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Current distribution of Nilgiri grass yellow *Eurema nilgiriensis* Yata (Lepidoptera: Pieridae), with an updated taxonomic key to *Eurema* of Western Ghats, India

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ABSTRACT: *Eurema nilgiriensis* Yata, 1990, the Nilgiri grass yellow, was described from Nilgiris in southern India. There are not many published records of this species since its original description, and it was presumed to be a high-elevation endemic species restricted to its type locality. Based on the external morphology (wing patterns) as well as the male genitalia, the first confirmed records of the species from Agasthyamalais and Kodagu in the southern Western Ghats, is provided here. This report is a significant range extension for the species outside the Nilgiris, its type locality. Ecological data pertaining to this species as well as the field identification key to all known *Eurema* of Western Ghats are also presented.

KEY WORDS: Nilgiri grass yellow, *Eurema*, Agasthyamalais, Kodagu. Western Ghats, rediscovery

INTRODUCTION

The grass yellows or small sulphurs of the genus *Eurema* Hübner, [1819], are relatively small, black-bordered deep lemon-yellow butterflies of open areas with circum-tropical distribution (Corbet and Pendelbury, 1992). They are seen in both the tropical and sub-tropical regions, and some members even inhabit the temperate zones as well (Yata, 1989). They are active in the morning and evening with the noon spent resting on underside of low foliage. Seasonal forms exist and sexual dimorphism is also developed in some species. Males are seen in large numbers in mud-puddling assemblages. Flowers are avidly visited. They occasionally migrate (Yata, 1989). Flight is weak and fluttering. Larval hostplants are from family Fabaceae (Nitin *et al*., 2018) and Rhamnaceae; and as far as it is known, only Rhamnaceae for the *andersoni* subgroup of *Eurema* (Yata, 1991). They are important pollinators and are also considered as pests of some agriculturally important plants (Yata, 1989).

Eurema has eight species in India (Yata, 1989), six of which are recorded from Western Ghats and Nilgiris of peninsular India viz., *Eurema andersoni shimai* Yata & Gaonkar, 1999*, E. blanda silhetana* (Wallace, 1867), *E. brigitta rubella* (Wallace,

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1867), *E. hecabe hecabe* (Linnaeus, 1758), *E. laeta laeta* (Boisduval, 1836) and *E. nilgiriensis* (Yata, 1990) (Evans, 1932; Wynter -Blyth, 1957; Larsen, 1987; Gaonkar, 1996; Kunte et al., 2018). Of these, *Eurema andersoni shimai* and *E. nilgiriensis* are rare as evident from the paucity of published records, but all the other species are common in the state of Kerala (Gaonkar, 1996). There is a single specimen of a male of *E. novopallida* Yata 1992 from south India in the collection of Smithsonian Institution (Washington) (Yata,1992), but this record needs further confirmation (Yata, 1989). The life cycle and flight periods of all the species are known (Kunte *et al.*, 2018), except for *E. nilgiriensis* Yata, 1990.

Following Yata (1991), the *andersoni* complex in *sari* subgroup of *Eurema* is represented by *Eurema andersoni shimai* and *E. nilgiriensis* in Western Ghats. The two taxa were earlier considered to be the same and have been variously treated by different authors under the common name -The One Spot Grass Yellow. *Eurema nilgiriensis* was described by Yata in 1990 from the Nilgiris from specimens in two private collections in Japan (Fig. 1). The species was separated from the very closely related *E. andersoni* based on the consistent external morphological features and the differences in male genitalia (Yata,1990). *Eurema nilgiriensis* was known to be restricted, and endemic, to the Nilgiri hills and there are no confirmed published scientific records after the type description in 1990. But, Yata and Gaonkar (1999) mentioned in a later paper that the species flies sympatrically with *Eurema andersoni shimai* in north and south of Palghat Gap of Western Ghats. Gaonkar (1996) considered that the species is 'Rare' and is seen in Kerala, Tamilnadu and Karnataka. However, there are no specific mention of specific locality details or museum specimens so as to confirm its presence in the Western Ghats proper. The northern and southern most range of this species was still unknown.

