Mario Carlo Battista Raviglione* - Fabrizio Boggio** - Marco Raviglione*** - Alberto Zilli****

First report of *Colias croceus* ab. *cremonae* in Italy (Lepidoptera Pieridae)

Riassunto: *Prima osservazione di* Colias croceus *ab.* cremonae *in Italia (Lepidoptera Pieridae)*.
Si segnala la prima osservazione per l'Italia dell'aberrazione *cremonae* Verity, 1911 di *Colias croceus* (Fourcroy, 1785), una forma estremamente rara caratterizzata dalla colorazione di fondo giallo-limone che sostituisce quella arancio tipica della forma nominale della specie. Tale peculiarità è dovuta ad una rara mutazione genetica che inibisce l'espressione della colorazione arancio/rosso dovuta a pigmenti della classe delle eritropterine, la cui mancanza determina l'assenza del colore arancio sulle ali e del colore rosa tipico delle antenne, zampe, frange alari e della pubescenza che riveste capo e torace. La presente segnalazione si basa su di un singolo esemplare maschio osservato il 7 ottobre 2021 nei pressi di Benna (Biella, Piemonte), ove *Colias croceus* era molto frequente. L'aberrazione è relativamente frequente alle Isole Azzorre (in particolare a Faial) ed è anche stata segnalata a Madeira e Hasmieh (Libano), sito di provenienza del primo esemplare conosciuto. Per quanto ci è noto, non risultava sinora rinvenuta in Italia e in gran parte dell'Europa continentale. Un'altra aberrazione gialla di *Colias croceus* nota come ab. *erateformis*, segnalata originariamente in Romania e più recentemente per diverse zone del Paleartico occidentale (soprattutto nell'area Mediterranea), differisce dalla precedente poiché il pigmento arancio/rosso è ancora presente.

Abstract: We report on the first observation for Italy of ab. *cremonae* Verity, 1911 of *Colias croceus* (Fourcroy, 1785). This is an extremely rare form characterized by a lemon-yellow background color instead of the orange color typical of the nominal form of *Colias croceus*. This peculiarity is linked to a genetic mutation that suppresses the expression of orange/red (and pink) coloration due to erythropterin pigments, so that their absence prevents the appearance of orange color on the wings and of the pink color normally observed on the antennae, legs, fringes, and the hair vestiture of the head and thorax. The present report is based on a single male specimen recorded on 7 October 2021 near Benna (Biella, Piedmont), where *Colias croceus* was abundant. The presence of this aberration is relatively frequent in the Azores Islands (particularly Faial) and has also been reported for Madeira and Hasmieh (Lebanon), the site of origin of the first specimen ever collected. This aberration was previously unrecorded in Italy and is yet unknown in most of continental Europe. Another yellow aberration of *Colias croceus,* known as ab. *erateformis,* originally recorded in Romania and, later, from other West Palaearctic (mostly Mediterranean) areas, is considered a different one in which the red pigment is still present.

Key words: *Colias croceus*, aberration, form, *cremonae*, *erateformis*, Lepidoptera, Pieridae, Piedmont, NW Italy, Biella, Benna, first observation.

Introduction

Colias croceus (Fourcroy, 1785) is a species characterized by remarkable variability, as it was soon noticed by Hübner (1799) with the identification of the female-limited form *helice*. During the last century, many authors have very creatively coined names for the different forms of this species, *e.g.*, Leraut (2016) lists some 57 named ones, while Verhulst (2000) recorded 142. Among such forms, the most interesting one for its yellow ground color is ab. *cremonae*. This aberration, expressed in individuals of both sexes, has, in fact, a bright lemon-yellow tinge that replaces the normal orange of the nominal form. The description and naming of this rare form are due to Roger Verity (1911a, 1911b), who substantially beat in time its legitimate author (cf. Bollow, 1930; Verity, 1947; Kudrna, 1983; Verhulst, 2000; Russell *et al.*, 2003), that is Andreas Bang-Haas (Bang-Haas A., 1912). In this article, we report on the first observation of ab. *cremonae* in Italy and provide information on both history of treatment and identification of this form, alongside data on its distribution and comments on the differences from the closely resembling ab. *erateformis* Niculescu, 1963.

