



***Phlomis tuberosa* L. (Lamiaceae) Confirmed as a Host Plant of *Paracossulus thrips* (Hübner, 1818) (Lepidoptera: Cossidae) in Bulgaria, with Notes on Habitats and Recommendations of a Survey Method**

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Abstract: *Paracossulus thrips* (Hübner, 1818) is a protected species in Europe through the Council Directive 92/43/EEC. Pupal exuviae belonging to this species were found at each of two patches at Chepan Mt. (Western Bulgaria) characterised by *Phlomis tuberosa* L. being a dominant plant species. This is the first record of this host plant of *P. thrips* in Bulgaria. Habitat types are provided for both patches of the host plant. Searching for exuviae is discussed as a preferred technique for monitoring this moth species.

Key words: protected moth species, pupal exuvia, vegetation, habitat types, western Bulgaria

Introduction

Paracossulus thrips (Hübner, 1818) is a Pontocaspian-Turkestanian faunal element, considered a post-glacial relict in the westernmost part of its distribution. Its distribution includes Hungary, Romania, Moldova, Serbia, Bulgaria, Turkey, Ukraine, Russia, Georgia, Armenia, Kazakhstan, Turkmenistan and Iran (SCHNAIDER 1978, ZAGULAJEV 1978, DE FREINA & WITT 1990, MACEK et al. 2007, YAKOVLEV 2019, ALIPANAH et al. 2021, RÁKOSY & GOIA 2021, RÁKOSY et al. 2021, BESHKOV & NAHIRNÍĆ-BESHKOVA, 2022). A report from Greece by GOZMÁNY (2012) has never been quoted before. Landscape, geographical position and absence of the host plant *Phlomis tuberosa*

L. (Lamiaceae) from the given locality make this record very suspicious. The records from Poland have been excluded by BAŁKOWSKI (2017) because they originated from areas outside the present borders of the country.

In Bulgaria, this lepidopteran species was reported from Burgas (REBEL 1916, BURESCH & TULESCHKOW 1943), Sliven Town (TSCHORBADJIEV 1919, BURESCH & TULESCHKOW 1943, GANEV 1984), Plovdiv Town (GANEV 1984), Reselets Village near Cherven Bryag Town (BESHKOV 1995) and below Topola village near Balchik Town on the Black Sea Coast (BESHKOV 1995, ABADJIEV & BESHKOV 2007). BESHKOV & NAHIRNÍĆ-BESHKOVA (2021) considered the report from Reselets Village as a result of a mis-

take. *Paracossulus thrips* has not been collected in Bulgaria between 1993 and 2020, although it was intensively searched for in north-eastern Bulgaria near to the localities where it had been collected before (the surroundings of Balchik Town). According to BESHKOV (2011), the localities near Balchik have been destroyed by human activities, such as golf courses and their accompanying infrastructure. In 2020 and 2021, the species has been found in eastern Serbia and western Bulgaria (BESHKOV & NAHIRNIĆ-BESHKOVA 2021, 2022). The new localities in eastern Serbia and western Bulgaria are very distant from the localities in Hungary, Romania and eastern Bulgaria.

Paracossulus thrips is a species listed in Annex II and Annex IV of the Council Directive 92/43/EEC. For almost 200 years after it had been described, nothing was known about the biology of its praeimaginal stages. POLUMORDVINOV (2002) mentioned *Artemisia* spp. as host plants in Russia. According to SUM (2014), DELI & DANYIK (2015), DANYIK et al. (2019) and PATALENSZKI et al. (2021), larvae of *P. thrips* live and feed within rhizomes and tubers of *Phlomis tuberosa* in Hungary. IACOB et al. (2021) proved that *Ph. tuberosa* is the host plant in Romania. In Bulgaria, *Ph. tuberosa* is distributed throughout the whole country up to 1200 m a.s.l. (ASSYOV & PETROVA 2012). It does not form monodominant communities but is found as an accompanying species in xerophilous phytocoenoses of grasslands of class *Festuco-Brometea*, shrublands of *Amygdalus nana* L., *Paliurus spinachristi* Mill. and, more rarely, in some forest stands of *Fagus sylvatica* L. (according to available data in EU-00-019 Balkan Vegetation Database and EU-00-013 Balkan Dry Grassland Database).

Transect-based counts of adults, using of light traps or semiochemical lures have been suggested as standard monitoring protocols for rare and critically endangered insect species (JONASON et al. 2014, LARSSON 2016). The attributes of species for monitoring include area or range of a species, relative abundance, phenology, demography, population dynamics and habitat requirements. Monitoring programmes for rare butterflies and moths are focused mainly on data collection about the adult stage. However, monitoring the non-adult stage has considerable importance for species with very short flight period and for species that are difficult to detect. Regular searches for empty pupal cases (pupal exuviae) can provide a potential additional tool for monitoring occurrence and relative abundance of rare species (RICHTER et al. 2013).

