The lifecycle and ecology of the Spinose Skipper – *Favria cribrellum* (Eversmann, 1841) in the Republic of North Macedonia (Lepidoptera, Hesperiidae)

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Abstract. The Spinose Skipper, *Favria cribrellum* (Eversmann, 1841) [formerly in *Muschampia*] is considered to be a very localised species in Eastern Europe occurring in only a small number of isolated colonies. Its ecology, especially relating to its host plant, has long remained unknown. Only in the last decade of research has more light been shed on the distribution and habitat requirements of this species in its western range. The host plant of the Spinose Skipper in the Republic of North Macedonia is revealed for the first time. Three eggs and three larvae were discovered in 2017 on a species of *Potentilla*, tentatively identified as *P. detommasii*, from a site near Govrlevo, SW of Skopje. The choice of a cinquefoil as a hostplant provides new evidence to support the species recent separation from the genus *Muschampia*.

Introduction

Favria cribrellum (Eversmann 1841), formerly placed in *Muschampia* Tutt, [1906] or the Spinose Skipper, is a rare and very localised hesperid species in Europe. It is recorded from several countries in Eastern Europe: Serbia (Dincă at al. 2010; Popović and Đurić 2014; Langourov 2019), the Republic of North Macedonia (Schaider and Jakšić 1989; Verovnik and Micevski 2009; Dincă et al. 2010; Davkov and Mérit 2018), Bulgaria (Kolev 2003; Dincă et al. 2010; Hoejgaard and Beshkov 2011; Langourov 2019; Wagner and Kolev 2019), Romania (Rákosy et al. 1997; Székely 2008), Ukraine (Nekrutenko and Tshikolovets 2005; Tshikolovets 2009, 2011), Russia (Southern Urals) (Eversmann 1841; Tshikolovets 2009, 2011) and more recently from Greece (Davkov and Mérit 2017, 2018). From Hungary no records have been confirmed; reports are most likely due to confusion with older records from Western Romania, once part of the Austro-Hungarian Empire, and at present the species should not be considered as a member of the butterfly fauna of this country (Dincă et al. 2010). It is estimated that the Spinose Skipper is present in only 30 sites across its European range (Dincă et al. 2010; Davkov and Mérit 2018) and has been designated a status of NT (Near Threatened) in the European Red List of Butterflies (van Swaay et al. 2010).

Outside Europe, *F. cribrellum* inhabits a large area stretching from Russia (Altai, Siberia, Amur), Kazakhstan, all the way to Mongolia and Northern China (Tolman and Lewington 1997; Gorbunov 2001; Tshikolovets 2009, 2011), however, it is considered an uncommon and localised species. There

has been much speculation regarding the choice of host plant of the Spinose Skipper. Several papers have been published during the last decade shedding light on the distribution and habitat requirements of this species in the western part of its range (Dincă et al. 2010; Davkov and Mérit 2018). Many authors have suggested a cinquefoil (*Potentilla* L.) species as the potential host plant (Rothschild 1914; Higgins and Riley 1980; Chinery 1989; Korshunov and Gorbunov 1995; Tolman and Lewington 1997; Gorbunov 2001; Nekrutenko and Tshikolovets 2005; Tshikolovets 2009, 2011; Dincă et al. 2010; Tshikolovets and Nekrutenko 2012). Davkov and Merit (2017, 2018) speculate that both *Potentilla deorum* Boiss. and Heldr and *Potentilla kionaea* Halácsy could be utilised as host plants by *F. cribrellum* in Greece. According to the observations of S. A. Andreev, in the Volga region (Tikhonov 2021) caterpillars develop on a species of *Marrubium* L. Finally, Wagner and Kolev (2019) discovered both eggs and larvae on *Fragaria viridis* Weston in the Sofia district of western Bulgaria.

