

To the biology of the European lantern fly, *Dictyophara europaea*, in the Middle Volga region of Russia

Damir Bogoutdinov^{1*}, Ilya Mityushev², Natalya Girsova¹, Tatyana Kastalyeva¹, and Nelly Chigina³

¹All-Russian Research Institute of Phytopathology, Department of Molecular Biology, 143050 Bolshie Vyazomy, Moscow Region, Russian Federation

²Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, Department of Plant Protection, 127434 Moscow, Russian Federation

³Samara State Agrarian University, Department of Foreign Languages, 446442 Ust-Kinelsky, Samara Region, Russian Federation

Abstract. The European lantern fly, *Dictyophara europaea* (Linnaeus, 1767) (Insecta: Hemiptera: Dictyopharidae) is an abundant species in Eurasia and North Africa, inhabiting the grassy vegetation of open spaces, and does not have the status of a pest of agricultural plants. The purpose of this study was to assess the relative prevalence of planthopper under conditions of eco- and agroecosystems on herbaceous and woody plants in the Samara region of Russia for the period 1992-2016. Along with natural vegetation, *D. europaea* was also registered on potatoes, barley and perennial fodder grasses, as well as on cherry, plum and black poplar. The feeding of *D. europaea* was observed on potatoes, watermelon, pumpkin, alfalfa, as well as on wild plants: steppe sage, tuberous rank, chicory, and on woody plants: common lilac and bird cherry. It was found that the abundance of *D. europaea* increased by 2.2 times in the 21st century compared to the 20th century. It is reported that under conditions of the Samara region of Russia, *D. europaea* can be a potential vector of phytoplasma belonging to the pigeon pea witches'-broom group – 16SrIX, which may have phytosanitary significance for cultivated plants.

1 Introduction

The European lantern fly, *Dictyophara europaea* (Linnaeus, 1767) (Insecta: Hemiptera: Dictyopharidae), is distributed in the southern regions of Europe. Its range includes Albania, Austria, Belgium, Bulgaria, Czech Republic, Denmark, France, Germany, Greece, Hungary, Italy, Moldova, Montenegro, Poland, Portugal, Romania, Serbia, Spain, Sweden, Switzerland, Turkey and Ukraine; apart from Europe, the species occurs in Afghanistan, China, Iran, Kazakhstan, Kyrgyzstan and Tunisia. The GBIF website (accessed 17/03/2023) lists 714 findings for *D. europaea*, including data from entomological collections, as well

