PLANTS PROTECTION AND QUARANTINE IN THE 21ST CENTURY: PROBLEMS AND DEVELOPMENT PROSPECTS

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The monograph is a collection of the results of actual achievements of domestic agricultural scientists, obtained directly in real conditions. The authors are recognized experts in their fields, as well as young scientists and postgraduate students of Ukraine. Research is conceptually grouped at 4 sections: ecologically oriented technologies for the protection of plants from harmful organisms; quarantine, invasive and adventitious organisms of agrocenoses, urbocenoses and forest plantations; monitoring and protection of biodiversity of agrocenoses, urbocenoses and forest plantations; resistance of plants to biotic and abiotic factors. The monograph will be interesting for experts in plant breeding, economics, plant protection, selection, agrochemistry, soil science, scientific workers, teachers, graduate students and students of agricultural specialties of higher education institutions, and for all those who are interested in increasing the quantity and quality of agricultural products.

Keywords: plant protection, environmental technologies, forest plantations, plant resistance, pests, quarantine, monitoring.

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SECTION 1. ECOLOGICALLY ORIENTED TECHNOLOGIES FOR THE PROTECTION OF PLANTS FROM HARMFUL ORGANISMS

SPECIES COMPOSITION OF INSECT PESTS OF SOYBEAN IN UKRAINE AND IN THE WORLD

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Soya – is the main albuminous and oily crop of the world agriculture. It takes an important place in the structure of crops, grain, fodder and food balance. This is a strategic crop in solving the global food problem that is why it is grown on all continents in the main agricultural regions of our planet. In recent years soya has no competitors by the rates of crops growth and production volumes. Though Ukraine takes the first place in Europe by area of soya cultivation, its yield still does not correspond to potential possibilities. One of the factors which limit potential productivity is pests. Soybean protection from them is an important and relevant component for getting stably high yields and raising the quality of seeds simultaneously. Especially effective it has been monitoring in recent years as a result of an increase of sown areas and yield due to implementation of intensive technologies for soya cultivation. However, it should be taken into account that many species of harmful insects damage soya at all stages of ontogenesis, at the same time the loss of yield can make 30–40%. Harmful insect species from the following series have been discovered on soya crops in the Eastern Forest-Steppe of Ukraine: Orthoptera, Homoptera, Hemiptera, Thysanoptera, Coleoptera and Lepidoptera.

Key words: *Soya; Pests; Insects; Species composition; Habitat; Plant protection.*

Introduction. One of the obstacles in obtaining soybean high yields can become harmful entomofauna, which remains studied not enough for the Forest-Steppe of Ukraine. Along with the expansion of this crop sowing areas the species composition of pests and their significance gradually increases. Most of them are polyphagous. In the favorable for development years pests can destroy up to 90 % of yield. It’s known, that harmful arthropods, which damage soybean can greatly decrease yield, influence the quality of seeding material, harm the grain during the storage, therefore the study of forming peculiarities of harmful entomofauna of soybean farm ecosystems is relevant. There is no common theory that explains the forming of entomological communities in agroecosystems of agricultural crops. It is known that each species in the conditions of its existence is inherent an optimal population density, which is hereditarily conditioned, and the deviation from which negatively affects the rates of reproduction and vital activity of individuals. An important factor is the potential of reproduction, as it determines the number, and hence the harmfulness and economic significance of the species.

Methods. In order to determine the dominant species of soybean pests which may have economic significance over 50 literature sources have been analyzed as for past and contemporary condition of soybean production in the world and the structure of entomological community of soybean agricultural habitat. After that, in 2018 on the base of the generally accepted methods the research of soybean harmful entomofauna on the fields in the Experimental Field “Experimental Farming Elitne” of V.Ya.Yuriev Institute of Plant Cultivation of National Academy of Science of Ukraine was started.

Results and Discussion. Analysis of literature sources indicates about the differences in species composition of pests on soybean. There are more than 500 potentially harmful species in the world fauna (Fedotov, 1999). In the whole world, approximately 380 species of harmful insects collected on soybean are described (Luckmann, 1971). The biggest number of them was found in the countries of the Asian Region. In Japan, for example, on soybean can be found 220 species of insects, 30 of them cause significant crop losses (Kobayashi, 1970). The greatest harm is caused by *Nezara viridula* L., *Leguminivora glicinivorella* Mats., *Etiella zinckenella* Tr. and *Matsumura phaseoli* Mats. (Atsushi, 1984; Le Viet Dung 1983).

Fletcher (1922) was one of the first who discovered 9 soybean pests in India. About 85 species of insects, which belong to six different rows of insects and ticks on soybean, were described in the state of Madhya Pradesh by an entomologist Gangrade (1962), and Saxena (1972) registered in the same state only 32 insects. In the early 1970s of the 20 century during the beginning of soybean growing in India, as a crop, only about ten small pests-insects were noticed, meanwhile in 19997 this number increased to an alarming figure of 270, except for 1 tick, 2 millipedes, 10 vertebrates and 1 snail (Singh, 1999). More than 65 insects damage soybean from the cotyledon to the stage of harvesting in Indian state of Karnataka (Rai et al., 1973; Adimani, 1976; Thippaiah, 1997). Among them Melanagromyza sojae Zehntner and Aproaerema modicella Deventer, cause 100% damage and a decrease in yield by 20–30 % (Singh & Singh, 1990).

The harmfulness of M. sojae Zehntner increased sharply in the third decade of August and the damage increased from 72.0 to 98.9 in the first decade of September (Singh & Singh, 1990a). According to some scientists' data (Berg, 1995) M. sojae Zehntner, as a rule, damages soybean throughout the season. At first, the damage is insignificant, reaches its maximum in 5-8 week after sowing, and decreases by the end of the season. The entomologist Patil (2002) has found out that the damage from M. sojae Zehntner was high in the states of Jahmandi (14.80%) and Mudhol (14.45 %) the district of Bagaltok, Gokak (16.20 %), Raibag (16.30 %) and Atana (14.45) in the district of Belgaum (Karnaka State). In the same state of Rai (1973) as registered 24 species of insects that feed on soybean, including the maximum damage was done by larvae of *Lamprosoma indicata* F., *Stomopteryx subsecivella* Zeller and *Diacrisia obliqua*, another scientist Adimani (1976) near Dharvad has described 59 species of insects, that belong to 6 rows.

In Thailand 17 species of insects were found on the soybean crops, among which *M. sojae* Zehntner dominates. When grown in mixed crops of corn, the same pests are found on it, their harmfulness also does not change. Soybean cultivation in a monoculture leads to an increase in the number of pests compared to conventional crop rotation (Yoshimeki, 1986). In tropical and subtropical Asia and the Pacific Ocean *M. sojae* Zehntner is also a dangerous soybean pest. Imago lays eggs on the leaves; larva after feeding on the leaves penetrates into the trunk of the plant, makes passes and pupates (Vander Goot, 1930). The damage is not visually noticeable on the plant. They can be seen only after the dissection of a stem. As a result of infection of soybean crops with *M. sojae* Zehntner can lead to damage to about 100 % of plants and a significant reduction in yield (Talecar & Chen, 1983).

Survey of soybean crops and researches of *M. sojae* Zehntner were carried out on the island of Kusu (Japan) (Suenaga, 1953). This pest is widespread and causes great harm to all legumes. Studies have shown that *M. sojae* Zehntner occurs from May to October. During the dissection of a soybean stem, it turned out that larvae appeared in June in small quantity. During the sowing of soybean at the end of May, in June, no damage was found. During the sowing in early June, the plants had 100 % damage to the stems. 4 generations are developed for a year. In North-East China and in Korea Epilachna vigintiomaculata Motsh and Laspeyresia glycinivorella Mats are widespread on soybean, which more than 80 % reduce grain yield (Avoy, 1979; Binh Nguyen, 1988). In such countries as Vietnam, Thailand and China the most harmful and widespread is *M. sojae*, which damages up to 90 % of soybean plants (Yoshimeki, 1986). In Indonesia the scientists note that Etiella hobsoni Butler destroys up to 80 % of soya beans (Atsushi. 1984; Atsushi, 1986; Atsushi, 1987).

Soybean has become widely spread in America, in such countries as Mexico, Brazil, Argentina, USA (Avoy, 1979). In the USA soybean by the sowing area occupies the third place after wheat and corn. In the state of Arkansas (USA) 267 species of pests were registered on soybean fields (Tugwell et al., 1973). Insect damage has increased significantly in recent years because of increased sowing areas (Schillinger, 1976). A large number of insects is found on soybean here, among which the most dangerous is *Helicoverpa* (=*Heliothis*) *zea* (Boddie), which mainly damages soya beans and leaves in some southern countries. Each caterpillar can damage 6–8 beans during the vegetation period (Rukovishnikov, 1978). Seeds are also damaged by *Leguminivora glycinivorella* (Obraztsov) and *Etiella zinckenella* Tr. (Kobayashi, 1980). Also great damage is caused by *Helicoverpa armigera* Hb, among beetles – *Epilachna varivestis* Mulsant. Leaves, flowers, young beans are being damaged (Funderburk, 1983). Nodules on the soybean roots are destroyed by larvae of flies Rivellia quadnifasciata Macquart from Platystomatidae family. Cotyledons in the soil and sprouts in cold springs are damaged by larvae of *Hylemya platura* Moig. Significant spread on soybean got bugs *Acrosternum hilare* Say, *Nezara viridula* L. and *Euschistus servus* Say, both adult individuals and larvae. They suck out the juice and damage all parts of the plants. Damage to underdeveloped seeds leads to significant changes in the chemical composition of soybean oil, the content of palmitic, stearic and oleic acids increases, and linolenic and linoleic decreases. Sowing qualities of seeds become worse (Reynard, 1976).

In some states of Brazil caterpillars of *Anticarsia gemmatalis* (Hüb) make up 80 % of the total quantity of caterpillars, which feed on soybean leaves (Tadd, 1976). Bugs damage the beans in the period of grain formation, one of them is the bug *Nezara viridula* L., its part makes up 60-68% of the total number of bugs on soybean crops (Jones, 1978), in connection with it the percentage of grains which was damaged by this species is up to 70 %, *Piezedorus guildini* Westwood – 25 %, by other species – 5 % (Ramachandran, 1992). In Argentina, the damage to seeds by bugs is 100 %. The most vulnerable plants to damage by sucking pests in the phase of beans setting. During this period, 10 bugs registered per m^2 caused 100 % damage to beans (Vaishamayan, 1980). In Egypt Spodoptera littoralis Boisduval does a great damage (Azab et al., 2001). Its caterpillars can damage more than 90 economically important plants, the main ones are soybean, cotton and others. For the last 25 years, an intensive use of pesticides against this Spodoptera littoralis Boisduval has led to resistance to insecticides treatments that are registered in the country (Aydin & Gurkan, 2006). In European countries, there are their differences in species composition of pests and their spread. So in Serbia 23 species of insect have been discovered. Caterpillars of *Etiella zinckenella* Tr. do the biggest damage (Simova, 1988). Lately *Vanessa cardui* L. has been doing a great damage to soybean crops. Analysis of literature sources allowed determining known outbreaks of a *Vanessa cardui* L. reproduction, which are registered in Europe – 1973, 1996, 2001 and 2005 years. In 1996 millions of *Vanessa cardui* L. appeared in Great Britain. In 2005 was observed the maximum outbreak of Vanessa cardui L. in history. The maximum movement of an insect was noted in sight of about three individuals per second (https://butterflyconservation.org/search?query=Vanessa+cardui). This pest is spread throughout the world. Mass reproduction on the coast of Northern Africa and the far parts of the Sahara, causes the migration of *Vanessa cardui* L. Flying over the Mediterranean Sea, butterflies settle throughout Europe, and the eastern part of migrants, flying in transit Asia Minor, reaches the coast of the Caucuses (https://1838.life/news/vanessa-cardui-iz-afriki-poselilas-na-sochinskom-poberezhe/). Butterflies of this species move in flocks and overcome up to 500 km per day, using passing airflows. In Europe, a new generation emerges over the summer. For a long time, scientists did not know if these insects come back in autumn to Africa, where their parents were born. In 2012 a group of radar entomology of the British agricultural research center Rothamsted Research confirmed, that the autumn migration really exists.

Only to the South butterflies fly at a big altitude, so they are rarely seen (https://polit.ru/news/2017/10/06/ps_vanessa_cardui/). In 2019, mass flying of *Vanessa cardui* L. was noticed throughout the world. A great number was observed in Central Asia, namely in Uzbekistan and Tajikistan. The last outbreak of *Vanessa cardui* L. was observed 5-6 years ago (https://www.fergana.agency/news/107561/). There is also evidence that a large number of these insects were seen in southern California. Scientists believe that such a mass flying has not been observed since 2005, when about a billion of *Vanessa cardui* L. flew over the region. *Vanessa cardui* L. flies with a speed of up to 40 km/h without stops. The flocks are so big that they are counted as birds flocks (https://oko-planet.su/pogoda/newspogoda/484944-v-kalifornii-massovoenashestvie-babochek.html). In March 2019 in Israel one of the biggest migration of this species was recorded. Especially many of these butterflies are in the coastal areas of Central and Northern part of the country, as well as in the Arava Desert. The previous mass migration of *Vanessa cardui* L. was recorded in 2014, but at that time they were ten times less. According to scientists calculations, in March of the same year from 700 million to 1 billion of *Vanessa cardui* L. flew over Israel toward Cyprus, Turkey and Southern parts of Europe. During the flying butterflies feed on nectar (https://tass.ru/obschestvo/6248978). The mass migration of Vanessa cardui L. did not pass by Russia. There are data that many butterflies settled on the coast of Sochi and such a big quantity was not observed earlier (https://1838.life/news/vanessa-cardui-iz-afriki-poselilas-na-sochinskom-poberezhe/). In Ukraine in 2019, there is also a great number of butterflies of this species. Bilyavsky Yu.V. was engaged in researches of

Vanessa cardui L. in Ukraine. In his article he represented the observation data for 2002–2009 years, was engaged in spread monitoring of this insect (Bilyavsky, 2010). Fokin A.V. was looking for the reasons for the mass appearance of *Vanessa cardui* L. in Ukraine. In his opinion, the mass appearance of the pest in 2009 in Ukraine is connected with butterflies migration from the South-Western region (Italy, Romania, Greece, Albania, Turkey) in the North-Eastern direction (Fokin, 2010).

Russian scientists A.N. Frolov and M.I. Saulych have made an area of *Etiella zinckenella* Tr. prevalence and zone of its harmfulness, within which was defined the zone of average harmfulness (South of Ukraine, Krasnodar and Stavropol Krai, Rostov region, Lower Volga region), where yield losses of pulse on average can be 5–6 %; the zone of low harmfulness, where yield losses, as a rule, are below the 5 % limit, in European part of the Former

USSR occupies the territory of pulse cultivation, in Asian part – the territory of soybean cultivation with an average temperature of July not lower than 20ººC.

Researches, which were carried out in Germany, show that great damage to crops is done by caterpillars of Spodoptera litura F. and *Thysanoplusia orichalcea* F. (Babu, 1979). In the South-East of France, where soybean is grown relatively recently, depending on the conditions the most harmful is *Tetranychus turkestani* (Ugarov & Nikolskii) (Blane, 1988). In Latvia, there are not many phytophagous on soybean, about 20 species. The most harmful is *Heliothis armigera* Hüb. (Singh, 1973). In Turkey, 18 species of insects and 1 species of tick were noticed on soybean. The most widely spread are *Tetranychus urticae* CL Koch., *Nezara viridula* L., *Spodoptera exigua* Hub., *Autographa gamma* L., *Heliothis armigera* Hub., and *Vanesa cardui* L. (Zumreoglus, 1987).

At the beginning of 90-s in the North Caucuses O.M. Shabalta and Thi Chat Nguien discovered 54 species of soybean photophagous, 20 of them are included in the list of soybean pests of Krasnodar Krai for the first time. From 54 known insects the most numerous are Lepidoptera – 20 species, Hemipterous – 12 species, Coleopterous – 8 species, Orthoptera – 7 species, Homopterous and Thysanoptera – 7 species. Besides, one species of tick was found (Shabalta, 1993; Shabalta, 1995; Shabalta, 1997). About 60 species of photophagous are registered in soybean crops, which is cultivated in the South-East of Kazakhstan on large areas. Among these insects, visible harm is done by *Tetranychus turkestanicus* Ug. et Nik., *Aphis fabae* Sc., *Aphis gossypii* Glov., *Cicadella viridis* L., *Psammotettix striatus* L., *Lygus pratensis* L., *Adelphocoris lineolatus* G., *Polymerus cognatus* F., *Graphosoma lineatum* L., *Thrips tabaci* Lind., *Agrotis segetum* Schiff., *Discestra trifolii* Hufn., *Heliothis viriplaca* Huf. and other insects. The time of intensive nutrition of photophagous coincides with critical periods in the life of plants,that along with other unfavorable conditions has a negative impact on productivity (Kuznecova, 1979).

According to A.I. Mishchenko data in conditions of the Far Eastern Region 78 species of insects were described, 45 of which were found for the first time (Mishenko, 1957). The most spread pests are Lepidoptera – 48 species (60 % of harmful fauna). Ticks by the number of species are significantly inferior to Lepidoptera (9 species or 11.5 %). This tendency concerns to beetles (8 species or 10 %), Orthoptera (7 species or 10 %). The part of other representatives of other rows (Homopterous Rhynchota, Thysanoptera and Diptera) does not exceed 10 % (Kulikova, 1971). As early as in 2000 in the Priamurye nearly 100 species of anthropodas were found, which can cause damage to soybean crops. The most spread pests are: *Luperodes menetriesi* Fald. – wide polyphage, which is typical for the Far-Eastern fauna and damages cotyledon, stem and leaves; *Loxostege st*ricticalis L. – polyphagous pest; *Laspeyresia glycinivorella* Mats. – damages beans (Mashenko, 2005). E.V. Litvinenko in 1999–2002 years carried out the research on the specification of species composition of soybean pests in Krasnodar Krai. In general, the author identified 207 species of insects and 2 species of ticks, including 98 species of phytophagous which damage soybean (Litvinenko, 2001)

In the conditions of Ukraine 68 harmful species were determined, among which the most dangerous are *Delia platura* (Meigen), *Sitona lineatus* L., *Loxostege sticticalis* L., *Etiella zinckenella* Tr., *Heliothis* dipsacea, *Tetranychus urticae* Koch. and Elateridae. This description of soybean photophagous is given in O.A.Grykun's works in 1976 (Grikun, 1981). Later, in 1983, the list of entomofauna expanded to 72 species, which belong to 10 genera and 39 families and three classes – insects, ticks and slugs. As of 2009, year it contains 114 species of anthropodas (Grikun, 2011).

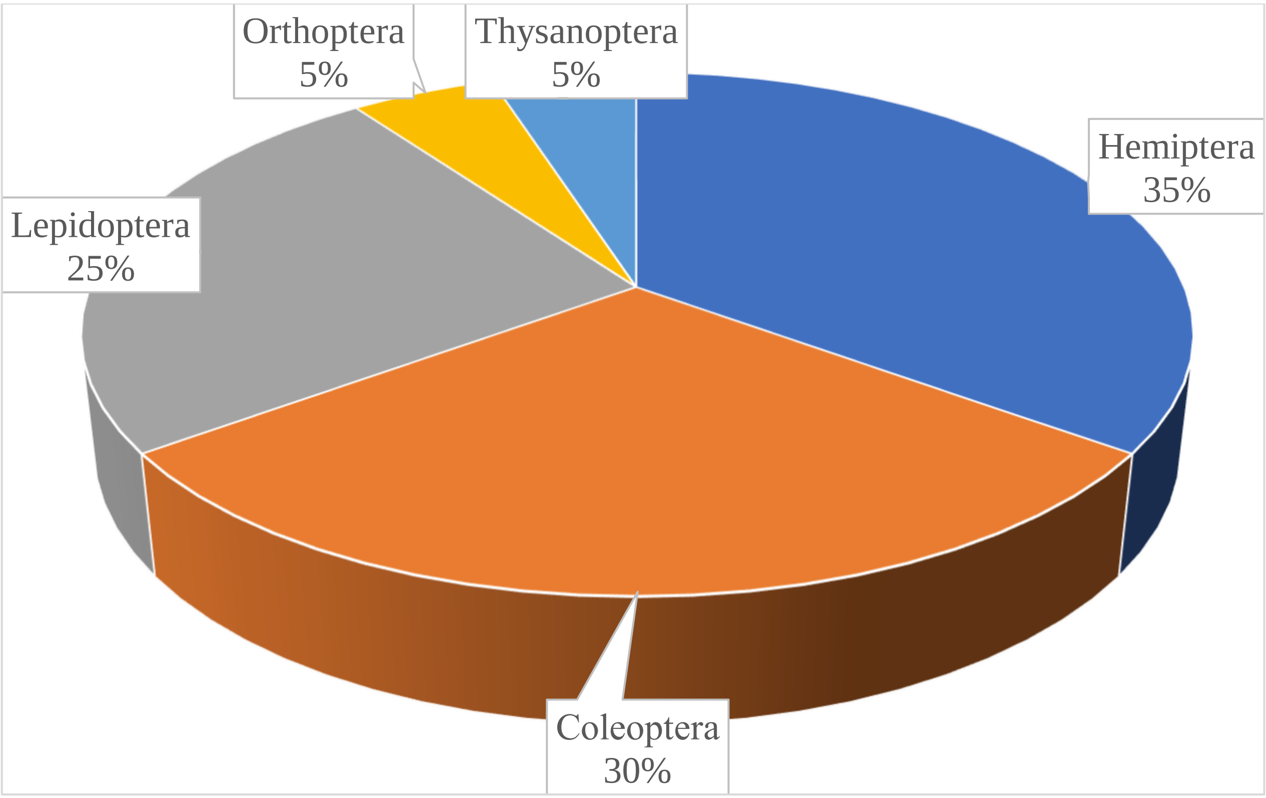

Fig. 1. Taxonomic structure of harmful soybean entomological complex in the Eastern Forest-Steppe of Ukraine

Table 1

Species composition of soybean polyphagous insects in the Eastern Forest-Steppe of Ukraine

Row	**Family**	**Species**	**Specia-lization**	**Frequency of occurrence**
Orthoptera	Tettigoniidae	*Tettigonia viridissima* L.	P	C
Hemiptera	Cicadellidae	*Stictocephala bubalus* F.	P	C
	Miridae	*Lygus pratensis* L.	P	D
		Lygus rugulipennis Popp.	P	SD
		Adelphocoris lineolatus Goeze.	P	Д
	Pentatomidae	*Dolycoris baccarum* L.	P	SD
		Piezodorus lituratus F.	P	D
		Palomena viridissima Poda.	P	C
Thysanoptera	Thripidae	*Thrips tabaci* Lind.	P	C
Coleoptera	Elateridae	*Agriotes obscurus* L.	P	C
	Curculionidae	*Sitona lineatus* L.	S	D
		Sitona crinitus Hrbst.	S	D
		Tychius quinquepunctatus L.	S	C
		Psalidium maxillosum D.	P	D
		Tanymecus palliatus F.	P	C
Lepidoptera	Noctuidae	*Autographa gamma* L.	P	C
		Chloridea viriplaca Hfn.	P	C

	Phycitida	*Etiella zinckenella* Tr.	S	C
	Pyraustidae	*Margaritia sticticalis* L.	P	C
	Nymphalidae	*Vanessa cardui* L.	P	R

Note: P – Polyphagous; S – Specialized Species; D – Dominant (more than 5.0% of the total number); SD – Subdominant (2.0–5.0%); C – Constant; (0.5–2.0%); R – Rare (less than 0.5%)

Analysis of species composition of pests on soybean crops from Experimental Field "Experimental Farming Elitne", V.Ya.Yuriev Institute of Plant Cultivation of National Academy of Science of Ukraine in 2018 indicates that in systematical relation the biggest quantity of harmful species belongs to the rows of Hemiptera – 35 % and Coleoptera –30 % of the total number of phytophagous insects. Lepidoptera belongs to the third largest group of species (25 %). Less numerous representatives are Orthoptera and Thysanoptera, which made up 5 % (each) of the total number of pests (Figure 1 and Table 1).

