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DIVERSITY OF HOPPER SPECIES (*HEMIPTERA: AUCHENORRHYNCHA*) IN THE VINEYARDS ESTABLISHED IN CONGAZ VILLAGE, COMRAT DISTRICT, REPUBLIC OF MOLDOVA

Svetlana GROZDEVA[1*], ORCID: 0000-0002-3850-4584,
Valeriu DERJANSCHI[1], ORCID: 0000-0003-4241-6453,
Irina MIHAILOV[1], ORCID: 0000-0002-6804-4742

[1]*Institute of Zoology, Republic of Moldova*
**Author for corresponding: Svetlana GROZDEVA – e-mail: svetlana.grozdeva.gargalyk@gmail.com*

Abstract. The paper presents the results of the monitoring of the hopper fauna in the vineyards established in Congaz village, Comrat district, Republic of Moldova. The observations were carried out from May to October 2022; as a result, there were detected 27 hopper species in the vineyard. Most of the species belong to the family Cicadellidae – 21 species, also there were identified members of families Membracidae – 1 species, Cixiidae – 4, Issidae – 1. Four out of those species are adventive imported from Asia (*Arboridia kakogawana, Japananus hyalinus*) and North America (*Scaphoideus titanus, Stictocephala bisonia*). Due to the use of the glue traps, there were obtained data on the seasonal dynamics of adventive hopper species and peculiarities of their behavior, as well as a number of potential vineyard pests were identified.

Key words: Hoppers, Fauna, Vineyards, Adventive species, Diseases.

INTRODUCTION

The Republic of Moldova has significant areas of grapevine. In 2012, the surface of fertile vineyards was about 129 thousand hectares, thus the country was ranked 13th in the word. The development of viticulture in the Republic of Moldova is based on favorable soil-climatic and geographic conditions for the vine cultures. Congaz village, where the research was conducted, is situated in the southern wine-growing region. The southern region is characterized by arid lands, different features of soil and climatic conditions. This area is favourable for the production of red and various dessert wines. One of the most serious problems, the sector of viticulture is facing, is related to the abandoned vineyards, which are littered with weeds and became nests of the spread of many types of pests and diseases. (Biroul Național de Statistică a RM, 2011).

Grape plants are damaged by numerous pests, as well as viral, phytoplasma, bacterial and fungal diseases. The list of pests of grapevine also includes hopper species belonging to order *Hemiptera*, suborder *Auchenorrhyncha*. The *Auchenorrhyncha* is one of the most abundant and species-rich insect groups associated with grapevine. Hopper species are phytophagous by type of feeding, as they feed by sucking saps from various parts of plants, and reproduce. Some hopper species evolve exclusively on cultivated (*Vitis vinifera*) and wild (*V. riparia*) grape varieties, being monophagous by type of feeding. Other species being polyphagous have a wider range of host plants, and vineyards can become an accidental feed source (Радионовская & Диденко, 2015; Chireceanu et al., 2022).

There are two types of damage related to the presence of *Auchenorrhyncha*. The first one is the direct damage as a result of their feeding, stinging and sucking the sap from plant tissues. In this context, as an example it can be mentioned the species *Arboridia kakogawana* (Martynov et al., 2019b). As a result of their feeding, characteristic small chlorotic spots appear on the upper side of the leaves along the veins, gradually capturing most of the leaf. Severely damaged leaves fall prematurely. The second one is related to the indirect damage generated by the ability of some species to act as vector for the economically important pathogens. One of the well-known species from this group is *Scaphoideus titanus* (Martynov & Nikulina, 2019a), an adventive species originating from North America, which is the vector of Canditus Phytoplasma vitis which causes phytoplasma disease of *Grapevine Flavescence Doree* (FD). The other planthopper species, *Hyalestes obsoletus* (Signoret, 1865), is known as a carrier of *Candidatus Phytoplasma solani*, responsible of Bois Noir (BN), the infection that is transferred from weeds to vineyards. (Chireceanu et al., 2019; Chireceanu et al., 2020; Chireceanu et al., 2022).