* Corresponding author: bogoutdinov@list.ru

as reports from individuals. The maximum amount of data is indicated for France (291 findings – 40.8%) and Germany (217 – 30.4%). There are also data on the distribution of the *D. europaea* in Bosnia and Herzegovina, Croatia, Israel, Macedonia, Sierra Leone, and Russia [2]. In the review information on *D. europaea* by G.K. Ganicheva (2014), Algeria, Armenia, Azerbaijan, Georgia, and Uzbekistan are also included in the range of the European lantern fly [3]. This planthopper has also been recorded in the Eastern Polissya of Belarus [4]. For Russia, from September 2015 to June 2022, data from 17 surveys are presented in geographic points with the following coordinates: 44.8N, 38.2E; 46.7N, 40.4E; 47.3N, 39.7E; 48.6N, 44.4E; 51.7N, 35.7E; 51.6N, 36.1E; 51.7N, 35.6E; 52.3N, 35.5E; 52.8N, 42.8E; 54.2N, 45.1E; 54.8N, 39.9E; 55.6N; 51.7E; 58.5N, 50.0E [2]. Based on these data, the Kirovo-Chepetsk line (58.5N, 50.0E) could be considered as the northernmost boundary of the range, and the south of Adygea (55.6N, 51.7E) the southernmost boundary. In the east of the European part of Russia, the range reaches the Urals, whereas in the Asian part it covers the southern part of Western Siberia [3, 5, 14]. According to the available information, the European lantern fly was first discovered as early as 1922 in Orenburg [3, 14]. The European lantern fly is a mesophilic species confined to forb associations in steppe habitats. *D. europaea* is a broad polyphage; in Europe its larvae were registered on agrimony – *Agrimonia* (Rosaceae Juss.), restharrow – *Ononis*, alfalfa – *Medicago* (Fabaceae Lindl.), in Ukraine – on sage – *Salvia* (Lamiaceae Martinov) [6]. Adults occur on plants of the celery family (Apiaceae Lindl.), yarrow – *Achillea* (Asteraceae Bercht. & J. Presl) and spurge – *Euphorbia* (Euphorbiaceae Juss.). In the Kharkiv region of Ukraine, it feeds on hybrid amaranth – *Amaranthus hybridus* L. (Amaranthaceae Juss.) [7]. In Central Asia, the species occurs along the banks of ditches and in gardens on cereal vegetation (Poaceae Barnhart) with an admixture of plantain – *Plantago* (Plantaginaceae Juss.) and bindweed – *Convolvulus* (Convolvulaceae Juss.), can damage melons (Cucurbitaceae Juss.), alfalfa – *Medicago*, carrots – *Daucus carota* subsp. *sativus* (Hoffm.) Schübl. & G. Martens (Apiaceae Lindl.) and beets – *Beta vulgaris* L. (Amaranthaceae Juss.), but mainly feeds on various weeds [5]. One generation develops per year, overwintering in the egg stage. Under conditions of Ukraine, larvae appear in May and can occur until autumn, adults – from July to September. In the 21st century in Europe, among the food plants, the following plant species are also identified: common yarrow – *Achillea millefolium* L., stinking hawksbeard – *Crepis foetida* L., rough sow thistle – *Sonchus asper* (L.) Hill. (Asteraceae Bercht. & J. Presl), couch grass – *Agropyron repens* (L.) Desv. ex Nevski, green foxtail – *Setaria viridis* (L.) P. Beauv. (Poaceae Barnhart), redroot amaranth – *Amaranthus retroflexus* L. (Amaranthaceae Juss.), perennial nettle – *Urtica dioica* L. (Urticaceae Juss.), old man's beard – *Clematis vitalba* L. (Ranunculaceae Juss.), and common toadflax – *Linaria vulgaris* Mill. (Plantaginaceae Juss.). In Serbia, in the research conducted on seedlings of meadow sage – *Salvia pratensis* L. (Lamiaceae Martinov), lanceolate plantain – *Plantago lanceolata* L., common toadflax – *Linaria vulgaris* Miller (Plantaginaceae Juss.) and English ryegrass – *Lolium perenne* L. (Poaceae Barnhart) individuals of *D. europaea* successfully developed from egg to adult. In these experiments, adult planthoppers demonstrated polyphage behavior, feeding on all available plant species without any species preference [8]. Observations of the field populations of *D. europaea* and adults kept in isolators made it possible to establish the morphological and behavioral features of all stages of development of the European lantern fly. The mating of the European lantern fly in Serbia was registered in August. From mid-August to mid-September, the mortality of inseminated males was noted both in the experiment and in the field. The average fecundity of females was 41.9 ± 11.0 eggs. The eggs are elongated oval, yellowish green, with a translucent chorion, 0.93×0.42 mm in size; the head end of the egg is pearly white, with a bunch of short processes (0.12×0.07 mm). To lay eggs, the female moving along the surface of the soil, collects dust-like soil particles with the end of her abdomen, which she holds together with

the secreted sticky liquid. The resulting moistened soil substance, with the help of movements of the anal segment and the vulva, turned into oval lumps, up to 4 mm in diameter. In these soil lumps, the female lays 2-4 eggs, over time, such a cradle fell off to the surface of the soil, where she overwintered. Thus, the female is able to lay up to 10-20 cradles with eggs, which are distributed at different points, which increases the safety of eggs under adverse effects of physical and biological factors. In the conditions of Serbia, the emergence of nymphs of the 1st generation took place in mid-May, their average size was 1.12 mm. At room temperature, after 3-4 days, nymphs of the 2nd instar, 2.60 mm in size, appeared, and after 5-6 days, nymphs of the 3rd instar, 3.63 mm in size. After 6-8 days, a molt was observed at the 4th instar, the body length was 5.19 mm, and after 7-10 days the nymphs molted at the 5th instar, the body length was 6.23 mm. In 8-12 days the 5th instar larvae turned into adults. Starting from the 5th instar, the nymphs change their variegated brown-white colour to green, which is also a feature of adults (Fig. 1). Thus, at room temperature, the period of development of nymphs to adults was 29-40 days. From the third instar, the larvae demonstrate active locomotion, which intensifies in subsequent instars. On average, the length of males was 8.49 (7.5-9.1), and females 10.0 mm (9.0-12.1).