Conclusion:

1. The analysis of literature sources shows that soybean is cultivated throughout the world in different countries of the world. Species composition of phytophagous of this crop is very diverse. With the expansion of soybean crops new pests appear and accumulate in agrocenosis of the crop. The number of species of pests is increasing every year, due to the adaptation of many phytophagous of local biocenosis to feed on soybean, which is caused by the expansion of sowing areas under this crop. Therefore, in order to control, it is necessary further observation of species composition of insects in soybean agrocenosis. In the course of a critical analysis of literature sources, we have noticed nearly the total absence of data on the species composition of soybean pests in the Eastern Forest-Steppe of Ukraine. Dominant species of pests, their biology, ecology and seasonable dynamics of quantity are not determined, and as a result, there are no reasonable recommendations as for protection measures against them. From this, it can be made a conclusion of the relevance of carrying out of researches in the Eastern Forest-Steppe of Ukraine and undeniable novelty of the obtained data.

2. During experiments, we have identified pests, which belong to six rows. Generally, 20 species were counted. No excess of economic threshold of harmfulness was observed.

3. Soybean plants are damaged at all stages of development, but the most vulnerable are in phenophases of sprouting, laying of generative organs, grain formation and grain ripening. Accounting on the surface of the soil and on plants is carried out throughout the active life of insects.

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INFLUENCE OF GROWING CONDITIONS ON THE DISEASE OF BEANS

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The importance of beans in the national economy and the scope of its use are revealed. It is shown how environmental conditions affect the growth and development of bean plants. The influence of weather conditions on the intensity of the development of bean diseases has been revealed. On the one hand, weather conditions either promote the growth and development of plants, or suppress them, as a result of which they lengthen or shorten their growing season. The harmfulness of the main diseases of beans is given and the symptoms of plant damage during the vegetation period of the crop are characterized. The most common diseases in the studied region are anthracnose, fusarium, bacteriosis. It was established that the Horoz, Gotika, Sambrero, and Igolomska varieties had the highest resistance to these diseases. Nespodivanka and Dokuchaevska varieties were susceptible to diseases.

Key words: *beans, fusarium, bacteriosis, anthracnose, harmfulness, plant protection*

Formulation of the problem. Beans are a valuable high-protein crop that is widely used in the national economy. Seeds and beans are a source of essential amino acids. A high content of aspartic acid, serine, threonine, leucine, arginine was found. Vitamins A, B, E, C are also found in seeds and fruiting bodies. Bean seeds contain K, Ca, P, Fe, Mn, Cu, S, Mg, traces of Co, Ni, and a small amount of Se. By the content of copper and zinc, beans exceed most vegetables. Also, flavonoids and coumarins were found in the aerial part of bean plants (Kovalov et al., 2010).

Bean pods are used in traditional medicine for the treatment of rheumatism and edema in kidney and heart diseases. Husks are used in the treatment of gout and cystitis. But the most important thing is the use of beans in the treatment of diabetes.

The decrease in the production of high-protein foods of animal origin, as well as the high cost of their production, make it necessary to increase the production of vegetable protein, including beans, the demand for which has increased significantly in recent years. Beans are a fairly profitable crop today.

It has been confirmed that the protein content of beans is close to meat (20–22 %) and exceeds fish (18–19 %), and in certain varieties, the content reaches 32 %. In addition, bean protein contains up to 30 amino acids, which indicates its unique biological value as a food crop (Mazur et al., 2021).

It is advisable to solve the problem of protein in Ukraine with the greater participation of adaptive varieties of beans, with the development of new elements of growing technology. Beans are a fairly profitable crop, the cost of growing them in 2010-2015 in Ukraine in general was about 175–192 % (Macibora, 1994).

When choosing a variety, first of all, it is necessary to pay attention to its zoning zone, because due to insufficient ecological plasticity, the variety that was formed in the conditions of the Steppe zone provided high productivity, but in the Right Bank Forest Steppe it cannot guarantee the expected results.

In Ukraine, the most favorable zone for growing beans is the Forest Steppe. This creates prerequisites for increasing the cultivated area of this crop.

Features of creation of environmentally plastic varieties of beans are increased adaptation to the influence of unregulated extreme environmental factors: drought, lack of heat and moisture during the growing season, epiphytotia. Also, common bean varieties should be particularly sensitive to regulated anthropogenic factors of the environment: fertilization, irrigation, use of chemical preparations. In addition, critical phases of plant ontogenesis should not coincide with the period of adverse factors (Golohorinska et al., 2005).

The state of studying the problem. Growing conditions play an important role in the formation of plant resistance to diseases. Air temperature and precipitation have a significant effect on the damage of plants by pathogens. On the one hand, weather conditions either promote the growth and development of plants, or suppress them, as a result of which they lengthen or shorten their growing season. On the other hand, meteorological conditions also affect pathogens, promote or limit their reproduction, spread and penetration into plants (Luchna, 2008).

In order to obtain stable varieties of common bean in terms of productivity, varieties characterized by high drought resistance are needed. In addition, varieties that are resistant to bacterial wilt due to moisture deficiency are needed. Low drought resistance, damage by bacterial wilt will contribute to a decrease in the yield of bean varieties. It is known that bacterial wilt is most harmful in years of drought, at an air temperature of +16 to +28 ºC (Bezugla, 2015).

Several types of bacteria are found on beans. They are quite harmful, and the intensity of their development directly depends on weather conditions.

Angular and brown spotting of beans has become widespread.

The causative agent of angular spotting is the bacterium *Pseudomonas savastanoi pv. phaseolicola* Gardan et al. All aerial parts of the plant are affected. Elongated light brown spots are formed on the stem, which later darken and spread. Small, angular reddish-brown spots are formed on the leaves, which are translucent. They can be placed all over the leaf plate in different numbers and are called "mosaic laying" (Beltyukova, 1974). Depressed brown spots form on the beans, from which gray exudate often flows.

Yellowish spots are formed on the seeds, which can cover the entire seed with intensive development of the disease. The seeds are formed small, underdeveloped and wrinkled. At a late stage of development, it acquires a cream shade, regardless of the variety (Patika, 2007).

The angular spotting of beans develops quite quickly in rainy weather at relatively low air temperatures. Plants that are affected in the phase of the first true leaves die. This is especially true for susceptible varieties. A plant that is affected before flowering blooms and forms seeds. However, it remains small and underdeveloped. Bean harvest losses from the disease can be 23-43 % (Patika, 2011).

Brown spotting of beans also affects all above-ground organs of the plant. The causative agent is the bacterium *Xanthomonas axonopodis* pv. *Phaseoli Vauterin* et al. Brown-yellow fuzzy spots are formed on the cotyledons. During the intensive development of the disease, the cotyledons are destroyed.

At first, small light yellow, chlorotic, rounded spots appear on the leaves. Over time, they increase in size, turn brown and acquire various shapes: rounded, irregular, elongated. Spots do not become angular. A characteristic feature is the presence of a yellow or dark green border. Often the spots merge. The tissue, in places of lesions, necrotizes and falls out, forming holes.

Elongated brown spots with a rusty tint are formed on the stems. Small oily dark green spots form on the beans. When the beans ripen, the spots acquire a rusty-brown shade.

Yellowish, rusty-brown spots of various sizes and shapes appear on the seeds.

Weather conditions affect the intensity of disease development. The pathogen is spread by raindrops, wind, dew drops and insects. In cool rainy weather, the intensity of disease development increases significantly (Hiramo Susan, 1994).

From literary sources, higher resistance to bacterial blight was characteristic of the best variety samples of common beans in conditions where the highest temperature indicators and a small amount of precipitation were observed (Mazur et al., 2021).

Fusaria are common components of soil biocenoses and non-pathogenic microflora of plants. In some years, the population of the fungus is dominated by pathogenic species that cause outbreaks of fusarium wilt in leguminous crops. Species and environmental conditions determine the type of disease manifestation. On beans, fusarium is manifested in the form of root rot and wilting of plants. Sometimes they can appear simultaneously (Poedinceva, 2019).

Withering of plants is manifested both in the seedling phase and in later periods of plant development. The disease manifests itself most strongly in the flowering-fruiting phases. Diseased plants lose turgor, their tops droop, leaves dry and curl. At the same time, the tissues of the root neck turn brown and crack, the roots rot. Plants are easily pulled out of the soil. The seeds are formed small and underdeveloped (Bezugla, 2014).

The search for varieties of beans that show high resistance to fusarium remains relevant. These include the varieties: UD0303600 and UD0303528. At the same time, their reaction to excess moisture in the initial phases of growth and development and the effect of high temperatures in the final phases of growth and development was minimal (Mazur et al., 2021).

Mechanisms of resistance to fusarium wilt have not been established before. According to field studies, bean varieties with a powerful root system are less affected by fusarium root rot pathogens (Bilgi, 2008).

Anthracnose is also a very dangerous disease of beans. The causative agent is the fungus *Clomerella lindemuthiana Shear* (anamorph of *Colletotrichum lindemuthianum* Br. et Cav.). All aerial parts of the plant are affected. Most often, the disease manifests itself during the formation of beans. At first, small red-brown round spots appear on young beans, which merge over time and can reach 1 cm in diameter. The spots take the form of ulcers, a convex and hard border of red or orange color appears around them. With late infection of plants, brown, slightly depressed, uniformly colored spots are formed on the beans.

The disease develops with air humidity above 60 %, the presence of dripping moisture and air temperature of 15-19 °C. The harmfulness of anthracnose increases in years with high air humidity. As a result of the disease, seedling thinning is observed, bean damage can reach 75-90 %, grain yield decreases by 50 %, seed germination – by 33 %. In a cold, wet spring, affected seeds do not develop or produce weakened, diseased seedlings (Yong-Yan Chen, 2007; Narasimha Rao S, 2022).

Materials and methods. Research on the topic of the dissertation was carried out in 2018-2021 at the research field of the Institute of Plant Breeding named after V. Ya. Yuryev National Academy of Sciences, located on the lands of the SE "Elitne", which is located in the Kharkiv district of the Kharkiv region in the eastern part of the Forest Steppe of Ukraine. The determination of the main diseases of common beans was carried out in accordance with the requirements of the "Methodology of examination of plant varieties of the cereal, grain and leguminous group for suitability for distribution in Ukraine" (Methodology..., 2016).

Research results. In the studies of V. A. Mazur and co-authors (2021), correlation-regression dependences of the average direct relationship between the potential seed yield of bean varieties and their disease resistance score (r = 0.374) were established, as well as between the potential seed yield of bean varieties and by their drought resistance score (r = 0.350).

Most of the varieties used in our research are characterized by fairly high resistance to diseases and arid environmental conditions. In particular, the Gotika variety has the highest resistance to diseases (9 points) and fairly high resistance to drought (7 points). Varieties Veselka, Panna, Nespodivanka, Nata, Galaktika, Mavka, Nadiya and Igolomska have high resistance to diseases (7 points) and medium and high resistance to drought (5-7 points). The Dokuchayevska variety has the lowest resistance to diseases and drought (Fig. 1).

The years of research, 2019–2021, were relatively dry. Precipitation fell unevenly in places with significant fluctuations in their amount compared to long-term indicators.

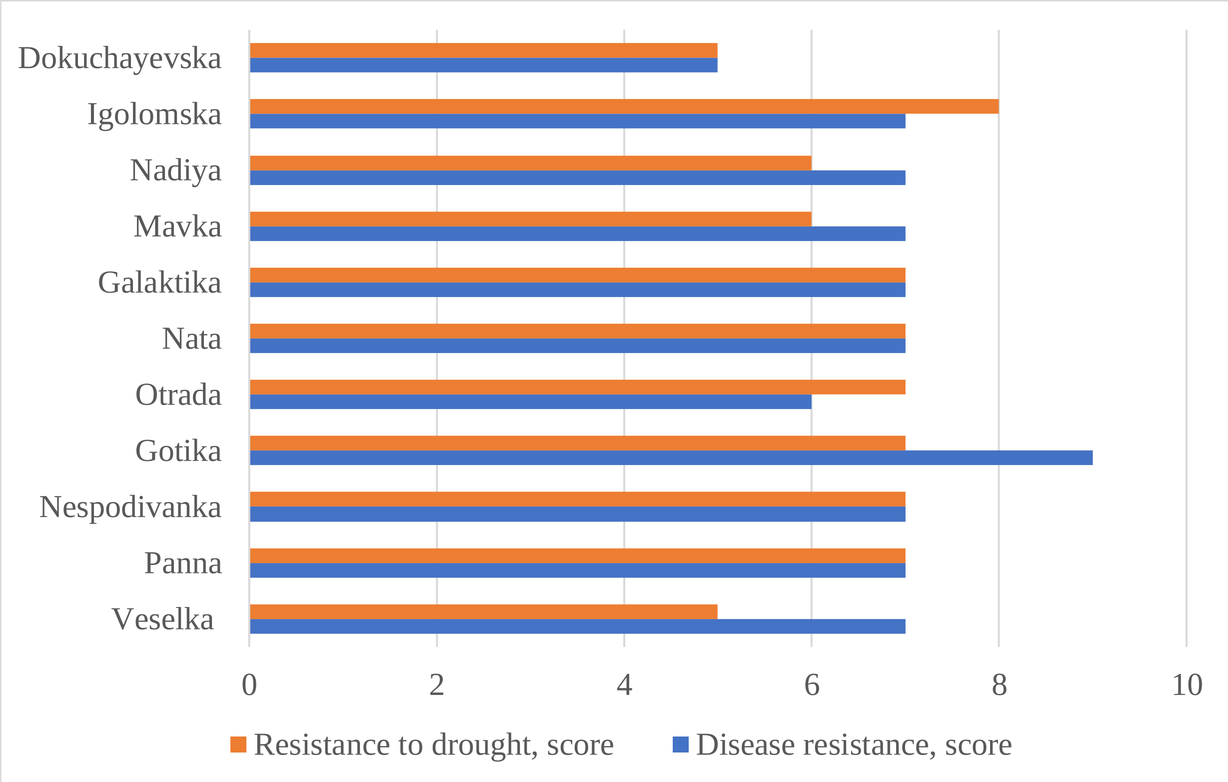

Fig. 1. Resistance of bean varieties to stress factors

2019 was the driest year, which led to premature ripening of bean varieties. The growing season of 2019 was the hottest for all years of research, with the least amount of precipitation. Under such weather conditions, the plants were weakened. This year, a strong degree of damage by fusarium was recorded, which manifested itself in the form of root rot and wilting.

May 2019 was cooler than the long-term average and with more precipitation, which adversely affected bean sprouts. The following months were drier. The prevailing conditions were favorable for the spread of fusarium root rot.

In 2020, there were also dry months during the bean growing season. However, after analyzing the conditions of the growing season in 2020, it can be said that this year was more favorable for the growth and development of beans, compared to 2019.

In 2021, during the sowing of beans, the moisture supply in the soil was sufficient. This contributed to the timely emergence of seedlings and further normal growth and development of bean plants.

Changes in the temperature regime, fluctuations in the amount of precipitation, relative humidity affect not only the growth and development of bean plants, but also the intensity of the development of diseases.

Root rot occurs throughout the growing season of beans. The severity of the disease depends on the period of development in which the plant was affected. It manifests itself in the form of quantitative losses of the crop and significant deterioration of its quality. The disease poses the greatest danger to the seedlings. Rotting of roots, hypocotyl and cotyledons is observed (Poedinceva, 2020; 2022).

The accounting of damage to bean plants by root rots showed that a large percentage of plants affected by fungi from the genus Fusarium Link was noted on Limeliqht, Dokuchayevska, Pervomajska, Nadiya, and Galaktikavarieties throughout the growing season of the crop (Fig. 2). Nata, Gold Marie, Madera, Slaviya and Ema varieties were affected to a lesser extent. The Igolomska, Sambrero, Gotika, Otrada, Yava and Veselka varieties were the most resistant.

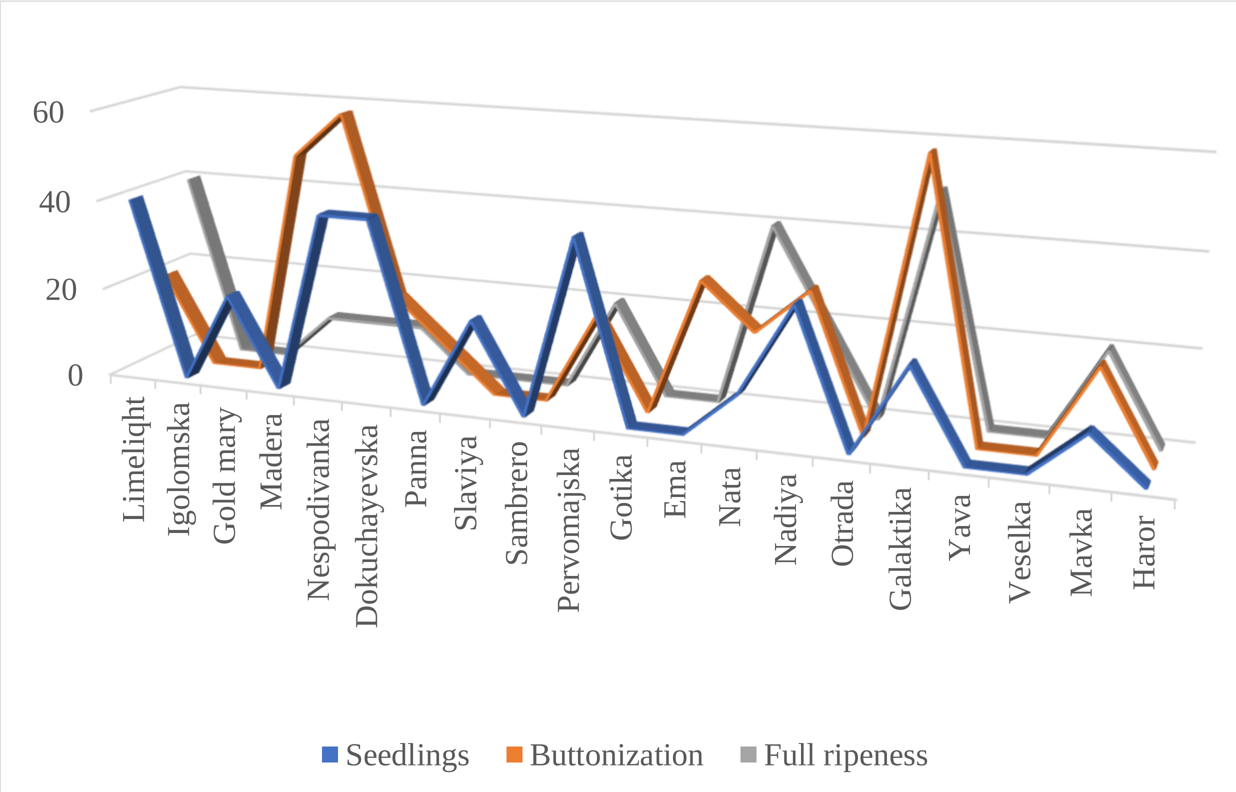

Fig. 2. Prevalence of bean root rot, average for 2018-2021, %

Anthracnose also occupies an important place. The disease causes the loss of seedlings, the deterioration of marketable and seminal qualities of seeds, and a decrease in yield.

In field and laboratory studies, it was noted that anthracnose appeared on the following varieties: Madera, Yasochka, Slaviya, Panna, Limeliqht, Gold Marie. Signs of the disease were detected during the formation of beans. The prevalence of anthracnose was in the range of 13-20%.

Conclusions. Variability of weather conditions plays a significant role in disease damage to bean plants, as all climatic factors affect the development of both plants and pathogens.

The varieties Igolomska, Sambrero, Gotika, Otrada, Yava, Horoz and Veselka showed the highest resistance to root rot, and the varieties Nespodivanka, Dokuchayevska and Galaktika were the most susceptible.

The Gotika variety showed the highest resistance to damage by the studied diseases: bacteriosis, root rot and anthracnose.

In order to limit the prevalence of these diseases, it is necessary to create conditions for the normal growth and development of bean plants. Seed treatment, sowing at the optimal time, destruction of the soil crust by harrowing, i.e. a number of measures aimed at creating the most favorable conditions for plant growth and development, must be mandatory.

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INFLUENCE OF PRE-SOWING SEED TREATMENT ON SUNFLOWER YIELD

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Improving the technology of growing sunflower hybrids through the use of plant growth regulators and microfertilizers at various stages of ontogenesis allows to significantly increase their seed productivity and is an effective technological measure that allows to increase the production of basic seeds and thereby accelerate the introduction of new hybrids into production. Stimulation of the reproductive processes of sunflower plants is primarily related to the positive influence of certain methods of application and combinations of growth regulators and microfertilizers on the growth and development of the hybrid, as well as knowledge of the patterns of variability of reproductive processes under their influence. The effectiveness of plant growth regulators and microfertilizers depends on the combination of drugs in different ways of application and varietal characteristics of the parental components of sunflower. In most cases, the yield of the parental

components and the sunflower hybrid increases significantly in the variants where the pre-sowing seed treatment with growth regulators and microfertilizers was supplemented by spraying the plants with drug mixtures. Moreover, double spraying is more effective than single spraying.
Key words: *poisons, plant growth regulators, sunflower, productivity, seeds*

Ukraine ranks second-third in the world in terms of the gross harvest of sunflower seeds. During 2010-2019, Ukraine is the largest exporter of sunflower oil. Ukrainian sunflower oil exports make up 60 % of the world market (Buryak, 2016). It should be noted that currently the level of utilization of the biological potential of oil crops is only 50 %. The main reasons for this are: instability of climatic conditions; non-compliance with the basic requirements of crop rotation and the technology of growing oil crops; insufficient amount of seeding equipment, as well as weak attention to the selection of varieties and high-quality seed material.

A significant obstacle to obtaining high yields of sunflowers is the most common diseases, which can cause a decrease in yield up to 25-50 %. The spread of pathogens is primarily caused by violations of crop rotation when placing sunflower crops.

The natural and climatic conditions of the zones of Ukraine, recommended for growing sunflower, correspond to the needs and features of this crop. At the same time, in connection with the significant variability of weather conditions in recent years and the forecasts of experts, the main place in production should be occupied by highly adapted hybrids that are resistant to drought and stressful increases in temperature, as well as resistant to significant fluctuations in temperature and moisture supply during the growing season (Optimizaciya, 2020).

One of the relevant elements of modern technologies is the use of plant growth regulators, biopreparations and microfertilizers for pre-sowing treatment of seeds, which stimulate the germination process, protect seeds during their long-term stay in adverse conditions, increase field germination of seeds, and contribute to the active development of the root system.

It is known that sunflower responds positively to the use of plant growth regulators for pre-sowing seed treatment. The use of growth regulators, such as AKM, increases the percentage of seed germination by almost 4 % compared to the control options. In addition, AKM treatment of sunflower seeds increased stem thickness along with an increase in plant leaf surface area and basket diameter. The growth regulator also increased pollen fertility, which affected the weight of 1000 seeds and yield, respectively (Anishin, 1998).

Formulation of the problem. When applying plant growth regulators, biological preparations and microfertilizers, it is taken into account that each of them is created to stimulate the growth, development and increase the productivity of certain agricultural cultures at appropriate doses, terms and methods of application (Rekomendacii, 2000).

Growth regulators and biological preparations should be used in the form of aqueous working solutions, which are prepared on the day of their use. The consumption rates of these drugs per ton of seeds or hectare of crops are small, so it is important that they are evenly diluted with water. To do this, mother aqueous solutions of these drugs are pre-prepared in a small amount of water, in a glass or enamel vessel with a tight lid, and then brought to the required volume of the working solution (Kirichenko, 2014).

