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Three Tropical *Lymantria* spp. Attracted by (+)-Disparlure, the Synthetic Sex Pheromone of the Gypsy Moth: Moth Abundance, Seasonality, and Trap Lure Effectiveness

Naoto KAMATA Laboratory of Ecology, Faculty of Science, Kanazawa University, Kakuma, Kanazawa, Ishikawa 920-1192, Japan

DAHELMI Jurusan Biologi, FMIPA, Universitas Andalas, Limau Manis, Padang 25163, Indonesia

ERNIWATI Balai Penelitian dan Pengembangan Zoologi, Puslitbang Biologi, LIPI, Jl. Raya Bogor Jakarta Km 46, Cibinong 16911, Indonesia

Koji NAKAMURA Laboratory of Ecology, Faculty of Science, Kanazawa University, Kakuma, Kanazawa, Ishikawa 920-1192, Japan

Paul W. SCHAEFER Beneficial Insects Introduction Research Laboratory, USDA-ARS, 501 S. Chapel St., Newark, Delaware 19713, USA

ABSTRACT Recent studies revealed that the sex pheromone of the gypsy moth, *Lymantria dispar*, (+)-disparlure (+D) [(7R, 8S)-cis-7,8-epoxy-2-methyloctadecane], is used as a pheromonal communication tool not only by *L. dispar* but also several temperate species of the genus *Lymantria*. We anticipated that some of the tropical *Lymantria* spp. possibly use +D as a communication tool, therefore, we set gypsy moth pheromone traps (GMPT) from August 1997 to August 1998 in the two locations in Indonesia; the university forest of Andalas University (UNAND), Padang, West Sumatra, and in the Bogor Botanical Garden (BBG), Bogor, West Java. No moths were caught in BBG, however 115 males of three *Lymantria* spp. were caught in UNAND. They include *L. singapura* (93 individuals, 80.9%) was the most abundant species, and *L. beatrix* (13 individuals, 11.3%) and *L. narindra* (9 individuals, 7.8%). The internal chemical agents (lures and insecticide) seemed to have been effective approximately 6 months for *L. singapura*, > 20 weeks for *L. beatrix*, and > 18 weeks for *L. narindra*. *Lymantria singapura* were collected continuously until the end of February with three apparent peaks. The intervals of each peak were approximately 8-10 weeks, The GMPT seemed to be a useful tool for monitoring seasonal flight of *L. singapura*. *L. beatrix* captures seemed to have two peaks, *L. narindra* captures were too few to draw conclusions. To clarify seasonality of moth flight for *L. beatrix* and *L. narindra* using pheromone traps will require more intensive research with increased numbers of traps and/or with more effective pheromone lures.

Key Words: (+)-disparlure / pheromonal communication / tropical *Lymantria* / seasonal abundance / generation cycles

(+)-disparlure (+D) [(7R, 8S)-cis-7,8-epoxy-2-methyloctadecane] is known as the sex pheromone of the gypsy moth, *Lymantria dispar* (L.), which is a serious forest defoliating pest in the northern hemisphere. In the USA, the gypsy moth pheromone trap (GMPT), a milk carton type trap using +D and an insecticide, has long been used as a monitoring tool (Schwalbe, 1981; Ravlin *et al.*, 1991).