The aim of this article is to report the host plant of *P. thrips* in Bulgaria and determine the exact habitat types where the moth lives as well as, on this



Fig. 1. Patch of *Phlomis tuberosa* in the Chepan Mt., 1128 m a.s.l., 18th June 2022.

basis, to recommend effective method for monitoring this moth species.

Materials and Methods

Studied sites

Four patches with *Ph. tuberosa* at localities where *P. thrips* is known were surveyed for pupal exuviae of *P. thrips* on 25th August 2022:

1. Chepan Mt., below Petrovski Krast Summit, N 42.94743°, E 22.94943°, 1128 m a.s.l. (Fig. 1). *Phlomis tuberosa* was a dominant plant species at this patch of 5 x 3 m² and consisted of 70 flowering plants and at least 100 leaf rosettes.

2. Chepan Mt., below Petrovski Krast Summit, N 42.94772°, E 22.94983°, 1133 m a.s.l. The patch of 2 x 2 m² had 50 flowering plants and at least 30 leaf rosettes of *Ph. tuberosa*.

3. Ponor Village W, N 42.914448°, E 23.129438°, 918 m a.s.l. This patch of 5 x 2 m² had 20 flowering *Ph. tuberosa* and at least 40 leaf rosettes.

4. Bezden Village N, N 42.914333°, E 23.095043°, 882 m a.s.l. This patch of 2 x 1 m² consisted of five flowering plants and at least 20 leaf rosettes. It is situated in a doline – a closed depression in a karst relief. The soil in the doline is deeper than in the surrounding rocky area and is suitable for *Ph. tuberosa*.

Vegetation

The study area is in Chepan Mt., which is a part of BG0000322 Dragoman site from the Natura 2000 network in Bulgaria and is located within the Dragoman municipality. The existing habitat diversity was mapped and investigated by GRIGOROV et al. (2021). The syntaxonomical diversity of grassland vegetation in the region was also studied by VASSILEV (2012) and VASSILEV et al. (2012).

Two vegetation plots (relevés) were surveyed at Chepan Mt. following the Braun-Blanquet approach (WESTHOFF & VAN DER MAAREL 1973). The shape of the sample plots was square and the plot size was 16 m², as recommended for grassland vegetation (CHYTRÝ & OTÝPKOVÁ 2003). The nomenclature of vascular plants followed DELIPAVLOV & CHESHMEDZHIEV (2003). The syntaxonomical status of the vegetation plots was assigned according to personal expert knowledge and literature sources. Habitat types were determined according to the Directive 92/43/EEC (Interpretation Manual of European Union Habitats 2013, KAVRAKOVA et al. 2009).

Results

Single pupal exuvia of male specimens were found at each of the two patches in the Chepan Mt. (Figs. 2–4). As *Ph. tuberosa* is the host plant of the nearest populations in Hungary and Romania, this is an indirect proof that this species is the host plant at Chepan Mt. *Artemisia alba* Turra was not present in those patches but it was found a few metres away.

Vegetation description

The predominant vegetation is xerophytic grasslands dominated by *Stipa eriocaulis* Borbás, *A. alba* Turra, *Satureja kitaibelii* Wierzb. Ex Heuff., *Thymus callieri* Borbás ex Velen., *Poa angustifolia* L. and *Festuca dalmatica* (Hack.) K. Richt. The dominant habitat type is 62A0 Eastern sub-Mediterranean dry grasslands (*Scorzoneratalia villosae*) / E1.21 Helleno-Balkan *Satureja montana* steppes, while both ex-



Fig. 2. Pupal exuvia of male *Paracossulus thrips* in the Chepan Mt. 1128 m a.s.l., 25th August 2022.



Fig. 3. Pupal exuvia of male of *Paracossulus thrips*, semidorsal view. Scale bar: 1 cm.