Is it crucial to know the status of plant and leafhoppers in the economics of grapevine. This information is necessary to make the analysis of the phytosanitary situation and to develop a system of protective measures. Early detection and monitoring are essential practices in preventing the spread of adventive species, as well as adopting the most appropriate management measures to established populations.

In addition to diseases and pests, the condition of grape bushes is often affected by unfavourable soil and weather conditions. In 2022, due to the drought, which was more noticeable in the south of the Republic of Moldova, in vineyards, severe hydrological stress was registered, and late-ripening grape varieties experienced a halt in growth and development. This affected the quality and quantity of the crop.

The aim of the present study was to investigate the species belonging to Auchenorrhyncha group detected in vineyards established in Congaz village, Comrat district in 2022, in terms of ecological characteristics and diversity of species, in order to provide background knowledge with scientific and practical utility in this field.

MATERIALS AND METHODS

The research was carried out in 2022 in the vineyards established in Congaz village, Comrat district. (46° 06’33’’N, 8° 36’16’’E). The location of research areas during this study are presented on the map in figure 1. The studied plantations were of 15-19 years old with a total area of 78 acres and were composed of national and international cultivars of *Vitis vinifera L.*: Cabernet Sauvignon, Flora (Lora), Victoria, Black Magic (Codreanca), Moldova, Lydia and others. The plantations belonged to owners in the area and were protected differently with chemical products against pests and diseases. The insect sampling was done using double-sided sticky traps (Card Cue Yellow, 12 x 25 cm), placed in a linear pattern on a row inside the plots (Figure 2). There was used one trap for each row. The sticky traps were installed diagonally along the aisles in order to evaluate the condition of the entire site more objectively.

The traps were changed every two-three weeks, from May to October. There were installed 184 traps during the research. The periods of installing the traps are shown in table 1. The specimens of hopper species were removed from the sticky traps and placed in test tubes with alcohol. In addition to using sticky traps, it was performed sweep-net sampling outside of the vineyards, on the road, for catching the hopper species *Hyalesthes obsoletus*.

Figure 1. *The location of the research point.*

Figure 2. *Fixed double-sided sticky trap. Image source: Grozdeva S.*

Table 1. *The dates of installation and removal of sticky traps*

Nr.	Period	Nr.	Period	Nr.	Period
1	28.05 -11.06.2022	4	16.07 - 03.08.2022	7	02.09 - 24.09. 2022
2	11.06 - 25.06.2022	5	03.08 - 20.08.2022	8	08.10 - 22.10. 2022
3	25.06 - 16.07.2022	6	20.08 - 02.09.2022		

Adult insects were determined by genus and species level using the microscope MBS-10. The male genitalia were dissected to accurately identify the species, following the taxonomic keys (Ануфриев et al., 1988; Емельянов, 1964, 2015). The specimens collected in this study are stored in the Museum of Entomology of the Institute of Zoology.

RESULTS AND DISCUSSIONS

As a result of researches conducted in the vineyards from Congaz village, Comrat district, during the vegetation season of 2022, more than 27 species of hopper species belonging to 4 families were caught on sticky traps, of which most are members of the family Cicadellidae (21 species), while the others are representatives of the families Membracidae (1), Cixiidae (4), and Issidae (1). Four of these species are adventive, imported from Asia and North America (in table 2 marked with an asterisk *). Table 2 presents the list of hopper species caught on sticky traps, providing information on the type of feeding, host plants and distribution area.

Thus, a significant part of hopper species listed in the table, due to their characteristic either polyphagy or oligophagy, is able to develop on grape plants in the conditions of the Republic of Moldova, and their life cycle is more or less connected with vineyards.