Images of duly identified species of *Eurema nilgiriensis* Yata, 1990 based on external morphology is given on http://www.ifoundbutterflies.org/ by Kunte *et al.* (Anonymous, 2018). But this is the first time that the species confirmation made based on male genitalia. The male genitalia is the most important characteristic for determination of *Eurema* species (Yata, 1989). It was in this context, the present study on the genital morphology of *E. nilgiriensis* was undertaken. Basic data on the ecology of this species, notes on its taxonomy, as well as a revised key for field identification of *Eurema* of Western Ghats.

MATERIALS AND METHODS

While documenting butterflies in the Shendurney Wildlife Sanctuary in Kerala during January 2018, a few individuals of *Eurema* were noted in the fringes of a secondary forest near Rosemala in Kollam district. Subsequently, similar individuals were recorded from Sollekolli and Makutta from Kodagu, in Karnataka during April and May 2018 (Fig.1). The butterflies were photographed in the field and images were compared with the type images of *Eurema* from Yata collections (1990) and also with the images of Paratypes from BMNH, London (Fig.2). Earlier in 2013 the corresponding author had sightings of similar morphs of *Eurema* in Thenmala in the Shendurney Wildlife Sanctuary. Two male specimens of similar morphs of *Eurema* were located from Thenmala regionin the insect collections of National Centre for Biological Sciences (NCBS), Bengaluru (Specimens NCBS-BH868 and NCBS-BH869). These specimens, and another from Kodagu (NCBS-AW839), were dissected for the male genitalia to confirm the species.

Taxonomy of *Eurema* follows Yata (1989;1991). The morphological features mentioned refer to the external morphology and coloration unless otherwise specified. The present work is based on three male specimens in NCBS collection and field images of *E. nilgiriensis*. The genitalia were studied by overnight soaking in KOH and dissecting under Stereo Zoom Microscope (HEADZ Model HD81) and preserved in glycerol. Illustrations and photographs of male genitalia were made using a Stereo Zoom Microscope. Nomenclature for genitalic structures follow Yata . (1989)The length of the forewing (FW) - from the wing base to the apex, was also measured.

RESULTS

***Eurema nilgiriensis* Yata, 1990** (Fig. 2- 6)

Specimens studied were from the post-monsoon cold months of December to April, representing the Dry Season Form (DSF) from Agasthyamalais and May-November Early Wet Season Form (WSF).

Material Examined (n=4):

NCBS-BH868: *Eurema nilgiriensis* Yata, 1990, Male, Rosemala, Shendurney Wildlife Sanctuary, Kollam District, Kerala State, India, 20th September 2013 at 150m above M.S.L, collected by NCBS team, Habitation near Secondary forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru India (Fig. 3 A, B).

NCBS-BH869: *Eurema nilgiriensis* Yata, 1990, Male, Kattalapara, Thenmala Reserve Forest, Kollam District, Kerala State, India, 5th October 2013 at 100m above M.S.L, Collected by NCBS team, Forest road near habitation. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru India (Fig. 3 C, D).

NCBS-AW839: *Eurema nilgiriensis* Yata, 1990, Male, Wet only, Nitin R., Makutta, Kodagu District Karnataka, 12th May 2018, at 700 m above M.S.L Evergreen Forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru, India.

NCBS-AZ862: *Eurema nilgiriensis* Yata, 1990, Female, Dry only, Nitin R. and G. S. Girish Kumar, Sollekolli, Kodagu District, Karnataka, 18th April 2018, at 750m above M.S.L Evergreen Forest. Deposited in the Research Collections Facility at the National Center for Biological Sciences (NCBS), Bengaluru, India (Fig. 3 E, F).

Additional records examined (n=10): Ten male specimens were observed, photographed and studied in the field from Rosemala, Shendurney Wildlife Sanctuary, Kollam District, Kerala State, India, during December 2017 to October 2018, at 100 above M.S.L, from a habitation near Secondary forest, but not collected (Table 1).