*Mario Carlo Battista Raviglione, 227 Impasse des Alouettes, 01280 Prévessin-Moëns, France. E-mail: raviglionemc@gmail.com
**Fabrizio Boggio, Via Torrione 19, 13900 Biella, Italy. E-mail: piscopo50@outlook.it
***Marco Raviglione, Via Delleani 39, 13900 Biella, Italy. E-mail: marco.raviglione@gmail.com
****Alberto Zilli, Insects Division, Natural History Museum, Cromwell Road, SW7 5BD London, UK. E-mail: a.zilli@nhm.ac.uk

Materials and Methods

Fieldwork was carried out in 2021 (13th September-7th October) in the municipality of Benna (Biella Province, Piedmont, Italy), where we ran into four butterfly surveys during the afternoon (14:00-17:00). The study area consists of a lowland grassland plain at an elevation of 250 m, converted from arable land, that extends to the south-east as far as to the industrial area of Massazza (Biella) and the north-west up to the eastern outskirts of Candelo (Biella) (Figs. 1 and 2). During our survey season, this vast grassland was rich in flowers of *Trifolium, Achillea*, *Centaurea* and other plants, that attracted plenty of butterflies.

Standard sampling with a butterfly net was used, associating photographic records whenever possible. The nomenclature followed here is that of the checklist by Balletto *et al.* (2021), although we retain the original spelling for "*croceus*" according to Nieukerken *et al.* (2020).

In addition to a review of the available literature, to further explore if other sightings of yellow aberrations of *Colias croceus* had been made in Italy, in January 2022 we issued a call for information among affiliates of the Associazione Lepidotterologica Italiana (ALI), inviting its members to report any such observations. We also consulted several websites identified through search engines using key words such as: *Colias croceus* aberration, *cremonae, erateformis*. These include: https://www.ukbutterflies.co.uk/aberrations.php?species=croceus; https://data.nhm.ac.uk/search;https:// www.britishbutterflyaberrations.co.uk/species/pieridae.

Field observation

On 7th October 2021, we had the chance to spot a male of ab. *cremonae* in the study area. Many butterfly species already known from the Biella province could be observed in the same biotope (cf. Raviglione *et al.,* 2019), namely *Colias croceus*, in large numbers and among them also some females of f. *helice*, numerous but less frequent *Colias hyale* (Linnaeus, 1758) and *Pontia edusa* (Fabricius, 1777), and further to these, *Papilio machaon* Linnaeus, 1758*, Pieris rapae* (Linnaeus, 1758)*, P. brassicae* (Linnaeus, 1758)*, Inachis io* (Linnaeus, 1758)*, Issoria lathonia* (Linnaeus, 1758)*, Melitaea phoebe* ([Denis & Schiffermüller], 1775)*, M. didyma* (Esper, 1778), *Brintesia circe* (Fabricius, 1775), *Maniola jurtina* (Linnaeus, 1758), *Coenonympha arcania* (Linnaeus, 1761), *C. pamphilus* (Linnaeus, 1758), *Polyommatus icarus* (Rottemburg, 1775) and *Lycaena tityrus* (Poda, 1761). The male of ab. *cremonae* was found late in the season when the remarkable abundance of *Colias croceus* made the detection of scarce mutations more likely.

The specimen of ab. *cremonae* collected is slightly worn (Fig. 3). It therefore required a thorough examination to confirm the typical features of such aberration. In addition to the greenish-yellow ground color of wings, the most reliable feature to immediately distinguish ab. *cremonae*, especially evident in fresh specimens, is the color of fringes on the underside, yellow instead of pink as in the nominal form. The absence of pink can also be noted in the hairy vestiture of the thorax, head, legs and the costal scales of the forewing. Finally, on the underside of ab. *cremonae* a brown col-

Figs. 1-2. The grassy plain near Benna (Piedmont, Italy) where *Colias croceus* ab. *cremonae* was found. 1) General view; 2) Close-up of a male *Colias croceus* in the biotope.

oration surrounds the discal spot of the hindwing, whereas on the upperside the same spot is greenish-yellow instead of orange.

Historical background

On 13th April 1910, Francois (spelled without cedille) Cremona (Fig. 4) collected a male of the yellow form of *Colias croceus* in Hazmieh, also known as Hasmich (Bang-Haas A., 1912) or Hasmieh (Bang-Haas O., 1916), in the outskirts of Beirut (Lebanon). Cremona, on whom there is very little biographical information available since 1886, collected specimens in the then-Syria (including today's Lebanon) for the renowned firm "Staudinger & Bang-Haas" in Dresden-Blasewitz (Hörn & Kahle, 1935), a company trading in Lepidoptera that had been founded in 1884 by Otto Staudinger (German, 1830-1900) and Andreas Bang-Haas (Dane, 1846-1925), after the marriage between the latter and Staudinger's daughter (Draeseke, 1962).