Fig. 4. Pupal exuvia of male of *Paracossulus thrips*, left – semilateral view, right – semidorsal view. Scale bar: 1 cm.

plored sites belong to habitat type 6210 Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites) / E1.222 Moesio-Carpathian steppes. Patches 1 and 2 in the Chepan Mt. had different vegetation composition and physiognomy. At patch 1, the dominant plant species were *Ph. tuberosa* and *F. dalmatica*. Patch 2 had denser and higher vegetation coverage and the dominant plant was *P. angustifolia* L. On flat and slightly inclined terrains with moderately deep soils vegetation, the dominant plants were presented by communities of alliance *Festucion valesiacaе*, whereas on territories with shallow soils and rocky outcrops they belonged to phytocoenoses of alliance *Saturejion montanae*. Xero-mesophilic communities of the alliance *Chrysopogono-Danthonion* that are typical for deep, humid soils and on western and northern slopes had a transitional species composition with communities of the alliance *Cynosurion cristati* of the *Molinio-Arrhenatheretea* class. Small patches were also formed by groups of shrubs, such as *Syringa vulgaris* L., *Crataegus monogyna* Jacq. and *Prunus spinosa* L. On the northern slopes of the mountain, the successional processes of invasion by shrubs and trees (such as *Quercus cerris* L., *Q. dalechampii* Ten., *Carpinus orientalis* Mill. and *Fraxinus ornus* L.) were well-presented and lead to forming a mosaic with grasslands. In the past (more than 40 years ago), the area around the sites had been used as grazing pasture, while nowadays it is abandoned.

Discussion

Selection of habitat

BESHKOV & NAHIRNIĆ-BESHKOVA (2021, 2022) described habitats where *P. thrips* was found in western Bulgaria as “Mountain petrophytic steppe 02E1 with *Stipa*, *Silene*, *Satureja*, *Artemisia alba*, *Amygdalus nana*, *Centaurea*, *Limonium*, *Crataegus*, *Rosa*”. However, this cannot reliably be considered as the habitat type where the species occurs as all records are merely of specimens attracted to light traps placed at localities where such habitat type is dominant. BESHKOV & NAHIRNIĆ-BESHKOVA (2022) described the habitat at a locality in Serbia as “dry rocky grassland with *Artemisia alba* Turra and *Satureja montana* L. with scattered trees and bushes: *Cornus mas* L., *Prunus spinosa* L., *Crataegus pentagyna* Waldst. & Kit. ex Wild., *Syringa vulgaris* L., *Quercus pubescens* Willd., *Fraxinus ornus* L., *Acer campestre* L. and *Rosa* sp. The habitat type can be identified as 02E1 Mountain petrophytic steppes. Relationships with habitat classifications: EUNIS: E1.21 Helleno-Balkan [*Satureja montana*] steppes; PAL. CLASS.:

34.311 Helleno-Balkan savory steppes; HD 92/43: 62A0 Eastern sub-Mediterranean dry grasslands (*Scorzoneretalia villosae*)”. However, this was a dominant type at that locality and since they detected just one specimen at light, it was not clear from where it had flown. As *Artemisia* was mentioned in the literature as host plant and BESHKOV & NAHIRNIĆ-BESHKOVA (2021) found *P. thrips* in western Bulgaria at localities with abundant *A. alba*, the same authors targeted such habitats. BESHKOV & NAHIRNIĆ-BESHKOVA (2022) were successful in finding *P. thrips* at six out of 16 (38 %) selected localities, which was a great success for such a rare species, without knowing that *Ph. tuberosa* was the host plant.

In Hungary, *P. thrips* was found in 6250 Pannonic loess steppe grasslands and exceptionally in habitat types 6210 and 6240* Sub-pannonic steppe grasslands (*important orchid sites) (PATALENSZKI et al. 2021), while in Romania it inhabits 6210 and 6240 (IACOB et al. 2021). Habitat types 6250 and 6240 are distributed in northern Bulgaria. In view that the northern Bulgaria is the least studied region in Bulgaria in terms of Lepidoptera, it is possible that new studies will discover *P. thrips*. On the other hand, northern Bulgaria is a plain area without mountains and the majority of the natural habitats have been destroyed by agricultural practices.

Phlomis tuberosa is present in rocky habitats 62A0/E1.21 at all studied localities but it is not abundant there. It is abundant in habitats 6210/E1.222 where the terrain is flatter and the soil layer is deeper. *Paracossulus thrips* has preferences for areas where such a rocky habitat type is dominant. It is not futile to search for *P. thrips* in habitats dominated by *Artemisia alba* but further selection of habitats to be studied for the presence of this species has to be more detailed and better justified. Selection of potentially suitable habitats for *P. thrips* should include abundant *Ph. tuberosa* with aggregated populations in an area where the dominant habitat type is 62A0/E1.21, 6210/E1.222, for instance in western Bulgaria and eastern Serbia; in northern and eastern Bulgaria, attention should be paid to habitat types 6210, 62A0, 6240 and 6250. *Phlomis tuberosa* is best searched for in June and July (when it flowers) but also in the first half of August and even until October when dry stems are still standing. The ecological preference of *P. thrips* is similar in Romania (IACOB et al. 2021). Since the habitat types in which *P. thrips* have been found and the dominant habitat types in the areas where *P. thrips* has been found in western Bulgaria are not present in the eastern part of the country, it is conceivable that the host plant may be different in the eastern area, e.g., *Artemisia* spp.

