SCALE PATTERN VARIATIONS OF *AEDES AEGYPTI* IN CHIANG MAI, NORTHERN THAILAND

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ABSTRACT. Abdominal tergal scale pattern variations of *Aedes aegypti* were studied in Chiang Mai, northern Thailand for specimens reared from eggs laid in ovitraps set monthly both indoors and outdoors in urban and rural areas. The populations predominantly consisted of the dark type form, regardless of macrohabitats (urban vs. rural), microhabitats (indoor vs. outdoor) or seasons (dry vs. rainy). Among 6,003 specimens, no individuals had pale-scales continuing from the tergal base to its apex on the third tergum and posteriorly.

INTRODUCTION

Aedes aegypti (Linn.) is variable in color, physiology, behavior and habitats where local populations exist (Mattingly 1957, McClelland 1974). Abdominal scale pattern of adults is genetically determined (McClelland 1960, Craig and VandeHey 1962, Craig and Hickey 1967, Hartberg et al. 1986), though the expression may be modified by temperature during larval development (Craig and VandeHey 1962). Mattingly (1957) recognized 2 subspecies, *Ae. a. aegypti* and *Ae. a. formosus* (Walker), which have been generally accepted by culicidologists (Knight and Stone 1977). *Aedes a. aegypti* is paler, domestic and pantropical except in Africa south of the Sahara where it is largely replaced by the darker and usually sylvan *Ae. a. formosus*. In the unique sympatric zone on the coast of East Africa, Trpis and Hausermann (1975) recognized 3 types of *Ae. aegypti* populations: domestic *Ae. a. aegypti* (pale, indoors, rain-independent population fluctuation), sylvan *Ae. a. formosus* (dark, forest, rain-dependent), and peridomestic *Ae. a. aegypti* (scale pattern variable from population to population, outdoors, primarily rain-dependent). A further study on scale pattern variations in Africa generally supported this scheme, though some peridomestic populations consist exclusively of *Ae. a. formosus* (VandeHey et al. 1978).

Correlation between scale pattern and habitat characteristics has rarely been examined in areas where *Ae. a. aegypti* solely occurs, though greater association of paler populations with man has been suggested (Hill 1921, McClelland 1974). For limited material from the Philippines, however, Mogi et al. (1984) failed to find a correlation between adult scale pattern and some habitat characteristics (urban vs. rural, indoor vs. outdoor, presence vs. absence of regular dry seasons). In the preceding studies on scale pattern variations (McClelland 1974, VandeHey et al. 1978, Mogi et al. 1984), specimens collected at sporadic intervals or derived from laboratory colonies at arbitrary generations were examined. This might have more or less complicated the results, since genetic structure may change seasonally and/or during colony maintenance. We observed an increase in the proportion of paler individuals during laboratory colony maintenance without intended selection (T. Okazawa and M. Mogi, unpublished data). On the other hand, genetic structure of *Ae. a. aegypti* populations in East African villages remained seasonally stable for variations at 23 isozyme loci (Tabachnick and Powell 1978).

The aim of this study was to examine the relation of adult abdominal scale patterns of *Ae. aegypti* in respect to habitat and season in Chiang Mai Province, northern Thailand, with standardized samples obtained throughout a whole year.

MATERIALS AND METHODS

Eggs of *Ae. aegypti* were collected monthly from October 1984 through October 1985 from 40 ovitraps distributed indoors/outdoors in urban/rural areas in/around Chiang Mai City, northern Thailand. The urban area was the inside and surroundings of ancient ramparts, constituting a densely populated town. The rural area comprised 4 villages, each 1–2 km north, south, east and west of the town, separated from the town mainly by rice field areas. Ovitraps used, collection procedures, and the local climate are described elsewhere (Mogi et al. 1988). Typically there are three distinct seasons, dry/hot (March and April), rainy/hot (May-September), and dry/cool (October-February). The study year, however, had a shorter dry/hot season (March) and a longer rainy/hot season (April–September).