Cremona forwarded the unknown form to Andreas Bang-Haas (Fig. 5), who decided to dedicate it to the discoverer (Bang-Haas A., 1912). However, a quarrel developed on the naming of this form, even though forms have no standing in zoological nomenclature. In fact, prior to the publication by Andreas Bang-Haas, his son Otto (Fig. 6), who would eventually take over his father's business, outlined in a letter to the Anglo-Italian

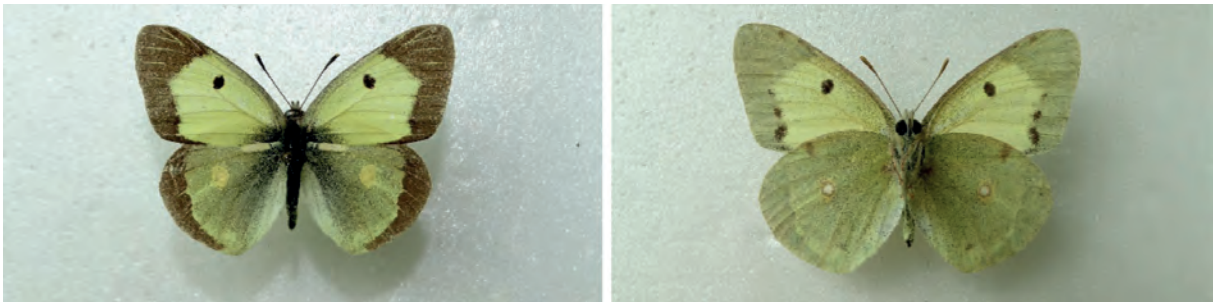


Fig. 3. The specimen of *Colias croceus* ab. *cremonae* collected near Benna (Piedmont, Italy) in dorsal (left) and ventral (right) views.

Figs. 4-6. Portraits of entomologists. 4) Francois Cremona in 1902 (from SDEI, 2022); 5) Andreas Bang-Haas (1846-1925) (from Draeseke, 1962); 6) Otto Bang-Haas (1882-1948) (from SDEI, 2022).

entomologist Roger Verity (1883-1959) dated 1911, the main features of the form, stressing the intention to publish the observation. Verity, who was about to finalize his Rhopalocera Palaearctica (1905-1911), anticipated their account by recording the new form in the last installment of his work. In fact, he wrote a note describing "*Colias croceus* (edusa)" as follows: "Staudinger a reçu de Syrie un ♂ de cette espèce, dont toutes les écailles orangées sont remplacées par une teinte verte semblable à celle qui s'observe assez fréquemment sur la côte [ab. *cremonae*, B. H., in litt.]" (Verity, 1911a: 358) (English translation reads: "Staudinger received from Syria a ♂ of this species, in which all the orange scales are replaced by a green tinge similar to that observed quite frequently on the costa"). Further to this, in the Index of his work, which is usually considered the part from which his new names date in consequence of more clearly expressed binominal or trinominal combinations (Kudrna, 1983), Verity (1911b), directly listed "cremonae (C. edusa) 358". It may be argued that with this trinominal combination, Verity (1911b) made the name *cremonae* available. However, as he reported in the same place on the page where the name is used infra-specifically, there is sufficient rationale for applying art. 45.6.1 of the Code (ICZN, 1999) and retain it as the name of an aberration, as also done by Kudrna (1983). Last but not least, as in the Index Verity (1911b) registered between square brackets the names "qui ont été donnés par un autre auteur d'après les descriptions et les figures parues dans cet ouvrage", and as there are no such brackets to *cremonae*, there is little doubt that Verity (1911a, 1911b), if not wholly intentionally, at least factually gained priority over the name. This circumstance was recalled and quite bitterly stigmatized by O. Bang-Haas (1916) (translated from German): "I wrote to Mr. Verity that we had received an e d u s a ♂ with greenish ground coloration, which my father would publish as ab. c r e m o n a e. On this brief communication, without having seen the specimen at all, Verity refers to himself as the author on p. XLIII of the preface to Rhop. Pal." (where for "preface" obviously Verity's (1911b) Index is meant, that was usually bound at the beginning of the collated work). In his article, Otto Bang-Haas (1916) clearly stated that Verity had never seen the specimen in question. Indeed, the original specimen is not in his collection now preserved at the Museum of Natural History 'La Specola' in Florence but is stored at Museum für Naturkunde in Berlin (Fig. 7). Eventually, O. Bang-Haas attributed ab. *cremonae* to his father (Bang-Haas A., 1912). Some authors still prefer to credit Andreas Bang-Haas for the naming of this aberration (Russell *et al.*, 2003; Russell, 2020b).