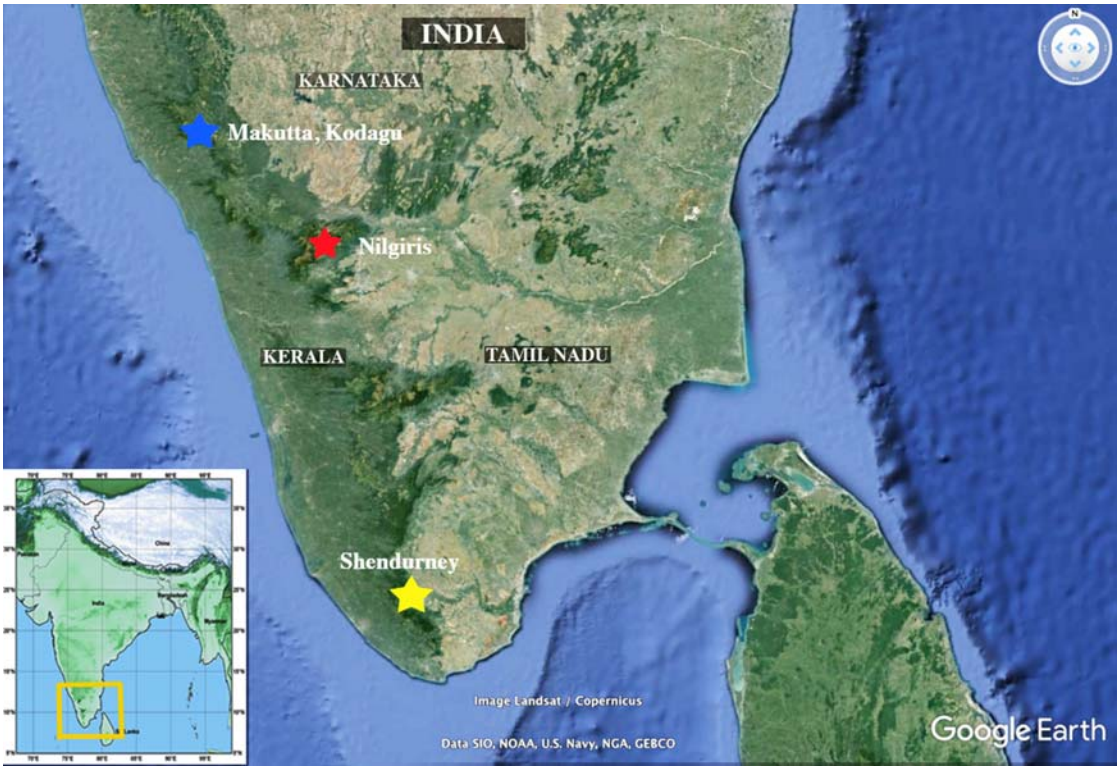

Fig. 1. Map of the study area in Western Ghats of southern India.

Fig. 2. Paratype of *Eurema nilgiriensis* Yata, 1990 (specimen code: BMNH(E) 2002-153).

Diagnosis (Fig. 2 - 6): **Male**

Antennae are chequered black and white, eyes greenish yellow, rest of the head yellow and legs paler yellow.

Underside: The ground color of the wings are yellow with chocolate colored apical patch on forewing and black streaks, chocolate brown patches and rings. *Underside of Forewing* (UnF): Yellow, usually with a well-defined apical chocolate patch occupying 2/5th of the distal spaces four & five, 4/5th of spaces 6 & 7 and middle 2/3rd of space 8. This patch produced outwardly as a dark, almost black triangular patch, towards the middle of space 3. A single '3' shaped mid-cellular spot present. This chocolate brown apical patch is very variable from a well-defined one to a barely traceable one depending on the season. The disco-cellular spot appears as a ring like spot occupying 3/4th of the disco-cellular vein. Male brand: pale grey, narrow and ending well before origin of vein 2. The faint reflection of the markings and excavations in space 2, 3 visible on UnF. Small triangular sub-marginal end-vein spots are black and they join to form a very thin but well defined sub-marginal line. Cilia blackish-brown. *Underside of hindwing* (UnH): Base of space 7 without a minute black spot. Similar to the FW, the full series of small triangular sub-marginal end-vein spots are black but they do not join to form sub-marginal line. Post-discal spots are shaped like lunules and are formed by black dusting and are contiguous in spaces 4,5 and 6. Lunule in space 2 shifted out and not in line with that in 2 and 4. Lunule in space 7 in line with the disco-cellular ring spot. The two basal lunules not in line in space 1a and 1b. One sub-basal ring shaped spot present in each of the spaces one above and one below the cell. The sub-basal and the discodal-cell spot or ring at the base of the cell not in line, the later being pushed slightly outwards.

