. ulysses* Forel (Robson and Kohout, 2005, 2007), as well as *Myrmatopa* species such as *P. constructor* and *P. flavicornis* from Southern Thailand (Noon-anant, 2009; Noon-anant et al., 2008) as well as species in other subgenera of *Polyrhachis* from Southern Thailand, such as *P. (Hemioptica) boltoni* Dorow & Kohout, *P. (Myrmhopla) armata* (LeGuillou) and *P. (Myrmhopla) muelleri* Forel (Noon-anant and Watanasit, 2003; Robson and Kohout, 2005, 2007).

On the other hand, there is no evidence that the two predominantly ground nesting subgenera, *Chariomyrma* and *Hagiomyrma*, such as *P. (Hagiomyrma) thusnelda* Forel, incorporate flat sheets of larval silk into their nest structure. Their nests are composed entirely of ‘carton’ material (Robson and Kohout, 2004, 2007). Additionally, spider silk has been found in the nests of at least four *Polyrhachis* species, including *P. (Cyrtomyrma) australis* Mayr, *P. (Cyrtomyrma) pilosa* Donisthorpe and *P. (Myrma) laboriosa* Smith (Robson and Kohout, 2007). The fourth species, *P. (Hedomyrma) turneri* Forel, constructs nests entirely from spider silk (Robson and Kohout, 2007).

The construction of nests with flat sheets of larval silk is common and has been found in representatives from seven of the nine ant subgenera, viz. *Cyrtomyrma*, *Hemioptica*, *Myrma*, *Myrmatopa*, *Myrmhopla*, *Myrmothrinax* and *Polyrhachis* (Robson and Kohout, 2005, 2007). However, it was difficult to clearly distinguish between *Myrmatopa* and the other arboreal nesting subgenera, such as *Myrmhopla* and *Myrmothrinax* based only on their nest material because the nests of these species (Noon-anant, 2009; Robson and Kohout,

2005, 2007), and *P. varicolor* are covered with carton material. Therefore, the use of larval silk and other nest materials, such as coarse or finely particulate material for nest construction might have evolved independently within the genus *Polyrhachis*, as has been claimed by Hung (1967) and Robson and Kohout (2005, 2007).

In this study, we found that *P. varicolor* had a polydomous colony structure and was generally monogynous, similar to other *Myrmatopa* species such as *P. gracilis cnemidata*, *P. constructor*, *P. flavicornis* (Noon-anant, 2009; Noon-anant et al., 2008), *P. lombokensis* (Robson and Kohout, 2007) and other arboreal species of *Polyrhachis*, found in the lowland tropical rainforest in Southern Thailand and West Malaysia, such as *P. (Hemipoptica) boltoni*, *P. (Myrma) nigropilosa* Mayr, *P. (Myrmhopla) bicolor* F. Smith, *P. (Myrmhopla) furcata* Smith and *P. (Myrmhopla) muelleri* (Dorow and Kohout 1995; Liefke et al., 1998; Noon-anant and Watanasit, 2003; Robson and Kohout, 2007). This situation differs from that of the polygynous colonies of a single species of the subgenus *Myrmatopa*, *P. osae*, found in the Solomon islands (Mann, 1919), and that of the polydomous nests and multiple queen colonies of a single arboreal species of *Polyrhachis* found in the lowland tropical rainforest of Southern Thailand and West Malaysia, *P. (Myrmhopla) dives* Smith (Liefke et al., 1998; Noon-anant and Watanasit 2003; Robson and Kohout, 2007).

One possible explanation for the finding that *Myrmatopa* species and the other arboreal species of *Polyrhachis* have a polydomous colony structure, is that it may reduce the distances between foraging sites and their nests (Sudd and Franks, 1987). Indeed, polydomous ants, like *Oecophylla longinoda* (Latreille), may well catch their food and bring it back to a central place

before they distribute the foodstuffs to the nearby nests (Hölldobler and Wilson, 1990; Sudd and Franks, 1987). Thus having a polydomous colony structure, with colony members distributed over several nests, might favor arboreal *Polyrhachis* species by allowing a larger foraging range in the lowland tropical rainforests of South East Asia.

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