It should be noted that Niculescu (1963) described a yellow form of *Colias croceus* from Romania as ab. *erateformis* because of its resemblance to *Colias erate*. It is unclear whether this form, of which there does not seem to be any specimens available, was the same as *cremonae*. Niculescu (1963) wrote (translated from Romanian): "Moreover, some resemble *erate* – with an extreme degree of paleness in the male. The resemblance is perfect and total and cannot be distinguished by drawing and coloring. These individuals deserve to have a name for which I propose that of *erateformis* nov. They have a sulphur-yellow wing color with the general appearance of the *erate* species. They differ from *erate* by their genital armor and the presence of the androconial macula. This is a beautiful example of the total similarity of two species that have identical habitus, and an instructive example of the errors that can be made by lepidopterologists who base their determinations solely on habitus, ignoring structural characters". Reportedly, Niculescu had a very small collection of butterflies, mainly exotic, which was acquired by two collectors from Bucharest who are probably no longer alive (László Rakosy, pers. comm., 10 January 2022). Therefore, there is neither original ma-

Fig. 7. The original specimen of *Colias croceus* ab. *cremonae* collected by F. Cremona and referred to by Verity (1911) and A. Bang-Haas (1912) preserved at Museum für Naturkunde, Berlin. 7a) Original illustration (from Bang-Haas O., 1916); 7b) Dorsal side; 7c) Ventral side; 7d) Labels (b-d by courtesy of Théo Léger & Viola Richter, Museum für Naturkunde, Berlin).

terial of ab. *erateformis* nor an image that could be analyzed and compared with ab. *cremonae*. Despite the absence of pictorial information about this aberration, from the available data, it is fair to assume its habitus to be nearly identical to that of *Colias erate* (Esper, 1805), and would, therefore, still show some orange pigment in the discal spot of the hindwing and pink suffusion at least along fringes on the underside.

Authors' interpretations of yellow forms of *Colias croceus*

A review of the literature shows that the authors who dealt with yellow forms of *Colias croceus* often referred interchangeably to aberrations *cremonae* and *erateformis*. These two forms, as mentioned above, are characterized by a yellow, rather than orange, color of the wings. However, as detailed below, ab. *cremonae* is unable to produce orange-red pigments, and scales of these colors or pink structures are completely absent. This determines an overall yellow-greenish hue. Ab. *erateformis*, instead, is described as identical to *C. erate* and, as such, it maintains the capacity to produce orange-red scales, particularly evident in the discoidal hindwing spot and the pink color of legs, antennae, and fringes. Some other yellow or white-yellow aberrations have similar characteristics, including *helicina* Oberthür, 1880, *flavomaculata* Braun, 1928, and *aubuissoni* Caradja, 1894. However, all these aberrations show orange and pink pigments.

Yellow forms have been observed by Meyer (1991) in Saõ Miguel and by Fuchs (1993) in Faial and other islands of the Azores's archipelago, where they were said to be quite common thanks to the great abundance of *Colias croceus* in those years. After a thorough assessment, Russell (2009) reported that a specimen collected by H.S. Fuller near Lewes in Sussex (England) in the 1920s and long believed to be *Colias palaeno* might have been instead *Colias croceus* ab. *cremonae*. Unfortunately, neither an image is available nor is the specimen in the Booth Museum (Brighton), where Fuller's collection is preserved, to probate the hypothesis. Salmon & Wakeham-Dawson (1999) recorded *Colias croceus* var. *cremonae* from the island of Madeira. The figure provided in their account agrees with typical ab. *cremonae*, where the orange and pink pigments seem to be absent (Fig. 8). Based on this observation, Russell (2020a) reinterpreted old records of *Colias hyale* from Madeira, concluding that these were instead misidentifications for *Colias croceus* ab. *cremonae*. Likewise, in 2020, Russell again corrected a published report of the previous year regarding the presence of *Colias hyale* among species of the Azores Archipelago and reinterpreted as *Colias croceus* ab. c*remonae* the observation in São Miguel Island that is not supported by any specimen in the local Museum (Russell, 2020b).