*Upperside of Forewing (*UpF): The general color is yellow costa bordered in thin but well defined black border. Apical triangular patch and termen thickly bordered in black. The yellow in space 2 more excavating into the black border than in space 3. The black apical patch forms an obtuse angle in the inner border in space 4. The black border is produced along the border of the dorsum for a short distance; hence, the yellow margin is concave internally in space 1b. *Upperside of Hindwing* (UpH): Yellow with a very thin black border along the termen, which is slightly produced along each vein for a very short distance.

Genitalia (Fig. 4, 5): The genus *Eurema* has multiple spine-like processes on the medial wall of the male valva (Fig. 4 D, 5A). The structure of *E. nilgiriensis* is in general agreement to the *Eurema sari–andersoni* group armature. Process 1 (P1) the process near the middle of the ventral margin of costa-ampulla of the valva is short as in all *Terias* subgenus. P2, a process beyond the middle of the dorsal margin of the valva, is developed as a prominent hump, clearly visible in the lateral view

Fig. 3. Images of specimens of *Eurema nilgiriensis* Yata,1990: NCBS-BH868, male, wet season form (A:Un & B:Up), NCBS-BH869, male, wet season form (C:Un & D:Up), NCBS-AZ862, female, dry season form(E: Un & F:Up).

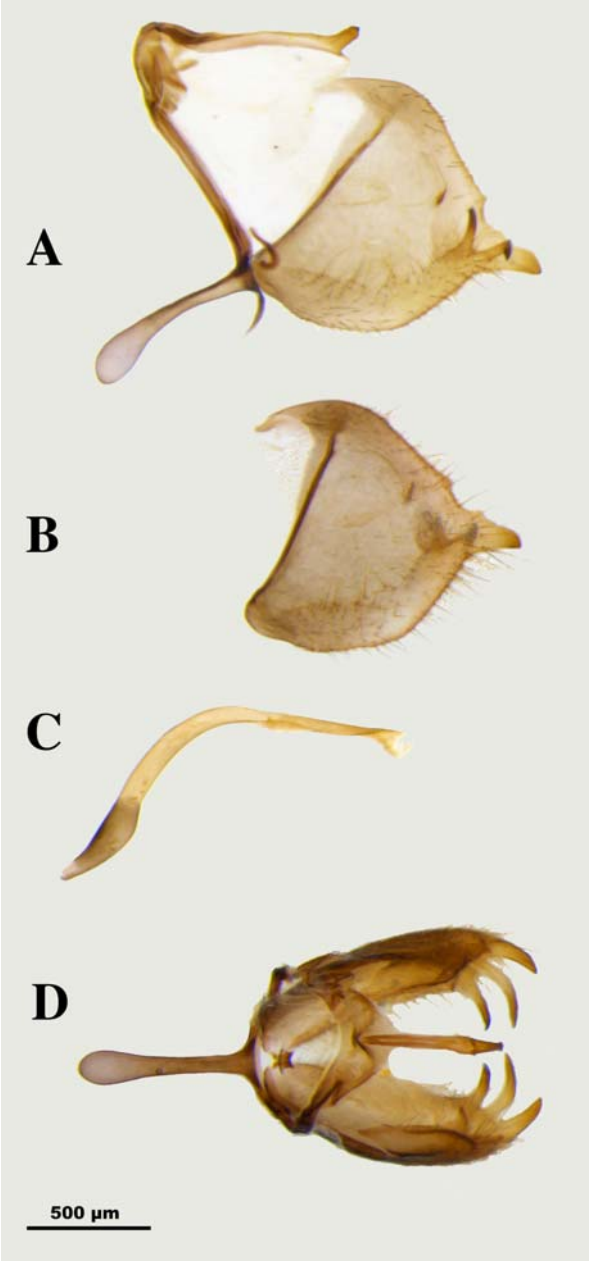

Fig. 4. Image of Male genitalia of *Eurema ni-lgiriensis* Yata, 1990 (NCBS-AW839)

(Fig. 4B, 5C). The P3 or the tip of the valva has a curved tip inwards. There is another small hump like process between P2 and P3, on the dorsal margin, visible in lateral view (Fig. 4A, 5D). The harpe of the valva bears the P4 and P5 arising as a bifurcated process with tips curved ventro-medially. The aediagus is as in the type specimen with a uniform curve with the dorsal convexity (Fig. 4C, 5B). The uncal projection is shaped like a snakehead