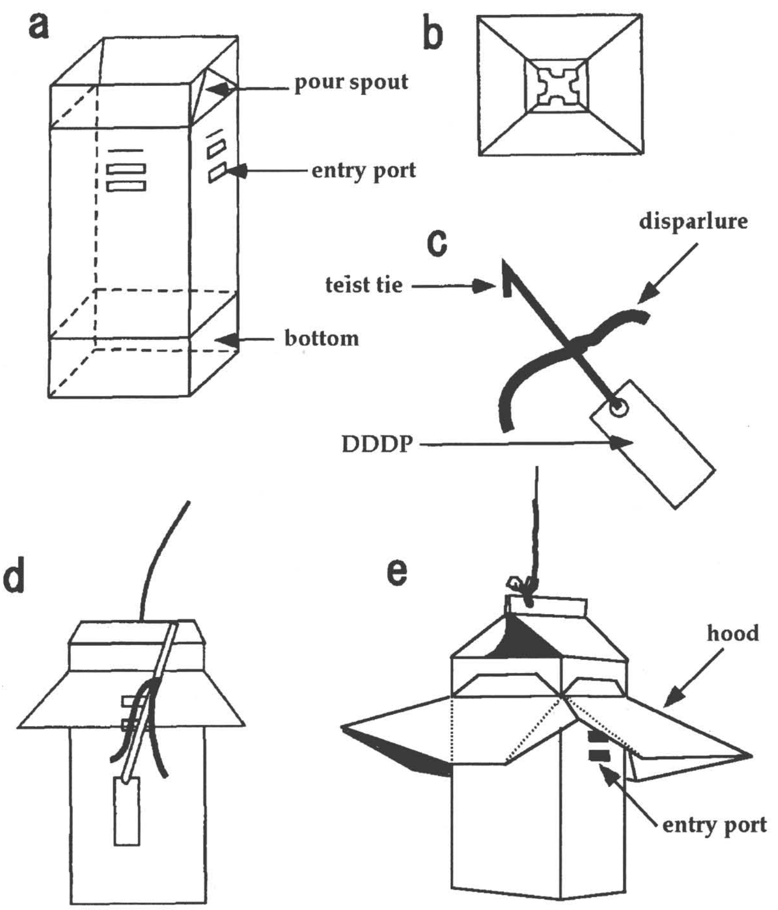

Fig. 1. A gyspy moth milk carton trap used in this research.
a: Trap body. b: Trap hood. c: Internal chemical agents (a (+)-disparlure wick and with a DDDP strip). d, e: Assembled Trap

These traps helped in the spatial analysis of expanding pattern of *L. diapar* in USA (Gage *et al.*, 1990; Sharov *et al.*, 1996, 1997a, b). The genus *Lymantria* (Lepidoptera: Lymantriidae) is more prosperous in the tropics than in temperate zones. For example, 23 *Lymantria* species were recorded on the island of Sumatra, Indonesia (Schintlmeister, 1996), although this number is the same as that of the whole of China (Chao, 1982, 1994). In southwestern China, 14 species were recorded in Yunnang Province alone (Huang *et al.*, 1987). While only 5 species (recorded as *Ocneria*) were reported in Russia (as the USSR) (Kozhanshikov, 1950). The genus *Lymantria* was thought to have originated in and radiated out from the tropics (Kozhanshikov 1950). Some species of *Lymantria* (= *Ocneria*) cause serious defoliation to woody plants; *L. dispar* to oaks in North America (Montogomery, 1988) and to larch in Japan (Higashiura & Kamijo 1978), and *L. monacha* to spruce and fir in eastern Europe (Bejer, 1988). Although this genus includes several serious pests, biological and ecological knowledge on tropical species are limited except for description of morphology and a rough distribution at an island level (Schintlmeister, 1994). No studies on population dynamics of these tropical *Lymantria* spp. have been done. Recent studies revealed +D is used not only by *L. dispar* but also *L. monacha*, *L. fumida*, and *L. lucessens* in Japan (Gries *et al.*, 1996; Schaefer *et al.* 1999; Schaefer & Kishida 1999). We anticipated that some of the tropical species of *Lymantria* probably use +D as a communication tool. In this preliminary study, we set a GMPT in each of two islands of Indonesia for a year. Species baited with +D, their seasonal occurrence, and trap effectiveness were determined for future studies on ecology of *Lymantria* spp. in the tropics.