Verhulst (2000) brought in some ambiguity by referring to populations from the Azores Islands as of f. *erateformis* Niculescu, 1963, and represented this as "strangely similar" to *Colias erate*. He also listed f. *cremonae* Verity, 1911 from Hasmich (Lebanon), describing it as similar in ground color to *Colias palaeno europomene* (Esper, 1778) although with a greenish suffusion. His illustrations portray under *erateformis* two males from Faial (Azores) that show no orange or pink pigment. Therefore, these specimens correspond to ab. *cremonae* (Fig. 9).

Figs. 8-9. Published pictures of yellow aberrations of *Colias croceus*. 8) Male of "var. *cremonae*" from Madeira (from Salmon & Wakeham-Dawson, 1999); 9) Males attributed to ab. *erateformis* but, in reality, ascribable to ab. *cremonae* from Faial (Azores) (from Verhulst, 2000: pl. 73, figs 7-8).

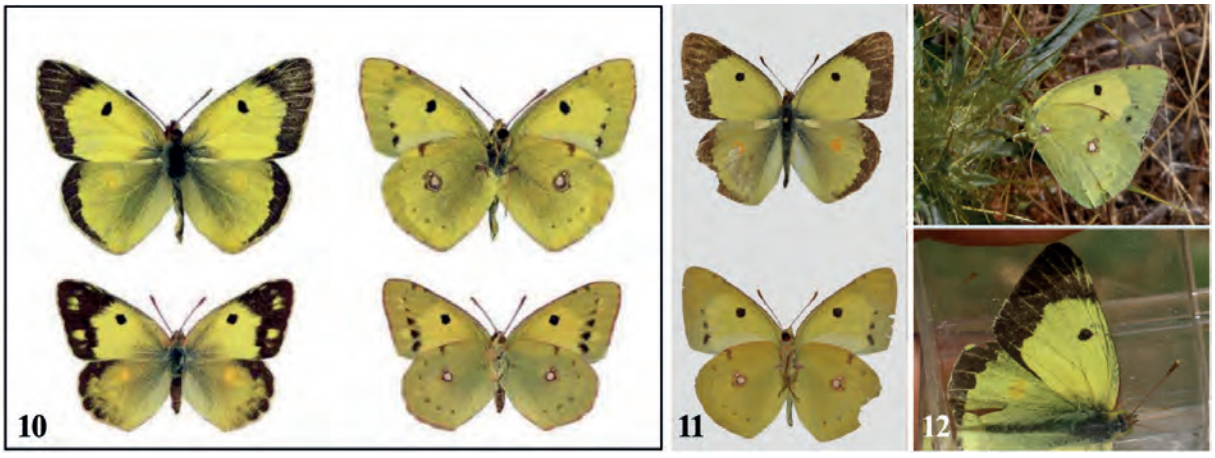
John *et al.* (2006) reviewed a previous publication by Makris (2003) that reported rare sightings of *Colias erate* in Cyprus. In their reassessment, these authors conclude that such records should instead be attributed to *Colias croceus* ab. *erateformis*. The published photographs show yellow aberrations with well-preserved orange spot (Fig. 10).

Similarly, Cuvelier & Mølgaard (2012) discussed a specimen from the island of Rhodes, confirming after its dissection that it was not *Colias erate* but *Colias croceus* ab. *erateformis*. This specimen is similar to those from Cyprus and clearly sports orange discal spot and pinkish fringes (Fig. 11).

Rowlings' (2022) website "EuroButterflies" shows a picture of a yellow form of *Colias croceus* photographed in Samos. The specimen, identified as ab. *cremonae* rather than *erateformis*, looks to be identical to that from Rhodes, being obviously endowed with pink pigment in the antennae and along the anal margin of forewings and exhibiting an orange discal spot on the hindwings (Fig. 12).

The British Butterfly Aberration website (2022) shows under ab. *cremonae* two males probably collected in the United Kingdom. One of these is almost identical to typical *Colias croceus*, while the other has a paler yellow-orange color but with pink fringes and orange discal spot more characteristic of ab. *erateformis* (Fig. 13).