Scientific studies have proven the feasibility of joint application of pesticides and growth regulators during pre-sowing treatment of seeds and when spraying crops, which significantly increases the effectiveness of poisons and plant protection products (Kirichenko, 2022).

The combination of seed treatment with plant growth regulators and subsequent spraying of crops with them makes it possible to control the process of crop formation throughout the entire growing season and allows for a stable increase in the yield of seeds of parent lines with high sowing qualities.

A. A. Astakhov determined that the pre-sowing treatment of sunflower seeds with stimulants increases the yield of the crop due to an increase in the weight of 1000 seeds and a larger number of filled seeds in the basket (Yacenko, 2022).

Under the influence of growth biostimulators, the genetic potential of plants, created in the selection process, is realized more effectively. Biometric parameters: leaf surface, plant height, basket diameter, weight of 1000 seeds tend to increase under the action of biostimulants. Their use more fully realizes the potential of sunflower plants and increases their productivity, resulting in an increase in yield by 0.24–0.39 t/ha (Kocherga, 2014).

Yeremenko research (2018) established that the formation of the yield of sunflower plants in the hybridization areas significantly depends on the hydrothermal conditions of the year - the share of participation of such a factor is determined at the level of 63 %. The highest effectiveness of AKM growth regulator is observed in years with stressful growing conditions, and during years with favorable conditions, the effect is significantly reduced.

Research materials and methods. Research on the effect of plant growth and development regulators on the yield of parental components was conducted together with the laboratory of seed breeding and seed science at the SE DG "Elitne" IR named after V. Ya. Yuryev in 2021-2022 according to the approved scheme and plan on the Kadet, Kosmos and Yarylo hybrids.

Kadet is a sunflower hybrid. Originator Institute of plant breeding named after V. Ya. Yuryev of the National Academy of Sciences and the Selection and Genetics Institute – National Center for Seed Science and Varietal Research of the National Academy of Sciences. Registered and included in the State Register of plant varieties suitable for distribution in Ukraine since 2011. High oleic. Drought resistant. Highly resistant to lodging, shedding, powdery mildew, downy mildew, rot resistant. The potential yield is 3.96 t/ha.

Kosmos is a confectionary type sunflower hybrid. At a plant stand density of 20,000 units/ha, it has the following characteristics: germination-flowering period 53–55 days; the period of germination-physiological maturity – 86–92 days; plant height 151–170 cm, basket diameter – 20.4–28.5 cm; the flat shape of the basket, the seed is large (12.0–14.5 cm long), elongated, black-gray in color with light-gray stripes; seed yield - up to 2.90 t/ha; high weight of 1000 seeds – 83.0–150.0 g; flaking 26.0–31.0 %; the oil content in the seed is 42.0–45.1%, the protein content in the kernel is 25.0 %.

Yarilo is a simple, mid-early ripeness group. Resistant to lupus races A-F. The yield potential is 3.5 t/ha. Resistant to lodging, shedding, drought-resistant. Over the years of testing, it exceeded the standard in terms of yield by 24 % and oil collection by 20 %. The hybrid is suitable for growing in problematic regions where the set of hybrids is limited due to the spread of virulent races of sunflower lupus. The economic effect of the implementation consists in reducing material and labor costs, increasing profit from the sale of plant products. Expected volume of implementation is 75 thousand ha. Due to implementation in problem regions, it is planned to receive up to 35 % increase in crop production from 1 hectare. The payback period of the development is for the 3rd year after the introduction of the hybrid into production.

The scheme of the study envisages the use of fungicidal poisons, plant growth regulators and microfertilizers.

Barion (Metalaxyl-m, 350 g/l.), fungicidal pro-poisoner for sunflower and rape seed treatment against powdery mildew, rot, verticillosis. Compatible with other pesticides and agrochemicals that have a neutral reaction.

Metalaxyl-m disrupts the synthesis of nucleic acids in pathogens and inhibits RNA polymerase (the pathogen's protein metabolism is disrupted). It has a powerful systemic effect. An important factor in the effective effect of the drug is the quality of seed surface coverage (sufficient and uniform). The effectiveness of the action depends on the quality of seed processing and its sowing in well-prepared moist soil. The quality of impregnation with the drug depends on the preparation of the seed material, the correct preparation of the working solution and the setting of the impregnation agent.

The drug is quickly absorbed by the seed and after germination is evenly distributed throughout the plant. In addition, it is redistributed in the soil, from where it is later absorbed by the root system. Thus, not only the seed and sprout are protected at an early stage, but also long-term protection against secondary infections is additionally provided.

Exor (Thiamethoxam, 600 g/l) Insecticidal poison for treating sunflower seeds, corn and other crops from a complex of soil and early post-emergence pests. Effectively controls a wide range of soil and early post-emergence pests over a long period.

Thiamethoxam is an active substance of systemic action. It is characterized by a high rate of absorption and movement by germinating seeds and young seedlings of cultivated plants. Thiamethoxam blocks nicotinic receptors in the postsynaptic membrane of the synapse, which are responsible for recognizing acetylcholine molecules. As a result, the transmission of the nerve impulse is blocked (stopped) and the movement activity of the pest is disrupted within an hour, which, in turn, prevents the continuation of the feeding process.

Raykat Start – root system development activator. pH 7-8. When used for pre-sowing seed treatment, the drug: increases field germination by 8-10 % and seed germination energy by 3-5 %; provides a guiding activating effect on the formation of a powerful root system, laying of lateral shoots; removes the phytotoxic effect of triazole-based poisons; increases the resistance of young seedlings to adverse growth conditions, stresses, diseases, and pests.

AKM is a semi-synthetic film-forming plant growth regulator with antioxidant action. Compatible with all agrochemicals, bacterial preparations, trace elements, pesticides registered in Ukraine, except for alkaline ones.

AKM in the pre-sowing treatment of seeds performs the function of a non-specific inducer of the protective functions of plants, which leads to an increase in their resistance to diseases. The antioxidant effect of this drug is manifested primarily in the protection against overoxidation of the main tissue biooxidants. It slows down the destruction of these bio-oxidants in conditions of low-temperature stress, which has a positive effect on the survival of seedlings, prevents a decrease in the activity of antioxidant protection enzymes.

Microkat Oil - contains: free amino acids of the α-group – 4.0%; N – 3.0 %; P_2O_5 – 1.0 %; K_2O – 12.0 %; Fe – 0.3 %; B – 0.03 %; Zn – 0.02 %; Mn – 0.1 %; CaO – 0.4 %; Mo – 0.01 %; Cu – 0.01 %; B – 1.0 %. Manufacturer Atlantica Agricola, Spain.

Avangard Stimul, *r. k.* (Potassium humate in terms of humic acids – at least 40 g/l, succinic acid – 3 g/l, trace elements, other biologically active elements (gibberellins, auxins, cytokinins)).

Humic compounds have a strong ion exchange and absorption capacity, they accumulate and long-term preservation of elements and substances that are needed for the nutrition of crops. They have a positive effect on the process of respiration and root formation in crops, increase their resistance to diseases. The roots of crops become longer and more branched, the content of chlorophyll in the leaves increases.

Gibberellins bring seeds out of the dormant stage and cause germination. Activate the growth of stems and leaves. The introduction of very small amounts causes not only an acceleration of growth, but also a significant increase in size and mass. The intensity of breathing increases, carbon assimilation by plants increases, cellulose biosynthesis increases and fiber accumulates.

The activity of enzymes that control the catalytic reactions of carbohydrate-phosphorus metabolism increases. As a result, the multiplicity of complex forms of phosphorus compounds and sugars increases in plant organs.

Auxins are phytohormones that activate the growth of roots, stems, and leaves in plants. Increase the flow of nutrients to them, improve their growth. Natural growth hormone.

Succinic acid is a biogenic growth stimulator. Accelerates the development of plants and ensures an increase in yield.

Research results. The use of growth regulators provides an opportunity to influence the most important processes in the plant organism in a targeted manner, to mobilize potential opportunities embedded in its genome by nature and selection. An important aspect of the action of growth regulators is increasing the resistance of plants to pathogens and adverse biotic and abiotic factors, as well as increasing productivity.

The sunflower seeds involved in the research had different similarities, which made it possible to more fully investigate the effect of pre-sowing treatment on yield. Kadet and Yarilo sunflower seeds had quite high indicators of laboratory germination: 96 and 98 %, respectively. Kosmos sunflower had low germination rates – only 76 %.

The yield of hybrids is the main selection feature, the formation of which depends on its components, which in turn are under the influence of environmental factors.

The highest yield on the control variant among sunflower hybrids was noted in Kadet – 2.25 t/ha, at 1.85 and 2.04 t/ha in hybrids Kosmos and Yarilo (Table 1).

Table 1

Seed yield of sunflower hybrids depending on the method of application of plant growth regulators and microfertilizers, t/ha, 2021

Version			Kadet	Kosmos	Yarilo	Average	+/- to control	
seed processing	spraying plants in phase							
	4 pairs of leaves	6 pairs of leaves					t/ga	%
Baryon + Exor (Etalon)	–	–	2,25	1,85	2,04	2,04	–	–
Standard + Raikat Start	–	–	2,34	2,04	2,10	2,16	0,11	6
Standard + Raikat Start	Microcoat Oily + Atlante	–	2,55	2,09	2,21	2,28	0,24	12
Standard + Raikat Start	Microcoat Oily + Atlante	Microcoat Oil, + Aminokat 30	2,56	2,10	2,30	2,32	0,28	14
Standard + AKM	–	–	2,43	1,95	2,20	2,19	0,15	7

Standard + AKM	Antistress + Endophyte L1 + Endobor	–	2,35	2,10	2,18	2,21	0,17	8
Standard + AKM	Antistress + Endophyte L1 + Endobor	Antistress + Endophyte L1 + Endobor	2,40	2,06	2,23	2,23	0,18	9
Standard + Avan. Start + Avangard Grow Amino	–	–	2,31	1,94	2,10	2,12	0,07	4
Standard + Avan. Start + Avangard Grow Amino	Avangard Bor + Avan. Sunflower + Avang. Grow Amino	–	2,50	1,99	2,22	2,24	0,19	9
Standard + Avan. Start + Avangard Grow Amino	Vanguard Bor + Avangard Sunflower + Avangard. Grow Amino	Avangard Bor + Avan. Sunflower + Avangard Grow Amino + Avang. RK	2,47	2,07	2,22	2,25	0,21	10
Standard + Avan. Start + Vanguard Grow Amino	Avang. Boron + Avangard Sunflower + Avangard. Grow Amino + Awang. Grow Humate +	Avangard Bor + Avan. Sunflower + Avangard Grow Amino + Avangard Grow Humate + Magnesium	2,48	2,06	2,24	2,26	0,22	11

	Magnesium Sulfate + Urea	Sulfate + Urea						
NIR $_{05}$			0,16	0,13	0,12	0,16		–

Research has established that the use of plant growth regulators and microfertilizers in 2021 made it possible to increase the seed productivity of hybrids by 0.07–0.28 t/ha or 4–14 %.

At the same time, the triple application of plant growth regulators and microfertilizers (pre-sowing treatment of seeds and spraying of plants in phases 4 and 6 pairs of sunflower leaves) turned out to be the most effective. In these variants, yield increases were 0.18–0.28 t/ha (or 9–14 %) on hybrids. The efficiency of the pre-sowing seed treatment itself was significantly lower - yield increases were 0.07–0.15 t/ha (or 4–7 %).

Double application of plant growth regulators and microfertilizers (pre-sowing treatment of seeds and spraying of plants in the phase of 4 pairs of leaves) ensured increases in seed yield at the level of 0.17–0.24 t/ha (or 8–12 %).

Table 2

Seed yield of sunflower hybrids depending on the method of application of plant growth regulators and microfertilizers, 2022, t/ha

Version			Kadet	Kosmos	Yarilo	Average	+/- to control	
seed processing	spraying plants in phase							
	4 pairs of leaves	6 pairs of leaves					t/ga	%
Baryon + Exor (Etalon)	–	–	1,68	1,40	2,03	1,70	–	–
Standard + Raikat Start	Microcoat Oily + Atlante	Microcoat Oil, + Aminokat 30	1,81	1,49	2,13	1,81	0,11	6
Standard + AKM	Antistress + Endophyte L1 + Endobor	Antistress + Endophyte L1 + Endobor	1,92	1,59	2,28	1,93	0,23	13
Standard +	Avangard Bor +	Avangard Bor +	1,85	1,54	2,22	1,87	0,17	10

Avan. Start + Avangard Grow Amino	Avangard Sunflower + Avangard. Grow Amino	Avan. Sunflower + Avangard Grow Amino + Avang. RK						
NIR $_{05}$			0,11	0,09	0,10	0,06		–

In 2022, the highest yield on the control variant among sunflower hybrids was recorded in Yarylo – 2.03 t/ha, with 1.68 and 1.40 t/ha in the Kadet and Cosmos hybrids (Table 2).

Research has established that the use of plant growth regulators and microfertilizers in 2022 made it possible to increase the seed productivity of sunflower hybrids by an average of 0.11–0.23 t/ha or 6–13 %.

At the same time, among sunflower hybrids, the most effective was the use of a complex of drugs AKM, Antistress, Endophyt L1, Endobor – an allowance of 0.23 t/ha or 13 %.

Conclusions

The effectiveness of plant growth regulators and microfertilizers depends on the combination of drugs in different ways of application and varietal characteristics of the parental components of sunflower.

The high efficiency of plant growth regulators and microfertilizers in increasing the seed productivity of sunflower hybrids in 2021 was found to be – 0.07-0.28 t/ha or 4-14 %. At the same time, the triple application of plant growth regulators and microfertilizers (pre-sowing treatment of seeds and spraying of plants in phases 4 and 6 pairs of sunflower leaves), additions of 0.18–0.28 t/ha (or 9–14 %) turned out to be the most effective.

In 2022, the complex application of plant growth regulators and microfertilizers allows to increase the yield of hybrid seeds by 4.7–13.0 %, depending on the drugs and the method of their application.

In addition, the use of plant growth regulators for the pre-sowing treatment of sunflower seeds provides: fuller realization of the potential of sunflower, reduction of agricultural resource costs, improvement of ecological purity of grown products and the environment due to reduction of pesticide load.

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RAPE POLLEN BEETLE (*BRASSICOGETHES AENEUS* FABRICIUS, 1775). LITERATURE REVIEW

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In the course of the literature critical analysis the authors paid special attention to the morphological, biological and ecological features of the rape pollen beetle, both in Ukraine and abroad; the authors came to the conclusion that despite the considerable number of literary sources devoted to the rape pollen beetle, there is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. The data obtained by the entomologists from different countries regarding the harmfulness of the rape pollen beetle and its economic

importance are quite controversial and also need experimental confirmation.

Key words: *rape pollen beetle, morphology, biology, ecology, harmfulness, economic threshold of harmfulness, integrated protection.*

Introduction. The rape pollen beetle (*Brassicogethes aeneus* Fabricius, 1775) is one of the most dangerous pests on Brassicaceae crops in all areas of their cultivation, as it can damage plants during the budding and flowering phases (Snizhok, 2007; Shpaar, 2007; Yakovlyev, 2007; Sekun et al., 2008; Chirkov & Moskalenko, 2009; Snizhok, 2009; Gordyeyeva, 2010 a; Gordyeyeva, 2010 b; Yevtushenko & Stankevych, 2010; Yevtushenko & Stankevych, 2011; Stankevych, 2011a).

The rape pollen beetle is widespread throughout Ukraine, annually causing significant damage to plantations and reducing seed yields (Kasyanov, 2011). The species range covers the entire Europe, the Caucasus, Asia Minor, and North Africa (Vasilev, 1987), but as to Central Asia, it is only found in Turkmenistan (Fig. 1) (Pavlovskij, 1941). N.A. Filippov (Filippov, 1978) pointed out that the rape pollen beetle was the most dangerous pest on Brassicaceae crops in Moldova. D. Shpaar (Shpaar, 2007) reported that the rape pollen beetle was the most dangerous pest on Brassicaceae crops in Germany, Poland and France.

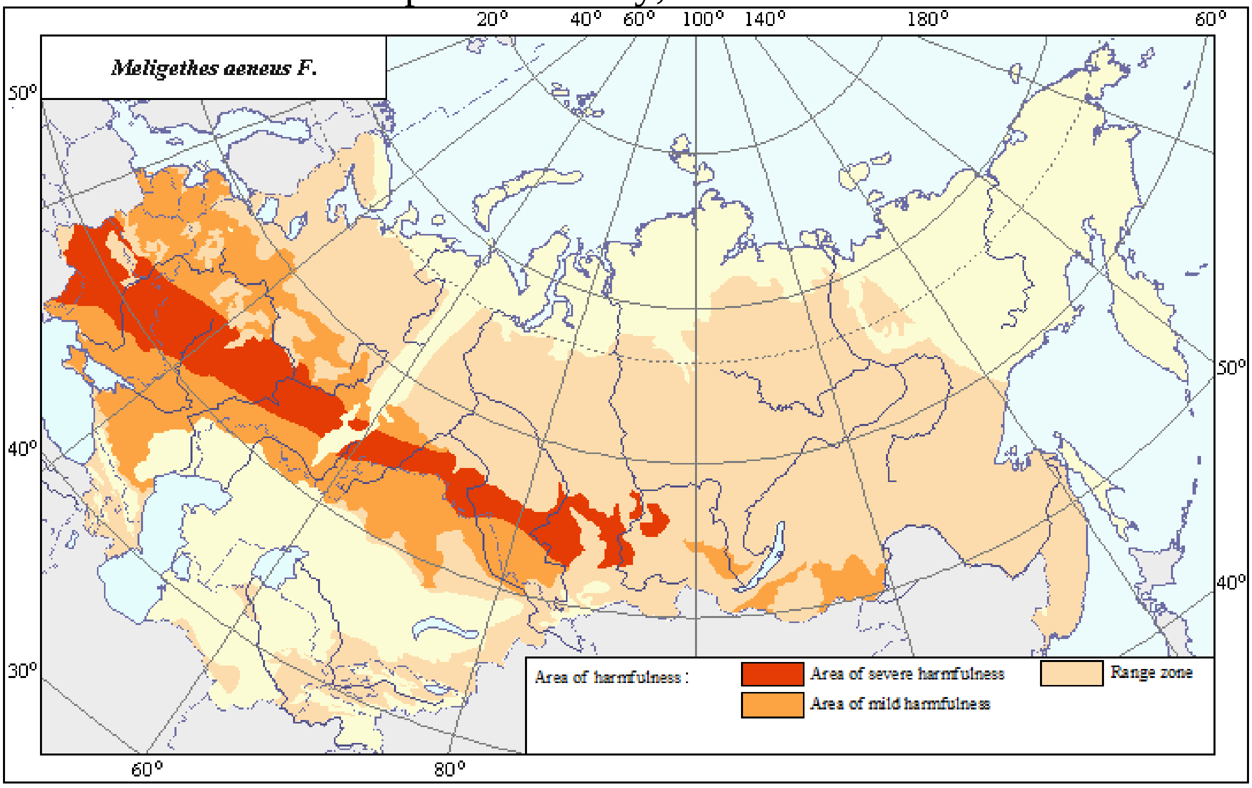

Fig. 1. Range zone and areas of harmfulness of the rape pollen beetle

It should be noted that the rape pollen beetle is not new to our country; it was mentioned as a pest both of rapeseed and of other Brassicaceae crops as early as in 1845 (O vrednyh nasekomyh, 1845) and its morphology, biology and ecology were described in detail the 19th century publications (Bramson, 1881; Keppen, 1882; Iversen, 1883; Lindeman, 1866; Blomejer, 1901).

N.N. Plavilshikov (Plavilshikov, 1994) defined the taxonomic status of the rape pollen beetle as follows: Class Insects – Insecta Leach, 1815; Subclass Winged Insects or Higher Insects – Pterygota Gegenbaur, 1878; Infraclass Neopterans – Neoptera Martynov, 1923; Division Holometabolic Insects – Holometabola; Hyperorder Coleopteroids – Coleopteroidea; Order Coleopterans – Coleoptera Linnaeus, 1758; Suborder Omnivorous Beetles – Polyphaga Emery, 1886; Family Sap Beetwles – Nitidulidae Latreille, 1802; Genus *Brassicogethes* Fabricius, 1775.

Materials and methods. The authors analyzed 157 literary and electronic sources from the late 19th to the 21st century. During the analysis, special attention was paid to the morphological, biological and ecological features rape pollen beetle in Ukraine and abroad. The data on the harmfulness of the rape pollen beetle and its economic significance are especially analyzed. In the course of the analysis special attention was paid to the methods and ways of controlling the rape pollen beetle in Ukraine and abroad. The protective measures were considered in such directions as agro-technical, physic and mechanical, chemical, biological, biotechnical and selective and genetic ones. Each of them is noteworthy and has both a number of disadvantages and indisputable advantages in comparison with other methods.

Results and discussion

Morphology, biological and ecological features and harmfulness of the rape pollen beetle

The imago is 1.5–2.7 mm in size; its body is flat, elongated, black with a green or blue metallic sheen (Fig. 2 A); the antenna are relatively short, with a three-segmented club; the legs are short and dark; the anterior legs are rarely reddish-brown; the anterior tibiae are finely serrated (Gerasimov & Osnickaya, 1961; Shapilo, 1986; Kasyanov, 2011). The body top is densely dotted; the gaps between the dots are not larger than the dots themselves.

The egg size is 0.3 mm; the egg is white, smooth, elongated-oval (Gerasimov & Osnickaya, 1961; Ivanov et al., 1985; Iskakov & Krasnikova, 1991).

The grub is 3.5–4 mm in size, worm-like, with three pairs of brown-black legs, pale gray, covered with small black warts; the head is brown (Fig. 2.B) (Gerasimov & Osnickaya, 1961; Abramik et al., 2010).

The pupa is 3 mm in size, free, flattened-ovoid, waxy-white; it turns yellow prior to the imago emergence and then becomes completely dark (Vasilev, 1988).

In Ukraine, sexually immature beetles overwinter on the soil surface under fallen leaves or under plant remains on the edge of forests, in gardens and parks. Beetles get out of overwintering housings in the second half of April – early in May (Bardin, 2000). It was published (Gar & Melnikova, 1986) that the main triggers for overwintering beetles to get out were the air temperature of 8.6 (± 0.6)°C and soil warming at a depth of 5 cm to 8.7 (± 0.8)°C. Mass swarming occurs at 13.8–14.6°C; however, other scientists give the following temperatures: 10.1–11.3°C (Gerasimov & Osnickaya, 1961; Gurova, 1963) and 10.7°C, with the sum of effective temperatures of 94.1–119.1°C (Snizhok, 2009).

A)

B) 

Fig. 2. Rape pollen beetle: A - imago; B - grub.
Training, Research and Production Center *Doslidne Pole (Experimental Field)* of VV Dokuchaev KhNAU (2011)

Several researchers (Gerasimov & Osnickaya, 1961; Laba, 2006; Gordyeyeva, 2010 a; Gordyeyeva, 2010 b; Yeshenko, 2010; Pisarenko & Gordyeyeva, 2010) reported that beetles first inhabited flowers of dandelion, buttercup, winter cress, and later appear on flowers of fruit trees (cherry-trees, apple-trees, etc.). We observed (Stankevych, 2011a; Yevtushenko & Stankevich, 2012; Stankevych, 2012f; Stankevych, 2012h) that after leaving wintering housings the rape pollen beetle additionally fed on dandelion, buttercup, small tumbleweed mustard, flixweed, field mustard, and winter cress. As E.A. Ivancova (Ivancova, 2010) described, the additional feeding lasts 12–15 days in the rape pollen beetle. Beetles appear on domestic Brassicaceae plants with the first green buds (Kulik & Shvecova, 1940; Lugovskij, 2011), which is mentioned by the vast majority of scientists, however, V.V. Stefanovskij (Stefanovskij & Majstrenko, 1990). noted that plants got inhabited as inflorescences formed. This period coincides with the first half of May. Beetles feed on the inner parts of flowers (pistils, stamens, pollen, petals). Damaged buds turn yellow and drop. Feeding mainly on pollen of full-blown flowers, the rape pollen beetle is less harmful, if anthesis is even and rapid. However, upon mass swarming, beetles can inflict significant damage during anthesis (Shapilo, 1986; Vlasenko, 1997; Krut', 2003).