MATERIALS AND METHODS

Field research was conducted in the university forest of Andalas University, Padang, in Sumatra (260 m a.s.l., UNAND) and in the Bogor Botanical Garden, Bogor, in Java (260 m a.s.l., BBG). A GMPT was comprised of a trap body, a trap hood, and internal chemical agents (a wick impregnated with 500 gg +D and a DDDP strip) (Fig. 1). The trap body consisted of a milk carton with two entry ports (8 X 12 mm) on each of the four sides (Fig. 1a). A trap hood was set above the entry ports (Figs. 1b, d, e). The DDDP strip was tied on one end of a twist tie and the disparlure wick were stapled on the tie approximately 5 cm above the DDDP strip (Fig. 1c). The twist tie hung off the pour spout of the milk carton adjusted so the dispariure wick was positioned centrally with respect to the entry ports. The pour spout was closed with a binder clip (Fig. 1d). Assembled traps were threaded with a approximately 30 cm length of cotton twine and suspended under the roof of existing buildings ca. 2 m above ground level. One GMPT was set in each of the two locations from 25 August, 1997 to 24 August, 1998. The traps were checked once every week, and captured moths were brought back to the laboratory and identified. The number of each species on each collecting date was recorded, then the seasonal capturing pattern was compared among species. The effective durations of the GMPT in tropics were discussed.

RESULTS

A total of 115 individual males of *Lymantria* were caught in UNAND while no moths were caught at BBG. Therefore, hereafter our results apply only to UNAND. Three species were caught in the GMPT; *L. singapura* Swinhoe (93 individuals, 80.9%), *L. beatrix* (Stoll) (13 individuals. 11. 3%), and *L. narindra* Moore (9 individuals, 7.8%). Fig. 2 shows the seasonal changes in the trap captures of these species. No moths were caught after March. *Lymantria singapura* were collected nearly continuously until late February (with no captures only on 14 October 1997 and 6 January 1998). Therefore, this species is likely to have existed throughout the period, and the GMPT seemed to be a useful tool for monitoring seasonality of flight for *L. singapura.* Three peaks (30 September 1997, 9 December 1997 and 3 February 1998) were evident. The interval between peaks was approximately 8-10 weeks. *Lymantria beatrix* and *L. narindra*were collected only intermittently while *L. beatrix* captures seemed to have two peaks from mid-September to mid-October and mid- December to mid-January. No clear fluctuation pattern was recognized in *L. narindra.* However, it is impossible to say this result indicates the reality of the moths flight because there remain the possibilities that zero