The data portal of the Natural History Museum (London) (2022) shows 2749 (+2 under the name *C. crocea*) specimens of *C. croceus* virtually all from the British islands. Of those, 21 specimens collected in England are labeled "*Colias croceus* ab. *cremonae*". However, none is really of greenish-yellow color,



Figs. 10-12. Illustrations of yellow aberrations of *Colias croceus*. 10) Male and female from Cyprus identified as ab. *erateformis* (from John *et al.*, 2006); 11) Male from the island of Rhodes identified as ab. *erateformis* (from Cuvelier & Mølgaard, 2012); 12) Male from the island of Samos identified as ab. *cremonae* but seemingly attributable to ab. *erateformis* (from Rowlings, 2022).

Figs. 13-15. Published pictures of yellow aberrations of *Colias croceus*. 13) Two males attributed to ab. *cremonae* (from British Butterfly aberrations, 2022); 14) Male considered as ab. *cremonae*, from Girona (Spain) (from Pérez De-Gregorio & Romañá, 2019); 15) Male from Levant considered as ab. *erateformis* (from Benyamini & John, 2020).

being all of them with a typical orange nuance, even more than what does appear in the pictures, a fact that can be stressed upon visual inspection of the samples. One specimen labeled BMNH(E)1121814 and collected in Kent is particularly pale; it was reported by Frohawk (1938) as ab. *chrysotheme*. None of them also seem to qualify for ab. *erateformis,* where the background color is yellow rather than uniform orange. Finally, a specimen labeled as *Colias croceus* from Devon, with no indication of aberrations (BMNH(E)500881), is indeed yellow-orange and close to the description of ab. *erateformis*.

In 2019, Pérez De-Gregorio & Romañá recorded a specimen of ab. *cremonae* from Caldes de Malavella (La Selva), near Girona, Catalunya, on 10 April 1988. They stated this form corresponded to the female ab. *helicina* Oberthür, 1880, and that it was the very first specimen ever observed in Spain. As this specimen shows a clear orange discal spot and orangish suffusion, it is unlikely to be consistent with ab. *cremonae* (Fig. 14).

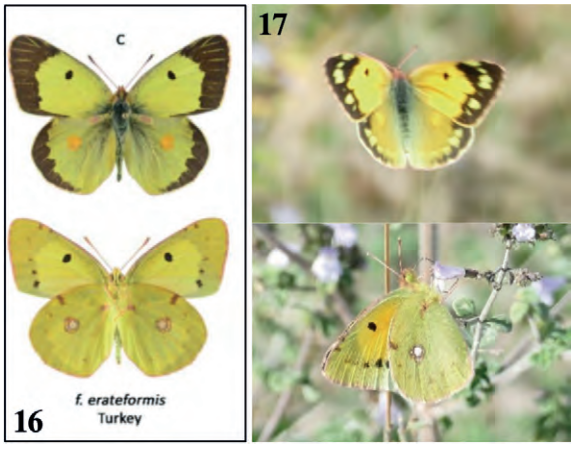
In their book on butterflies of the Levant, Benyamini and John (2020) show an image (Fig. 15) of a pale-yellow male that they attribute to f. *erateformis*. The authors describe it as "resembling the eastern species *C. erate* and being extremely rare and not limited to any geographical zone". They stress that in the past, such specimens have led to misidentifications in Cyprus (John *et al.*, 2006) and that ab. *erateformis* is also known to occur in Israel. Finally, the authors suggest that hybrids of *C. croceus* and *C. erate* have been observed.

In the article by Hutsebaut *et al.* (2020), there is an illustration of ab. *erateformis* from Konya (Turkey) (Fig. 16), though yellow forms had not been recorded in Turkey by Hesselbarth *et al.* (1995).

A further specimen collected in Madeira, that was attributed to ab. *cremonae* by Leraut (2016: 388, fig. 12), has a clear orange dominance in the wings and the discal spot, features that are not compatible with the absence of orange/red (and pink) pigmentation characteristic of ab. *cremonae*.