As B.A. Gerasimov (Gerasimov & Osnickaya, 1961) noted, when the crop was damaged in the budding phase (10 beetles per 100 buds), the yield loss was 72.5%, but when the crop was damaged during anthesis (10 beetles per 100 flowers), the yield loss was 35.9%. When flowers were slightly damaged, they did not fall off and distorted curved pods developed. However, L.M. Ovchinnikova (Ovchinnikova, 1971) and V.N. Voskresenskaya (Voskresenskaya, 1973) reported that, when the crop was infested in the budding phase with a population density of 5 beetles and 10 beetles per plant, the yield decreased by 1.0–16.7% and 2.5–20.5%, respectively. If beetles infested plants during anthesis, even the population density of 15-20 beetles per plant led to no decrease in the yield and even a gain in the yield of 3.66 ± 0.12% to 7.00 ± 0.12% was observed. This is attributed to the fact that the rape pollen beetle acts as a pollinator (to some extent) during the anthesis. Nevertheless, with an increase in the population density to 30 beetles per plant, the yield was reduced by 2.66 ± 0.11%. L.V. Sorochinskij (Sorochinskij, 1988) published data that at a population density of 70 beetles per plant, the yield loss amounted to 82%. Бернд Хонемайєр from the University of Rostock (Germany) reported that at the rape pollen beetle population density of 1.5 beetles/plant during anthesis, the yield decreased by 22.2%, at 5.5 beetles/plant - by 55.5%, and at 11 beetles/plant – by 66.4% (Krut, 2003). The degree of the rape pollen beetle–induced damage to plants is also associated with Alternaria affection of rapeseed plants. Pathogens use beetle-damaged flowers to penetrate the plant (Sytnyk, 1997). In Germany, the economic threshold of harmfulness (ETH) (Kirch & Basedow, 2008) for the rape pollen beetle is currently 2 beetles/plant, but it is being discussed that this parameter may be changed to by 5-6 or even 8-10 beetles/plant. In Austria, the rape pollen beetle ETH is 6 beetles per plant on winter rape and 2 beetles per plant on spring rape (Szith, 2009). In Norway (Andersen, Kjos, Nordhus & Johansen, 2008), the ETH is 1-2 beetles per plant in the budding phase.

M.V. Krut’ (Krut’, 2003) pointed out that The ETH was 0.5–1.0 beetles/plant during the flower bud formation, 2.0 beetles/plant 14 days before anthesis, and 2.5–3.0 beetles/plant prior to anthesis. At the Institute of Cruciferous Crops of NAASU, the ETH for the rape pollen beetle was defined as follows: 1 beetle per plant during the bud formation, 2-3 beetles per plant in the phase of enlarged buds, and 5-6 beetles per plant at the anthesis onset (Abramyk et al., 2010; Gordyeyeva, 2010a; Gordyeyeva, 2010b). The beetle population density is particularly high in areas adjacent to afforestation belts and shrubs.

It is interesting that I.V. Kozhanchikov (Kozhanchikov, 1929) and N.L. Saharov (Saharov, 1934) emphasized that the presence of the rape pollen beetle in no way prevented the Brassicaceae seed plants from giving high yields of seeds.

After 12–15 days (usually during the third 10 days of May), females lay eggs in buds that have not yet bloomed with stamens. According to different references, the female lays from 1 to 10 eggs in one bud (Gerasimov & Osnickaya, 1961; Osmolovskij, 1972; Ivanov et al., 1985; Milashenko & Abramov, 1989; Iskakov & Krasnikova, 1991; Leisker, 2007; Ivancova, 2010). The total number of eggs laid by 1 female is 40–50 eggs (Maksimov, 1990). Four–twelve days later, depending on the temperature, grubs that live in buds and flowers, feeding on pollen, hatch (Gerasimov & Osnickaya, 1961; Gurova, 1963; Bardin, 2000). Different researchers reported various duration of the embryonic period: from 4 to 14 days (Gorodnij, 1970; Ovchinnikova, 1971).

Only with a dense infestation of flowers, grubs can significantly damage them (Gerasimov & Osnickaya, 1961). G.Ye. Osmolovskij (Osmolovskij, 1972) published data that grubs inflicted significant damage only at a population density of 3 or more grubs per flower. However, Ya.P. Bardin (Bardin, 2000), L.I. Bud’ko (Bud’ko, Rovba & Shaganov, 2008) and Ye.A. Ivancova (Ivancova, 2010) believed that grubs of the rape pollen beetle could cause significant damage. Ya.P. Bardin (Bardin, 2000) reported that several grubs could feed simultaneously on some flowers, moving from flower to flower, from plant to plant, and completely destroying the inflorescence. V.V. Markov (Markov, 2006) and L.I. Bud’ko (Bud’ko, Rovba & Shaganov, 2008) published data that grubs also intensively fed on young pods. With mass emergence, grubs of the rape pollen beetle reduce seed yields and often completely destroy seeds. However, the Swiss researcher F. Hani (Hani, 1988) thought that grubs feeding on flower pollen did not do any harm to plants.

Grubs live 10–30 days, then they mine into the soil (Orobchenko, 1959; Gerasimov & Osnickaya, 1961; Milashenko & Abramov, 1989; Bardin, 2000) to a depth of 1.5–5.0 cm (different researchers reported different figures) and pupate (Maksimov, 1990; Abramik et al., 2010).

The pupal stage lasts 10 to 16 days. In late May – early June, young beetles of a new generation emerge and also feed on flowers of different plants. Around the end of July, when Brassicaceae oil crops ripen, the new generation of beetles fly to overwintering housings (Orobchenko, 1959; Milashenko & Abramov, 1989).

G.Ye. Osmolovskij (Osmolovskij, 1972) reported that in the northern regions of Russia the rape pollen beetle had one generation per year, while in the central and southern regions - two or three generations. Ye.A. Ivancova (Ivancova, 2010) reported that in the Volga region the rape pollen beetle gave 1-3 generations per year. R.Ya. Kuznecova (Kuznecova, 1975) pointed out that in the northern regions of Russia the rape pollen beetle had one generation per year, while in the southern regions it gave 2-3 generations. In Sweden and Norway (Andersen, Kjos, Nordhus & Johansen, 2008; Wivstad, 2010), the pest produces one generation per year. The vast majority of researchers believed that in Ukraine the rape pollen beetle gave two generations (Gurova, 1963; Gorodnij, 1970), but G.M. Kovalchuk (Kovalchuk, 1987) thought that only one. V.P. Orobchenko (Orobchenko, 1959) published data about 3-4 generations. A. Podkopayev (Podkopayev, 1933) also wrote that the rape pollen beetle gave several generations per year. V.P. Fedorenko (Fedorenko et al., 2008) emphasized that in Ukraine the rape pollen beetle gave 1-2 generations per year. Z.I. Gurova (Gurova, 1963) wrote that in the eastern forest-steppe of Ukraine the full development cycle of the first generation of the rape pollen beetle took 36–42 days, and of the second generation – 26-29 days.

The maximum use of its natural enemies is an important factor limiting the rape pollen beetle numbers.

According to F. Keppen data (Keppen, 1882), the scarlet malachite beetle *Malachius aeneus* eats *M. aeneus* grubs and wasps of the genus *Microgaster* parasitize in grubs.

The endoparasite *Diospilus capito* Nees (Hymenoptera: Braconidae) parasitizes in *M. aeneus* grubs (Ovchinnikova & Voskresenskaya, 1972; Voskresenskaya, 1973).

In Germany, major main natural enemies of the rape pollen beetle are the parasitoid *Phradis morionellus* (family Ichneumonidae), which develops in *M. aeneus* grubs and pupae, and nematodes of the genera *Steinernema* and *Heterorhabditis*, which infest up to 10% of *M. aeneus* pupae in the soil (Brust, 1991; Nitzsche & Ulber, 1998; Nielsen & Philipsen, 2005; Susurluk, 2005; Ehlers, R.-U. (2006).

In Switzerland, the natural enemies of *M. aeneus* grubs are parasitic wasp of the genera *Isurgus* and Diospilus, and the imago number is regulated by the microsporidium *Nosema meligethi* I. et R. (Lipa & Hokkanen, 1991).

Protection against the rape pollen beetle

Information on protection against the rape pollen beetle has been known since the mid-1800s. Beetles were recommended to be collected with sweep-nets or shaken in bags early in the morning or in cloudy weather (Bramson, 1881; Keppen, 1882; Iversen, 1883; Blomejer, 1901). In the 1930s, there were recommendations to sprinkle plants with calcium orthoarsenate, sodium fluorosilicate or anabadust, to spray with copper acetoarsenite and barium chlorate at the budding onset and to repeat spraying twice or three times with an interval of 6-7 days, to shake beetles in a bucket of water with a little kerosene on the water surface (Podkopayev, 1933; Shyogolev, Znamenskij & Bej-Bienko, 1937). In the 1940s, shaking plants in the morning was recommended to protect against *M. aeneus* imagoes. During the budding phase, but always prior to anthesis, twice or three-time sprinkling with calcium orthoarsenate or sodium fluorosilicate with talc in a ratio of 1 : 6 and anabadust was applied. It was also reported that in experiments of the Novosibirsk Plant Protection Station good results were obtained from spraying with a pyrethrum extract (Moric-Romanova, Berezhkov & Davydov, 1941). In the 1950s - 1960s, several researchers (Zambin, Turaev & Shumilenko, 1953; Orobchenko, 1959; Gerasimov & Osnickaya, 1961) recommended twice or three-time sprinkling plants with pesticide dusts such as dichlorodiphenyltrichloroethane (DDT), hexachlorane, sodium fluorosilicate, calcium orthoarsenate, anabadust or metaphos in the budding phase; there are also data that in other countries insecticide toxaphene, which, like DDT and hexachlorane, is an organochlorine compound, but as the author stated, was much safer for bees, was used. In the 1970s, sprinkling plants with hexachlorane or metaphos, or with a mixture thereof was recommended (Gorodnij, 1970).

In 1974, A.A. Moskalyova (Moskalyova, 1974) for the first time presented data on the effectiveness of microbial products such as Entobacterin with a titer of 30 billion spores of *Bacillus turingiensis var galloriae*, Dendrobacillin with a titer of 20 billion spores of *Bacillus turingiensis var dendim titer*, Boverin with a titer of 6 billion spores *Beauveria bassiana (Bals) vuil* to control the rape pollen beetle numbers. These agents were used alone or in mixtures with chlorophos. The mortality of beetles from biological products amounted to 45%, and from mixtures with chlorophos - to 93%.

In 1973, as part of a research project, to protect against the rape pollen beetle at a population density of 20 insects/plant, plants were twice sprayed with malathion, azinphosmethyl, phosalone or with hexachlorocyclohexanes (HCH) during the budding phase (Rape seed production, 1973). V. Teuteberg (Teuteberg, 1973) in Germany recommended to carry out 1-2 sprayings with chlorfenvinphos prior to anthesis and 4-5 treatments with HCH during anthesis. In Czechoslovakia (Vilinskiy, 1974), plants were sprinkled with toxaphene at the anthesis onset. A.A. Moskalyova (Moskalyova, 1974), to control the rape pollen beetle numbers, also recommended a number of organophosphorus compounds such as dichlorvos, cartap hydrochloride, tetrachlorvinphos, diazinon, dimethoate, phosphamide, phosalone, and cyanox, the effectiveness of which ranged 28 to 100%, as well as a biological product, Bitoxibacillin (BTB-202), with a titer of 40 billion disputes, the efficiency of which was 100%.

A.A. Gortlevskij (Gortlevskij & Makeeva, 1983) recommended spraying with thiodan at a population density of 6–8 insects/plant in the budding phase. O.A. Ivanov (Ivanov et al., 1985) recommended spraying with chlorophos, thiodan, dichlorvos, malathion, or with phosphamide at a population density of 2–3 insects/plant before budding and with 1% suspension of Bitoxybacillin before anthesis P.I. Zajcev (Zajcev, 1987) indicated that the effectiveness of fenvalerate was 90% and of metaphos - 70-80%. V.T. Piven (Piven, 1988) recommended protecting plants against the rape pollen beetle by spraying with thiodan or fenvalerate in the budding phase A.P. Tuzlukova (Tuzlukova, 1987) published data on a high effectiveness of organophosphorus insecticides (metaphos, phoxim, pirimiphos-methyl) in mixtures with trace elements (boron and molybdenum) in the control of the rape pollen beetle.

In the early 1990s, V.V. Stefanovskij (Stefanovskij & Majstrenko, 1990), to protect plants against the rape pollen beetle, recommended spraying with insecticides such as pirimiphos-methyl, permethrin, phoxim, phosalone, malathion, methylparathion, fenvalerate and cypermethrin in the budding phase and adding dimethoate or etaphos to the soil simultaneously with sowing. N.G. Vlasenko (Vlasenko & Kulagin, 1993**)** recommended trap crops as a method of controlling the rap pollen beetle numbers, i.e. about 10% of the planned cultivation area is allocated for a trap crop. According to his data, this way is used to protect spring rape against the rape pollen beetle in Finland. Spring rape itself, but sown a week earlier than the main crop, acts as a trap crop. N.G. Vlasenko (Vlasenko & Kulagin, 1993**)** used winter cress, mustard and oil radish as trap crops in Siberia.

The white turnip is used as a trap crop in Switzerland (Buchi, 1990).

Recently, the range of insecticides recommended for the protection of Brassicaceae oil crops against the rape pollen beetle has been so widened that there is no need to dwell on each agent. Several researchers recommended spraying with one of the permitted insecticides to protect plants in the budding phase (Chehov, 2001; Chervonenko, Tereshenko & Ishenko, 2003; Laba, 2006; Lazar et al., 2006; Gordyeyeva, 2007a; Gordyeyeva, 2007b; Sahnenko, 2007; Shpaar, 2007; Zhuravskij & Sekun, 2007; Fedorenko et al., 2008; Sytnyk, 2008; Mazur et al., 2009; Snizhok, 2009; Abramyk et al., 2010; Ivancova, 2010; Krasilovec, 2010; Yeshenko et al, 2010; Kasyanov, 2011; Kyforuk et al., 2011).

As per the List of Pesticides and Agrochemicals Approved for Use in Ukraine, in 2020, 88 insecticides were recommended to be sprayed on Brassicaceae oil crops to protect them against the rape pollen beetle during the growing period; of them, 36 insecticides (40,9 %) are synthetic pyrethroids, 19 insecticides (21,6%) – neonicotinoids, 5 insecticides (5,7%) – organophosphorus compounds, 1 insecticides (1,1%) – pyridinecarboxylides, and 27 insecticides (30,7%) are combined products.

When regulating the rape pollen beetle numbers, vegetating plants are sprayed with permitted insecticides before anthesis to prevent mass extermination of bees (Bardin, 2000; Stankevych, Teslina & Ozhga, 2010; Stankevych, 2010; Stankevich & Fedorenko, 2011; Stankevych, 2012f; Stankevych, 2012h). The need to expand the range of insecticides to control the rape pollen beetle numbers arises from the fact that this beetle rapidly becomes resistant to pyrethroids, which are now widely used worldwide to protect rapeseed. In addition, pyrethroids lose their insecticidal properties after a long exposure to temperatures above 25°C and direct sunlight. This was menthioned by D. Shpaar (Shpaar, 2007) as early as in 2007. According to his data, in 2004 in Germany, the resistance of the pest to pyrethroids was 10%, in 2005 - 20%, and in 2006 – as high as 50% and in most areas the yield losses amounted to 70-80%. After that, neonicotinoids and new organophosphorus compounds were mandatorily included in the protection algorithm, and the next year the phytosanitary situation improved. Moreover, organophosphorus compounds appeared to be more effective than neonicotinoids (Burghause & Schackmann, 2006; Heimbach, Thieme & Mulle, 2006). In 2005, at a meeting of a special commission on insect resistance to synthetic pyrethroids in Germany (Fachausschuss Pflanzenschutzmittelresistenz, 2005), data on the effectiveness of some agents against the rape pollen beetle were presented. For example, the highest mortality of beetles was recorded with beta-cyfluthrin application (40–92%), while lambda-cyhalothrin only killed 8–77% of beetles. In addition, it was reported that beetles that had become resistant to pyrethroids overwintered much better and left overwintering houses much earlier than it had been expected. The genetic mechanism of developing resistance to synthetic pyrethroids in the rape pollen beetle was studied in Sweden and described in detail in J. Pernestal publication (Pernestal, 2009). Since in Sweden, starting from the 1980s, only pyrethroids were used to control the rape pollen beetle numbers, in 2009, there was not a single synthetic pyrethroid insecticide left on the pesticide market that would be effective in controlling the pest. To date, the rape pollen beetle numbers are limited to insecticides belonging to other chemical groups (Sundgren et al., 2008). In 2007 in Norway, it was noted that synthetic pyrethroids almost did not regulate the rape pollen beetle numbers, because due to their continuous long-term use, beetles had developed cross-resistance to these insecticides (Andersen, Kjos, Nordhus &

Johansen, 2008), and today, to control this pest, neonicotinoid insecticide Biscaya (24% oil dispersion) is used. However, it is not advisable to use only this insecticide, as resistance to it may also develop (Andersen, Kjos, Nordhus & Johansen, 2008). In Switzerland, the most promising trend in controlling the rape pollen beetle numbers is the cultivation of resistant rapeseed varieties, including genetically modified ones (Ammann & Vogel, 1999), and, in Germany, the cultivation of trap crops is important (Hirthe, 2010; Hirthe & Jakobs, 2010; Michel. & Hirthe, 2010).

Conclusions

1. The analysis of the literary data indicates that despite the considerable number of the literary sources devoted to the rape pollen beetle, there is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified.

2. Modern systems of plant protection, consist in developing and implementing the integrated measures that preserve the crops from the harmful organisms while being the safest for the environment, animals and humans.

3. The transition to such integrated systems involves the application of a biological method of pest control, reducing the number of pesticide treatments, the ability to use the preparations of selective action together with the entomophages, etc. An important reserve in this program is the activation and use of natural resources of the beneficial insects (parasitoids and predators) which limit the number of harmful insect-phytophages.

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APPLE-BLOSSOM WEEVIL (*ANTHONOMUS POMORUM* LINNAEUS, 1758): MORPHOBIOECOLOGICAL FEATURES AND HARMFULNESS IN UKRAINE AND IN THE WORLD

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In the course of the literature critical analysis the authors paid special attention to the morphological, biological and ecological features of the apple-blossom weevil in fruit plantations, both in Ukraine and abroad; the authors came to the conclusion that despite the considerable number of literary sources devoted to the apple-blossom weevil, there is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. In particular, the relationship between the phenology of the apple varieties of different time of ripening and the period of egg- laying as well as between the period of summer diapause of the pest and its concentration places during the summer diapause and during hibernation remains unclear. There is also a lack of data on the density of the hibernating beetles of the apple-blossom weevil under the dead bark on the trunks and boughs, in the surface layer of soil and plant litter of the crown projection per apple tree; the knowledge of these facts would allow to calculate the pest density in the next spring in order to protect the apple trees before blossoming. The data obtained by the entomologists from different countries regarding the harmfulness of the apple-blossom weevil and its economic importance are quite controversial and also need experimental confirmation.

Key words: *apple-blossom weevil, morphology, biology, ecology, harmfulness.*

One of the most dangerous pests of the generative organs of the apple tree before fruit formation is the apple-blossom weevil – *Anthonomus* *pomorum* L., belonging to a line of sheathed-winged beetles, or Coleoptera beetles of the weevil (Curculionidae) family. The apple-blossom weevil is distributed throughout the territory of Ukraine, but it causes the greatest damage in the areas of Polissia, Forest-Steppe and in the foothills of the Crimea. It is also distributed in the European part of the Russian Federation, in the north towards Leningrad, in the Caucasus, and in the Prymorskyi Krai, especially in the gardens located near the forests where wild apple- and pear-trees grow (Alekseieva, 1985; Vasiliev, 1976, 1988; Rodionov, 1932).

In the former USSR the apple-blossom weevil is the most numerous in the middle zone (Mozgovyi, 1932). It is distributed throughout the territory of the former USSR, except Turkmenistan and Western Siberia; but it is of particular economic importance in the Moscow and Ivanovo regions, in the Gorky Krai, the Upper Volga Region, and in the valleys of the Caucasus rivers (Chugunin, 1937). As for the foreign countries, the apple-blossom weevil is found in the Eastern and Western European countries, in the greater part of Asia, in Korea, Japan, Northern China, the USA, Romania, and Greece (Batiashvili, 1959; Vasiliev, 1988; Mozgovyi, 1932; Hull, 1985; Niemczyk, 1994; Progar).

Materials and methods

The authors have analysed 104 literary and electronic sources from the end of the 19th up to the 21st centuries. In the course of the analysis special attention was paid to the morphological, biological and ecological features of the apple-blossom weevil in fruit plantations, both in Ukraine and abroad. The data concerning the harmfulness of the apple-blossom weevil and its economic importance have been analysed in particular.

Results and discussion

The total length of this beetle is 3–5 mm, the head capsule is 1,25 mm long (Diamandidi, 1923; Schreiner, 1907; Schreiner, 1915). The body is dark brown, brownish gray or fulvous brown in colour. The head capsule is long, thin and slightly bent. The elbowed-clavate antennae and legs are reddish or reddish-brown, the antennal clava and thickened part of the femura are dark brown (Ambrosov, 1976; Borisoglebskaia, 1975; Borisoglebskaia, 1977; Diamandidi, 1923; Savzdarg, 1956). The thorax of the beetle is white. Across the hind part of the elytra there is an oblique light gray stripe which forms an obtuse angle, the apex of which is directed towards the posterior part of the beetle body, and the entire strip has a dark border (Figure 1) (Vasiliev, 1924; Ginzenberg, 1912; Krikunov, 2002;

Schreiner, 1915; Schreiner, 19150). The egg is elongated, watery-white, and 0,5–0,8 mm long. The larva is 5–6 mm long; it is bent and legless, narrowed to the posterior end, yellowish-white in colour and has a small dark brown head (Figure 2).

Figure1. Imago of apple-blossom weevil
(original photo)

Figure 2. Larva of apple-blossom weevil in a damaged button
(original photo)

The pupa is 4–6 mm in length, pale yellow, and has two spines at the end of the abdomen (Figure 3) (Viangeliauskaite, 1992; Kolesova, 1995; Rodionov, 1932).

According to M.T. Aristov (1925) the apple-blossom weevil hibernates in the surface layer of soil, beneath the fallen leaves, and only a small proportion of the individuals can overwinter under the scales of the tree bark.

In the Forest-Steppe zone of Ukraine, especially in the young orchards, the apple-blossom weevil hibernates in the soil near the root collar or near the trunk at a depth of 2–3 cm; it also can overwinter under the fallen leaves in the orchard or near it or in the hedgerows and in the forests under the wild apple- and pear trees, or under the scales and in the bark cracks (Vasiliev, 1988; Yanovskyi, 2003).

Some authors (Drozda, 2000; Krikunov, 2002; Filippov, 1990) inform that the beetles hibernate in the surface layer of soil, beneath the fallen leaves, in the bark cracks, and in the hedgerows.

The imagoes of the apple-blossom weevil (69–88%) lie predominantly in the soil at a depth of up to 5 cm near the trunks and they are absent outside the pans (Litvinov, 2004).