Table 2. *Diversity of hopper species captured on yellow sticky traps in grapevines from Congaz village, Comrat district, in 2022*

Nr.	Family/species	Type of feeding	Distribution area
CICADELLIDAE			
1.	*Anaceratagallia laevis* (Ribaut, 1935)	Polyphagous feeding on different species of herbaceous dicotyledons	Panatlantic-eucontinental-hyadean
2.	*Anaceratagallia ribauti* (Ossiannilsson, 1938)	Polyphagous, *Plantago* sp., *Trifolium* sp.	Western-Palearctic
3.	**Arboridia kakogawana* (Matsumura, 1932)	Monophagous, on *Vitis* sp.	Adventive species, is native to Asia
4.	*Arthaldeus striifrons* (Kirschbaum, 1868)	Oligophagous, on *Festuca rubra*, *Schedonorus* sp., *Trifolium* sp.	Pan-European
5.	*Austroagalli sinuata* (Mulsant & Rey, 1855)	Polyphagous, *Ononis* sp., *Solanum tuberosum*, *Zea mays*	Trans-Palearctic
6.	*Austroasca* sp.		Trans-Palearctic
7.	*Emelyanoviana mollicula* (Boheman, 1845)	Oligophagous, on *Salvia* sp., *Mentha* sp., *Verbascum* sp., *Artemisia* sp.	Western-Palearctic
8.	*Empoasca* sp.	Polyphagous, *Vicia* sp., *Medicago sativa*, *Amaranthus hybridus*, *Acer* sp., *Ulmus* sp.	Holarctic-Oriental
9.	*Eupteryx atropunctata* (Goeze, 1778)	Polyphagous, on *Lamium* sp., *Arctium* sp., *Verbascum* sp., *Melissa officinalis*, *Salvia* sp.	Pan-European
10.	*Eupteryx stachydearum* (Hardy, 1850)	Oligophagous, on *Lamium* sp., *Stachys* sp., *Melissa officinalis*, *Salvia pratensis*	Pan-European
11.	*Eupteryx urticae* (Fabricius, 1803)	Oligophagous, on Parietaria sp., Urtica dioica, occasionally Tanacetum vulgare subsp. siculum	Western-Palearctic
12.	*Fieberiella florii* (Stal, 1864)	Polyphagous, on *Ligustrum vulgare*, *Prunus spinosa*, *Rosa* sp., *Rubus* sp.	Holarctic
13.	**Japananus hyalinus* (Osborn, 1900)	Monophagous, on *Acer campestre*, *A. platanoides*, *A. pseudoplatanus*	Adventive species, is native to Eastern Asia
14.	*Macropsis* sp.	Narrowly monophagous, *Populus* sp., *Salix* sp.	Holarctic
15.	*Macrosteles sexnotatus* (Fallen, 1806)	Narrowly polyphagous, on *Avena sativa*, *Carex* sp., *Dactylis glomerata*, *Festuca* sp.	Trans-Palearctic
16.	*Platymetopius rostratus* (Herrich-Scaffer, 1834)	Monophagous, on *Centaurea* sp.	Southwestern-Palearctic
17.	*Psammotettix* sp.	Oligophagous, on *Corynephorus canescens*, *Phleum phleoides*, *Triticum* sp., *Avena* sp., *Cynodon dactylon*, *Stipa* sp.	Holarctic
18.	*Psammotettix confinis* (Dahlbom, 1850)	Oligophagous, on *Agrostis* sp., *Corynephorus* sp., *Festuca* sp.	Holarctic
19.	**Scaphoideus titanus* (Ball, 1932)	Oligophagous, on *Vitis vinifera*	Originally a North American species
20.	*Zygina flammigera* (Fourcroy, 1785)	Oligophagous, on *Crataegus* sp., *Malus* sp., *Prunus* sp., *Rosa* sp.	Trans-Palearctic
21.	*Zyginidia scutellaris* (Herrich-Scaffer, 1834)	Narrowly polyphagous, on *Agrostis* sp., *Avena* sp., *Carex* sp., *Dactylis* sp., *Echinochloa* sp.	Palearctic

MEMBRACIDAE			
22.	**Stictocephala bisonia* (Kopp & Yonke, 1977)	Polyphagous, oviposition invariably on a wood plant, subsequently the larvae develop on herbaceous plants	Originally a North American species
CIXIIDAE			
23.	*Hyalesthes obsoletus* (Signoret, 1865)	Polyphagous, on *Galium verum*, *Convolvulus arvensis*, *Ranunculus* sp., *Urtica dioica*	Southwestern-Palearctic
24.	*Reptalus quinquecostatus* (Dufour, 1833)	Polyphagous, on *Convolvulus* sp., *Malus* sp., *Prunus* sp., *Solanum tuberosum*, *Tamarix* sp.	European
25.	*Reptalus panzeri* (Low, 1883)	Polyphagous, on *Acer* sp., *Artemisia* sp., *Clematis* sp., *Prunus* sp., *Rosa* sp.	Trans-Palearctic
26.	*Cixius* sp.	Mostly species polyphagous, larvae at the roots, adults free on the leaves	Will be specified
ISSIDAE			
27.	*Agalmatium bilobum* (Fieber, 1877)	Polyphagous, on *Avena sativa*, *Vitis vinifera*	Holoarctic