Following the call for information that we issued through the *Associazione Lepidotterologica Italiana*, we were contacted by Pierluigi Curcio, who forwarded a photograph taken in Sanza (Salerno province, Italy) in October 2021 showing a yellow form of *Colias croceus* that exhibits an orange suffusion and is, therefore, attributable to ab. *erateformis* (Fig. 17). Specimens referable to ab. *erateformis* have been reportedly collected by Joseph Grieshuber in Pfaffendorf, Görlitz (Sachsen, Germany) on 6.IX.2002 and along the Elbrus Range (Dizin, Iran) at an elevation of 2700-3000 m on 17.VI.2001 (J. Grieshuber, pers. comm., 2022).

Finally, searches of nature observation platforms, such as iNaturalist and Ornitho did not result in detection of ab. *cremonae*. iNaturalist listed 12,193 observations referring to *C. croceus* (12 May 2023), but aberrations are not signaled or especially highlighted, and the vast majority of images do not allow assessment of the dorsal features.



Figs. 16-17. *Colias croceus* ab. *erateformis*. 16) Male from Konya (Turkey) (from Hutsebaut *et al.*, 2020); 17) Female from Sanza, Salerno (southern Italy) (photo by Pierluigi Curcio).

Shedding clarity on the yellow aberrations

The long and often confusing history about the recording of yellow aberrations of *C. croceus* requires some insights. An early article by Russell *et al.* (2003) already attempted to shed light on the expression of such forms. Their study revealed that ab. *cremonae* is more frequent in males than females, and that there are also rare white females (f. *helice*) of ab. *cremonae*, which these authors described as ab. *cremonaehelice*. These individuals are both rare and difficult to spot because they are similar in all respects to f. *helice*, though they lack the pink pigment on the wing fringes, legs, antennae, pubescence, and orange on the discal spot. Russell and co-workers thus suggested that ab. *cremonae* could be expressed by a recessive mutation

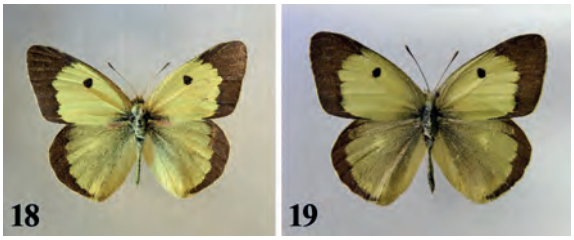
blocking the synthesis of such pigments (termed "red" and "orange").

This phenomenon has recently been studied by Hutsebaut *et al.* (2020), who analyzed the various forms of *C. croceus* occurring in the Azores. Their research focused on the polymorphism of this species, which also occurs in many other Coliadinae species together with the ancestral "*alba*" polymorphism that produces white-colored females sharply distinct from yellow-orange ones (Robinson, 1971). Coloration in Pieridae, including the Coliadinae, is determined by pigments of the pterine group contained in granules located in the transverse ridges of the scales. Among such pigments, most relevant are leucopterins, xanthopterins, and erythropterins, which absorb light at different wavelengths (ultraviolet, violet and blue, respectively), thus producing white, yellow and orange/red coloration (Hutsebaut *et al.*, 2020). The normal forms and the white females of *C. croceus* are an expression of the '*alba*' polymorphism at the autosomal locus BarH-1, with *helice* females being produced by the dominant '*alba*' gene that is expressed only in this sex. Such polymorphism, which also appears to be modulated by environmental factors, affects the downstream pathway of pterin biosynthesis, so that when '*alba*' is carried by a female, it leads to low levels of xanthopterins and erythropterins, and hence to the white coloration of f. *helice*. In their work, Hutsebaut *et al.* (2020) also studied the male and female ab. *cremonae* and the female ab. *cremonaehelice* found in Faial, Azores. They suggest that the rare lemon-yellow forms depend on polymorphism at another locus where homozygosity of a recessive allele suppresses synthesis of "orange/red" pigment(s) by preventing the transformation of precursor xanthopterins into erythropterins. Such polymorphism, aptly called '*cremonae*', can, in turn, combine with the '*alba*' polymorphism to produce the ab. *cremonaehelice*. Laboratory evaluations were also carried out via breeding experiments with *cremonae* individuals only. Russell *et al.* (2003) and P.J.C. Russell (pers. comm. 2022) observed that crosses *cremonae* x *cremonae* invariably produced sterile eggs. As *cremonae* individuals are considered to be homozygous for the recessive character suppressing erythropterins, in theory, their offspring should not differ in this respect from their *cremonae* parents, but the fact that eggs from *cremonae* x *cremonae* matings are unfertile suggests that the genetic basis of the '*cremonae*' polymorphism is more complicated. It possibly involves other loci that affect or modulate viability in *cremonae* individuals that derive from matings of *croceus* parents that are heterozygous for the character *cremonae*.