Discovery of the host plant significantly improved knowledge on distribution of *P. thrips* in Hungary and several new populations were found in the country (DELI & DANYIK 2015).

Defining standard sampling technique on a unit of area is a prerequisite for obtaining comparable results between sites and years. PATALENSZKI et al. (2021) recommended a sampling square of at least 100 m² and at least two hours for counting exuviae.

Reasons why searching for exuviae is the best method for monitoring *P. thrips*

The searching for exuviae has several advantages for monitoring *P. thrips*. These are:

Simplicity: Searching for pupal exuviae involves only gently moving dry plant material around the host plant *Ph. tuberosa* on the surface of the ground. Tools that can be used are sticks, tweezers, hand rake, etc. It is quicker and easier than digging up rhizomes and tubers of the host plant. Using light traps requires much more time, equipment and energy.

Certain identification: Pupal exuviae are highly characteristic for this species. The pupae have two remarkable dentate semi-rings on the dorsal side of the abdominal segments (Figs 3, 4).

Independence of weather and time of day: In contrast, adults fly only on warm nights. They are active two-three hours after sunset, rarely during the night and dawn and never during the day (PATALENSZKI et al. 2021, DANYIK, personal observation).

Plants can be examined over a long period: The optimal period for searching for pupal exuviae is two-three months from the beginning of the flight period (PATALENSZKI et al. 2021).

Finding of exuviae shows the exact place of development: When collecting specimens by light trapping, it is not clear where the specimens have flown from and where they developed; thus, the exact place and habitat type cannot be determined. Despite the fact that *P. thrips* is not a good flyer (SUM 2014, DELI & DANYIK 2015, IAKOB et al. 2021, PATALENSZKI et al. 2021), several habitat types can still be present in a relatively small area of, e.g., 100 m radius from a light trap. As mentioned above, at the same place with different habitat types, *Ph. tuberosa* plants can be differently distributed: in some habitat types, they are densely grouped while, in others, individual plants can be present or even absent. Caterpillars pupate in the ground, close to the host plant they feed on, and the distance between the host plant and pupation site can be just a few centimetres. It is less likely for larvae feeding on roots, rhizomes and tubers to move far away from their host plant and then pupate. Pupal exuviae directly indicate that the larva pupated there

and, most probably, has fed in the very close vicinity.

Collecting population data: This method can provide information about population characteristics (relative abundance of the species in the habitat and abundance trends). It is possible to estimate population size and trends (PATALENSZKI et al. 2021, DANYIK, unpublished).

Non-invasive technique: Searching for pupal exuviae involves only gently moving dry plant material on the surface of the ground. Digging for rhizomes and tubers destroys host plants and the habitat of *P. thrips* and other organisms. Light collecting can disrupt the activity of adults and other nocturnal animals.

Conservation

As mentioned above, *Ph. tuberosa* occurs in flatter terrain and deeper soils than the dominant vegetation at *P. thrips* localities. Thus, we assume that lowlands surrounding localities where *P. thrips* was found in eastern Serbia and western Bulgaria (Vidlič Mt., Chepan Mt., Tri Ushi hills, plateau above Slivnitsa) could have possibly been strongholds of *Ph. tuberosa*. Nowadays, those areas are mostly arable lands. Exact habitat type and structure must be taken into consideration when managing habitats. Dry rocky grasslands as a dominant habitat type at the localities of occurrence of this species should not be neglected. While such habitats are probably not used either by larvae because *Ph. tuberosa* is rare there or by adults because they do not feed as their proboscis is reduced, such habitats could be used for resting places or stepping stones for adults while dispersing.

Phlomis tuberosa has aggregated populations in the studied habitats. Thus, any destruction of even 1–2 m in a radius around the host plant would be detrimental for *P. thrips*. To ensure conservation of this species, establishment of protected micro-localities should be considered. An action plan for conservation of populations of *P. thrips* in Bulgaria is in preparation. The fact that the host plant differs from that previously thought will turn the research on this species in a different direction. Further studies should target *Ph. tuberosa* at already known localities, especially those at Plovdiv, Sliven, Burgas, Balchik and Kavarna and in the wider surroundings as well as to search for pupal exuviae using the recommended technique.

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