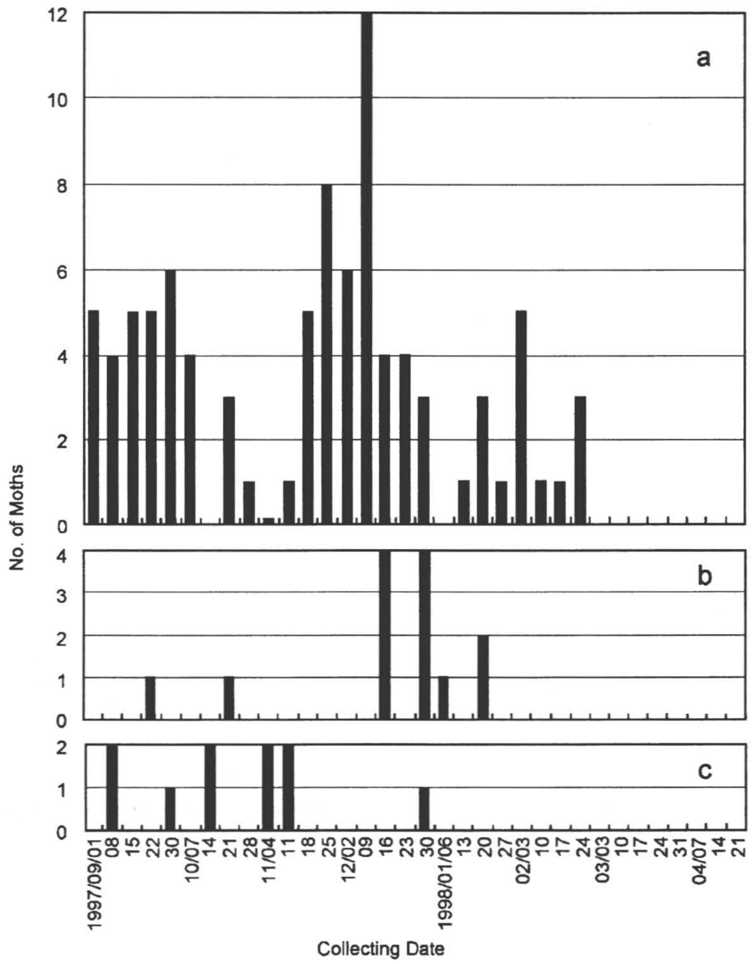

Fig. 2. Number of male moths captured by gypsy moth pheromone trap; a milk carton trap with (+)-disparlure wick and a DDVP strip, August 1997 - August 1998, at the University Forest of Andalas University, Padang, West Sumatra, Indonesia. The graph shows data until mid-April, because no moths were caught thereafter. No moths were caught in the Bogor Botanical Garden, Bogor, West Java, Indonesia.
a: *Lymantria singapura* Swinhoe. b: *Lymantria beatrix* (Stoll). c: *Lymantria narindra* Moore

captures were caused by low density of these two species during those periods and/or that +D was not a strong attractant to these moths.

DISCUSSIONS

Lymantria singapura was recorded from Burma, Malaya, Borneo, Indonesian Archipelago to Lombok (Barlow, 1982). The larva has been recorded from *Pinus* (Pinaceae) in Peninsular Malaysia (Holloway 1999).

Lymantria beatrix was recorded from Thailand (Schintlemeister, 1989), India (Singh, 1982), and

Sumatra and Java (Schintlemelster, 1994). This species was reported to cause serious defoliation to mango, *Mangifera indica* L., during October - November in India (Singh, 1982). Mango and pomegranate, *Punica granatum* L., are the only recorded host plants in Thailand (Beller & Bhenchitr 1936). Four larval parasitoids of *L. beatrix* were also recorded in India (Singh & Kumar, 1991).

Lymantria narindra was recorded from Malaya, Sumatra, Java, Bali, and Borneo (Barlow, 1982). Schlntlemeister (1994) records *L. narindra* on "Cinnamomum" in W. Malaysia, which we presume to be cinnamon.

There is relatively little knowledge on these three tropical *Lymantria* species except for some records of adult collecting dates. Moth captures ended in late February. However, this result was probably not the reality of the moth flight because there are some records that these species were caught during the periods of March - August (Schintlemeister, 1984, 1994). The trap probably became ineffective after March. In fact, many individuals were caught in March - August of 1999, when we replaced the disparlure wick and the DDDP strip to new ones at the intervals of four months (Kamata *et al.*, unpublished data). The internal chemical agents was likely to be effective for six months for L. *singapura*, at least 20 weeks for L. *beatrix*, and 18 weeks for *L. narindra*. According to these results, it is adequate to replace the disparlure and DDDP strip at least 3 times a year in future studies. However, more detail study will be necessary to determine these intervals replacing the internal chemical agents because evaporation rate is possibly greatly influenced by temperature and humidity, and because no data are available for dry seasons (April - August) when evaporation rates of chemicals are supposed to be high. Seasonal flight of *L. singapura* was likely to have 8-10 wk cycles. Flight activity of some nocturnal moths was reported to be strongly influenced by the lunar cycle (approximately 4 weeks) (Brown & Taylor, 1971; Bowden, 1981; Muirhead-Thomson, 1991). However, it seems less possible for *L. singapura* because the cycle of this moth had a longer periodicity than the lunar cycle and because most data supporting this hypothesis were those obtained by light traps. To test this hypothesis statistically, the collecting intervals should be short (one or two days). Some tropical insects were reported to have so-called a generation cycle; the cycle is generated by a generation, and the periodicity of the cycle relates to the developmental period (Knell, 1998). To test this hypothesis, knowledge on total moth development is essential. To determine the reality of the seasonal flight *of L. beatrix* and L. *narindra,* the possible approaches include:

