The Yellow Butterfly Species of the Genus *Eurema* Hübner Causing Severe Defoliation in the Forestry Plantations of Albizzia, *Paraserianthes falcataria* (L.) Nielsen, in the Western Part of Indonesia

Ragil S.B. IRIANTO[a], Kazuma MATSUMOTO[b] and Kusdi MULYADI[c]

[a] *Forest and Nature Conservation Research and Development Centre (Jl. Gunung Batu 5, Bogor, Indonesia)*

[b] *Forestry Division, Japan International Research Center for Agricultural Sciences (JIRCAS) (Ohwashi 1-2, Tsukuba 305, Japan)*

[c] *Palembang Reforestation Technology Centre (Jl. Kolonel Burian, Palembang, Indonesia)*

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Abstract

Pierid butterflies of the genus *Eurema* occurring in forestry plantations of albizzia, *Paraserianthes falcataria*, in five localities in Sumatra, Java, and Kalimantan were investigated. In total four species, *E. blanda*, *E. hecabe*, *E. alitha* and *E. sari*, were identified. When the yellow butterflies were abundant, *E. blanda* predominated. The population of *E. blanda* fluctuated markedly. It decreased in the dry season and increased in the wet season, sometimes resulting in an outbreak, whereas those of *E. hecabe* and *E. alitha* were more stable. *E. blanda* was the species responsible for the severe defoliation of albizzia plantations. "*E. hecabe* as serious defoliator of albizzia" has often been mistaken for *E. blanda*. *E. alitha*, which has been mistaken for *E. hecabe*, was also considered to be of minor importance as a pest and *E. sari* seldom occurs. *E. hecabe* and *E. alitha* did not occur together in our samples.

Additional key words: Pieridae, tropical forest pest, population outbreak

Albizzia, *Paraserianthes falcataria*, is a multi-purpose tree belonging to the family Leguminosae which is commonly planted as a shade tree in tea, coffee and cacao fields, and as a tree for timber or pulp production, often associated with various agro-forestry systems, in Southeast Asia. In the forestry plantations, there are frequent outbreaks of a yellow butterfly belonging to the genus *Eurema* (Lepidoptera: Pieridae) whose larvae cause almost total defoliation. The species so far reported to be responsible for this severe defoliation has been either *E. blanda* or *E. hecabe* or both in the Philippines[9, 10], Malaysia including the northern part of Borneo[1, 14, 20] and Indonesia[4, 7, 15].

However, several Asian *Eurema* species are very similar in appearance and in some of the earlier reports the species may have been misidentified. For example, Dammermann[4] reported that the larvae of "*Terias hecabe*" (=*Eurema hecabe*) which caused severe defoliation on albizzia, were yellowish green and had a black head. Kalshoven[6] mentioned that *E. brigitta* caused local defoliation of roadside trees, *Adenanthera* sp. and *Pithecellobium* sp., and that the larvae were gregarious and black headed. However, the larvae of *E. hecabe* and *E. brigitta* are all fully green and solitary, while a black head and gregarious nature is only observed in the larvae of *E. blanda* within this genus. Yoshii[20] mentioned that *E. blanda* causing severe defoliation in an albizzia plantation in Sabah had been mistaken for *E. hecabe* before his examination. Also, Shirôzu & Yata[13] stated that four local forms of *E. alitha* from Sumatra, Java, Lesser Sundas and Palawan had been mistaken for *E. hecabe*. Curiously, the occurrence of *E. alitha* in albizzia plantations had not been reported by the forest entomologists despite frequent reference to the defoliation by *E. hecabe*.

The present study aims at confirming that *Eurema* species occur in albizzia plantations and that outbreaks result in heavy defoliation of the trees in the western part of Indonesia. Relative abundance of the confirmed species and their seasonal population changes were also examined.