Materials and methods

During the period from 2014 to 2017 several field trips were conducted at a site near Govrlevo, SW of Skopje in the Republic of Northern Macedonia with the aim of unearthing the host plant of the Spinose Skipper. The locality was previously known to both authors as an area where healthy populations of the butterfly occurred. The first visits to the site were carried out between 9.v.2014 and 22.v.2014 by the second author. All other surveys were undertaken by the first author, the first one on 30.iii.2016, the second on 15.viii.2016, the third between 13–14.v.2017, the fourth on 2.vi.2017 and the last on 14.viii.2017. During their initial visits the authors concentrated on searching for plants of the *Phlomis* L. genus, but they also inspected the leaves of several *Potentilla* species found at the site. It wasn't until 13.v.2017 that the host plant was discovered and three eggs collected. Several seedlings and a number of mature plants were dug up from the habitat at this time and placed in wet cloth in a plastic bag and kept moist until the end of the field trip. In addition, a quantity of soil from the habitat was taken in order to help nurture the relocated host plants. In total, 11 plants in different stages of development were removed from the site. The newly hatched larvae were placed onto plant seedlings. The roots of these seedlings were immersed in water in a plastic bottle, with a wad of cotton wool placed at the base to stop the young larvae from falling into the water. The upper part of the plant was covered with a plastic bottle, and some fine netting was placed over the opening to prevent the larvae from escaping, and to prevent potential predators from entering the container. The remaining plants were placed in water. All these plants reacted well to their new environment and started growing new roots in the first week. For the first two weeks the larvae were kept indoors under artificial light (for a 12-hour period) before being transferred onto potted plants. The pots were taken outside and kept in a sheltered, shady place. These plants, collected at the habitat in Govrlevo, had been transferred to black plastic pots, each 12 cm in diameter, and left in partial shade. Three, evenly spaced, wire hoops were inserted into the soil of each pot to form a framework over which a covering of fine netting was emplaced and secured to the rim of the pot using an elastic band. One larva was placed in each pot.

Results

Habitat

The habitat of *F. cribrellum*, SW of Skopje in the Republic of North Macedonia, is an area of limestone at an elevation of 625 m, situated on an open hilltop carpeted with low-growing vegetation (notably *Anthyllis vulneraria* L. and cinquefoil species in May) along with sparsely interspersed

dwarf-conifer bushes, *Juniperus communis* L., many of which have died, leaving their dried up snags laying in situ (Fig. 1). In addition, a long-stemmed Poaceae species grows commonly in this area, widespread over much of the surrounding landscape. To the north, south and east there are a number of operating quarries, and there is concern that the habitat could potentially be destroyed; hence, in the opinion of both authors, the site is in urgent need of conservation.

Egg sampling

An intensive search for the host plant of *F. cribrellum* was carried out between 9–22.v.2014 by the second author. Male specimens were observed flying in a small area over an open hilltop near Govrlevo, in the municipality of Sopište, SW of Skopje on 19.v.2014 (Fig. 2). Two females were collected for ovipositing, one of which was discovered on a flowerhead in overcast conditions and appeared to be freshly emerged (Fig. 3). An intensive search was undertaken in the immediate area and sprigs of a number of possible host plants, primarily *Potentilla* species, were collected for a captive rearing experiment. One species of *Potentilla* appeared to be common at this site. In structure it resembled *Potentilla recta* L., but its hairy leaves and stem were significantly different (Fig. 4). On 29.v.2014, in captivity, a single egg was laid on a leaf of one of the cut stems of this cinquefoil species, but the ovum failed to hatch and was presumed infertile. Unfortunately, the second female died in a fold in the netting before laying any eggs. A new plan of action, focusing on locating an ovipositing female in its natural habitat, was undertaken during May, 2017. On the morning of 13.v.2017, with this in mind, the first author visited the same area surveyed by the second author during May, 2014. After an intensive search a female was found resting on a rock, and, after waiting for circa 45 minutes, the butterfly became active, whereupon FF witnessed her laying a single ovum on a small plant close to the area where it had settled. After laying the egg, the female flew away without laying any additional ova. The egg was laid on the underside of a leaf of a *Potentilla* species (Fig. 5). No more females were observed ovipositing that day. On the following day another female was observed laying an ovum on what appeared to be the same plant species. After searching for more eggs on similar plants, a third ovum was collected.