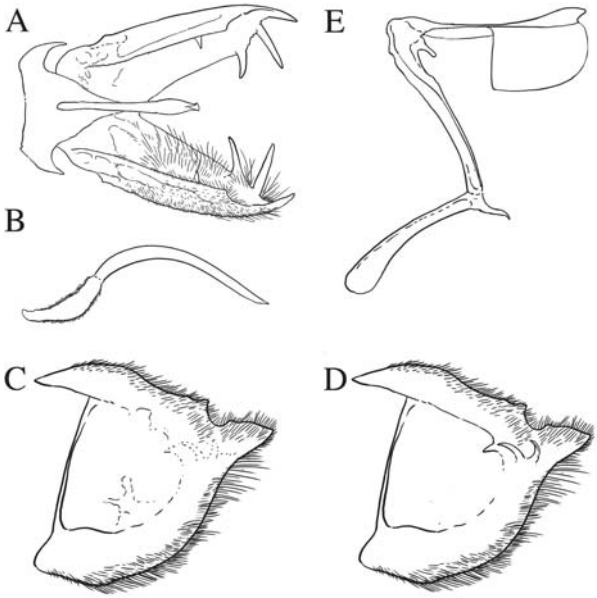

Fig. 5. Illustrations of male genitalia of *Eurema nilgiriensis* Yata, 1990, based on NCBS-BH868 and NCBS BH869

Fig. 6. Field image of *Eurema nilgiriensis* Yata, 1990 from Shendurney Wildlife Sanctuary, Kerala

(Fig. 4A, 5E) and not triangular as in *Eurema andersoni shimai* Yata and Gaonkar, 1999. Thus the male genitalia is in perfect agreement to that of the Type specimen in Yata (1990).

Female: Coloration similar to males, except that the UpF black border is almost right angled at vein 4.

Measurements: Male*:* FW 1.8-2.0 cm (n=3), Female: 2.2 cm (n=1)

Ecological Notes: In contrast to other *Eurema* in south India, the species from *andersoni* subgroup - *E.andersoni shimai* and *E. nilgiriensis* are forest insects and are seen flying amongst thick evergreen and secondary forests. According to Yata and Gaonkar (1999), both apparently fly together in the high elevations. Interestingly, all our records of *E. nilgiriensis* are from below 300m in the Agasthyamalais and below 750m in Kodagu as far its is known, well below the Shola-Grasslands (>1800m). The species was found in a habitation near a secondary forest at 100-150m elevations in Rosemala in Shendurney Wildlife Sanctuary during December 2017 to January 2018. In Kodagu the species was recorded at an elevation of 700-750m in an evergreen forest in April and May 2018. The butterflies were active from 9 am and were seen flying very low within three feet from ground

Table 1. Details of specimens/photographs of *Eurema nilgiriensis* Yata, 1990 examined

No	Locality	Elevation	Collected	Sex	Date	Collector/Photographer
1.	Rosemala, Shendurney, Kerala	150m	Yes	Male	September 2013	NCBS Team
2.	Kattalapara, Thenmala, Kerala	100m	Yes	Male	October 2013	NCBS Team
3.	Kattalapara, Shendurney, Kerala	110m	No	Unsexed	December 2017	Kalesh Sadasivan
4.	Rosemala, Shendurney, Kerala	200m	No	Unsexed	December 2017	Kalesh Sadasivan
5.	Rosemala,Shendurney, Kerala	200m	No	Unsexed	January 2018	Kalesh Sadasivan
6.	Kattalapara Shendurney, Kerala	100m	No	Unsexed	January 2018	Kalesh Sadasivan
7.	Kattalapara Shendurney, Kerala	200m	No	Unsexed	January 2018	Kalesh Sadasivan
8.	Kattalapara Shendurney, Kerala	150m	No	Unsexed	March 2018	Kalesh Sadasivan
9.	Sollekolli, Kodagu, Karnataka	750m	Yes	Female	April 2018	Nitin.R
10.	Makutta, Kodagu, Karnataka	700m	Yes	Male	May 2018	Nitin.R & G. S. Girish Kumar
11.	Kattalapara Shendurney, Kerala	110m	No	Unsexed	October 2018	Kalesh Sadasivan
12.	Kattalapara Shendurney, Kerala	300m	No	Unsexed	October 2018	Kalesh Sadasivan
13.	Kattalapara Shendurney, Kerala	110m	No	Unsexed	October 2018	Kalesh Sadasivan
14.	Rockwood, Shendurney, Kerala	300m	No	Unsexed	November 2018	Kalesh Sadasivan