Materials and Methods

1) Sampling in albizzia plantations

Eurema butterflies were collected with an insect net by one or two persons for 30 min., 1 h or 2 h on sunny days in the daytime (between 9:00 and 13:00) in the albizzia plantations in Jasinga (private plantation of a local owner; West Java Prov.), Benakat (Benakat Trial Plantation of the Palembang Reforestation Technology Centre; South Sumatra Province), Tebing Tinggi (plantation of P.T. Wirakarya Sakti; Jambi Prov.), Ngancar (plantation of Perum Perhutani; East Java Prov.) and Kenangan (plantation of P.T. ITCI Hutani Manungal; East Kalimantan Prov.) as follows:

Locality	Date	Collection system
Jasinga	6 Sep. 1993	2 pers., 2 h
	18 Oct. 1993	2 pers., 2 h
	21 Dec. 1993	2 pers., 2 h
	9 Feb. 1994	2 pers., 2 h
	13 Apr. 1994	2 pers., 2 h
	10 Jun. 1994	2 pers., 2 h
Benakat	19 May 1992	2 pers., 2 h
	6 Aug. 1993	2 pers., 2 h
	21 Aug. 1993	2 pers., 2 h
	2 May 1994	1 pers., 30 min.
Tebing Tinggi		
	3 Aug. 1993	2 pers., 30 min.
Ngancar	8 Mar. 1994	2 pers., 1 h
Kenangan	14 Feb. 1995	2 pers., 1 h

The abundance of each species was determined according to the method of Chew[3], i.e., by calculating the number of individuals sampled per collector-hour. Information on the seasonal changes in abundance of each species at the same site was supplied based on the results of repeated sampling in Jasinga and, to a lesser extent, in Benakat. Samples were collected when a large number of butterflies was observed in Tebing Tinggi, Ngancar and Kenangan.

The specimens were identified based on the

examination of the external characteristics and male genitalia.

2) Description of an outbreak

During our stay in Benakat from May 1 through May 15, 1994, we observed an outbreak of butterflies. Marking, release and recapture (MRR) census of the adult butterflies was carried out along a 300 m section of a dirt road in an 11-year-old albizzia plantation from May 3 to 7. On May 3, 4, 5 and 6, the adults were collected with an insect net, and felt-tipped pens with ink with different colors were used to make dot marks on the undersurface of the two hind wings to indicate the date of capture and recapture. The insects were released and species and sex were recorded at the time of each capture. Individuals injured by handling were not released. At the last census on May 7, all the individuals captured were immediately killed and the mark, species and sex of the specimens were determined in the laboratory. The Jolly[8]-Seber[12] method was applied to estimate the population size and survival rate.

We also collected mature larvae and pupae on May 5, 1994, for determining the butterfly species, sex ratio, parasite species and the rate of parasitism.

Along with the above field procedures, information of interest, such as occurrence of immature forms and behavior of adults, was also recorded.

Results

1) Species composition and relative abundance

Figs. 1, 2 & 3 show the abundance of *Eurema* species in each sample. Total numbers of individuals of each *Eurema* species captured during the MRR census in Benakat in May, 1994, are also indicated in Table 1. In total four species were identified, i.e., *E. blanda*, *E. hecabe*, *E. alitha* and *E. sari*. *E. blanda* was the most abundant species among the *Eurema* butterflies (e.g., when total capture/collector-hour >10), and an outbreak of *E. blanda* occurred in Benakat in May, 1994. This outbreak resulted in almost total defoliation of all the older albizzia stands in the Trial Plantation (11 to 14-year-old and slightly more than 200 ha in area; exact area is unknown due to recent loss by illegal clearing and fire). The sample from Tebing Tinggi also represents a local outbreak of minor importance which resulted in ca. 60% defoliation of a young and small isolated albizzia stand (three-year-old, 0.52 ha). The albizzia trees mostly