Rearing report

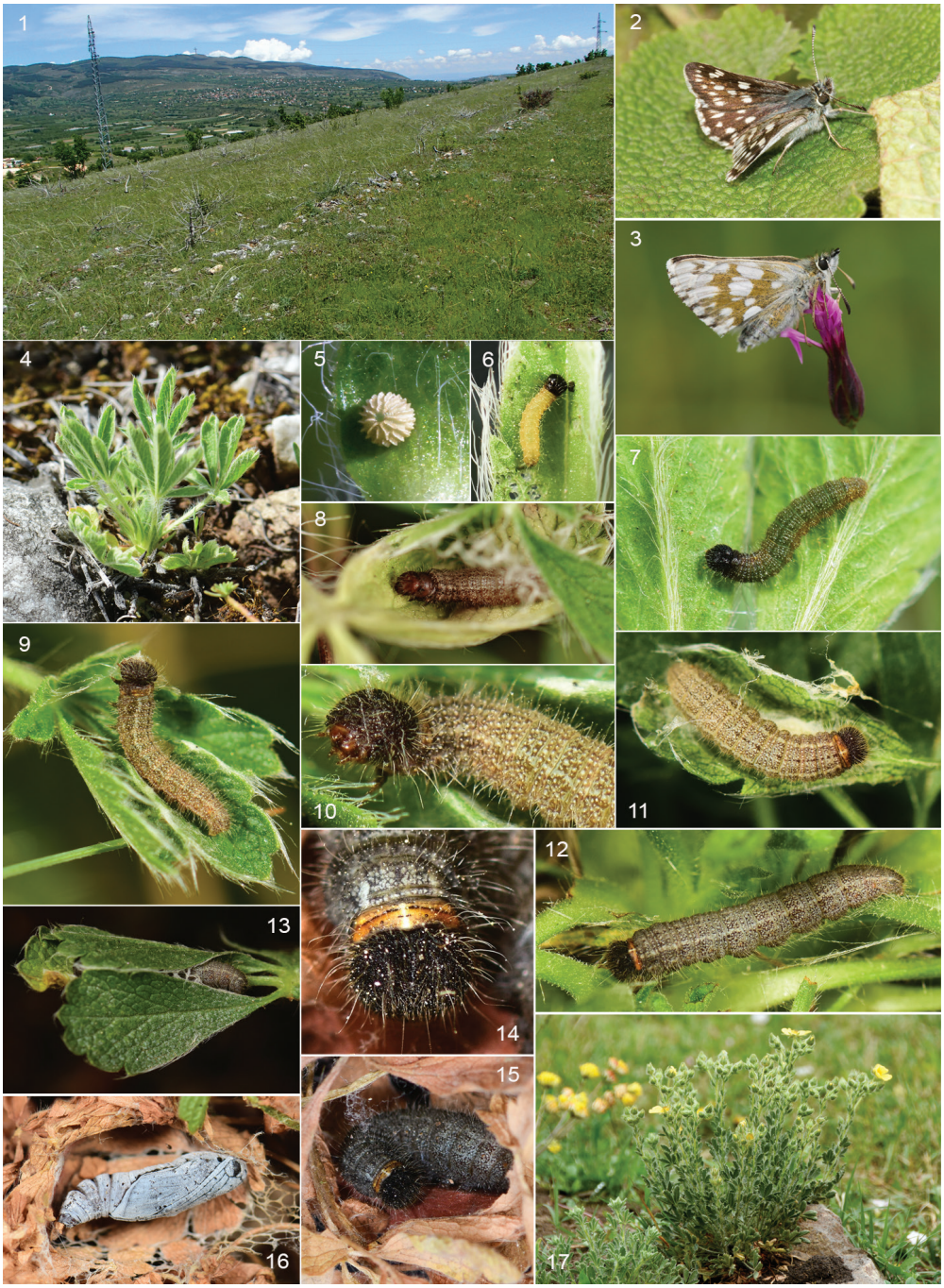
The first egg hatched on 20.v.2017, the second on 21.v.2017, while the third egg failed to hatch. The emerging larvae ate their way out through the top of the ova before settling on the leaves of their host plant; at this stage they did not eat (Fig. 6). Between 21–25.v.2017 the caterpillars commenced feeding on the leaves, but only in small amounts, leaving the cuticle intact. During this period the larvae did not construct any noticeable shelters. On 25.v.2017 one larva died for no apparent reason. On the same day the remaining larva constructed a small web on the leaf on which it had been nourishing and continued eating small amounts of the leaf, again leaving the cuticle intact, until 29.v.2017, after which time no new feeding was observed. The caterpillars did not eat for the following three days, presumably moulting during this period. On 1.vi.2017 fresh feeding was observed, only this time parts of the whole leaf were congested. On 2.vi.2017 the first author revisited the site in the Republic of North Macedonia and found a larva in a leaf shelter on the aforementioned *Potentilla* species. The caterpillar was collected and placed in a second rearing container. Over the following days both larvae continued to ingest the leaves of their host plant, mostly during the day, only exiting their shelters for a short period of time (Fig. 7). The caterpillars instantly retreated to their shelters if disturbed (Fig. 8). On 15.vi.2017 one larva was moved to a fresh host plant together with its silken-web shelter. It was conspicuously motionless at this time,