amongst herbaceous vegetation, in shade, along a village path. In a transect at Shendurney Wildlife Sanctuary, of 500m of half an hour duration we could find three individuals in a path leading to a habitation bordering a lowland secondary forest. All of them were avidly nectaring on low-growing herbs like *Rungia* (Fig. 6). If disturbed they flew into the relatively thicker undergrowth of the jungle. Males were seen occasionally on damp patches and on dead millipedes on road-kills in mixed assemblages, but always singly and never in swarms, in contrast to some other *Eurema*. Females were seen ovipositing on Bombay Smythea *Ventilago bombaiensis* Dals. (Rhamnaceae), a common woody climber seen in the undergrowth of evergreen forests, riparian tracts and Myristica swamps.

DISCUSSION

The Nilgiri grass yellow *E. nilgiriensis* was presumed to be restricted to the Nilgiri Mountains of southern India. Now confirmed its presence in Shendurney region of Agasthyamalais and Kodagu in the Western Ghats proper, based on external morphology and structural details of male genitalia. This is a significant range extension for the species into the southern Western Ghats, outside the type locality, Kodagu being the known northernmost and Agasthyamalais being the known southernmost localities where the species has now been confirmed. Unlike reported in Yata and Gaonkar (1999) the species is found at low elevations (<200m) and mid-elevations (<750m) in suitable habitats on the western slopes of the southern Western Ghats. The habitat of *E. nilgiriensis* is lowland evergreen, semi-evergreen, and Myristica Swamp forests in Agasthyamalais and low- and mid-elevation evergreen forests in Kodagu. Thus it may be reasonably presumed the species was probably collected from a low- to mid-elevation habitat from western Nilgiris and is not a high-elevation Shola-Grassland species as projected in literature (Yata, 1991; Yata and Gaonkar, 1999). In Agasthyamalais the species is not sympatric with *E. andersoni shimai* at least in the low elevations, but in Kodagu they fly together in the mid-elevations. Male genitalia dissection should be done for species confirmation in case of any ambiguity or confusion with *E. andersoni shimai*, as the latter may have equal excavations on spaces 2 and 3 UpF. With respect to the legal protection and conservation status, *E. nilgiriensis* is not listed under Indian Wildlife (Protection) Act, 1972 or Red-listed by IUCN hence a critical assessment is warranted, as is for all the butterfly taxa in the Western Ghats. The extent of variation in coloration, genital morphology and the details of early stages are in preparation and shall be published elsewhere. The status of this species seems to be locally common in suitable habitats. A simple field identification key for *Eurema* of Western Ghats is provided below which can be complimented with genitalia dissection of males, which is confirmatory in case of any taxonomic confusion.

Key to the grass yellows *Eurema* Hübner, (1819) of Western Ghats

The following is a key to the known *Eurema* of Western Ghats based on external morphology modified from Evans (1932) and Yata (1989).

1. UnH Post-discal spots in spaces 4, 5 fused to form a band.....*Eurema* Hübner (1819)

1) Post-discal spots joined to form parallel bands.....…*Eurema laeta* (Boisduval, 1836)

2) Post-discal spots not forming parallel bands.....*Eurema brigitta* (Stoll, 1780)

2. UnH Post-discal spots in spaces 4 and 5 always separate….....….*Terias* Swainson, 1758

1) UnF with one spot in cell, UnH base of space 7 without a minute black spot

a) UpF space in 3 deeply excavated than 2 .....*Eurema andersoni* (Moore, 1886)

b) UpF space in 2 deeply excavated than 3 ...….....*Eurema nilgiriensis* Yata, 1990

2) UnF with 2 or more spots in cell, of which one or all may be absent occasionally

a) UnF with 2 cell spots, UnH with base of 7 no black spot ...*Eurema hecabe* (Linnaeus, 1758)

b) UnF with 3 cell spots, UnH with base of 7 with a black spot..... .....*Eurema blanda* Boisduval, 1836

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