Adults reared from eggs laid in each trap were fed on mice ca. 3 days after the completion of emergence and allowed to lay eggs on wet paper towels (the same material for ovitraps). The first generation eggs, dried once, were submerged into aged tap water within 1 month after oviposition. A small amount of dried yeast and ground cock-

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roach pellets was added into the water to accelerate the hatch. Most larvae hatched within 2 days. About 400 larvae were reared in a 25 × 30 × 5 cm pan with ca. 1.5 liters of water at 28°C and L:D=16:8 h. From each cohort, scale patterns of ca. 100 males and 100 females were examined within 3 days after emergence.

Abdominal tergal scale pattern was recorded following McClelland (1974) and quantified following the CKM system proposed by Hartberg et al. (1986). McClelland (1974) discerned continuity and discontinuity of pale scales (excepting those consitituting the basal band and lateral spots) on each tergum. This distinction is useful to describe the whole variation of scale pattern, but in scoring could lead to excessive emphasis of minor differences, rating of which may be influenced by subjectivity or falling off of a few scales. In the CKM system, only the presence or absence of pale scales (excepting the basal band and lateral spots) on each tergum is considered for scoring.

Scale pattern of each specimen was first classified into one of McClelland's 30 pattern grades (from the darkest F to the palest Q in alphabetical order with suffix numerals for subdivision), then converted into one of 8 CKM classes (from the darkest 0 to the palest 7 in ascending order). The numerals (0–7) correspond to the number of terga with pale scales delimited as above. Pattern grade F (CKM class-0), G and H (class-1), and J–Q (classes 2–7) satisfy Mattingly's (1957) definitions of *Ae. aegypti formosus, Ae. a. aegypti* (type form), and *Ae. aegypti* var. *queenslandensis* (Theobald), respectively. To avoid confusion, the latter 2 categories are designated in this paper as the dark type form and the pale type form, respectively, since many authors use the term "type form" as an equivalent of the nominal subspecies.

RESULTS

Pooled frequencies of scale pattern classes peaked at class-1 regardless of sex, macro-(urban vs. rural) or micro-(indoor vs. outdoor) habitats (Table 1). More than 95% of each sex fell into this class, which agrees with the dark type form. A few males and 4 females (3 from urban/indoor and one from rural/indoor) fell into class-0 which satisfies the definition of *Ae. a. formosus* insofar as the abdominal tergal scale pattern is concerned. Specimens falling into the pale type form (classes 2–7) were also very rare (males) or few (females). The palest specimen belonging to class-7 was a single female from rural/indoor samples. However, the pattern grade of this individual was J, which means that pale scales continue from the base to apex only on the first tergum. A few females had continuous pale scales on the first 2 terga (pattern grade K), but no specimens had continuous pale scales on the third tergum and posteriorly (no specimens had pattern grades of L–Q).

Differences of scale pattern class frequencies were examined statistically by Kolmogolov-Smirnov test for 2 large samples (Sokal and Rohlf 1973) for all pairs of habitats in each sex. Out of 12 (6 for each sex) possible combinations, the difference between females from urban/outdoor and those from rural/outdoor was significant ($0.05 > P > 0.01$). Urban/outdoor and rural/outdoor females included the minimum and maximum proportions of individuals falling into the pale type form, respectively.

Monthly frequencies of scale pattern classes also peaked at class-1 without exception (Table 2). The unique urban/outdoor sample obtained in August is presented in Table 1. In months not included in Table 2, samples were not obtained because of: 1) absence of positive traps

Table 1. Frequency distributions of scale pattern classes (0–7[a] with observed pattern grades in parentheses) of *Aedes aegypti* in Chiang Mai, northern Thailand