Further analysis of the scientific literature along with authors' observations allowed to characterize some hopper species, which may be potential pests of grape plantations, including information about their biological and ecological characteristics. It is about the species: *S. titanus, A. kakogawana, J. hyalinus, H. obsoletus, S. bisonia*.

The main object of the study was American leafhopper *Scaphoideus titanus*, a species which develops one generation per year. It overwinters in the egg stage under the bark of grape bush stems. Larvae emergence from eggs in conditions of the Republic of Moldova lasts from the first decade (middle) of May to the first decade of July, and usually larva goes through five stages of development within 50-55 days. During their development, a significant number of young larvae die. According to the literature data, the death of larvae of the first, second and third instars reaches 50%. In the conditions of 2022, the first imago specimens were caught on sticky traps in the period 25.06 - 16.07, the last specimens were caught in the period 02.09 - 24.09 (Figure 3). On average, the imago lives for about a month depending on the weather conditions of the particular year. Adults are active at night and twilight, are capable of flight and can fly 25-30 meters, moving away during their lifetime at a distance of up to 500 meters from the place of development (Timuș et al., 2013; Martynov & Nikulina, 2019a; Гроздева, 2022).

Scaphoideus titanus is a vector of *Candidatus Phytoplasma vitis*, the pathogen, *Flavescence doree* of grapevine. Depending on the grape variety, the pathogen causes yellowing or reddening of the leaves, the edges of which are wrapped to the underside. Young shoots lose turgor and sag. Necrosis develops on the buds, black spots form on the shoots, and in winter the affected shoots often turn black and die. Inflorescences dry out and crumble. All this leads to crop loss and a decrease in its quality.

Within its natural range, leafhopper may be found in shady forests on forest edges and river valleys. In Europe, *S. titanus* generally is feeding and reproduces on *Vitis* sp., it develops not only on introduced American types of grapes, but also on Eurasian *Vitis vinifera L.*, significant areas of which making it the main feeding plant. Imago of *S. titanus* in USA may be found on different species of *Amaranthaceae, Apiaceae, Asteraceae, Chenopodiaceae, Fabaceae, Poaceae, Rosaceae, Ulmaceae*. Researches have shown that despite facultative polyphagia, only older larvae can complete their life cycle on representatives of other families with a high mortality rate. None of the plant

species, except representatives of the genus *Vitis*, showed the passage of the full life cycle of *S. titanus* from egg to egg (Martynov & Nikulina, 2019a).

The second species, *Arboridia kakogawana*, known as Japanese grape leafhopper, is an adventive species, which was described by Matsumura from Honshu Island in Japan in 1932 under the name *Zygina kakogawana*. The natural habitat of Japanese grape leafhopper covers Japanese Islands, Korean Peninsula and the south of the Far East. *A. kakogawana* is reported as an important pest of cultivated grapevine (*Vitis vinifera L.*) in areas of its native zone in East Asia and in the invaded regions of Eastern Europe. At present the species is continuing to disperse rapidly, expanding its distribution.

A. kakogawana was found in 2018-2019 during an inspection of the grape plantations, that was carried out in the central and southern regions of Moldova (Chisinau, Criuleni District, Causeni District, UTA Gagauzia) (Бондарчук et al., 2020).

During the whole period of research, a number of 71 adult *A. kakogawana* were caught on sticky traps on grapevine. The population dynamics of adult Japanese leafhopper on vine in 2022, based on trapping on sticky traps, showed that adults of *A. kakogawana* had an active development period on the vine from late May and early June to late September. The first adults in the amount of 6 specimens were caught on sticky traps in the period lasting from the end of May till the beginning of June. The last adults were trapped in the second half of September. Maximal number of specimens on grapevine was recorded in the second half of August and in September (Figure 3).