Fig. 1. *D. europaea*, adult (photo by Ilya Mityushev)

Adults are very active during the day, often changing positions and food sources. The period of activity in the adult stage lasts up to four months (from late June to early October), the peak of occurrence was in mid-August and early September. As the drying of herbaceous vegetation occurs, active migration of adults to drought-resistant plants such as sage, clematis, trees and shrubs was noted in August. Therefore, when counting insects at the end of the growing season, an erroneous idea can be created about the preferential food specialization of planthoppers of this species [8].

D. europaea individuals communicate with each other using vibration signals [9].

In England (2014), it was shown that the average body weight of the *D. europaea* is 22.9 ± 0.7 mg. The hind legs are 50% longer than the front legs with a ratio of 1:1 and 1:1.5. The hind legs provide the main driving force when jumping. The jump is ensured by rapid and simultaneous pressing of the trochanters of both hind legs, actuated by the large muscles of the chest and accompanied by extension of the shins. When jumping, there was no movement of the wings and no noticeable rotation of the body in any plane, which reflects the stabilizing effect of the elongated shape of the body. When jumping, the starting speed was 4 m/s^{-1} , which is close to the maximum speed known for insects 5.8 m/s^{-1} (for

Engela minuta, Dicytyopharidae), and the height and length of the jump reached 100 cm, which is 100 times greater than the body length [10]. There is no data about the direct harm of the planthopper when feeding on plants, but in studies conducted in Europe it is known that the European lantern fly could be a vector of different groups of phytoplasmas: 16SrII-E, 16SrV-C and 16SrXII-A, for the latter it was experimentally confirmed [9]. This fact aroused an increased interest in the study of *D. europaea*, and made it possible to expand the knowledge of its biology. Transmission routes for plant vector-borne diseases are determined by the vector's preference for feeding on host plants that act as common hosts for the vector and pathogen, as well as the ability of the vector to acquire the pathogen from the host and inoculate other plants. Accordingly, *D. europaea* is considered as a potentially versatile vector of various phytoplasmas, therefore, knowledge of its biology is crucial for understanding the epidemiology of phytoplasma diseases[8, 11,12].

2 Materials and methods

Ability to act as a vector in the transmission of several groups of phytoplasmas, as well as the lack of information on relationship of *D. europaea* with cultivated plants, provoked our interest in the research of this planthopper. Counts carried out in the central zone of the Samara region of Russia (Kinelsky district) in 1992-2016, as well in some years in Bogatovsky (2013), Kinel-Cherkassky (1993), Stavropolsky (1993) and Volzhsky (1996) districts.

Insects caught by sweeping net (25-100 double sweeps per count) after being killed in the killing bottle were kept on cotton mattresses, species identification was performed using identification tables of insects [13], the results of the identification were recorded in the register and recalculated for 100 sweeps of the net. Between 1992 to 2015, from May to September, regular counts were carried out every 7-10 days on different types of cultivated plants in the fields and nearby vegetation. From 7 to 103 counts were carried out annually each 5-18 days during the vegetation period. There were no accounts in 2003-2005. Counts and identification of species were carried out by the authors of the article and graduate students of the Plant Protection Department of the Samara State Agricultural Academy. The data on insect counts were used for graduation theses and were not previously published. Planthoppers caught in 2011-2012 were placed in 70% ethanol, and some of them were analyzed for the presence of nucleic acid at All-Russian Research Institute of Phytopathology, according to the protocol by Tanne et al. (2001) with slight modification. Comparison of RFLP profiles with published profiles was used to identify the detected phytoplasmas [16]. To confirm the taxonomic affiliation at the group and subgroup levels, selected phytoplasma preparations were subjected to RFLP analysis with restriction enzymes: AluI, HaeIII, HhaI, HpaII, KpnI, MseI, RsaI, and BstUI [16, 17].