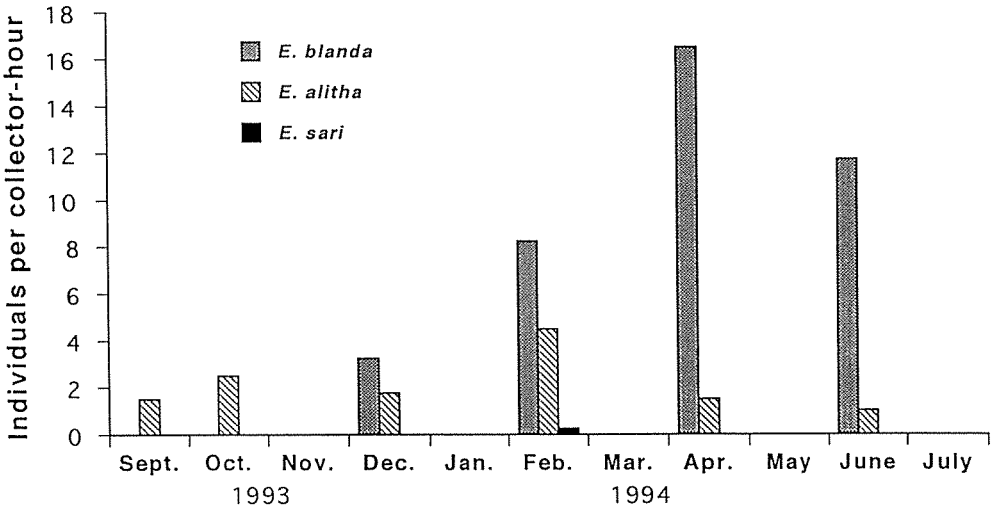

Fig. 1. Number of individuals of *Eurema* butterflies sampled per collector-hour on different occasions in Jasinga, West Java Prov

survived defoliation and only a few dead trees were found in Benakat (it remains to be determined whether *E. blanda* was responsible for the death of the trees). However, die-back of the branches following the attack by *E. blanda* was relatively common in Benakat, and was also observed in Jasinga and Tebing Tinggi.

Although either *E. hecabe* or *E. alitha* species occurred together with *E. blanda*, the former two were not detected in the same location, and their number was smaller than that of *E. blanda* when the yellow butterflies became abundant. In the course of the field survey, *E. blanda*, *E. hecabe* and *E. alitha* were all confirmed to feed on albizzia during the larval stage, whereas *E. sari* seldom occurred, and its immature stage was not observed. Since the former three species were concentrated on the albizzia plantation at each sampling site, it is likely that their populations mainly depended on albizzia, even though there could have been a few alternative food plants, such as wild-growing or artificially planted *Pithecellobium*, *Parkia*, and *Sesbania* species which were observed around the albizzia plantations.

In repeated sampling in Jasinga, *E. blanda* was not detected in September and October 1993 (at the end of the dry season in that year), indicating that this species was very rare, and the incidence gradually increased thereafter until April, 1994, (the end of the wet season), whereas the population of *E. alitha* was rather stable and remained at a low level with only a small increase

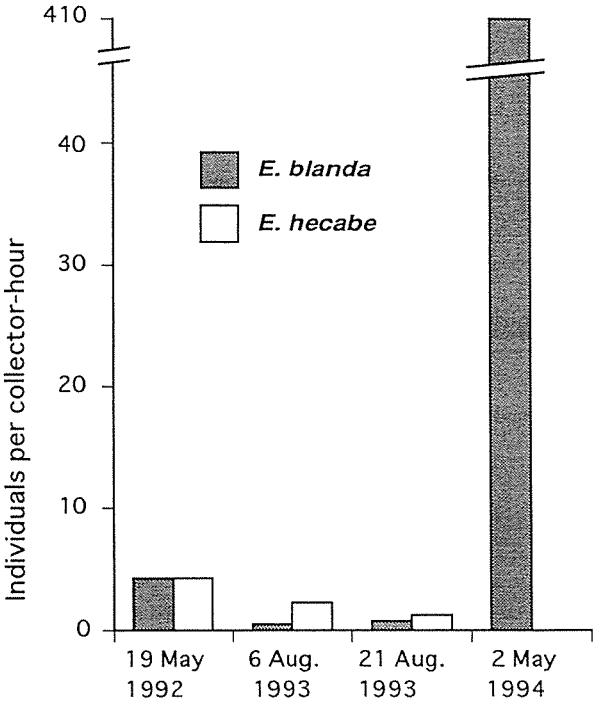

Fig. 2. Number of individuals of *Eurema* butterflies sampled per collector-hour on different occasions in Benakat, South Sumatra Prov