presumably in readiness to moult. Between 18–26.vi.2017 the two larvae did not show any signs of activity, both resting in their shelters. On 26.vi.2017 the first larva constructed a new, tube-shaped, shelter using three leaves. From 26–30.vi.2017 both caterpillars were observed feeding, consuming small amounts of their host plant (Figs 9, 10). Between 1–5.vii.2017 there were no signs of feeding, resulting in the first larva moulting on 5.vii.2017, the second on 6.vii.2017. Over the following days the caterpillars could be observed feeding for short periods during the daytime, both measuring approximately 10 mm in length. From 20.vii–2.viii.2017 there were no signs of feeding, the larvae remaining motionless in their shelters, and their behaviour suggesting the commencement of a summer aestivation period. On 14.viii.2017 the first author revisited the site near Skopje, this time finding two more larvae housed in their leaf shelters. Several other silken webs were discovered, but these had been discarded. The host plant at the site appeared desiccated, looking unsuitable for larval consumption, making the aestivation hypothesis more plausible.

The larvae resumed feeding during the first week of September (Fig. 11). In order to avoid the winter diapause, two caterpillars were placed on rooted host plants in plastic bottles inside the apartment of the first author and kept under a regime of continuous (artificial) light. However, in this situation the plants did not thrive, started to wilt, and, as a consequence, one caterpillar died on 15.ix.2017. The remaining three larvae were placed outside, each in individual pots containing growing host plants, two covered with netting and one without netting (in order to give the plant as much light as possible). Between 15–25.ix.2017 the larvae continued to feed, noticeably when the temperature exceeded 20 °C, and during this time they constructed new shelters made out of several leaves spun together from silk to form a larger web. The larvae continued to actively feed until the end of October (Fig. 12), at which time they were observed nourishing during the early afternoon when temperatures fluctuated between 11–13 °C. If disturbed the caterpillars immediately stopped feeding, and if they felt threatened they quickly retreated to their shelters. The two caged larvae entered winter diapause in their fourth instar (Fig. 13); the third caterpillar that had been exposed to the elements could not be found. During the winter months the larvae were kept outside, but were protected from direct rainfall. However, during an extremely cold period in January (temperatures plummeting to -19.4 °C on the 10.i.2018.) the cages were placed under a cold frame for two weeks. On 3.iv.2018 the sole surviving larva resumed feeding. By 17.iv.2018 this remaining larva constructed a new shelter and moulted into its final larval stage. During the following days it continued to routinely feed and was regularly observed outside its silken web. On 29.iv.2018 it once again made a new shelter constructed from older leaves that had been spun together (Figs 14, 15). It continued to eat during the day, regularly seen feeding between 1–3 pm On 5.v.2018 the larva took up a rigid posture within its silken cradle and by 8.v.2018 it had pupated (Fig. 16), resulting in the emergence of a male on 21.v.2018.