Under the conditions of the middle part of Russia the adult beetle overwinters in the surface layer of soil (2–3 cm), mostly located at a distance of up to 20–30 cm from the trunk. The beetles also overwinter in the soil cracks. In the soil the beetles are placed for hibernation both under the fruit and ornamental trees located in or near the orchard. Especially many beetles hibernate under the shelter belt trees. The flight of the beetles to these trees takes place in the summer, when the juveniles are especially active after leaving the buttons. A small amount of the hibernating beetles is also found under the bark of fruit and ornamental trees (Chugunin, 1937, 1946).

In the Khabarovsk Krai the beetles overwinter under the fallen leaves and in other hidden places (Shtundiuk, 1969). K.A. Mamaiev and others (1981) also note that the beetles hibernate under the fallen leaves and in the cracks of the tree bark.

In the Orel region the bulk of the beetles (55%, mainly the females) overwinters in the cracks and under the bark scales of the tree trunks at height of up to 40 cm. The males prefer to place themselves in the cracks between the trunk and the soil; the single specimens were found in the soil (Nikolaieva, 1973).

S. Toepfer, H. Gu, S. And Dorn (Toepfer, 2000) indicate that dried leaves are the most attractive place for the imagoes of the apple-blossom weevil hibernation. Under the conditions of Switzerland, depending on the apple tree variety, 47–64% beetles of the apple-blossom weevil hibernate in the orchards. One beetle moves at the distance of 19 m. on the average. At the same time about one third of the beetles populate the first tree they come across; and the rest of the population moves further, mainly along the tree rows. Such distribution leads to a “marginal effect” when the greatest damage to the buttons is found in the trees located near the forest (Gamina, 1991; Kashirskaia, 1991; Toepfer, 2002).

In the spring the populating of the apple-blossom weevil begins from the old orchards and forest stands (Kolesova, 1996). In the spring the beetles of the apple-blossom weevil begin to show activity at a temperature of 6°C (Figure 4) (Vinokurov, 1917; Slavgorodskaia-Kurpiieva, 1993; Chugunin, 1946; Schreiner, 1915). According to the data of C. Hausman, J. Samietz, and S. Dorn (2005) the females and males of the hibernated beetles choose the warmest areas. In Belarus the migration of the apple-blossom weevil from the hibernating places coincides with the date when the maximum daily temperatures steadily exceed 5°C (Matveichik, 1998). The populating of the crown coincides with the beginning of the bud swelling in the apple tree when the average daily air temperature reaches 6°C (Aristov, 1931; Vovk, 1926; Zabrodina, 2006; Kolesova, 2005). The apple-blossom weevil populates the crown of the apple tree with the first April thaws. The beetles hibernated in the bark cracks of the trunks and in the soil near the tree trunk leave the hibernating places first. The beetles hibernated in the pan soil leave their hibernating places later when there is no snow and the soil is dry (Bezdenko, 1958).

From the moment the buds swelling the beetles move to the tree crown and begin their nutrition. The mass populating of the tree crown by the beetles is observed at an average daily temperature of 8–10°C (Zabrodina, 2006, 2007; Kolesova 2005; Savzdarg, 1956). In Moldova the intense beetle migration is observed at a temperature of 9,6–14,6°C (Gamina, 1991). After reactivation, when the buds begin to swell, the beetles begin their nutrition making the holes in the buds and eating away the vegetative and sexual parts of the bud, which is the germs of the leaves and buds, through these holes. Piercing the bud, the apple-blossom weevil makes a hole necessarily in the places of the scales dispersion. The bleeding sap in the form of cell sap drops shining in the sun is secreted through the holes made by the beetles. This type of damage is called "spring sap-exudation" (Aristov, 1932; Borodin, 1917; Kolesova, 1996; Korchagin, 1980; Okroshiashvili, 1996; Soshnikov, 1989; Chugunin, 1938). Under temporary lowering of temperature up to 0°C the beetles stay on the branches and withstand this period without causing damage (Kolesova, 2005).

Figure 3. Pupa of apple-blossom weevil in a damaged button (original photo)

Figure 4. Spring populating of crown by beetles of apple-blossom weevil (photo by the author)

In cold weather the activity of the beetles is reduced: they become freeze in the branching or near the fruit-bearing spurs. The imago body colour merges with the tree bark, so it is not easy to find it. After migration from the hibernating places the beetles first populate the pear tree (if available), which develops 5–7 days earlier than the apple tree (Shevchuk, 2006).

The role of meteorological factors in the apple tree blossoming and in the maturation of the sexual production of the weevil is crucial. The genital organs of the apple-blossom weevil are not yet developed after awakening in the spring and therefore the extra nutrition is required to begin the activity of the genital glands. The necessity for the extra nourishment in the spring is an unfavourable factor for the apple-blossom weevil, which puts it into a critical situation during the years of lush blossoming, when the trees vigorously undergo the preparatory stages of blossoming.

The trees begin their life cycle in the spring when the snow comes off from the ground. At the same time the weevils begin to divide into groups: the beetles hibernated under the snow cover are delayed compared with those that hibernated in the open places. Direct solar radiation quickly brings them to life; and positive phototropism leads them to the buds where they start extra nutrition (Troitskii, 1925). During early-spring nourishment and egg-laying the beetles, being very sensitive and fearful, bend their legs and fall to the ground even under little threat. The method of controlling the weevils by shaking them off on the tarpaulin is based on this fact. This feature of the beetles is not constant and changing with the fluctuation in temperature. The absolute fall of the beetles on the tarpaulins when shaking off takes place at a temperature of up to 10ºC. At a higher temperature the beetles hit the branches when falling and immediately spread their wings and fly away (Chugunin, 1935, 1938, 1954).

Usually the egg-laying does not last long because the buttons of the apple trees develop in a friendly and fast way in the warm spring. And vice versa, the cool spring delays the development of the buttons and contributes to a longer period of the egg- laying, and thus more damage is done to the orchard (Savzdarg, 1956; Samoilovich).

Depending on weather conditions the beetles can gather on the tree tops or on lower branches in large numbers. In this regard the density of the eggs differs in one or another part of the crown (Aristov, 1932).

The intensity of the weevil distribution and the population density of the pest on the plantation depend on the weather conditions, chemical treatments and close location of the orchard-protective belts in which the wild apple tree grows. The orchards that have not been treated with the pesticides are the most populated (Matviievskii, Loshchitskii, Tkachev, 1987).

The most intense flight of the beetles takes place during the button exposure period, when the females lay eggs in bulk. Depending on the temperature, the egg- laying by the females of the apple-blossom weevil may last up to 30 days in the cold and prolonged spring or reduce to 10–15 days in the warm and friendly spring. The fertility of the apple-blossom weevil is 52–82 eggs per female on the average, and the potential fertility of the females is up to 100 eggs. In some years, characterised by a very short period from the beginning of the inflorescence formation to the apple-tree blossoming, the females lay only 57,3% of eggs. In such years the egg-laying occurred when the air temperature lowed to 3,6°C, whereas the species development threshold was within the limits of 6°C. The population in the fruit trees in the orchard was different. In the central part of the orchard it did not exceed 2–10 beetles, whereas in the trees of the same orchard near the forest- and orchard-protective belts the population density was up to 30–40 specimens per tree (Matviievskii, Loshchitskii, Tkachev, 1987).

According to the observations of A.M. Sokolov and R.A. Sokolova (1974) the apple-blossom weevil damages that part of the crown where the buttons are suitable for the egg-laying; so in the years when the egg-laying process took place early the weevils mostly damaged the buttons from the south side of the crown, and in the years when the egg-laying process took place late the weevils damaged the crown from the north side.

The beetles lay the eggs into the buttons of a certain stage of development; so the egg-laying period lasts from 10 to 20 days. The optimum temperature for the egg- laying ranges from 12 to 15°C. During this interval the females realise the potential stock of the eggs as much as possible. The egg production of the females ranges from several to 80–100 pieces (Batiashvili, 1959; Drozda, 2000; Slavgorodskaia-Kurpiieva, 1993; Tertyshnyi, 1988).

According to the data of V.F. Drozda (2000) the lower pest fertility at high temperature is caused by a shorter egg laying period even if in the trees there are enough buttons in the corresponding phase of development. At high temperature the apple-blossom weevil lays fewer eggs not only because the females do not have time to lay off their entire stock due to the rapid opening of the buttons, but also because at high temperatures the normal course of the females' ovogenesis is disturbed. This was shown by the results of the preparation of the females in their lifetime while keeping them at different temperatures. The functional disorder of the female sexual system is observed already at a temperature of 20°C. It is also important that the female lay the most part of the eggs within the first 3–5 days. Too low temperatures during the egg-laying period also have a negative influence on the fertility of the apple-blossom weevil. Not only the maximum fertility but also an increase in the total pest number is revealed within the limits of the optimal temperatures

(12–15°C). Under natural conditions the reproduction rate (the population growth rate) was 18,4 at a temperature of 12°C; at a temperature of 15°C it was 20,6, whereas at too low and too high temperatures this index was 7,3–9,1. This indicates that even under the extreme conditions the natural regulatory mechanisms do not significantly affect the number of the apple-blossom weevil.

According to the data of O.F. Nikolaieva (1973) the egg-laying into the green buttons begins in the phenophase of the apple tree flower-bud bursting at an average daily temperature of 10–11°C. The females prefer the early blossoming apple varieties such as White Transparent and Moscow Grushevka, in which the damage of the buttons reaches 50–80%. During this period they cause less damage to the pear trees (up to 2% of the buttons).

Before the phase of button separation some beetles may be ready to lay eggs even under the most unfavorable conditions. But the number of the eggs that they have laid depends on the external conditions, mainly on the course of blossoming. The experiments carried out at the Applied Entomology experimental station (Troitskii, 1925) showed that the daily maximum number was 5 eggs, and for the period of 28 days there were 36 eggs.

In Georgia the fertility rate of the apple-blossom weevil females reaches 30–100 eggs, but the entire stock of the eggs is realised during the prolonged spring, when the buttons of the apple trees open slowly (Okroshiashvili, 1996). According to the data of Ya.V. Chugunin (1935) each female lays from 50 to 100 eggs.

The experiments carried out by M.M. Tretiakov (1982) showed that the highest fertility of the apple-blossom weevil (40,5 eggs per female) was observed at a temperature of 15°C, and the lowest fertility (22,5 eggs per female) was observed at a temperature of 25°C; there was no egg-laying at a temperature less than 10°C.

Juveniles go to hibernation early (July – August) after feeding on the leaves of fruit trees. The fat body of the beetles is well developed, and the genitals are in a juvenile state and heavily entangled in the trachea. In the spring they need extra nutrition in order the ovaries become mature. The ovaries of the females became mature in 7–10 days when feeding in the chambers at a temperature of 10–11°C, but at a temperature of 5–6°C the maturation was delayed. During the experiments in the laboratory the egg-laying of one female was artificially interrupted after laying 20 eggs, and the female went to the second hibernation. The following year it continued the sexual activity and laid another 19 eggs. During the preparation of another female whose egg-laying was artificially interrupted but it continued to feed for another month, a highly developed fat body and "juvenile" ovaries were found. Thus, the ability of the apple-blossom weevil to have two hibernations and to the renewing of the interrupted sexual activity was experimentally demonstrated (Troitskii, 1925). M.M. Tretiakov (1982) also indicates the possible recurring hibernation.

So, in the absence of the appropriate buttons for laying eggs by the females of the apple-blossom weevil at the right time they go to hibernation and wait for the next spring, when they can lay eggs again. In such a way the preservation of the species is secured. The appearance of the weevils on a mass scale after a year of poor blossoming of the apple tree is explained by the fact of double hibernation (Triapitsyn, 1982).

V.A. Vasiliu (1998, 1999) observed the behaviuor of the apple-blossom weevil imago during the day and noted that in the morning and early in the afternoon they were on the peripheral part of the crown, and late in the afternoon, when the air temperature reached more then 20°C, they migrated to the shadow central part of the crown. At the same time the ability of the apple-blossom weevil female to lay eggs was reduced as the result of the insignificant damage of the buttons in the central part of the crown in comparison with its peripheral part both under the thickened and thinned crowns (Vasiliu, 1998, 1999).

During the egg laying the female makes a hole in the button, eats away its sepals and petals, then turns around and lays one egg in the middle of the button, and then closes the hole with its excrement and bites as if a plug (Chugunin, 1935). M. Shcherbynovskyi (1925) notes that the female always carefully examines the young buttons; and if the egg has already been laid into the button, the other female never lays another egg into the same button.

The egg is usually placed between the stamens and the pistils and sometimes between the anthers. The egg-laying continues until the phenophase of the buttons staining. The embryonic development of the egg lasts from 3 to 10 days, depending on the temperature (Chugunin, 1935), but it can be delayed up to 20 days (Borisoglebskaia, 1977; Vasiliev, 1984; Savzdarg, 1956; Tertyshnyi, 1988).

In Georgia the beginning of the egg-laying period was observed at the beginning of the button separation in the pear trees of the Beurre Bosc variety. The egg-laying lasts until the beginning of the apple tree late-ripening varieties blossoming. The beetles that came out of the hibernation places later lay the eggs into the buttons of the quince-tree which blooms later than the other fodder plants. In general the egg-laying by the apple-blossom weevil is noted into the buttons of the apple, pear, quince, cherry, sweet cherry and some other species (Batiashvili, 1959).

After leaving the egg the larva feeds first on the anthers and only after casting the coat it begins to destroy the stamens and pistils completely. From this time the larva becomes very voracious and secretes a large number of excrement which glues the petals of the button and thus does not allow them to open. If the egg is laid late, namely in the phenophase of the button opening, then the larva does not have time to glue the petals with its excrement, and the button is opening. In this case the larva is killed by the direct sunbeams. After the larva has glued the petals, it eats away the contents of the buttons causing the petals to deprive of nourishment; they become brown, dry and form the caps. The damaged buttons do not open; they become well visible against the background of the apple tree blossoming (Borisoglebskaia, 1975, Chugunin, 1938).

V.V. Vassiliu (1999) and B.M. Litvinov (2004) noted in their works that the ovary can be formed from the buttons damaged by the larvae. The share of such ovaries reached 2–3% of the total number of the damaged buttons. But after a while such ovaries fell off.

In the early and hot spring, when the air temperature reaches 20°C during a week period, the buttons simultaneously and relatively quickly open, and the larvae do not have time to glue the petals and fall off to the ground, but due to the lack of legs they are not able to get back to the tree; as a result they die and in such a way reduce the number of the pests (Batiashvili, 1959).

Light frosts do not influence the apple-blossom weevil larvae and they successfully complete the development even in the buttons of the apple trees damaged by the frost.

The larva of the apple-blossom weevil casts the coat twice, i.e. it has three ages. The total life expectancy of the larvae from the egg stage to the pupal transformation varies from 15 to 20 days. Before pupation the larva frees oneself from the excrement and glues the button even more tightly (Figure 5). The mass pupation of larvae takes place during the end of the apple tree blossoming. The pupal stage usually lasts from 7 to 12 days (Zabrodina, 2006, 2007; Vasiliev, Degtiarova, Shestopalova, 1976; Chugunin, 1935).

As V.P. Vasiliev (1961, 1984, 1988) notes the pupal stage at a temperature of 14–18°C lasts 9–11 days, and at a temperature of 22°C it lasts 6 days.

It takes 10–18 days on the average to develop the larvae in Belarus. The mass pupation of the larvae is dated to the end of the apple-tree blossoming. The beginning of pupation under the climate of Belarus takes place 4–6 days after the end of the Antonivka apple variety blossoming. The pupal stage of the apple-blossom weevil larva lasts up to 12 days (Bezdenko, 1958).

Figure 5. Larva of apple-blossom weevil in a damaged button
(photo by the author)

If the cap is removed from the damaged button, then the larvae or pupa could be seen on the receptacle; when touching, they start to move vigorously demonstrating their viability (Borisoglebskaia, 1977).

Unlike the larvae the pupa of the apple-blossom weevil has all the organs of an adult insect, but they are in the embryonic state. Before the juvenile leaves the pupa its proboscis and head become dark in colour (Kolesova, 1996; Savkovskii, 1990; Chugunin, 1935).

When leaving the pupa the juvenile has a yellow colour for 2–3 days. By the time the coverings become dark and hard, the beetle stays in the button and then bites a round hole with a diameter of its body width and goes out (Bezdenko, 1958).

In the Forest-Steppe zone the beetles' coming out begins in the third decade of May and ends in the first decade of June (Vasiliev, 1961; Savkovskii, 1990).

Each stage of the apple-blossom weevil development needs a certain sum of effective temperatures (SET). Thus, the egg laying begins at SET of 38–50°, larval revival – at 80–85°, and pupation – at 194–206°; the complete cycle of development ends at 373–382° (Nikolaieva, 1973).

The biological cycle of development from the egg to imago lasts 25–35 days, and in the years with cold and rainy spring it lasts 35–50 days. If we add the period of 10–15 days, which precedes the egg-laying, then the complete cycle of development lasts up to 35–50 days, and under the unfavourable conditions it lasts up to 65 days (Sevesku, 1966).

The revival of the beetles new generation takes place during the phenophase of throwing down of redundant ovary of the apple tree (Bezdenko, 1958; Sorochinskyi, 1998).

In some years the coming out of the apple-blossom weevils coincides with the revival of the larvae of the oyster-shell bark louse and the beginning of the first butterflies of the codling moth revival, and this fact should be taken into account when organizing the protective measures to control the adult beetles of the apple-blossom weevil (Bezdenko, 1958).

After the revival the beetles feed on the leaves. They skeletonise the leaf parenchyma, and as a result the leaves become dry. The beetles also feed on the fruits making numerous pricks in them. The weevils partially fly to the borders of the orchard or populate in the orchard trees, and even in those trees that have not blossomed this year. At an average daily air temperature of 23–25°C they fall into a state of summer diapause (temporary rest). The period of such rest for the apple-blossom weevil lasts till the end of the summer. At this time it sits almost motionless under the bark and only with the beginning of the leaf fall, when the temperature lows significantly, migrates to the hibernating places (Bezdenko, 1958; Vassiliu, 1999; Vasiliev, 1984; Yevtushenko, 2008; Zabrodina, 2008; Chugunin, 1950; 1954).

The repopulation of the apple-blossom weevil takes place during the nourishment period of the juveniles. At the end of the nourishment the apple-blossom weevil leaves for the diapause and hibernation and temporarily places under the old dead bark. In the autumn, when the weather is cold, the beetles already crawl out of the bark to hibernate in the soil or in the litter; and at this time the beetles no longer fly, but crawl along the trunk moving into the soil. This indicates that the movement of the beetle into the soil from the trunk and boughs is a secondary fact which was formed under the conditions of the severe north climate. The data of the experiments carried out by Ya.V. Chuginin (1950) at the state farm “Novinki” of the Gorky region for the period of 1925–1926 indicate that the beetle leaves the crown before the middle of July; and the analysis of the materials when using the trapping bands put on the trunks indicates that the beetles appear in the bands only in the first days of October. Thus, the author faced the problem concerning the location of the beetles during July, August and September. For this purpose the bark from the trunks and boughs was removed and then analysed. From the obtained materials it is seen that all stock of the beetle migrates under the tree bark at the end of the nourishment and remains there till the moment of passing on to hibernation. In the middle part of Russia the apple-blossom weevil migrates under the dead bark of the branches and trunk at the end of the nourishment and stays there for some time waiting for the cold weather, and then moves to the soil.

Ya.V. Chugunin (1950) carried out the similar experiments in the Crimea in 1938. The beetles moved from the crown under the bark of the trees where they stayed for hibernation but did not migrate into the soil. The soil and bark analysis conducted during the winter of 1938 did not confirm this data. The number of the beetles did not correspond to the stock of the apple-blossom weevil which was determined during the spring shaking off. The author did not notice the phenomenon of the beetles' movement from the tree trunk and boughs into the soil. In the Crimea the beetles stay in the places where they were after the end of the nourishment throughout the winter and only in the spring, with the beginning of the fruit trees development, the weevils begin to move from the hibernating places to the buds.

The same experiments were carried out by M.D. Yevtushenko and I.V. Zabrodina (2008, 2009) in the orchards of the Kharkiv region and as a result of these experiments the location of the beetles of the apple-blossom weevil under the bark during the summer diapause and hibernation and their ratio on the tree trunk, on the main boughs, in the soil and in the litter have been determined.

The question regarding the connection of the insect population cycles with the long-term dynamics of the solar activity is being discussed in domestic and foreign literature. The theory of the population dynamics cyclic character explains the regularities of the population autowave cyclic processes of development, functioning and change of the population structure in synchrony with the cyclic character of the external environment. The regularity in the solar activity changes and the cyclic character of mass reproduction of the main pests of the apple trees in space and time, as well as the availability of the historical materials on the population number outbreaks make it possible to predict the beginning of their next population cycles in a given region (Beletskii, 2008; Dovhan, 2009; Yevtushenko, 2005).

The mass reproduction outbreaks are known for many insect species. These outbreaks often develop synchronously in different regions of the globe testifying to the global cause of this phenomenon.

The mass reproductions of the apple-blossom weevil in Ukraine were noted in 1910–1913, 1922–1924, 1937–1939, 1956–1957, 1966–1968, 1986–1988, 1990–1993, and in 2002–2009 (Beletskii, 1987, 2008).

The apple-blossom weevil has always been considered one of the most dangerous pests of the apple trees. Its harmfulness increases especially during the years of poor yield, when the fruit buds are killed by the frost; and nowadays it increases especially in the orchards with no protective measures or where the application of the insecticides is limited. According to the scientific sources the damage caused by the apple-blossom weevil is significant if 70–80% of buttons are damaged during the normal blossoming and the damage of up to 50% of flowers is not economically noticeable. The most noticeable damage of the buttons is observed in the years with poor blossoming of the apple trees, as well as in the years with cool spring when the trees are budding slowly (Borisoglebskaia, 1975; Volodichev, 1974; Kudas, 2002; Shevchuk, 2006; Sevesku, 1966).

A.N. Kazanskyi (1915) calls the apple-blossom weevil a pest of the first-class. The apple-blossom weevil is undoubtedly one of the main causes of fruit-bearing periodicity, if it is not the single cause of it. If one female lays only 20 eggs during the egg laying period, then it will be sufficient to have even 50 females per tree in order they could cause 100% damage to the tree in the presence of 1000 buttons per tree. Considering that the number of the males and females of the apple-blossom weevil is approximately the same, so the population of 100 specimens per tree will be enough to destroy 1000 buttons. Usually the spring stock of the apple-blossom weevil in the orchard accounts to 200–300 specimens, and sometimes it reaches up to 500–600 specimens per tree. In the latter case the weevil can destroy the crop of the trees with moderate blossoming even in the fruitful years (Kazanskyi, 1915; Chugunin, 1954).

According to the literary data (Boldyrev, 1989; Vynnychenko, 1988; Volodichev, 1974; Matviievskii, Loshchitskii, Tkachev, 1987) the yield losses caused by the apple-blossom weevil often reach 100%, and this situation can be recurred from year to year.

The main harm to the apple plantations is caused by the larva of the apple-blossom weevil which feeds inside the buttons.

The question concerning the attitude of the apple-blossom weevil to the apples variety is of great importance from the point of view of the varieties characteristics and selection. It is well known that a tree produces many times more flowers than it can further hold the fruits (Grossheim, 1925).

The damage caused by the apple-blossom weevil can not be determined by the proportion of the buttons damaged by it, because the apple tree yields no more than 20% of the useful ovary and throws down the remaining 80% as the excess which can not be grown. In the Crimea the apple-blossom weevil causes especially significant damage in the valleys of the rivers Belbek, Kachi, and Karas. The damage to the buttons caused by it in the valleys of these rivers often reaches 90% and even 100% (Chugunin, 1938).

The shortage of nutrition as a factor affecting the size of the beetle is especially clearly revealed in the work of M.N. Nikolska (1926); from this work it is seen that the oppression of the buttons with *Psylla mali* Schm. leads to insufficient size of the beetles which has been found biometrically.