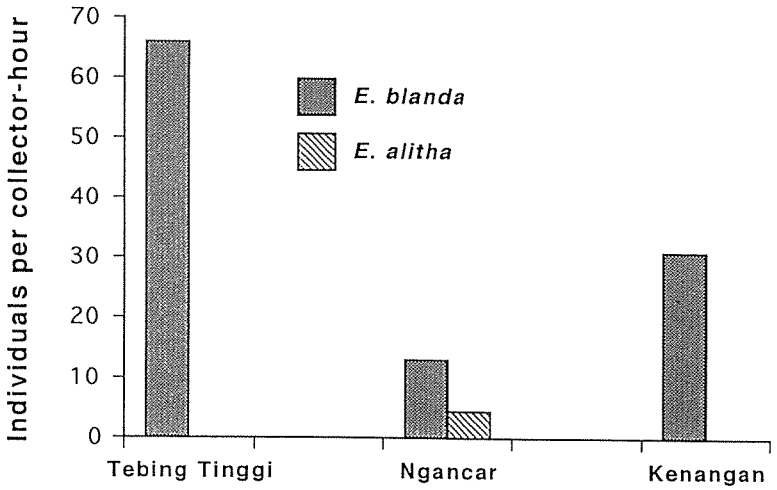

Fig. 3. Number of individuals of *Eurema* butterflies sampled per collector-hour in Tebing Tinggi, Jambi Prov., on August 3, 1993, Ngancar, East Java Prov., on Mar. 8, 1994, and Kenangan, East Kalimantan Prov., on February 14, 1995

in February, 1994 (Fig. 1).

The samples from Benakat also suggested that the population of *E. blanda* fluctuated more widely than that of *E. hecabe* and that it increased in the wet season and decreased in the dry season. Population of *E. blanda* was low and lower than that of *E. hecabe* in August, 1993 (middle of the dry season). The small sample in May 1992 was representative of that in the early dry season, because in 1992 the wet season ended in early April, whereas the wet season extended to late May in 1994. The outbreak of *E. blanda* in May, 1994, suggested that the population increased during the wet season (usually from November through April, with considerable annual variation) (Fig. 2).

Samples from Tebing Tinggi, Ngancar and Kenangan were also collected in the wet season in each locality, and they fully or mostly consisted of *E. blanda* (Fig. 3).

2) Nature of outbreak in Benakat

(1) Population size

Table 2 shows the marking ratio and the Jolly-Seber estimates of the population size of *E. blanda* in Benakat in May, 1994. Although we marked nearly 20,000 individuals in total, the marking ratio was always low, less than 1%, due to the very high population level. Therefore, the population size and the survival rate were only roughly estimated. The population size estimated for males ranged between ca. 35,000 and ca. 824,000, suggesting that there were several ten to hundred thousand males in the census area on each census day. Female population size on May 4 could not be estimated due to the lack of recapture. The available estimates of the female population size were ca. 40,000 on May 5 and ca. 800 on May 6. The latter was apparently an underestimate, because we captured 1,104 female individuals on May 6, and this was clearly only a small proportion of the female population in the census area as indicated by the low marking ratio. Total number of males in the census area during the period between May 3 and May 5 (N_T) was estimated to be 1,078,460 by,

$$N_T = \hat{N}_2 + \sum_{i=2}^{4} \frac{\hat{B}_i}{\sqrt{\hat{\phi}_i}},$$

where $\hat{N}_2$ is the population size on the second census day, $\hat{B}_i$ is the number of individuals which

Table 1. Total number of individuals of each *Eurema* species captured during mark-release-recapture census in Benakat, South Sumatra Prov. from May 3 throught May 7, 1994

E. blanda		*E. hecabe*		*E. sari*		
Male	Female	Male	Female	Male	Female	Total
16635	3333	2	0	2	0	19972

Table 2. Marking ratio (α_i) and Jolly-Seber estimates of population size ($\hat{N}_i \pm$ SE) of males and females of *Eurema blanda* along a 300 m section of dirt road in an albizzia plantation in Benakat during the period May 3 through 7, 1994

		Male		Female	
i	Date	α_i	$\hat{N}_i \pm$ SE	α_i	$\hat{N}_i \pm$ SE
1	May 3	0.0000	–	0.0000	–
2	May 4	0.0012	266076.4±295731.4	0.0000	–
3	May 5	0.0009	824216.8±618631.6	0.0032	40894.3±63758.5
4	May 6	0.0047	35205.3±32577.0	0.0027	828.8±3122.7
5	May 7	0.0051	–	0.0070	–

joined the population between ith and (i+1)th censuses and surviving on the (i+1)th census day, and $\hat{\phi}_i$ is the survival rate from ith to (i+1)th census.