3 Results and Discussion

Due to the absence of data on *D. europaea* in the Samara region, I.Sh. Shakurov (2005) included the species in the list of the first record in the region. In 2002, he caught *D. europaea* on plants of the couch grass – *Elytrigia repens* (L.) Desv. ex Nevski. (Poaceae) [14]. In our surveys, *D. europaea* has been caught since 1992 and was found in Kinelsky (I – the village of Ust-Kinelsky, 53°16'06" N 50°34'53" E), Stavropolsky (II – from Bolshaya Ryazan 53°15'43" N 49°18'00" E) and Bogatovsky (III – Bogatoye village, 53°03'41" N 51°19'59" E) districts of Samara region. From 1992 to 1999 in 14 counts, 71 individuals were caught, on average 5.1 specimens (1-12) per 100 sweeps of the net per count, while their number averaged 26% (4-67) of the total number of all planthoppers. From 2002 to

2016, 647 specimens were caught in 58 counts. On average 11.2 specimens (1-84), they accounted for 29% (2-100) of the total number of captured planthoppers. Thus, in the 21st century, the abundance of the European lantern fly grew up 2.2 times (11.2/5.1) more than in the 90s of the 20th century, and the proportions in relation to other planthopper species changed slightly – 26 and 29%, respectively. The increase in the number of planthoppers may be due to climate change.

In the Kinelsky district of the Samara region (53°16'06" N, 50°34'53" E), *D. europaea* was caught in different biocenoses in 73 counts, including for the period from 1992 to 2002 in 22 counts: in 1992 (3), 1995 (1), 1997 (9), 1999 (9) and from 2002 to 2016 in 51 counts: 2002 (2), 2006 (9), 2007 (2), 2009 (5), 2011 (10), 2012 (7), 2013 (10), 2014 (5), 2016 (1 account). The earliest record of *D. europaea* was done on 30/06/1995 (Stavropol district) and the latest record on 11/09/1992 (Kinel region). The average estimated date (over the accounting years) of the emergence of the imago of *D. europaea* for the central zone of the Samara region was June 16. On average, there were 10.3 specimens of *D. europaea* per 100 double sweepings with an entomological net (1-84), which averaged 32.6% (1-100) of the total number of caught planthoppers.

In addition to natural vegetation, we have also recorded of *D. europaea* on crops: potatoes – *Solanum tuberosum* L. (1997, 2006, 2007, 2009, 2011, 2012) – an average of 5.9 (1-17) specimens, barley – *Hordeum vulgare* L. (2014) – 8 specimens, rapeseed – *Brassica napus* L. (1999) – an average of 5 (2-8) and forage grasses: alfalfa – *Medicago sativa* L. (1992, 1999) – an average of 4.3 (2-12), clover – *Trifolium pratense* L. (1992) – 3, goat's rue – *Galega orientalis* Lam. (1992, 2009) – an average of 9.5 (9, 10) and mallow – *Malva verticillata* L. (2011) – an average of 2.5 (2-3) specimens. This planthopper was also caught in 2013 on woody plants: cherry – *Prunus* subgen. *Cerasus* (Mill.) A. Gray, plum – *Prunus domestica* L. (Kinelsky district) and black poplar – *Populus nigra* L. (Bogatovsky district) on average 6 (5, 5, 8) specimens. For 30 counts, the average number of captured *D. europaea* on monocultures was: 5.5 individuals /100 sweepings.

For all the years of research, *D. europaea* was not registered on wheat (*Triticum*), sweet clover (*Melilotus albus* Medik), awnless brome (*Bromus inermis* Leyss.), chickpea (*Cicer arietinum* L.), oats (*Avena sativa* L.), millet (*Panicum miliaceum* L.), Sudan grass (*Sorghum × drummondii* (Nees ex Steud.) Millsp. & Chase), as well as on trees: apricot (*Prunus armeniaca* L.), small-leaved elm (*Ulmus parvifolia* Jacq.), smooth elm (*Ulmus laevis* Pall.), common birch (*Betula pendula* Roth.), pear (*Pyrus communis* L.), English oak (*Quercus robur* L.), white willow (*Salix alba* L.), white poplar (*Populus alba* L.), western thuja (*Thuja occidentalis* L.), Scots pine (*Pinus sylvestris* L.), common ash (*Fraxinus excelsior* L.), Tatar honeysuckle (*Lonicera tatarica* L.) and Siberian pea tree (*Caragana arborescens* Lam.). However, taking into account the polyphagous nature of *D. europaea*, one cannot exclude the colonization of these crops in July-September, when they migrate to plant species that retain succulence.

On natural vegetation (edges and roadsides of fields, along forest belts, steppe meadows, floodplains), *D. europaea* was identified in 37 counts in 1999, 2002, 2006, 2007, 2011, 2012, 2013 on average 12.2 (2-52) specimens/100 sweeps. This is 2.2 times more than on monocultures.