This leafhopper is known to be multivoltine. As reported by current literature, the Japanese leafhopper can develop between two and four generations per year depending on the geographical area. It overwinters in the adult stage under the bark of trees in nearby forests, after leaving the grapevine in early October. In Romania, in 2018, adults of *A. kakogawana* had an active period on the vine from early June to mid-November. Based on records of four maximum densities, the authors assume that *A. kakogawana* developed up to four generations on cultivated grapevine in the studied area in 2018, each of them lasting about one month. In climatic conditions of the South Coast of Crimea, A. kakogwana developed 3-4 generations per season being active from April till October. In Krasnodar Territory and Rostov Province there were 2 generations per year (Gnezdilov et al. 2008; Радионовская & Диденко et al. 2015; Chireceanu et al., 2019). The number of generations developed by hopper species in conditions of the Republic of Moldova, is not identified; the obtained data indicates three generations, however these facts should be studied objectively.

Imagoes and nymphs concentrate on the underside of grape leaves, forming dense colonies, mainly along the central and lateral veins of the leaf. As a result of their feeding, characteristic small chlorotic spots appear on the upper side of the leaves along the veins, gradually capturing most of the leaf. Severely damaged leaves fall prematurely. The number of damaged leaves by the end of summer – early autumn (August – September) can reach its maximum, amounting to 80-90% of the total number of leaves on the vine. The intensity of damaged leaves of different grape varieties may vary. Thus, the reduction of the photosynthetic leaf surface area during the period of berry growth and ripening negatively affects crop quality. Weakened and damaged plants are also less resistant to adverse environmental factors. A high population of hopper species can become the main reason for the delay in berries ripening and for the reduction of their quality (Martynov et al., 2019b). At present, the transfer of dangerous diseases caused by hopper species has not been studied sufficiently, as well as the issue related to possible consequences of tissue incisions during the egg-laying by hopper species. The examined plants were damaged by ticks, symptoms of fungal diseases were also noticed, but symptoms of leafhopper damage were not observed.

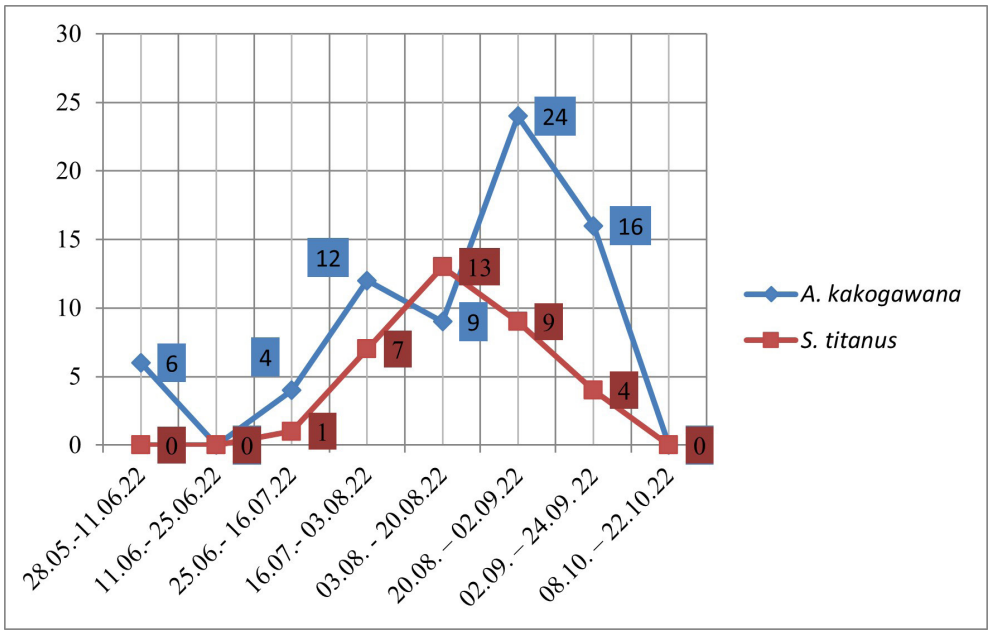

Figure 3. *Number of adults of A.kakogawana and S. titanus collected on yellow sticky traps (YSTs) in 2022.*