According to the data of Ya.V. Chugunin (1932) the apple-blossom weevil becomes a pest when the damage caused by it to the buttons reaches 70% and only if the damage reaches 85–95% then the yield will be lost completely. The apple-blossom weevil can be considered a pest only in some cases where the ratio of the flower stock and the number of the beetles lead to the complete destruction of flowers.

The strength of the button development is definitely closely related to the blossoming time and the duration period of this stage of buttons: the stronger the button, the earlier it begins to blossom and the shorter is the period of the button stage because the buttons are exposed from the buds almost simultaneously; but due to the fact that stronger buttons grow more intensive and quickly they begin blossoming earlier than the other buttons. It can be concluded that the weaker the button is, the longer it is in the button stage, and thus there is a risk of attack by the female of the apple-blossom weevil. Therefore, the weaker buttons are damaged more than the strong ones and the longer the blossoming period, the more damage is caused (Chugunin, 1932).

Yu. H. Mozhovyi (1932) came to the same conclusion. Since, regardless of the inflorescence structure, the largest proportion of damage falls on one of the lateral groups of the buttons, so the female does not “choose” the strongest buttons when laying the eggs; the female needs to place the entire stock of the eggs and its activity is limited by the short blossoming period. In this situation it is important only to have the buttons in the desired state. Therefore, the female uses the first button she can find among the slowly vegetating lateral buttons (Mozhovyi, 1932).

M.M. Troitskii (1925) informs that under any average damage to the buttons in the tree there are both severely damaged inflorescences, including the inflorescences with totally damaged buttons, and slightly damaged ones; and even there are absolutely undamaged buttons. To determine the degree of damage caused by the pest it is necessary to know the nature of the damaged buttons distribution according to the inflorescences. In fact the number of the undamaged inflorescences is much larger than that of the damaged buttons because the females quite often lay the eggs into two adjacent buttons at the same time which leads to an increase in the proportion of the completely damaged inflorescences and this happens in 25% of cases (Troitskii, 1925).

Having considered the materials about the importance of the apple-blossom weevil in the periodicity of fruit-bearing and having analysed these materials from the point of view of the fruit tree biology, in particular the apple trees, Ya.V. Chugunin (1950) came to the conclusion that the apple-blossom weevil should be considered as one of the most harmful insects in horticulture. Causing damage to the buttons by 50–100% during the years of poor yield, the weevil destroys the potential crop yield completely. During the productive years it either destroys the yield completely when the trees are heavily populated (500–600 specimens/tree) or reduces it to scanty sizes. In the years of weak blossoming the proportion of the populated buttons can be taken as the rate of harmfulness of the apple-blossom weevil; thus the decline in the yield level caused by the apple-blossom weevil under these conditions is equal to the proportion of the buttons populated by it. Thus in the presence of a small number of flowers the proportion of the useful ovaries often reaches 70–80%. It means that 3–4 fruits could be produced from each of the five flowers damaged by the weevil; and these fruits could ensure the rich yield at the expense of increasing their size (Chugunin, 1950).

In nature there are the appropriate adaptations of the development stages of *Anthonomus pomorum* L. to the time of the apple-tree blossoming and their study is of practical interest. One of the task of the researches carried out by T.M. Ritus-Potapova (1928) in the orchard of the A.K. Timiriazev Agricultural Academy was to clarify the question of how different varieties of the apple trees respond to the damage caused by the apple-blossom weevil and to determine the role of the meteorological factors in the rate of the apple-blossom weevil development and in the time of the apple trees blossoming. The author found out that all varieties of the apple trees exposed the buttons much later than the eggs of the beetle females had matured and that the exposed buttons of all varieties required more heat than it was needed for the sexual maturation of the weevils. Early- and late-ripening varieties can not avoid the damage even in the case when an interval in the time of the buttons exposure of some varieties would be significant. Usually the egg-laying by the apple-blossom weevil is extended depending on the meteorological conditions (Ritus-Potapova, 1928).

The harmfulness of the weevil changes depending on the condition of the fruit trees and the strength of their growth. More stable trees can produce bumper yield under the same amount of the preserved ovary, and the feeble trees will produce poor yield (Chugunin, 1954).

Most researchers consider the apple-blossom weevil as one of the dangerous pests of the apple trees. However, some authors (Chizh, Filiov, Havryliuk, Chukhil, 2008, Troitskii, 1925) believe that under the abundant blossoming this species may be useful normalizing the blossoming and fruit-bearing.

Other authors (Litvinov, 2004) consider such a statement to be false. According to their studies (absolute calculations) the yield capacity of the trees treated with the insecticides when controlling the apple-blossom weevil was higher by 50% than the yield capacity under the control even under the abundant blossoming of the apple trees. At the same time under the control the undamaged buttons prevailed over the fruits obtained from the yield about six times more. In this regard the researchers suggest that the apple-blossom weevil may have selectivity: the females prefer to lay eggs in the productive buttons. Therefore, it is impossible to rely on the apple-blossom weevil as a regulator of "blossoming and fruit-bearing" even in the case of the abundant blossoming of the apple tree. In addition the apple-blossom weevil greatly reduces the yield of fruits from the peripheral part of the crown. According to the experiments carried out by V.V. Vassiliu (1998) in this case the apple fruits harvested from the peripheral part of the crown significantly surpass the fruits harvested from the central part of the crown by the content of micro- and macroelements, vitamins and sugar and therefore they are more valuable.

The selective ability of the apple-blossom weevil regarding the buttons for the egg-laying is not directed towards the strong and most rapidly blossoming flowers but vice versa, it is directed towards the weak outer flowers of the cyme which surround the strong central flower and lag behind in development.

In addition in each cyme the apple tree has 5–6 flowers that do not open at the same time. At first the central flower opens and in 2–3 days other 2 and more flowers will join it.

There are also differences in the time of blossoming between the separate cymes. On the tops of the branches the cymes open earlier and they open much later at the base. This biological feature prevents from the slight lowering of temperature that is very common in spring.

In the regions where the early spring is changed by summer rapidly and abruptly the button stage of the apple tree is limited to 7–10 days while in the northern and highlands regions the stage of the buttons exposure extends to 3 weeks or more. Thus, the egg-laying period in these areas is 3 times longer (Aristov, 1932).

These conclusions are supported by M.T. Aristov (1926), who showed that the biological minimum of temperatures of the apple-blossom weevil and the apple tree coincides and reaches 6 ºC. But regarding the apple-blossom weevil it corresponds to the curve of the maximum daily temperature course and regarding the apple tree it corresponds to the curve of the minimum daily temperature course. The maximum daily temperature reaches 6ºC for the period of 2–3 weeks before the minimum temperature reaches this degree. This fact gives the apple-blossom weevil an advantage because it can always be ready to lay the eggs.

In some orchards of the northern regions of Ukraine the density of the apple-blossom weevil population in the fruit trees was 50–70 specimens per tree and it was equal to 100% population. The uneven population of the orchards by the apple-blossom weevil caused a different degree of damage to the buttons, it constituted 0,18–42,5%. The lowest damage to the buttons (0,18–0,2%) was found in the young orchards treated with the pesticides and in which there were the trees with the thin-story crown shape under the turf covering and without it. There were not much more damaged buttons in the young orchards shaped as palmate. In the old orchards the share of the damaged buttons was much higher (2,4–5,4%) and only in some parts it reached 10%. The maximum damage to the buttons was noted in the orchards which did not undergo the chemical treatment; and it reached 42,5% in the first three rows located near the forest. The population of the buttons in the eighth-tenth rows was 2%. The reason for the intensive population of the first rows is the migration of the beetles from the hibernating places (Matviievskii, Loshchitskii, Tkachev, 1987).

A.M. Sokolov and R.M. Sokolova (1974) note that when determining the resistance of the variety to the apple-blossom weevil, the degree of the generative organs development should be taken into account not only in the crown of the tree, but also in the inflorescence cyme and it should be compared with the course of egg laying by the weevil under given meteorological conditions. The morphological features of the inflorescence, namely the density of the cyme and buttons and the pubescence of the sepals are also important (Sokolov, Sokolova, 1974).

In the years of mass reproduction of the apple-blossom weevil the losses can reach up to 80–90% of the crop yield in the centres of damage unless the protection measures from this pest are carried out. The proportion of flowers damaged by the weevil can reach up to 95% as for the apple trees and it can reach up to 4–5% as for the pear trees depending on the intensity of the damage. The apple plantations located near the forests are damaged most often (Lanak, 1972).

Damaging the buds, buttons and leaves of the apple and pear trees the apple-blossom weevil has caused great damage in Kirov, Bilohorsk and Simferopol districts of the Crimea, especially in the orchards adjacent to the forest where there were wild-growing apple and pear trees (Livshits, 1961).

During the unproductive years for the apple tree, the apple-blossom weevil partly places its offspring in the pear and cherry trees. But the cherry tree is not a favourable substrate for the larvae feeding, and the beetles turn out much smaller in size (Vitkovskii, 1926).

The harmfulness of the apple-blossom weevil in the Kiev region is manifested when 60% of the Jonathan variety buttons and 80% of the Snowy Calville variety buttons are damaged. Comparing the maximum fertility of the apple-blossom weevil (80 eggs per female) and the number of buttons, that is 2–3 thousand per the Jonathan apple tree variety which begins to bear fruit, 3–5 thousand buttons of 10 year-old tree of Snowy Calville variety and 5–10 thousand flowers of 12–25 year-old tree, the authors come to the conclusion that 17–30 females cause damage to 60% of buttons of the Jonathan variety, 30–50 females cause damage to 80% of buttons of 10 year old tree of Snowy Calville variety, and 50–100 females damage the 15 year old tree of the same variety. If to add that the sexual index of the apple-blossom weevil reaches 1,0:0,8 (10 females per 8 males) then the number of the beetles that could cause the above-mentioned damage would be even greater (Matviyevskii, Loshchitskii, Tkachev, 1987).

The researches of V.V. Volkodav and V.P. Konverska (2002) carried out under the conditions of the Research Centre “Variety” (town of Berezan of the Kyiv region) testify to the high number and harmfulness of the apple-blossom weevil. The pest development at low temperatures (7–8°C), the absence of the specialised entomophages and intensive migration contributed to its considerable abundance. Thus, during the phenophases of a “green cone” and “buttons exposure” the imago number was 35–47 specimens per 2 linear metres of branches. The damage rate of the trees caused by the apple-blossom weevil depended on the variety. The varieties “Tsyhanochka”, “Fialka”, “Vohnyk”, and “Slava Peremozhtsiam” were the most resistant to the damage; their rate of damage was 5–7%. The varieties “King David”, “Novosilkivske Zymove”, “Ornament”, “Radohost” and “Svitlytsia” (40–50%) were the most attractive to the pest. The damage rate of other varieties was 15–35% (Volkodav, Konverska, 2002).

According to Yu.P. Yanovskyi (2003) the apple-blossom weevil also reduces the yield capacity of the nursery-seed orchards by 24–40% and the seed yield by 24–70%. The beetle of the apple-blossom weevil destroys all the vegetative buds on the seedling in one day.

According to the researches carried out by V.F. Drozda (2001) the apple- blossom weevil causes considerable damage to the seedlings and rootstocks in the nursery fields, to the pistil of the vegetative propagated rootstocks, nursery-graft and especially to the nursery-seed plantations of the apple trees. In the absence of protection in the nursery one female destroys 97,9–100% of the buds of the 2 year-old seedling a day; in the nursery orchards it causes damage to the buds and lays the eggs into the buttons of the apple tree, thus reducing the yield by 16,1–29,7%.

In the orchards of the Kharkiv region the apple-blossom weevil has destroyed the flowers of the apple trees in Ohultsi by 26,4%, in Krasnokutsk – by 23,0%, in Kupiansk – by 15–22%, and in Izium – by 9%, and it destroyed the flowers of the pear trees by 3,3% in Ohultsi and by 16% in Krasnokutsk. The apple varieties were not damaged equally. Pepinka Lithuanian was damaged by 8% and White Transparent was damaged by 11,5% (Kamyshnyi, Soloviova, 1927).

For the last nine years the apple-blossom weevil has caused significant damage to the apple trees buttons in the orchards of the Scientific and Research Farm of Kharkiv national agrarian university named after V.V. Dokuchaiev. The greatest damaged was done to the Jonathan (81%), Boiken (77,5%), Titovka (81%) and Common Antonivka (62%) varieties (Zabrodina, 2002, 2007).

According to the data of Ye.Sh. Gamina (1991) this pest can damage up to 60–90% of buttons of the apple tree.

In the last two decades the harmfulness of the apple-blossom weevil has increased in several European countries (Hausmann, Samietz, Dorn, 2004). The maximum damage to the buttons is observed along the perimeter of the orchard, that is, in the rows that are closer to the forest belt (Gamina, 1991; Kashirskaia, 1991).

In Belarus (Bezdenko, 1958) the economic losses caused by the apple-blossom weevil are enormous. In some years it damages the buttons so much that during blossoming the trees seem to be burnt. However, these damages are not the same. It has been found out that the weevil causes the greatest damage during the years of the long spring development of the orchards.

The flowers in the apple trees of summer varieties are more damaged than those in the trees of winter varieties. In 1954 on the farm named after the Red Army in Belarus the summer varieties were damaged by 72%, and winter varieties were damaged only by 45%; on the farm named after Lenin the summer varieties were damaged by 80% and winter varieties – by 12%. When estimating the damage caused by the apple-blossom weevil it was found out that the share of the buds damaged by the beetles after their migration from the hibernating places reached up to 36,4% regarding the quickly-ripening varieties of the State Fruit Nursery and it reached 29,6% regarding the late-ripening Antonivka variety.

After the buds opening the leaves were eaten away along the edges by 50% or they had the holes. The damaged leaves developed significantly worse than the healthy ones (Bezdenko, 1958).

In the Orel region (Kryzhanovskii, 1974) during the extra nourishment period the beetles can damage up to 60–80% of the apple fruit buds and up to 80–90% of the pear buds, causing the death of more than half of the buttons; at the same time they greatly damage the apple varieties which have larger buds, namely the Brown striped, Borovynka and Common Antonivka varieties.

In the apple orchards of Moldova (Vynnychenko, 1988) the apple-blossom weevil also reaches a very large number and causes the considerable damage.

According to A.P. Yakymchuk and M.M. Muten (2008) the decrease in the number of chemical treatments in the apple orchards of Moldova in recent years has led to an increase in the number of the apple-blossom weevil, previously considered a minor pest. For example, in 2003 the apple-blossom weevil which number was above the threshold was found in the area constituted 53,3% of the inspected 11,9 thousand hectares. In some foci the apple-blossom weevil damaged 60–80% of the buds.

Under the conditions of Dagestan (Batiashvili, 1959) the apple-blossom weevil also damaged the apple tree most severely, it damaged the pear tree to a less extent. The zone of the greatest damage covered two natural zones: the Northern and Southern Mountain ones. In some areas of this zone the damage caused by the apple-blossom weevil reached up to 90% (the Khunzakh district).

In the Transcaucasus in general and in Georgia in particular the apple-blossom weevil is a common pest. In some years, especially in the unproductive ones, it caused great losses of the apple and pear crops (60–80% on the average), usually in the places where no effective measures of protection have been carried out (Batiashvili, 1959).

In Lithuania in 1968–1969 the larvae of the apple-blossom weevil damaged 20–25% of the apple flowers and 33% of pear flowers (Livshits, Petrushova, 1979).

The weevil caused the greatest damage in the northern regions of the apple cultivation in the cold spring when the blossoming was delayed and the females had time to lay off their entire stock of the eggs. In such years the apple-blossom weevil can destroy more than 70% of buttons. The damage caused by it is especially dangerous in the years with poor blossoming of the apple trees (Zhemchuzhyna, Stepina, Tarasova, 1985; Rilishkene, Zayanchauskas, 1985).

In Bosnia and Herzegovina the apple-blossom weevil damaged up to 100% of the apple buttons (Batinica, 1958).

Conclusions

1. The analysis of the literary data indicates that despite the considerable number of the literary sources devoted to the apple-blossom weevil, there is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. In particular the relationship between the phenology of the apple varieties of different periods of ripening and the period of egg-laying, as well as between the period of summer diapause of the pest and its concentration places during both the summer diapause and the hibernation remains unclear.

2. There is no data on the density of the hibernating beetles of the apple-blossom weevil under the dead bark on the trunks and boughs, in the surface layer of soil and plant litter of the crown projection per apple tree; the knowledge of these facts would allow to calculate the pest density in the next spring in order to protect the apple trees before blossoming.

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FLEA BEETLES (*PHYLLOTRETA SPP.*). LITERATURE REVIEW

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In the course of the literature critical analysis the authors paid special attention to the morphological, biological and ecological features of the flea beetles , both in Ukraine and abroad; the authors came to the conclusion that despite the considerable number of literary sources devoted to the flea beetles, theirs is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified. The data obtained by the entomologists from different countries regarding the harmfulness of the flea beetles and its economic importance are quite controversial and also need experimental confirmation.

Key words: *flea beetles, morphology, biology, ecology, harmfulness, economic threshold of harmfulness, integrated protection.*

Introduction. *Phyllotreta* Steph. is one of the most numerous genera of flea beetles in the subfamily *Galerucinae* and comprises, according to V. Putele’s data (Putele, 1970), more than 160 species, and according to foreign scientists’ reports (Konstantinov, 1996; Lee et al., 2011), this genus comprises more than 250 species of flea beetles. V.B. Kostromitin (Kostromitin, 1980) noted that on the territory of the former USSR over 30 species were found and V.F. Paliy (Palij & Avanesova, 1975) mentioned about 50. N.N. Plavilshikov (Plavilshikov, 1994) wrote that on the territory of the European part of the former USSR there were 21 species and M.Ye. Sergeev (Sergeev, 2007) published data on 22 species.

S.V. Dedyuhin (Dedyuhin, Nikitskij & Semyonov, 2005) reported that 13 species lived in Udmurtia and 12 species – in the Lipetsk region of Russia (Curikov, 2009).

Representatives of the genus damage plants of such families as *Gramineae, Brassicaceae, Malvaceae, Asteraceae, Chenopodioideae, Moraceae, Leguminosae* and *Polygonaceae* (Palij & Avanesova, 1975).

Flea beetles, which more or less damage *Brassicaceae* crops, include 19 species (Kostromitin, 1980) or, as V.N. Shyogolev reported (Shyogolev, Znamenskij & Bej-Bienko, 1937), - 11 species. According to N.A. Filippov data (Filippov, 1978), 12 species were observed in Moldova, but G.I. Konchukovskaya (Konchukovskaya, 1978) had only data on 10 species. Yu.N. Bezdelnyj (Bezdelnyj, 1984) particularized 9 pest speciess in the Altai Territory. According to N.L. Saharov data (Saharov, 1934) mustard was damaged by 9 species in the Saratov region. There were 13 species in Tatarstan (Kosov, Rameev & Lopaeva, 1952). V.P. Razumov (Razumov, 1971) recited 7 species of flea beetles damaging Brassicaceae crops in the Gorky region of Russia; Ye.V. Levkovich (Levkovich & Levkovich, 2006) – 6 species in the Penza region; and A.P. Smirnov (Smirnov, 2009) 5 species – in the Leningrad region. In the Non-Chernozem Belt of Russia, as T.I. Manaenkova described (Manaenkova, 1991), the dominant species was the small striped flea beetle (89.8%). V.G. Osipov (Osipov, 1986) pointed out that in Belarus, Brassicaceae crops were damaged by 6 species of flea beetles. Six species were also found to be pests in the Leningrad region. Of them, the predominant species was the turnip flea beetle (Guseva & Koval, 2007). According to K.A. Gorbatko data (Gorbatko, 2010), 4 species were widespread in the Central Ciscaucasia, of which the cabbage flea beetle was predominant (40% in the total population). In Ukraine, Brassicaceae crops are damaged by 6 species of flea beetles belonging to the genus *Phyllotreta* Steph. (Minkevich, & Borisovskij, 1949; Gerasimov & Osnickaya, 1961). In Taiwan, (Chen, Ko & Lee, 1990) the predominant species on Brassicaceae crops is the striped flea beetle. The striped flea beetle is the most common species of *Phyllotreta spp.* in the world (Zhao et al., 2008) and it is the most dangerous pest of Brassicaceae plants in Canada (Soroka & Elliot, 2011). In Turkey, the predominant species is the small striped flea beetle.

V.P. Vasilev (Vasilev, V.P. et al., 1988) wrote that the cabbage flea beetle and the small striped flea beetle predominated in the forest-steppe of Ukraine, accounting for 60–90% of the total *Phyllotreta spp.* number. O.M. Lapa (Lapa et al., 2006) pointed out that the cabbage flea beetle predominated in the South of Ukraine, while the small striped flea beetle, the striped flea beetle and the turnip flea beetle – in the North. M.P. Sekun (Sekun et al., 2008) believed that the cabbage flea beetle and the small striped flea beetle predominated in the woodlands and forest-steppe, while the turnip flea beetle – in the South of Ukraine.

Cabbage flea beetle (*Phyllotreta atra F.* and *Ph. atra var. cruciferae* Goeze.). It lives in the European part of Russia, the Caucasus, Central Asia, Kazakhstan, Siberia, and Primorye, being one of the most widespread pests in the steppe zone from the Baikal region to the Balkans. Outside the former Soviet Union, it can be found in Western Europe, Asia Minor, Central Asia, and northeastern Africa. Variation *cruciferae* predominates in more northern regions. In the early 1920s, it was brought to the west coast of North America, then quickly spread throughout the continent and became the predominant species, inflicting significant damage to *Brassicaceae* crops (Palij & Avanesova, 1975; Kostromitin, 1980).

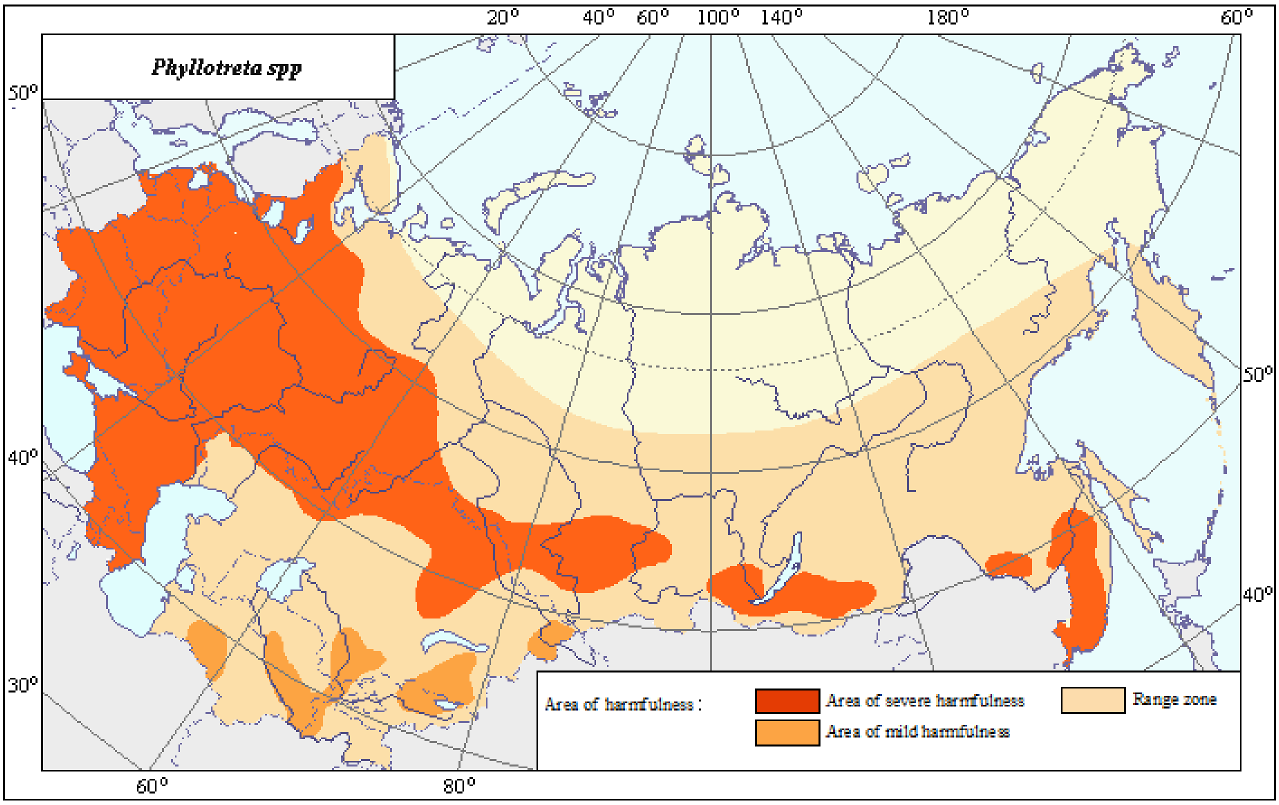

Fig. 1. Range zone and areas of harmfulness of *Phyllotreta spp.* flea beetles

Small striped flea beetle (*Ph. undulata* Kutsch.). Its area (except Ukraine) is the European part of the former Soviet Union, the Caucasus, Siberia, Primorye, Central Asia, Kazakhstan. It is one of the most dangerous pests of *Brassicaceae* crops, annually damaging plants in Karelia, the Leningrad, Moscow, Gorky, Kalinin, Pskov, Arkhangelsk, Perm, Kirov, Vologda regions, Western and Eastern Siberia, the Middle Urals, Yakutia and the Far East. Significant damage was observed in Belarus, the Smolensk, Kaluga, Tula, and Ryazan regions, Chuvashia and Tatarstan. Outside the former Soviet Union, it ranges in Europe, with the exception of Greece, Asia Minor, and Algeria. *Ph. undulata* was brought to the United States (Samedov, 1963; Palij & Avanesova, 1975; Kostromitin, 1980).