Adult description

Specimens from Govrlevo in the Republic of North Macedonia, like those from Bulgaria, Serbia, and Romania, are dark in comparison to type specimens from the Southern Urals, Russia. From Mt. Olympus, Greece, a new subspecies, ssp. *inexpectata* (Davkov and Mérit 2017), has been described. In comparison to specimens from the Republic of North Macedonia, they have extensive white markings (similar to type specimens from Southern Russia). As mentioned in their paper, “DNA analysis could not demonstrate any subspeciation, but a biological cline was initially suspected, also, genotypic analysis and the genitalia examination do not confirm the phenotypic results” (Davkov and Mérit 2017). It appears that the race from Mt. Olympus has been given



Figures 1–17. *Favria cribrellum* from Suva Planina, Republic of North Macedonia: **1.** Habitat at Govrlevo, 19.v.2014; **2.** Adult female, 26.v.2014; **3.** Adult male, 20.v.2014; **4.** Young host plant in its habitat; **5.** Ovum, 28.v.2014; **6.** L_1 larva, 24.v.2017; **7.** L_2 larva, 3.vi.2017; **8.** L_2 larva in shelter, 3.vi.2017; **9.** L_3 larva, 27.vi.2017; **10.** L_3 larva, close-up up of mouth parts, 27.vi.2017; **11.** L_4 larva, 12.ix.2017; **12.** L_4 larva, 27.x.2017; **13.** L_4 larva in silken tent, 28.x.2017; **14.** L_5 larva, close-up of head, 29.iv.2018; **15.** L_5 larva, 29.iv.2018; **16.** Pupa, 8.v.2018; **17.** *Potentilla detommasii* in its habitat, 20.v.2014. – Photographs by F. Franeta and M. Gascoigne-Pees.

subspecific rank based on the observation that, if compared with specimens from the Balkans, its forewings have extensive white markings. On Mt. Olympus it flies at a higher elevation and, not surprisingly, is on the wing later in the year.