Sex	Habitat		0 (F)	1 (G,H)	2 J_1)	3 (J_2,K_1)	4 (J_3,K_2)	6 (J_5)	7 (J_6)	n[b]	
Male	Urban:	Indoors	51	1,174	2					1,227 (6)	
		Outdoors	13	287						300 (1)	
	Rural:	Indoors	36	1,162	1	1				1,200 (6)	
		Outdoors	1	299						300 (3)	
	Total		101	2,922	3	1				3,027	
Female	Urban:	Indoors	3	1,175	32	4	4			1,218 (6)	
		Outdoors		300	1	1				302 (1)	*
	Rural:	Indoors	1	1,094	35	7	21		1	1,159 (6)	
		Outdoors		261	26	3	6	1		297 (3)	*
	Total		4	2,830	94	15	31	1	1	2,976	

[a] No individuals belonged to scale pattern class 5.
[b] n = sample size with the number of months sampled in parentheses.
* Frequency distributions are significantly different ($p < 0.05$).

Table 2. Monthly frequencies of scale pattern classes (0–7) of *Aedes aegypti* in Chiang Mai, northern Thailand

Habitat	Month year	Season[a]	Male 0	1	2	3	n[b]	Female 0	1	2	3	4	6	7	n	
Urban indoor	Jan. 1985	DC	1	129			130		117	1					118	
	Mar. 1985	DH	2	97			99		92	7	1				100	
	Apr. 1985	RH		100			100		89	11					100	
	Jun. 1985	RH	27	369	2		398	3	389	5	1	1			400	
	Jul. 1985	RH	7	293			300		291	5	2	2			300	
	Aug. 1985	RH	14	186			200		197	3					200	
Rural indoor	Oct. 1984	DC	7	93			100		83	6		10		1	100	
	Nov. 1984	DC	5	95			100		99	1					100	
	Apr. 1985	RH	6	194			200		160						160	
	May 1985	RH	13	287			300	1	293	6					300	
	Jun. 1985	RH	4	394	1	1	400		359	22	7	11			399	
	Jul. 1985	RH	1	99			100		100						100	
Rural outdoor	Apr. 1985	RH		100			100		92	8					100	*
	May 1985	RH		100			100		72	18	3	6	1		100	**
	Jun. 1985	RH	1	99			100		97						97	

[a] DC = dry/cool, DH = dry/hot, RH = rainy/hot.
[b] n = Sample size.
*, ** Frequency distributions are significantly different (* $p < 0.05$, ** $p < 0.01$).

due to low population density, 2) no hatch from collected eggs or 3) inclusion of only *Aedes albopictus* (Skuse). Monthly frequencies for indoor samples did not differ significantly from each other when tested for all 15 pairs of months in each sex, though the difference between October and April rural females approximated to a significant level. For rural/outdoor samples, May females included significantly more individuals belonging to the pale type form than April or June females. This also indicates that the significant differences in scale pattern frequencies between urban/outdoor and rural/outdoor females (Table 1) is almost entirely due to the inclusion of May samples into the latter. There were no constant tendencies correlated with conspicuous seasonal shifts in the climate (dry/cool-dry/hot-rainy/hot) or with the course of the long rainy season.

DISCUSSION

Rural/outdoor females from May included significantly more individuals falling into the pale type form than other samples. Gravid female *Aedes (Stegomyia)* mosquitoes move from container to container leaving a few eggs in each container (Rozeboom et al. 1973). The eggs in each trap were laid probably by multiple females, but, for samples from a single trap, a possibility remains that small sample size biased the frequency distribution of scale pattern classes. Even in this rural/outdoor May sample exceptionally biased to paleness, dominance (72%) of the dark type form holds true. The abdominal tergal scale pattern of *Ae. aegypti* in Chiang Mai may be characterized by: a) predominance of the dark type form, b) absence of specimens with continuous pale scales on the third tergum and posteriorly and c) no clear correlation with habitats/seasons. This may be the first report to show the local stability of scale pattern characteristics in *Ae. a. aegypti* with systematic sampling and standardized specimens.