(1) To increase the number of traps. (2) To develop and use more effective synthetic lures. And (3) To monitor adult abundance by other methods such as light traps. It is known that some *Lymantria* species use a blend of several different chemical compounds rather than one compounds: e.g. sex pheromone of *L. monacha* containes not only +D but also 2-methyl-Z7-octadecene (Z7) and (+)-monachalure (+M) [(7R, 8S) -cis-7,8-exopy-octadecane] (Gries *et al.*, 1996, 1997). Therefore, *L. monacha* males in Japan were more strongly attracted to monachalure (blend of the three compounds) than to disparlure (+D) (Gries *et al.*, 1997). If more effective lures for both *L. beatrix* and *L. narindra* can be developed, it will possibly be a powerful tool to determine flight seasonality and detailed distributions. Several species use the same chemical compound as a component of their specific sex pheromone: e.g. +D is used not only by *L. dispar* but also *L. monacha, L. fumida, L. lucescens* in Japan (Gries *et al.*, 1997; Schaefer et al, 1999; Schaefer & Kishida, 1999). In this study, three tropical species were added to this list of species which respond to the same chemical compound, +D, i.e. being used as a pheromonal communication tool. To determine mechanisms of reproductive isolation,

including seasonally of flight, diel periodicity of pheromone communication, and species specificity of pheromone blends should logically follow. This will all help to understand a complicated puzzle of evolution and the process of speciation within this genus.

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鎌田直人，DAHELMI，ERNIWATI，中村浩二，P. W. SCHAEFER

マイマイガの人工合成フェロモン (+)-disparlure に誘引された熱帯産 *Lymantria* 属3種

最近の研究により，マイマイガの性フェロモン成分である(+)-disparlure (+D) [(7R, 8S)-cis-7,8-epoxy-2-methyloctadecane] が，マイマイガばかりでなく，*Lymantria* 属の他の種によっても性フェロモンとして使われていることが明らかにされてきている。熱帯に棲息する *Lymantria* 属の中にも +D を性フェロモンとして利用しているものがいるのではないかと考えられたため，1997 年 8 月から 1998 年 8 月までの 1 年間，インドネシアのスマトラ島パダンにある Andalas 大学の演習林と，ジャワ島ボゴールにあるボゴール植物園内に，マイマイガのフェロモントラップ（GMPT）を設置し，約 1 週間間隔で捕獲された蛾を回収した。GMPT は，牛乳パックの 4 側面に 4×8 mm のスリットをそれぞれ 2 つずつ空け，+D を 500gg 滲み込ませたフェロモン剤（米国 TRECE 社製）と DDDP 殺虫剤を中につるしたものである。ボゴール植物園では 1 個体も捕獲されなかったが，Andalas 大学の演習林では，*Lymantria* 属 3 種の雄成虫が採集された。採集されたのは，*L. singapura* (捕獲個体数 93 個体, 全捕獲個体数の 80.9 %，以下同じ)，*L. beatrix* (13 個体, 11.3 %)，*L. narindra* (9 個体，7.8 %)であった。トラップ内部の化学成分（+D と DDDP）の有効期間は，*L. singapura* で 6 ヶ月以上，*L. beatrix* で 20 週以上，*L. narindra* で 18 週以上と推定された。*L. singapura* と *L. beatrix* では，約 8-10 週間隔のピークが認められたが，*L. narindra* では捕獲個体数が少なく明瞭なピークは認められなかった。GMPT は熱帯の種でも，個体群動態のモニタリングに有効であることが確かめられたが，捕獲頭数の少ない *L. beatrix* と *L. narindra* については，より有効な合成フェロモン剤の開発が望まれる。