(2) Survival rate

Mean survival rate per day and mean longevity of the two sexes of *E. blanda* in the MRR census area were calculated by the Scott[11] method revised by Tabashnik[17] based on the daily survival rate estimated for May 3, 4 and 5 for males and May 4 and 5 for females by the Jolly-Seber method (Table 3). The survival rate was very low and the butterflies of both sexes lived only about one day on average in the census area. Since the Jolly-Seber method does not enable to discriminate losses due to death and emigration, the low survival rate could have been due to emigration.

(3) Sex ratio

Out of the 14 larvae and 152 pupae collected on May 4, 134 emerged to adults including 72 males and 62 females, without significant difference from a 1:1 sex ratio (G-test, G=0.7470, df=1, n.s.).

(4) Parasitism

Of the other 32 individuals, five larvae died before pupation, and 21 pupae without parasitism. Only the other six pupae (all collected as pupae) were parasitized by *Brachymeria lasus* (Hymenoptera: Chalcididae), hence the rate of parasitism was 3.95%, and we did not find any other parasites. Beside the above-collected immature forms, one larva was found dead, presumably due to the attack by a heteropteran predator, and six pupae were eaten by ants (the ants may have been scavenging already dead pupae) on May 4.

Table 3. Mean survival rate per day ($\hat{\phi}_m$) and mean longevity ($\hat{L}_m$; in days) for males and females of *E. blanda* adults based on the Jolly-Seber estimates of survival rate in Benakat during May 3 to 6, 1994

	Male	Female
$\hat{\phi}_m$	0.415	0.352
$\hat{L}_m$	1.1	1.0

(5) Behavior of adult *E. blanda* during the outbreak

Adults of *E. blanda* exhibited mass migration. Shortly before 11:00 (West Indonesian Local Time), on May 4, we noticed that many butterflies were flying to the West. Thereafter, unidirectional mass migration (always to the West) was observed everywhere in the Benakat region every morning, approximately between 9:30 and 11:00, during our stay there (until May 15).

However, not all the individuals of *E. blanda* was involved in this migration. Many individuals were also seen resting (mostly females) in the shrubs along the forest edge and undergrowth in the forest, or sucking water in aggregation at puddles (always males). We noticed that the males were gathered on stems of an acacia tree, *Acacia mangium*, in some plantation compartments and were sucking the wood sap flow. Wood sap sucking is common in some other butterfly groups, such as Nymphalidae and Satyridae, but unusual in Pieridae.

Discussion

Eurema species as pests of albizzia have been misidentified in previous publications[4, 6]. So-called severe defoliation by *E. hecabe* reported in later publications[7, 9, 10, 14, 15, 16] seems to be a repetition of the earlier errors or, in recent studies the species may have also been misidentified. In the present study, it was confirmed that (1) there were four *Eurema* species in the albizzia plantations, (2) the population of *E. blanda* fluctuated more widely than that of *E. hecabe* or *E. alitha* and *E. sari* seldom occurred in Benakat and Jasinga, (3) the most abundant species when the yellow butterflies became abundant was *E. blanda* in all the sampling sites, (4) and *E. blanda* was the species which caused heavy defoliation in Benakat and Tebing Tinggi. Therefore we reached the conclusion that the species responsible for the severe defoliation of

albizzia plantations was *E. blanda*, while *E. hecabe* and the other species were of minor importance from the view point of forest protection.

The defoliation seldom resulted in the death of the albizzia trees in forestry plantations, but branch die-back wsa occasionally observed, and the effects of the damage on the growth of trees had never been examined so far. Defoliation and branch-die back are likely to be more serious problems in tea, coffee and cacao plantations where albizzia is planted as a shade tree.