Discussion

A detailed description of the larval morphology and the development stages of the Spinose Skipper is not given in this paper since Wagner and Kolev (2019) already presented a very accurate account of the preimaginal stages, and our observations, in the main, concur with their description. However, contrary to the finding of Wagner and Kolev (2019) who state that the L1 larva "creates a typical *Muschampia* shelter by cutting half of the leaflet width circularly and folding this part to the other side", FF noted that the L1 larvae did not construct any shelter and remained on the tip of the leaves feeding on small amounts of leaves, leaving the cuticule intact. The first shelter was constructed at L2 stage at which time he witnessed a larva folding two leaves together. It is worth noting that both groups of authors observed the caterpillars entering a summer diapause. While visiting the habitat in the Republic of North Macedonia during August, the first author noted that the host plants had entered a summer dormancy to avoid desiccation, hence making them unsuitable for larval development. Both authors unsuccessfully attempted to induce the larvae to bypass a winter diapause by exposing them to constant light during the later stages of their larval development, confirming the species is undisputedly univoltine. However, the most interesting observation relates to the species host plant. At the time of egg sampling, the information regarding the host plant in Bulgaria published by Wagner and Kolev (2019) was not available to MGP and FF, and a wide range of plants were treated as possible host plant candidates. After observing females laying eggs, a plant sample was collected and presented to the Faculty of Biology, University of Belgrade, where it has been provisionally identified by Professor Gordana Tomović as *Potentilla detommasii* Ten. (Fig. 17). Taking into consideration the choice of host plant of the Spinose Skipper, it is worth noting that all species from the Western Palaeartic region that were considered to be in the *Muschampia* genus, prior to the recent taxonomic rearrangment (Zhang et al 2020) were known to feed on plants from the genus *Phlomis*: *M. proto* (Ochsenheimer, 1816) on *Phlomis crinita* Cav., *P. bovei* De Noé, *P. fruticosa* L., *P. lychnitis* L., *P. herba-venti* L. and *P. pungens* Willd.; *M. alta* (Schwingenschuss, 1942) on *P. fruticosa*; *M. proteides* (Wagner, 1929) on *P. brachyodon* (Boiss.) Zohary ex Rech.f., *P. kurdica* Rech.f. and *P. chrysophylla* Boiss.; *M. mohammed* (Oberthür, 1887) on *P. crinita* and *P. bovei*; *M. tessellum* (Hübner, 1803) on *P. samia* L., *P. tuberosa* (L.) Moench. and *P. pungens*; while the host plant of *M. leuzeae* (Oberthür, 1881) is believed to be a species of *Phlomis* (Tolman and Lewington 1997; Benyamini and Avni 2001; Tshikolovets 2011, Hinojosa et al. 2021). Similarly, all other species of the *Muschampia* genus prior to the recent taxonomic changes, that have a documented lifecycle, use plants of the genus *Phlomis* (Dincă et al. 2010). Consequently, and understandably, it was assumed that the Spinose Skipper would also utilise *Phlomis* as its larval host plant. However, having observed ovipositing on a cinquefoil species and, having taken into consideration the information published by Wagner and Kolev (2019), regarding the development of larvae in Bulgaria on *Fragaria viridis*, it can be concluded that the choice of host plant (Tribe Potentilleae) differs substantially from that of the *Muschampia* genus sensu stricto (prior to Zhang et al 2020) which utilise plants of the genus *Phlomis* or *Muschampia* sensu lato (after Zhang et al. 2020), mostly plants from the Lamiaceae family. Using nuclear and

mitochondrial DNA data, Zhang et al. (2020) found that *M. cribrellum* is not monophyletic with the genus *Muschampia* and thus is best assigned to the monotypic genus *Favria* Tutt, 1906, which is sister to the genus *Gomalia* Moore, 1879. Interestingly, representatives of the genus *Gomalia* are morphologically very different, when compared to *Favria*, particularly the egg and larval stages, as is their choice of *Abutilon* Mill. species (Malvaceae) as host plants (Benyamini 1990; Cock 2016). Finally, in light of the currently available data, Wiemers et al. (2020) proposed changing *Muschampia cribrellum* to *Favria cribrellum* as was used in the current taxonomic checklist of European Butterflies (Wiemers et al. 2018).

Conclusion

The host plant of the Spinose Skipper in the Republic of North Macedonia is a cinquefoil species. Several other species of cinquefoils were recorded at the site near Skopje. However, it was evident that the butterfly only utilises one species for oviposition. This plant species was growing in the driest parts of its habitat, in some places in large groups and in other situations as individual specimens. All three eggs were found on seedlings, each with six to eight leaves. After several field trips and rearing attempts, the authors have proved conclusively that the host plant of *F. cribrellum*, in the Republic of North Macedonia, belongs to the genus *Potentilla*, tentatively identified as *Potentilla detommasii*. This information, coupled with the data presented by Wagner and Kolev (2019) on the lifecycle of the species in Bulgaria, puts an end to any long-established speculations regarding the host plant of the Spinose Skipper. It is likely that in other habitats throughout its range, the species utilises different *Potentilla* species or other plants from the tribe Potentilleae. The utilisation of a host plant from the tribe Potentilleae both in Bulgaria and in the Republic of North Macedonia supports the molecular differentiation of this species from the genus *Muschampia*, whose species with a known lifecycle feed almost exclusively on species of Lamiaceae.

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