The third species, *Stictocephala bisonia* (Kopp & Yonke, 1977), is originally a North American species that is univoltine and winters as egg. Its oviposition is preferably on *Crataegus* sp., *Malus domestica*, *Populus* sp., *Prunus persica*, *Pyrus communis*, *Quercus* sp., *Salix* sp. Each egg is deposited singly in a 2 mm deep and 2-6 mm long cut in the bark of a young, 1-2 cm thick shoot. Groups of 6-12 eggs are deposited in a semicircular arc. All this results in a serious disturbance of shoot development, and, when repeated, to large-scale malformations. The suction damage caused by larvae is less dramatic, except in grape vines where infected shoots may turn discoloured and die off. Larvae can be found mainly on *Medicago sativa L.*, *Datura* sp., *Solanum* sp., *Trifolium pratense L.* (Гроздева, 2022).

The planthopper *Hyalesthes obsoletus* is a stolbur phytoplasma vector, which causes grapevine yellow disease *Bois Noir. H. obsoletus* is a polyphagous species (more than 50 host plants), but grapevine is not a preferred host (adults can feed on it, but the insect cannot complete its life cycle on it). H. obsoletus has one generation per year, including 5 larval stages. In summer, females lay their eggs on the stems of host plants near the soil surface. Larvae hatch and migrate into the soil, along the roots. In spring, L4 and L5 migrate towards the soil surface, and adults emerge in the soil. Adults are good flyers and they leave their host plants to explore the environment and find sexual partners. Direct control of *H. obsletus* is not envisaged, as grapevine is not a host for the insect. Many aspects related to the biology of *H. obsletus* have to be studied. In conditions of 2022, the first imagoes of planthopper were caught on sticky traps installed on the vineyard rows in the period of 28.05-11.06 (1), the largest number was caught in the period of 25.06-16.07 (34) (Figure 4). (Бондарчук & Хаустов, 2020; Хаустов et al., 2020; Haustov & Bondarciuc, 2021).

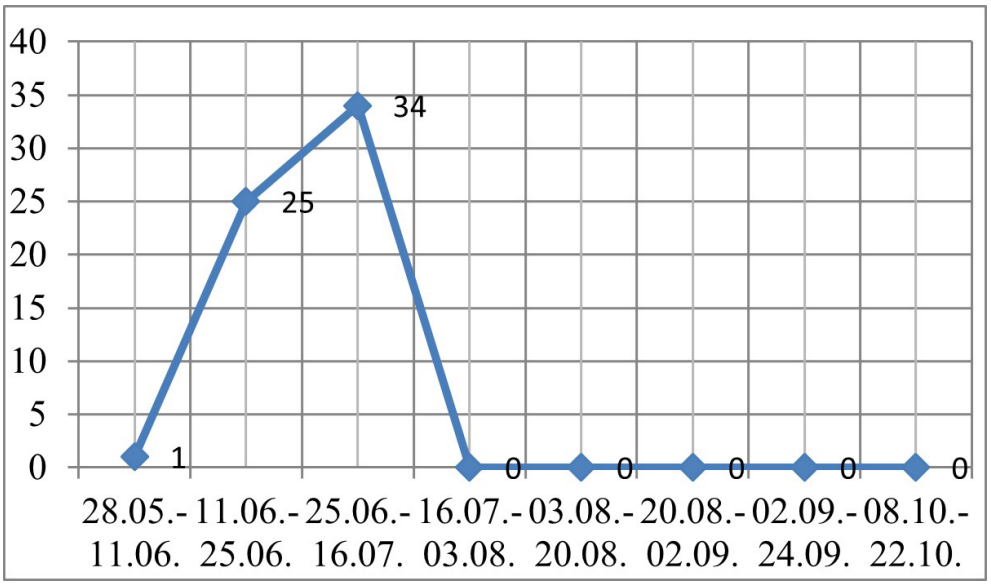

Figure 4. *Number of adults of H. obsoletus collected on yellow sticky traps (YSTs) in 2022.*