Larvae of the last instars were caught with a sweeping net twice: on 09/07/2010 on natural vegetation (8 adults and 1 nymph) in the Kinel district and on 17/07/2013 on grassy vegetation under an apple tree – *Malus domestica* Borkh. (4 adults and 8 nymphs) in the Bogatovsky district. The rare occurrence when sweeping with a net can be explained by the sedentary lifestyle of nymphs in the early stages of development and the presence of nymphs at the base of the plant stem. Among the cultivated plants, we observed the feeding of the *D. europaea* on potatoes (*Solanum tuberosum* L., Solanaceae), watermelon (*Citrullus lanatus* (Thunb.) Matsum. & Nakai.), pumpkin (*Cucurbita pepo* L., Cucurbitaceae), alfalfa

(*Medicago sativa* L., Fabaceae), as well as on wild plants: steppe sage (*Salvia subincisa* Benth., Lamiaceae), tuberous vetchling (*Lathyrus tuberosus* L., Fabaceae), and chicory (*Cichorium intybus* L., Asteraceae). As for woody plants, *D. europaea* was found on leaves of the common lilac (*Syringa vulgaris* L., Oleaceae) and bird cherry (*Prunus padus* L., Rosaceae). In 1994, planthoppers, including 1 European lantern fly, were placed in an isolation ward with nightshade plants: potato (*Solanum tuberosum* L.), tomato (*Solanum lycopersicum* L.), tobacco (*Nicotiana* L.) and petunia (*Petunia* Juss.). In 5 days, the *D. europaea* remained alive, therefore this period many times exceeds the time required for the transmission of phytoplasma infection to plants and indicates the absence of an antifeedant effect.

In 2011 and 2012, in 17 and 25% of the analyzed adults of *D. europaea*, respectively, caught in the Kinelsky district of the Samara region on natural vegetation nearby the potato field, phytoplasmas were identified; the analysis was performed at the All-Russian Research Institute of Phytopathology. In 2011 they were identified as phytoplasmas of the pigeon pea witches'-broom group – 16SrIX [15]. This is the only insect species in which this phytoplasma species has been identified in the Russian Federation and, as far as we know, the first case in the world of its detection in *D. europaea*.

Thus, in the research conducted in 1992-2016, the European lantern fly was registered in the Bogatovsky, Kinelsky and Stavropol districts of the Samara region of Russia. Despite the lack of published information, this species is not new to the region, as previously assumed, and the increase in its abundance is associated with climate warming. In our records, it has been detected since 1992. Nevertheless, since 2002 its abundance has increased by 2.2 times compared to the 90s of the 20th century. Taking into account the boundaries of the distribution of the species in Russia, much north of the Samara region, *D. europaea* can be found in all districts of the region, as well as in the neighboring Orenburg region, and may have a long-term status in the fauna of the Middle Volga region. In the Samara region, for the first time in Russia, it has been established that the following crops can be food plants of *D. europaea*: potatoes, barley, alfalfa, clover, goat's rue, cherry, plum, and also black poplar. Thus, being polyphagous, *D. europaea* prefers to inhabit the forbs of natural vegetation, where its numbers were on average 2.2 times greater than on crops (plantings) of monocultures. It was also noted that the number of *D. europaea* in weedy fields of crops and along the edge of crops was significantly higher than in the center of the field or on crops without weeds. The maximum number of planthoppers in the Samara region was detected in July-August, as well as on natural vegetation since 2002. During the years of detection of the European lantern fly, it averaged 32.6% of the number of caught species of the insect suborder Auchenorrhyncha Dumeril, 1806.

Although a number of invasive hemipterans have been introduced to Russia over the past three decades [18], the present research emphasises the importance of studying of biology and harmfulness of aboriginal species.

4 Conclusion

For the first time in Russia and European countries, the ability of *D. europaea* to colonize cultivated plants, including herbaceous and woody species, has been shown. Originally in the Russian Federation and in the world, a phytoplasma of the pigeon pea witches'-broom group – 16SrIX was found in the planthopper in Samara region. Taking into account the polyvector nature of *D. europaea* to different groups of phytoplasmas shown in Europe, it can be assumed that in some years it may have phytosanitary significance in the distribution of phytoplasmas in plant communities not only in the Middle Volga. This fact should be taken into account when studying the epiphytology of phytoplasma diseases and developing methods for their control.

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