CONCLUSIONS

To properly depict the distribution of the yellow forms of *Colias croceus,* one needs to make two basic assumptions. The first is that ab. *cremonae* is indeed deprived of the capacity to synthesize orange/red pigments, as suggested by Hutsebaut *et al.* (2020), hereafter the absence of pink color on the fringes, antennae, legs, thoracic hairs and of orange in the discal spots. The second concerns the interpretation of what is ab. *erateformis.* That needs to be based upon the wording by Niculescu that "the resemblance is perfect and total and cannot be distinguished by drawing and coloring (from *Colias erate*)". Contrary to ab. *cremonae* of *Colias croceus*, *C. erate* has evident orange/red pigments in fringes, thoracic hairs, antennae, legs and discal spot. Therefore, for recording reasons of these genetically based forms, we suggest proceeding in analogy to rulings of zoological nomenclature and strictly adhere to features of the original specimens that served for their descriptions, these being the male from Hazmieh collected by F. Cremona for ab. *cremonae* and by inference after the wording used by Niculescu (1963), pale lemon-yellow individuals with orange/red pigments visible in the pink fringes, antennae, thoracic vestiture and legs as well as in the orange discal spot (and occasionally general suffusion) for ab. *erateformis*. The very same concepts for the two aberrations have been followed by Hutsebaut *et al.* (2020).

In the light of these assumptions, the rare ab. *cremonae* has been found so far in Lebanon, Azores (especially the island of Faial) (Meyer, 1991; Fuchs, 1993; Russell *et al.*, 2003; Russell, 2020b; Hutsebaut *et al.*, 2020; Collection N. Grillo at the Museum of Natural History "Giacomo Doria" of Genoa, Italy) (Figs. 18-23), Madeira (Russell, 2020a; Salmon & Wakeham-Dawson, 1999), and Piedmont (Italy). The other yellow form shows residual orange/red pigment distinguishable as ab. *erateformis* has been observed so far in Romania (Niculescu, 1963), Cyprus (John *et al.*, 2006), Rhodes (Cuvelier & Mølgaard, 2012), Samos (Rowlings, 2018), Turkey (Hutsebaut *et al.*, 2020), Israel (Benyamini & John, 2020), Catalunya, Spain (Pérez De-Gregorio & Romañá, 2019), Campania, Salerno (southern Italy) (Pierluigi Curcio, pers. comm. 2022),



Figs. 18-19. *Colias croceus* ab. *cremonae* from Faial (Azores), males ex Collection Nunzio Grillo (Museo di Storia Naturale Giacomo Doria, Genoa, Italy).

Figs. 20-23. *Colias croceus* ab. *cremonae* from Faial (Azores), male (upper images) and female (lower images) ex Collection Peter Russell (dorsal and ventral sides).

Sachsen (Germany) and Elbrus range in Iran (Joseph Grieshuber, pers. comm. 2022). Fig. 24 shows a distribution map for aberrations *cremonae* and *erateformis.*

Yellow forms of *Colias croceus* have been observed in various areas of the West Palaearctic region, but the appreciation of their actual distribution has been hampered by frequent confusion in the usage of their names. We support, therefore, the distinction after the clear criteria proposed by Russell *et al.* (2003) and Hutsebaut *et al.* (2020) of ab. *cremonae* as being completely incapable of synthesizing orange/red pigment, while other aberrations such as *erateformis* maintain that capacity, although to a limited extent. We concur that further biochemical and genetic studies are crucial to shed more light on these rare forms.

Mapping the precise distribution of rare aberrations of common butterfly species provides important baseline information for assessing the ecological genetics and the evolutionary fate of such interesting forms in the wild. Further to this, the populations hosting these forms also become sources of valuable specimens in the analysis via crossing experiments of the formal genetics of color polymorphisms.

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Fig. 24. Distribution map of *Colias croceus* aberrations *cremonae* and *erateformis* in the West Palearctic region as documented through available publications, website consultations and personal communications. The round yellow circles refer to ab. *cremonae* and the orange triangles refer to ab. *eratiformis*.

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