In conditions of the Republic of Moldova, planthopper was observed on *Convolvus arvensis L.*, during the period of mass flight; the planthopper could be also seen on *Xanthium strumarium L.*, on *Fallopia convolvulus L.* and on other herbaceous plants (Haustov & Bondarciuc, 2021). The habitat of the insect is essentially non-cultivated areas, in this case it is an abandoned land which bordered with the experimental site, namely the aisle and the road between the plots. In some plantations, every second interval between the vine rows was permanently covered with a mixture of plants, in others the inter-rows were partially covered or free of weeds, as they were not controlled by tillage and standard herbicides. In the abandoned plots no control has been applied for several years. In addition to the sticky traps, the planthopper *H. obsoletus* was also found in the material, which was obtained by sweep-net sampling on plants in inter rows. Mowing was usually carried out in the days of removing and installing sticky traps. On 25.06.2022, more than 200 specimens of this species were caught with 100 strokes. The next mowing was carried out on 16.07.2022; the number of specimens in the selected sample was also equal to 0, same with the situation of sticky traps. The peak of the capture occurred at the end of June, and specimens were abundant both inside and outside the vineyards, thus the results obtained from the sticky traps and from the mowing were similar. The literature review clarified the situation a bit. Phytoplasma disease Bois noir in European vineyards is caused by phytoplasma, that is mainly transmitted by the planthopper *H. obsoletus*. There are two main molecular types of phytoplasma, which may be found on *Convolvulus arvensis L.* and *Urtica dioica L.*, respectively. In summer, H. obsoletus females lay eggs on the ground near the roots of their herbaceous hosts, and nymphs complete their development from late summer to the next spring. However, in field bindweed and stinging nettle plants, the phenology of *H. obsoletus* is different According to the results obtained by the authors, it was observed that adult emergence begins earlier on *C. arvensis* than on *U. dioica*, which were conformed with the results from different European countries, such as Italy, Germany and Serbia (Mori et al., 2020).

Since only *C. arvensis* was present at the experimental site, we did not have the opportunity to compare the spatial distribution and phenology of *H. obsoletus* adults between inside and outside the vineyards in relation to the presence of the two herbaceous host plants.

Figure 5. *General view of the experimental site and the border area, 11.06.2022.*

Image source: Grozdeva S.

The species *Japananus hyalinus* has attracted authors' attention because it has been observed in vineyards, since, according to literature data, the speceis is monophagous and prefers different species of Maple (*Acer* sp.) (Гроздева, 2022). The dry conditions of year 2022 and the absence of maples nearby could be the reason, that leafhopper expanded the range of its host plants. It is too early at this stage to make any conclusions, but further researches should be carried out in this direction in order to clarify the behavior of this adventive leafhopper species the climatic conditions of the Republic of Moldova.

Literature data indicate that such species as: *Reptalus panzeri*, *Reptalus quiquecostatus*, *Cixius wagneri* are potential causal agents of *Bois Noir Phytoplasma* (Chireceanu, 2016).

CONCLUSIONS

Research data presented in this study highlighted the presence of a consistent number of plant and leafhopper insects on the grapevines established in the south of the Republic of Moldova. These results are in accordance with many other results recorded by the literature presenting this agro-ecosystem as a suitable host for a large range of species of Auchenorrhyncha.

During the growing season of 2022, at least 27 hopper species from 4 families were identified in the vineyards, most of which being the representatives of the Cicadellidae family – 21 species. The species *Arboridia kakogawana* (Matsumura, 1932), *Japananus hyalinus* (Osborn, 1900), *Scaphoideus titanus* (Ball, 1932) and *Stictocephala bisonia* (Kopp & Yonke, 1977) are adventive species imported from Asia and North America.

There are also many other types of weeds in the vineyards, which compete with the grape plants and serve as food for harmful insects, mites and nematodes, including disease vectors.

Therefore, this study provides basic information about the species presence and diversity of the Auchenorrhyncha fauna collected in the vineyards established in Congaz village, Comrat district.

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Conflict of interests
The authors declare that they have no conflict of interests.

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