Turnip flea beetle (*Ph. nigripes* F.). On the territory of the former USSR, it is very widely spread: forest-steppe and steppe of the European part of Russia, the Caucasus, Central Asia, Kazakhstan, Western Siberia. *Ph. nigripes* usually damages plants together with *Ph. atra* and *Ph. undulata*. Mass reproduction occurs in years with warm springs and normal precipitation in the Southern Urals, southern Western Siberia, sometimes in the Kursk, Voronezh and Penza regions. Outside the former USSR, it is known in Europe, Asia Minor, and northwestern Africa (Samedov, 1963; Palij & Avanesova, 1975; Kostromitin, 1980).

Turnip flea beetle or yellow-striped flea beetle (*Ph. nemorum* L.). Within the former USSR, in addition to Ukraine, the range of this species is large and covers the entire European part, the Caucasus, Eastern and Western Siberia, the Far East and the republics of Central Asia. Mass reproduction occurs in humid regions of the Baltic countries, Belarus, the Leningrad, Smolensk, Kaliningrad, Vologda, Pskov, and Moscow regions, the Caucasus. It can be found in Karakalpakstan and Uzbekistan. In wet years, it also appears in arid areas. Outside the former USSR, it is widespread in Western Europe and Asia Minor (Samedov, 1963; Palij & Avanesova, 1975; Kostromitin, 1980).

Striped flea beetle (*Ph. striolata* Fabr. = *Ph. vittata* Fabr.). On the territory of the former USSR, it inhabits the entire European part, the Caucasus, Kazakhstan, Siberia, Primorsky Kray. The striped flea beetle number is growing in Siberia and the Far East. Outside the former USSR, the range of *Ph. striolata* is very large: it ranges in Europe, Japan, China, Mongolia, Thailand, on the island of Sumatra, South Africa, USA. In North America, it is a serious pest of *Brassicaceae* crops (Samedov, 1963; Palij & Avanesova, 1975; Kostromitin, 1980).

Horseradish flea beetle (*Ph. armoraciae* Koch.). In addition to Ukraine, it lives wherever horseradish (*Ph. armoraciae* feeds only on horseradish) grows, which is harmed by both imagoes and larvae. The range of the species covers the southeastern European part of Russia, the Caucasus, Central Asia, Kazakhstan, Central, Eastern and Western Siberia, the Leningrad, Novgorod, Moscow, Ryazan, and Ulyanovsk regions, Central and Southern Urals, Bashkortostan, Tatarstan, Mordovia. It lives in the Baltic countries and Uzbekistan. Outside the former USSR, it ranges in Europe (except the Iberian Peninsula), Canada, and the United States (Samedov, 1963; Palij & Avanesova, 1975; Kostromitin, 1980).

Several European researchers, Hoffmann (Hoffman & Schmutterer, 1983), Yonen (Johnen, 2006; Johnen & Klingenhagen, 2006), Knoll (Knoll, 1997), and Volker (Volker, 2003) noted that it was *Phyllotreta spp.* flea beetles that were most harmful species on rapeseed in Belgium, Bulgaria, Germany, Poland, Slovakia, and France.

In the Russian Empire, *Phyllotreta spp.* flea beetles significantly damaged to cabbage and mustard plantations, so as early as in the late 1800s, such scientists as K. Lindeman (Lindeman, 1866), K.P. Bramson (Bramson, 1881), F. Keppen (Keppen, 1882), K.A. Purievich (Purievich, 1893) and P.M. Stejnberg (Shtejnberg, 1907) conducted thorough research into their biological features and effective measures to control them. In 1908, *Phyllotreta spp.* flea beetles were included in the list of the most harmful insects for agriculture.

Information on the harmfulness of *Phyllotreta spp.* flea beetles in the eastern forest-steppe of Ukraine was published in the early 1900s, where pests of the Kupyansk, Bohodukhiv and Valkiv Uyezds were described. It was noted that 3 species of *Phyllotreta spp.* were harmful: *Ph. atra* F., *Ph. undulata* Kutsch. and *Ph. nemorum* L.

We revealed that all 6 species of flea beetles that were common in Ukraine could be found in the eastern forest-steppe of Ukraine (Stankevych & Fedorenko, 2009; Yevtushenko, Stankevych & Fedorenko, 2009; Krasilovec et al., 2011; Krasilovec, Kuzmenko, Litvinov & Stankevich, 2011; Stankevych, 2011c; Stankevych, 2012d; Stankevych, 2012e).

Materials and methods

The authors analyzed 196 literary and electronic sources from the late 19th to the 21st century. During the analysis, special attention was paid to the morphological, biological and ecological features flea beetles in Ukraine and abroad. The data on the harmfulness of the flea beetles and its economic significance are especially analyzed. In the course of the analysis special attention was paid to the methods and ways of controlling the rape pollen beetle in Ukraine and abroad. The protective measures were considered in such directions as agro-technical, physic and mechanical, chemical, biological, biotechnical and selective and genetic ones. Each of them is noteworthy and has both a number of disadvantages and indisputable advantages in comparison with other methods.

Results and discussion

Taxonomic status and morphological features of Phyllotreta spp. flea beetles

V.B. Kostromitin (Kostromitin, 1980) and N.N. Plavilshikov (Plavilshikov, 1994) specified the taxonomic status of the genus *Phyllotreta* is follows: Class Insects - *Insecta* Leach, 1815; Subclass Winged or Higher Insects - *Pterygota* Gegenbaur, 1878; Infraclass Neopterans - Neoptera Martynov, 1923; Division Distinct-Stage Insects – *Holometabola*; Superorder Coleopteroids – *Coleopteroidea*; Order Coleopterans - *Coleoptera* Linnaeus, 1758; Suborder Omnivorous Beetles - *Polyphaga* Emery, 1886; Family Leaf Beetles - *Chrysomelidae* Spribala, 1802 Aphthonini; Genus *Phyllotreta* Stephens, 1836.

Representatives of the genus *Phyllotreta* have an elongated and mostly flattened body; the body is unicolourous (black, blue, greenish, metalescent or black with a yellow pattern on elytrons). The head with indistinct frontal tubercules or without them; the frontal carina is flat or sharp, narrow. The labrum is square with a notch on the anterior edge; the mandible is five-toothed; the antennae are 11-segmented. The pronotum in most species is square, narrower at the elytron base; the clypeus is small, semi-oval; the shoulder humps are mostly convex. Almost all species have well-developed hind wings. The body length varies 1.3 to 3.5 mm (Troickij & Shegolev, 1934; Shyogolev, 1960).

Eggs of *Phyllotreta spp.* flea beetles are light yellow, semi-translucent, elongated-oval, 0.34–0.4 mm long and 0.1–0.2 mm wide (Narzikulov, 1968). However, according to N.N. Bogdanov-Kat'kov data (Bogdanov-Kat'kov, 1920), the egg size is 0.6–0.9 mm.

Larvae of most species are off-white, yellow or yellowish. On the surface of the segments, there are smooth, shiny sclerotized plates, arranged in a certain order. There is one hair on each plate. Some plates merge together, and then the number of hairs increases according to the number of merged plates. The head and the last segment are light yellow. The tergite of the last abdominal segment is without cancellated structure, has a rounded posterior edge or one upfracted short chitin hook (Gilyarov, 1964)

Pupae of all species are free, yellowish, 2–3 mm (up to 4 mm) long, always develop in the soil (Shyogolev, Znamenskij & Bej-Bienko, 1937; Palij, 1962; Shapiro, 1964).

Characteristic features of *Phyllotreta spp.* flea beetles that are common in Ukraine are the following:

The upper part of the body is unicolourous: black, blue or greenish.

Cabbage flea beetle. The antennae are black, except for the first three red-yellow segments. The proximal part of the legs is grayish brown (Fig. 2.E). The head, pronotum and elytrons are evenly dotted. The color is black with a faint metallic tinge. The length is 1.8–3.0 mm (Gerasimov & Osnickaya, 1961; Bej-Bienko, G.Ya. (1980).

Turnip flea beetle. The antennae and legs are completely black. The upper part of the body is blue or greenish with a metallic tinge (Fig. 2.F). The head and anterior back are finely dotted. The length is 2.0–2.8 mm (Palij & Avanesova, 1975).

Turnip flea beetle. There are yellow stripes on the elytrons with a rather subtle notch in the middle or almost parallel (Fig. 2.A). The tibiae and legs are red or yellow (as B.A. Gerasimov (Gerasimov & Osnickaya, 1961) described). The frons and at least the frontal part of the crown are not dotted. The head and pronotum are metalescent. The main 3 segments of the antennae are yellow. It is one of the largest species: 2.5–3.5 mm (Gerasimov & Osnickaya, 1961; Lopatin, 1986).

Small striped flea beetle. The black side border on the elytrons does not expand or expands very gradually and peripherally into the yellow stripe (Fig. 2.B). The legs are black and only the tibiae are sometimes slightly reddish. The frons has a transverse dotted stripe only above the tubercules; the crown is not dotted (Troickij & Shegolev, 1934). The length is 2.0–2.8 mm (Lopatin, 1986).

Striped flea beetle. On the elytrons, there is a yellow stripe with a deep outer notch in the middle and a small notch near the shoulder hump (Fig. 2.D). There are sometimes 2 spots. Black stripe in the middle, with parallel edges, narrowed only at both ends. The length is 1.8–2.7 mm and the width is 1.1–1.4 mm (Gerasimov & Osnickaya, 1961; Palij & Avanesova, 1975; Lee et al., 2011).

Horseradish flea beetle. The elytrons are yellow; only the narrow border on their outside and the stripe on the neck are black (Fig. 2.C). The head and pronotum are black. The top of the femora, tibiae, legs and the first 3 segments of the antennae are yellow. The length is 3.0–3.5 mm (Gerasimov & Osnickaya, 1961).

Biological and ecological features of Phyllotreta spp. flea beetles

Phyllotreta spp. flea beetles have similar biological features (Laba & Sytnyk, 2006). Sexually immature imagoes overwinter in the upper layer of the soil, in cracks of greenhouse frames, under fallen leaves on forest edges and in protective forest belts (Shyogolev, Znamenskij & Bej-Bienko, 1937). However, L.I. Bud’ko (Bud’ko, Rovba, & Shaganov, 2008) published data that eggs overwinter in the soil in Belarus and larvae emerge from them in spring (at 5–6°C), which damage seedlings. Sometimes imagoes get into soil cracks between roots and imbed themselves in the soil. They rarely overwinter in meadows and fields. Imagoes normally overwinter in the upper layer of the soil, where the temperature is -4°C under the snow cover. *Phyllotreta spp.* flea beetles seldom overwinter far from the places of their autumn feeding and are satisfied with any cover in the immediate vicinity of the autumn habitat, and hence their spring appearance is close to those places where *Brassicaceae* plants grew in the previous year. In spring, beetles come out of overwintering housings and feed additionally (Dobrovolskij, 1950; Kasyanov, 2011). The appearance of beetles is closely associated with air temperature (Marchenko, 2011). First they appear in areas that are well warmed up. T.G. Yefremova (Yefremova,1970) reported that in the southern regions of Ukraine beetles appeared as early as during the third ten days of March, while in the northern and central regions – in the second ten days of April, and in Kamchatka (Semakov, 1966), for example, beetles leave overwintering housings in early June.

M. Zambin (Zambin, Turaev & Shumilenko, 1953) believed that flea beetles came out of overwintering housings when the average daily temperatures rose to 11°C. Different species of *Phyllotreta spp.* do not become active simultaneously; their activity onset depends on the spring weather: the later spring comes and the cooler the weather is, the later flea beetles appear (Skripnik & Zhuravskij, 2004). At this time, there are no cultivated plants in the fields and beetles feed on various *Brassicaceae* weeds, but after seeds germinate or after seedlings are planted in the soil, beetles move to them, inflicting considerable damage. *Phyllotreta spp.* imagoes begin to fly at an air temperature of 14–16°C (Lopatin, 1986). During the day, the intensity of flight changes significantly: it increases as the air temperature rises and decreases markedly when the cool evening comes. In the evening, imagoes are sluggish and one can easily count them. N.N. Bogdanov-Kat'kov (Bogdanov-Kat'kov, 1920) reported that the maximum activity of imagoes was observed during the day at ≥17°C. According to V.N. Shyogolev observations (Shyogolev, Znamenskij & Bej-Bienko, 1937), imagoes are most active from 10 a.m. to 1 p.m. and later from 4 p.m. to 6 p.m. Nevertheless I.S. Iskakov (Iskakov & Krasnikova, 1991) reported that flea beetles actively fed after 6 p.m. if the air temperature did not drop below 18°C. Excursions of flea beetles are sharply reduced in cloudy weather and completely stop in rainy weather. Winds can carry flea beetles hundreds and thousands of meters away.

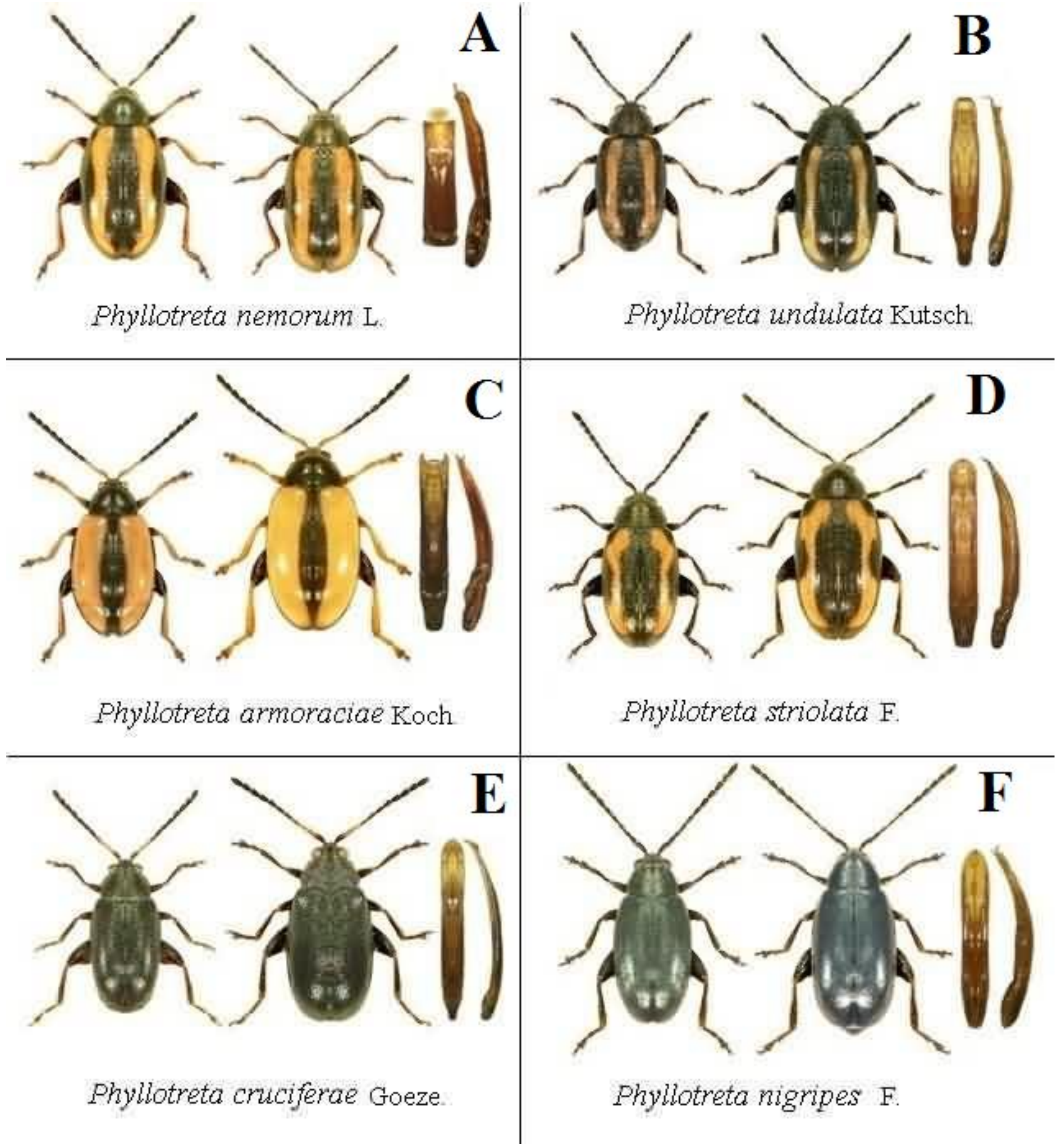

Fig. 2 *Phyllotreta spp.* flea beetles and male genitals: A) turnip flea beetle; B) small striped flea beetle; C) horseradish flea beetle; D) striped flea beetle; E) cabbage flea beetle; F) turnip flea beetle

The distance of flea beetle excursions depends on wind speed. In spring, in favorable weather, the *Phyllotreta spp.* flea beetle numbers are stable and they are more or less evenly distributed in different landscapes, but gradually they got accumulated at certain stations. *Phyllotreta spp.* flea beetles migrate from one station to another throughout the growing period. Beetles move more intensively before egg laying; they migrate to *Brassicaceae* fields. Obviously, domestic plants are better food for flea beetles. By the end of May, tissues of wild plants become coarser; the formation of generative organs requires the outflow of macronutrients from leaves, the amounts of water and protein in leaves decreases sharply; and this is most likely to make beetles migrate to young, intensively growing, water- and protein-rich leaves of domestic plants.

I. In winter, imagoes spend their fat reserves. *Phyllotreta spp.* flea beetles start feeding immediately after spring activation. M.G. Alimbekova (Alimbekova, Kukshina & Nikitina, 1949) indicated that imagoes could survive without food for 10–12 days, but according to other researchers' data (Kostromitin, 1980), the life span of imagoes without food was 5–6 days in a laboratory experiment.

In spring after overwintering, *Phyllotreta spp.* flea beetles always need extra nutrition. We observed (Stankevych, 2011c; Yevtushenko, & Stankevich, 2012) that after *Phyllotreta spp.* had left their leaving overwintering housings, they could be found on *Sisymbrium*, flixweed, charlock mustard and winter cress. At this time, the quality of food is not important, but as reproductive products ripen, additional nutrition can be only satisfied by *Brassicaceae* plants or by very taxonomically close *Capparaceae* and *Resedaceae* plants. Of the species of *Phyllotreta spp.* that are common in Ukraine, none can be classified as monophagous, as even such seemingly specialized species as the horseradish flea beetle, feed on at least several plant species. Thus, most species belong to broad or to narrow oligophages. Mustard oils or their glucosides contained in plants are believed to be active attractants for *Phyllotreta spp.* flea beetles and play an important role in the insect's choice of the host plant. At various times, it was experimentally shown that even bean leaves, which are not normally consumed by *Phyllotreta spp.* imagoes, become edible to them after such leaves had been seasoned in a 0.5% aqueous solution of a mustard oil glucoside for 18 hours. Plants of the families *Resedaceae*, *Chenopodiáceae*, *Gramíneae* and *Asteraceae* can be suitable food for *Phyllotreta spp.* flea beetles. *Phyllotreta spp.* imagoes damage plants of the families *Amaranthа́ceae*, *Polygonа́ceae* and *Fabáceae* if only other food is not available. For example, O.V. Gordiyenko (Gordiyenko, 2008) pointed out that *Phyllotreta spp.* flea beetles together with *Chaetocnema spp.* flea beetles were the main pests on buckwheat seedlings. Although under natural conditions flea beetles can feed on some plant species that are not their eating habits, the normal development of *Phyllotreta spp.* flea beetles only occurs when they feed on *Brassicáceae* plants. M.G. Alimbekova (Alimbekova, Kukshina & Nikitina, 1949), D.S. Shapiro (Shapiro, 1964) and

V.F. Paliy (Palij, 1962) even emphasized that it was imposible for *Phyllotreta spp.* flea beetles to eat non-*Brassicáceae* plants. Feeding on *Brassicáceae* plants promotes the development of viable and fertile specimens of *Phyllotreta spp.* Eating leaves of plants of other families is not typical for *Phyllotreta spp.* flea beetles; it is rather random than typical, though can be sometimes very noticeable. *Phyllotreta spp.* flea beetles very willingly feed on many *Brassicáceae* crops, for which they are permanent and mass pests. *Phyllotreta spp.* flea beetles inflict the greatest damage to mustard, rapeseed, cabbage, turnip, and oil radish; radish, false flax, horseradish, rutabaga and white turnip are also severely damaged by *Phyllotreta spp.* flea beetles (Bogdanov-Kat'kov, 1920).

The period of additional feeding lasts from 5 to 60 days (Bogdanov-Kat'kov, 1920; Palij & Avanesova, 1975; Kostromitin, 1980).

After imagoes complete additional feeding and reach sexual maturity, they mate and lay eggs, mainly in fields sown with cultivated *Brassicáceae* plants; *Ph. nemorum* lay eggs on wild *Brassicáceae* plants (Alimbekova, Kukshina & Nikitina, 1949; Palij, 1954). Eggs are laid in the soil, and larvae that hatch from eggs feed on small roots of *Brassicáceae* plants, without causing significant damage (Kolesnik, 2007). A.V. Melnik (Melnik, 2007). reported that the flea beetles laid eggs in holes gnawed in roots of *Brassicáceae* plants. *Ph. striolata* females gnaw holes in the main root of a plant and lay eggs in there; larvae develop inside the roots of oil radish, radish and other *Brassicáceae* crops. *Ph. nemorum* lay eggs on the underside of leaves of *Brassicáceae* plants, mainly white charlock and radish. Larvae gnaw into leaves and live there until pupation. V.N. Shyogolev (Shyogolev, Znamenskij & Bej-Bienko, 1937) pointed out that *Ph. undulata* females also laid eggs on leaves of *Brassicáceae* crops and larvae developed in leaves. Females of the horseradish flea beetle lay eggs (sometimes up to 16 eggs) near the horseradish collet (Kostromitin, 1980). According to B.V. Dobrovolskij data (Dobrovolskij, 1950), females lay about 20 eggs near roots. The total productivity of females is about 40 eggs (Lopatin, 1986); according to D.N. Kobakhidze data (Kobahidze, 1957), it ranges 40 to 60 eggs. N.N. Bogdanov-Kat'kov (Bogdanov-Kat'kov, 1920) reported that flea beetles lay single eggs or egg clusters on the surface of plants. Most researchers thought that the duration of embryonic development depended on the soil temperature and lasted from 3 to 15 days (Dobrovolskij, 1950; Kobahidze, 1957; Gerasimov & Osnickaya, 1961; Shutak, 1973; Palij & Avanesova, 1975; Kostromitin, 1980).