Chiang Mai populations of *Ae. aegypti* use both indoor and outdoor containers, and are strongly rain-dependent in both urban and rural areas, fluctuations of which follow the alternation of dry/rainy seasons (Mogi et al. 1988). In contrast, *Ae. aegypti* populations in Bangkok, central Thailand, are rain-independent under year-round availability of water-filled jars (Sheppard et al. 1969, Tonn et al. 1969). Bangkok populations are also dominated by the dark type form and lack the individuals with pattern grades paler than K (McClelland 1974). This uniformity and independence from habitat characteristics of adult scale pattern in Thailand is in marked contrast to the scheme in the sympatric zone of the two subspecies in East Africa, and consistent with Mattingly's (1957) inference from some specimens that in the Indomalayan area the dark type form is dominant and the pale type form is rare.

Analyzing the genetic variation at isozyme loci, Tabachnick and Powell (1979) concluded that Asian (India, Indonesia and Taiwan) populations of *Ae. aegypti* were genetically less variable than populations in other geographical regions. It is likely that the genetic background of the founder population delimits the scale pattern variation of *Ae. aegypti* in Thailand.

The whole situation in Asia, however, seems

Table 3. Frequency distributions of scale pattern classes (0–7) of Philippines *Aedes aegypti* rearranged from the original data used in Fig. 1 of Mogi et al. (1984)

		Male									Female								
Island	Code[a]	0	1	2	3	4	5	6	7	*n*	0	1	2	3	4	5	6	7	*n*
Luzon	LUTU-1		7	3	6	9	5	12	1	43		2	4	1	9	8	1	27	52
(north)	LUTU-2	2	23	2	9	7	6	1		50		11	2		5	9	8	14	49
Luzon	LUMA-1	2	37	1	2	4	6	2		54		25		1	3	3	3	17	52
(central)	LUMA-2		4				1	1		6		5					3	3	11
	LUMA-3	1	18	5	2	12	6	12		56	1	12	3	1	5	11	7	15	55
	LUMA-4	1	38		1	9	1			50		36	3			4	3	4	50
Palawan	PAPU-1		33	5	3	4	5			50		28	2	4	10	3	2	1	50
Mindanao	MIKI-1	1	35	4	2	6	4	4		56		21	3	6	8	5	3	7	53

[a] Used in Mogi et al. (1984).

more complicated than expected from a simple founder effect. McClelland (1974) described adult scale patterns of 17 strains from 10 Asian countries other than Thailand (from Saudi Arabia through Taiwan). Mogi et al. (1984) described scale patterns of 8 Philippine strains. Among them, some are dominated by the dark type form as in Thailand, but some are more variable in scale pattern, including specimens ranging from the dark type form to the palest (pattern grade Q) at various proportions. Scale pattern variations of Philippine *Ae. aegypti* shown using the McClelland's (1974) system (Mogi et al. 1984) are rearranged following the CKM system based on the original data (Table 3). Clearly the Philippine populations include the pale type form much more often, especially towards the north. This marked contrast between Thailand and Philippine populations of *Ae. aegypti* might suggest the possibility of multiple introductions of populations with different scale pattern into Asia. In some circumstances, local adaptation might also have contributed to the formation of scale pattern characteristics of *Ae. aegypti*. The polymorphic concept of *Ae. aegypti* (McClelland 1974, Scott and McClelland 1977, Hartberg et al. 1986) may be applied to some of these situations, especially when populations of different origins intermix. Precise knowledge on geographical distribution of scale pattern characteristics is basic to deepen our understanding of dispersal and adaptation of *Ae. aegypti* in Asia.

ACKNOWLEDGMENTS

The authors are grateful to I. Miyagi, T. Toma, M. Tsukamoto, M. Horio and T. Deesin for cooperation and advice during the field study, and T. Sota for useful comments on the manuscript. This study was supported in part by the Overseas Research Grant No. 58041058 from the Ministry of Education, Science and Culture, Japanese Government.

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