The population of *E. blanda* increased throughout the wet season, and outbreaks occurred late in the wet season. Based on our experience in the field, females of *E. blanda* always oviposit on fresh growth of the host plant, and it is likely that their population increase is promoted by the flush of albizzia during the wet season. However, though *E. blanda* usually becomes very abundant late in the wet season, outbreaks that may cause total defoliation of an albizzia plantation occurred only occasionally. For example, we did not record such a remarkable increase in the population of *E. blanda* in Jasinga, and, according to the foresters of Perum Perhutani, there had been no severe defoliation by the yellow butterfly in Ngancar. Factors controlling *E. blanda* outbreaks are unknown, but as far as the outbreak in Benakat is concerned, the *E. blanda* population clearly escaped attacks by parasites.

The mass migration observed in Benakat may be related to the extremely high density (Fig. 2; Table 2) and depletion of the albizzia foliage, the larval food resource. However, it remains to be determined why the flight direction was so fixed. Similar unidirectional migration has been reported for other insects, especially butterflies, and the mechanisms and adaptive significance of this behavior have not been elucidated[2, 19]. Unidirectional flight was associated with the emigration of the butterflies, resulting in a low survival rate.

Beside the severe defoliation caused by *E. blanda*, the presence of the *Eurema* fauna in the albizzia plantations poses several interesting ecological problems, e.g., mechanisms inducing or inhibiting sympatry of these species, differences in population levels and population fluctuation patterns that may require further investigations. Ecological interactions between the very closely related species *E. hecabe* and *E. alitha* are particularly interesting. Fukuda[5] who also reported that the two species were spatially segregated in Los Banõs, Luzon, suggested that this phenomenon was due to difference in host preference between the two species. In our study, however, since both species were considered to depend on albizzia, host preference may not play a role in the separation of the two species. According to Yata[18], these two species are almost fully sympatric and often fly mixed together in artificially modified vegetation, such as grassland. Presently, since we have examined only five albizzia plantations, it remains to be determined whether these two species are always separated from each other in the plantations, and this aspect must be confirmed on a larger number of samples.

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インドネシア西部のアルビジア造林地において食葉害を引き起こしているキチョウ属（*Eurema*）

ラギル　S.B.　イリアント[a)]，松本和馬[b)]，クスディー　ムリヤディ[c)]

[a)]森林自然保護研究センター
(Jl. Gunung Batu 5, Bogor, Indonesia)

[b)]国際農林水産業研究センター林業部
（〒305　つくば市大わし1-2）

[c)]パレンバン造林技術センター
(Jl. Kolonel Burian, Palembang, Indonesia)

摘　要

アルビジア（モルッカネム；*Paraserianthes falcataria*）は東南アジアに広く植栽されている多用途の早生樹であり，その造林地では時折キチョウ属（*Eurema*）の１種が大発生し，激しい食葉害を引き起こしている。該当種はこれまでキチョウ（*E. hecabe*）とされたりタイワンキチョウ（*E. blanda*）とされたりしてきたが，過去の文献の中には明らかにタイワンキチョウをキチョウと誤同定したものが含まれている。今回，インドネシア西部のスマトラ，ジャワ，カリマンタンの計５箇所のアルビジア造林地で発生しているキチョウ属を調査したところ，タイワンキチョウ，キチョウ，アリタキチョウ（*E. alitha*），サリキチョウ（*E. sari*）の４種が認められたが，アルビジア造林地にキチョウ属全体の個体数が増加したときの優占種は常にタイワンキチョウであった。タイワンキチョウの個体数は増減が著しく，乾季には少なく，雨季に増加した。雨季の増加は時に造林地全体のアルビジアがほぼ完全に葉を失うほどの大発生となった。一方キチョウやアリタキチョウの個体数は比較的低いレベルで安定しており，またサリキチョウはきわめて稀であって，これらのアルビジアに及ぼす食葉害の影響はさほど重要ではないと考えられた。これまで重要食葉害虫としてキチョウが挙げられてきたのはおそらく誤同定やその無批判な引用によるものであろう。また今回の調査で確認されたアリタキチョウは，最近までキチョウと混同されてきた種であるが，キチョウとアリタキチョウが同所的に発生している例はなかった。

キーワード：シロチョウ科，熱帯林業害虫，大発生