Larvae of the horseradish flea beetle penetrate into horseradish leaf stalks, where they further develop; they can also develop in the main veins of cabbage, mustard and rapeseed leaves. Having completed feeding, *Ph. nemorum* and *Ph. armoraciae* larvae, come out of leaves and pupate in the soil, like other species. The development of larvae lasts 14–30 days (Dobrovolskij, 1950; Kobahidze, 1957; Osmolovskij, 1972; Shutak, 1973; Palij & Avanesova, 1975; Kostromitin, 1980). All species of *Phyllotreta spp.* flea beetles pupate exclusively in the soil at a depth of 1–12 cm (Shyogolev, Znamenskij & Bej-Bienko, 1937; Dobrovolskij, 1950). The development of pupae takes from 8 to 17 days (Bogdanov-Kat'kov, 1920; Shutak, 1973; Palij & Avanesova, 1975; Kostromitin, 1980). The whole development lasts from 27 to 50 days (Bogdanov-Kat'kov, 1920; Palij & Avanesova, 1975; Kostromitin, 1980).

At the end of July, a new generation of flea beetles emerges. Young beetles also feed on different *Brassicáceae* plants and, when it gets cold, they move to overwintering housings. Most researchers (Kovalchuk, 1987; Fedorenko et al., 2008) thought that *Phyllotreta spp.* flea beetles developed one generation throughout Ukraine, while V.D. Pyatakova (Pyatakova, 1928) and A. Podkopayev (Podkopayev, 1933) noted that *Ph. atra* and *Ph. nemorum* could develop even three generations in Ukraine. KK Fasulati (Fasulati, 1963) reported that in Transcarpathia *Ph. undulata* gave two generations and V.T. Melnychuk (Melnychuk, 1996) published data on two generations of *Ph. undulata* in the forest-steppe. D.N. Kobakhidze (Kobahidze, 1957) noted that *Phyllotreta spp.* flea beetles had two generations per year on the Black Sea coast. According to N.N. Bogdanov-Kat'kov (Bogdanov-Kat'kov, 1920) and L.V. Sazanova (Sazanova, 1955) data, *Phyllotreta spp.* flea beetles develop 2 generations in the southern regions of the former USSR. In the Magadan region (Bardysheva, 1967), *Phyllotreta spp.* flea beetles give 1 generation per year. A.A. Solovyova (Solovyova, 1970) reported that flea beetles gave in 3 generations Kyrgyzstan and 1 generation in the highlands (1500 m above sea level). In the Central Caucasus, as K.A. Gorbatko (Gorbatko, 2010) mentioned, there is one generation of flea beetles per year.

In summer, when a new generation of beetles appears or after harvesting early *Brassicáceae* crops due to lack of food, *Phyllotreta spp.* flea beetles migrate to wild plants, especially if they grow nearby. Of the wild *Brassicáceae* plants, beetles prefer nasturtium, *Sisymbrium*, hoary alyssum, flixweed, hoary pepperwort, colewort, *Alliaria*, wallflower, winter cress, white charlock, stock, pennycress, etc. *Ph. undulate* and *Ph. atra* eat leaves of the shepherd's purse and *Ph. nigripes* – leaves of the candytuft (Bogdanov-Kat'kov, 1920; Moric-Romanova, Berezhkov & Davydov, 1941; Zambin, Turaev & Shumilenko, 1953; Gerasimov & Osnickaya, 1961; Kostromitin, 1980). Trophic specialization determines the spread of *Phyllotreta spp.* flea beetles. Stable food reserves are available near human settlements, where cultivated, weed and ornamental plants belonging to the family *Brassicáceae* are abundant. In natural biocenoses, edible plants are poorly represented; *Phyllotreta spp.* flea beetles are sure to live there, but in smaller numbers. It was published (Kostromitin, 1980) that the numbers of beetles that overwintered and their offspring were always higher in fields of cultivated plants than on wild vegetation growing near the fields. An agrocenosis of *Brassicáceae* crops is populated faster and damaged more severely than a *Brassicáceae* crop grown in a mixture with other crops (Satalkina & Ancupova, 1993). Thus, the diversity of vegetation can reduce the numbers of *Phyllotreta spp.* flea beetles and prevent their mass reproduction.

Harmfulness of Phyllotreta spp. flea beetles

Data on the harmfulness of *Phyllotreta spp.* flea beetles have been available since 1841 (Bogdanov-Kat'kov, 1920). The damage from them was so significant that in some years (1841, 1851, 1867, 1888, 1911, 1913, 1915) they destroyed all planted cabbage seedlings and oilseed fields (Bogdanov-Kat'kov, 1920).

The damage caused by *Phyllotreta spp.* flea beetles to fields depends mainly on their numbers, migration capacity, phase of the plant development, feeding intensity, weather, etc. The feeding activity of beetles depends on weather factors. Beetles start feeding after the dew evaporates and the air temperature reaches 7–9 °C. As the temperature rises, the feeding intensity increases. The optimal temperature for active feeding of beetles is within 18–25 °C (Shejgerevich, 1988); its further increase to 27–29 °C noticeably reduces the feeding intensity; and at 30–32 °C almost all beetles leave plants. In the evening, when the air temperature drops to 11–12 °C, the activity and intensity of feeding lessen and after 9 p.m. beetles probably go into the soil for the night, because early in the morning they can be detected only on the soil surface.

In most species of *Phyllotreta spp.* flea beetles, imagoes do harm; larvae develop in the soil, feeding on small roots, and do not have a significant impact on the plant growth and development (Fokin, 2008; Pysarenko & Gordyeyeva, 2009). However, *Ph. nemorum* larvae penetrate into leaves and live there until pupation. Larvae of the horseradish flea beetle develop inside the middle veins of horseradish and cabbage leaves (Palij, 1962; Kostromitin, 1980).

Fig. 3. *Phyllotreta spp.* flea beetles on spring rapeseed leaves Training, Research and Production Center *Doslidne Pole (Experimental Field)* of VV Dokuchaev KhNAU (the first 10 days of June, 2019)

A) 

B) 

Fig. 4. Plants damaged by young imagoes of *Phyllotreta spp.* A) Damaged pod; B) Damaged stem. State Enterprise "Experimental Farm *Elitne"* of the Plant Production Institute named after VYa Yuriev of NAAS (2012)

Beetles appear en masse on young *Brassicáceae* plants, i.e. on seedlings (grown from seeds in the fields or planted from pots) (Palij, 1962). They eat cotyledons and the youngest, apical leaves, scrape the epidermis of leaves, resulting in ulcers of different diameters (Fig. 3) (Pysarenko & Gordyeyeva, 2009) and, according to N. P. Kosmodemyanskij data (Kosmodemyanskij & Kulik, 1967) skeletonize leaves of *Brassicáceae* plants upon mass reproduction.

As N.N. Bogdanov-Kat'kov (Bogdanov-Kat'kov, 1920) observed, one flea beetle gnaws out an ulcer of 2.5–3.0 mm in 10 minutes and in total one flea beetle gnaws out 14–15 mm² of the leaf surface per day. V.D. Pyatakova (Pyatakova, 1928) pointed out that 10 flea beetles ate 430 mm² of the leaf surface at 14.3°C 720 mm² at 20.6°C.

Beetles of the new generation very often damage stems, flowers, pods, and fruits (Fig. 4) (Susidko & Pisarenko, 1991). Ulcers are grouped in several places and often on the edges of cabbage leaves; on rapeseed, mustard, radish, white turnip, rutabaga and radish, ulcers are scattered over the entire surface of leaves. Damaged tissues get dry, discolor and small holes are formed on leaves (Legatov, 1929). Upon severe damage, leaves turn yellow, their normal development is broken and they dry up. Plants lag behind in growth and young plants die.

Recently, however, their numbers on *Brassicáceae* crops have increased several-fold compared the above figures. Biotic factors (predators, parasites, pathogens) do not limit the numbers of *Phyllotreta spp.* flea beetles within the ETH, so insecticides are used to protect plantations against them (Osipov, 1986). D.M. Korolkov (Korolkov & Durnovo, 1926) pointed out that in hot weather, upon mass development, flea beetles were able to obliterate seedlings on the germination day. After beetles have eaten up 50% of the leaf surface of cotyledons, plants quickly lose their vitality, many of them die, and survivors give significantly reduced yields. In years of their mass reproduction, *Phyllotreta spp.* flea beetles completely wipe out young shoots (Zambin, Turaev & Shumilenko, 1953). Flea beetles also damage seed plants of *Brassicáceae* crops, eating out small (1.5–2.0 mm in diameter) ulcers on buds and pods (Troickij & Shegolev, 1934; Shyogolev, 1960). Damage to leaves of older plants delays their growth and reduces yields. Flea beetles willingly feed on flower heads, especially on wild *Brassicáceae* plants right after coming into blossom. One can often watch flea beetles on the leaf surface unbending parts of the flower head and gnawing at the base of the flower rachis. They often completely gnaw through rachises and flowers dry up. Oil crops are damaged to varying degrees by *Phyllotreta spp.* flea beetles. Brown mustard, white mustard, Chinese radish and spring rapeseed seedlings are more severely damaged, while spring turnip rape seedlings are slightly less attackable, colewort seedlings are little damaged, and false flax seedlings are almost invulnerable (Kostromitin, 1980). According to M.V. Kalyuga data (Kalyuga, 1970), different *Brassicáceae* crops are unequally valued food for insects that feed on them. Their nutritional value is determined by contents of nitrogen and monosaccharides.

Protection measures against Phyllotreta spp. flea beetles

Information about measures to control *Phyllotreta spp.* flea beetles has been available since the mid-nineteenth century. K.P. Bramson (Bramson, 1881) and F. Keppen (Keppen, 1882) recommended growing *Brassicáceae* plants in shady sites, because, in their opinion, they are unfavorable conditions for flea beetles. They also recommended exterminating flea beetles by gathering them with a sweep-net or with tar-anointed boards, which were placed on a small cart. The moving cart makes flea beetles jump and they got stuck to the tar. V.Ye. Iversen (Iversen, 1883) recommended carrying wooden frames with stretched tar-anointed cloths above plantations and thus catching frightened beetles. Vegetating plants were recommended to be sprinkled with ash, lime dust, or with ground bird or horse manure (Shtejnberg, 1907). This operation had to be repeated after each rain. Plants could be also watered with so-called "wormwood water" (a handful of wormwood in a bucket of water) (Iversen, 1883). It was recommended to add gypsum, guano, garlic or wood ash to wormwood water. F. Keppen (Keppen, 1882) recommended spreading horse manure between plant rows with its subsequent burning as an effective measure. He observed that flea beetles, which were frightened by acrid smoke, completely left the field one hour later. It was recommended to repeat this operation every ten days. A. Blomejer (Blomejer, 1901) published data on the effectiveness of sprinkling the perimeter of rapeseed fields with dry horse manure (the band width was 2-4 m), which prevented attacks of flea beetles on fields in spring. F. Keppen (Keppen, 1882) also recommended double seeding rates because in this case flea beetles did not kill all plants. The following F. Keppen (Keppen, 1882) and V.Ye. Iversen (Iversen, 1883) recommendations are also of interest: to sow seeds of wild *Brassicáceae* plants/*Brassicáceae* weeds near plots of domestic *Brassicáceae* plants, then most flea beetles fed on the former and there could be caught with sweep-nets. This can be considered as the start of using trap plants. V.Ye. Iversen

(Iversen, 1883) recommended pre-sowing one-day soaking *Brassicáceae* seeds in garlic or sulfur mixture and sowing the seeds as early as possible, before flea beetles appear en masse. In the fields of *Brassicáceae* crops, it was mandatory to eradicate *Brassicáceae* weeds (Iversen, 1883).

A. Blomejer (Blomejer, 1901) wrote about the low efficiency of sweep-nets, tar-anointed boards and tobacco dust sprinkling and emphasized that good fertilizers and tillage, i.e. agronomic measures should be priorities.

In a review of pests of Kupyansk Uyezd (Obzor vrednyh nasekomyh Kupyanskago uezda po nablyudeniyam 1905 goda, 1906), it was recommended to use long boards with a tar-anointed cloth nailed in the upper part. The cloth bottom was left dry. Then two workers carried it across the field, touching plants with the lower edge and catching frightened flea beetles. Putting this contrivance on a cart, one could make a so-called "Gottingen cart" and significantly accelerate the catch of flea beetles.

P.N. Stejnberg (Shtejnberg, 1907) demostrated the effectiveness of sprinkling plants with Thomas slag. This by-product of cast-iron production, in addition to its negative effect on flea beetles, is a valuable phosphorus fertilizer, which is still used at present. In P.N. Stejnberg publication (Shtejnberg, 1907), copper acetoarsenite or Schweinfurt green was mentioned for the first time as an insecticide against *Phyllotreta spp.* flea beetles.

In the 1920s, to protect crops against *Phyllotreta spp.* flea beetles, it was recommended to spray plants with copper acetoarsenite, barium chlorate and lead orthoarsenate, to apply sticky catchers, to sprinkle plants with Thomas slag or with ash, and to eradicate *Brassicáceae* weeds (Bogdanov-Katkov, 1920; Korolkov & Durnovo, 1926).

In the 1930s, it was recommended to spray with copper acetoarsenite, barium chloride, calcium orthoarsenate, sodium orthoarsenate, or with sodium silicofluoride, to sprinkle plants with calcium orthoarsenate powder, anabadust, nicotine sulphate dust or with tobacco dust mixed with lime, eradicate *Brassicáceae* weeds and to sow early (Shyogolev, Znamenskij & Bej-Bienko, 1937). There were manual, horse and even aviation sprinklers. Due to these measures, the white mustard yield increased by 40-60%; the brown mustard yield – by 20%; and the spring rapeseed yield – by 70–330%. V.N. Shyogolev (Shyogolev, Znamenskij & Bej-Bienko, 1937) also mentioned the high effectiveness of pyrethrum (a number of its derivatives, synthetic pyrethroids, were later synthesized) and the inexpediency of mechanical measures on large areas and advised to focus attention on agronomic measures (eradication of weeds, optimal timeframe for sowing).

In the 1940s, mandatory weed control was recommended and, upon mass reproduction of flea beetles, sprinkling with a mixture of tobacco dust and lime, pyrethrum and ash, copper acetoarsenite, calcium orthoarsenate, sodium silicofluoride, anabadust or nicotine sulphate dust and ash with kerosene or kreoline was recommended. Sodium orthoarsenate and copper acetoarsenite were used for spraying. A mixture of treacle and starch paste was used as a sticking agent (Moric-Romanova, Berezhkov & Davydov, 1941). N.L. Saharov (Saharov, 1947) demonstrated the necessity for double sprinkling with calcium arsenate: during germination and before anthesis, which completely eliminated the danger of pests. 100% of *Phyllotreta spp.* flea beetles died within 12-24 hours. For the first time, it was also mentioned about the necessity to get rid of fallen seeds, which are left in great numbers after the harvest of *Brassicáceae* oilseed crops and a reservoir of flea beetles. V.F. Palij (Palij, 1948) for the first time published data on the effectiveness of dichlorodiphenyltrichloroethane (DDT) to control *Phyllotreta spp.* flea beetle numbers: 5% powder at Ramon Research Station in 1946. The population density of flea beetles was 240 insects/m^2 before treatment and the sprinkling efficiency was 100% for 12 days. M.G. Alimbekova (Alimbekova, Kukshina & Nikitina, 1949) was first to publish data on the use of hexachlorane against flea beetles in 1947.

In the 1950s, it was recommended to sprinkle crops with hexachlorane or DDT, anabadust or nicotine sulphate dust, calcium orthoarsenate, sodium silicofluoride, pyrethrum and tobacco dust during germination and before anthesis to protect plants against *Phyllotreta spp.* flea beetles. As to agrotechnical measures, it was recommended to eradicate *Brassicáceae* weeds, to remove fallen seeds, to sow early (Dobrovolskij, 1950; Velichko, 1951; Kosov, Rameev & Lopaeva, 1952). In addition, for the first time, pre-sowing powdering seeds of *Brassicáceae* crops with hexachlorane or DDT was recommended to protect seedlings against flea beetles (Zambin, Turaev & Shumilenko, 1953). A.K. Leshenko (Leshenko, 1956) presented data of Uman Agricultural Institute that DDT, 5% powder or with hexachlorocyclohexane (HCH), 7% powder at a dose of 8-10 kg/ha completely killed flea beetles within 2-3 days.

In the 1960s, it was recommended to powder seeds with hexachlorane; during the growing period, fields were to be sprinkled 2-3 times with DDT, hexachlorane, anabadust, nicotine sulphate dust, metaphos, pyrethrum, sodium silicofluoride or with calcium arsenate (Bardysheva, 1967;

Gerasimov & Osnickaya, 1961; Narzikulov, 1968). M.P. Kosmodemyanskij (Kosmodemyanskij & Kulik, 1967) recommended treatment of seeds with hexachlorane, 12% powder within one – two months before sowing and double sprinkling with DDT, 5.5% powder, hexachlorane, 12% powder, chlorophos, 0.2% WP or with metaphos, 2.5% powder during the growing period.

In the 1970s, it was recommended to spray plants with organophosphorus compounds such as chlorophos, metaphos or with malathion and to sprinkle them with calcium arsenate, sodium silicofluoride or with hexachlorane during the growing period (Gorodnij, 1970). W. Teuteberg (Teuteberg, 1973) cites data that in West Germany, in order to control *Phyllotreta spp.* flea beetle numbers, rapeseeds were first moistened with linseed oil or kerosene and sweat powdered with hexachlorane. In France, Sweden, and Denmark, seeds of *Brassicáceae* oilseed crops were powdered with hexachlorane (Thompson, 1972; Mattson & Ohlsonn, 1974; Schadlinge des Rapses und ihre Bekampfung, 1974). and, when the pest density was 2–3 beetles/m of the row, the fields were sprayed with mineral-oil emulsion of parathion to protect plants against *Phyllotreta spp.* flea beetles. In Poland, according to D. Malinowska data (Malinowska, 1974), seeds were powdered with hexachlorane and fields were sprinkled with gamacarbatox to protect plants against *Phyllotreta spp.* flea beetles. In Canada (Regnault, 1973; Rapeseed Canada's «Cinderella» Crop, 1974), treatment of seeds with insecticides containing hexachlorane or carbofuran and malathion spraying were used to control *Phyllotreta spp.* flea beetle numbers. G.I. Konchukovskaya (Konchukovskaya, 1978) recommended applying organophosphorus insecticides Rogor (dimethoate), 40% EC or formothion, 25% EC to the soil concurrently with sowing and using diazinon, 60% EC, Valexon (phoxim), 50% EC, Gardona (tetrachlorvinphos), 50% WP, Elocron (dioxacarb), 50% WP, dilor, 80% WP, phthalophos, 20% EC, phosalone, 35% EC and chlorophos, 80% EC (at a working fluid concentration of 0.1%) during the growing period. These agents were 99-100% effective.

In the 1980s, it was recommended to spray plants with gamma isomer of HCH, 50% WP, polychlorcamphene, chlorophos, 50% EC or with metaphos and to sprinkle with HCH, 12% powder at a flea beetle population density of 2 beetles/m of a row. Concurrently with sowing, it was advisable to apply granulated phosphamide or HCH. Prior to sowing, seeds were treated with HCG, fenthiuram (Gortlevskij & Makeeva, 1983; Ivanov et al., 1985; Shtanko, 1987). Other researchers recommended spraying with phosphamide, chlorophos, dichlorvos, HCH or with metaphos at a population density of 20–30 beetles/m² (Ivanov et al., 1985). V.D. Gajdash recommended the same agents, but at a population density of 5 flea beetles/m² (Gajdash, 1998). A.A. Moskalyova (Moskalyova, 1985) remarked that the efficiency of such organophosphorus insecticides as Actellic (pirimiphos-methyl) and Volaton (phoxim) was high. V.G. Osipov (Osipov, 1986) published data on the high efficiency of seed treatment with fenthiuram or with HCH and application of granular diazinon or phosphamide into the soil, while spraying of seedlings with chlorophos and phosphamide were ineffective. In P.I. Zaycev experiments (Zajcev, 1987), the effectiveness of sumicidin and metaphos was 97% and 85%, respectively. O.N. Serebrennikova (Serebrennikova, 1988) reported that in 1988, as per the list of pesticides permitted for the control of *Phyllotreta spp.* flea beetles, the application of dimethoate into the soil concurrently with sowing was allowed and seedlings could be sprayed with thiodan and deltamethrin. V.T. Piven (Piven, 1988) recommended spraying of seedlings with a mixture of chlorophos and metaphos, polychlorocamphene or with sumicidin to protect seedlings against *Phyllotreta spp.* flea beetles. V.G. Osipov (Osipov, 1986) remarked that it was highly effective to apply granular diazinon into the soil concurrently with sowing. N.Z. Milashenko (Milashenko & Abramov, 1989) was one of the first researchers who recommended protecting seedlings by incrustation of seeds with insecticides.

In the early 1990s, it was recommended to spray plants with sumicidin, thiodan, trichlorometaphos or with malathion and apply ammophos-based dimethoate into the soil concurrently with sowing to protect plants against *Phyllotreta spp.* flea beetles (Stefanovskij & Majstrenko, 1990). In the mid-1990s, I.M Mazur (Mazur et al., 1997) remarked that spraying seedlings with synthetic pyrethroids such as deltamethrin, cypermethrin, and lambda-cyhalothrin was a reliable way to protect rapeseed and mustard against *Phyllotreta spp.* flea beetles. These agents are less toxic than organophosphate insecticides and are used at much lower doses.

At the beginning of the 21st century, plant protection is becoming more environmentally friendly. Preference is given to less toxic agents applied at low doses. Pre-sowing protection has been prioritized. Thus, P.D. Sherbak (Sherbak, Sherbak & Majfat, 2001) recommended treatment of seeds with 20% Semafor FC, a triplex insecticide containing biphenthrin, thiamethoxam, the effectiveness of which on seedlings amounted to 85% and the duration of the protective effect was 45 days from the treatment date.

V.P. Fedorenko (Fedorenko et al., 2008) recommended protecting seedlings by treating seeds with 20% Chinuk FC, an insecticide containing imidacloprid and beta-cyfluthrin, and 25% Cosmos 250 (fipronil) FC and, if the ETH was exceeded in the germination phase, spraying with synthetic pyrethroids (deltamethrin, 2.5% EC; cypermethrin, 25% EC or with others) was recommended.

Recently, the range of insecticides recommended for protection of Brassicáceae oilseed crops against *Phyllotreta spp.* flea beetles has become so vast that it is impossible to dwell on each product. Many researchers recommended pre-sowing treatment of seeds or spraying in the phase of 2-4 leaves with one of the permitted insecticides to protect seedlings (Yakovenko, 2005; Lapa et al, 2006; Lazar et al.; 2006; Gordyeyeva, 2007a; Gordyeyeva, 2007b; Zhuravskij & Sekun, 2007; Zhuravskij, Sekun & Skripnik, 2007; Yakovlyev, 2007; Bud’ko, Rovba & Shaganov, 2008; Snizhok, 2008; Sytnyk, 2008; Sekun, 2009; Gordyeyeva, 2010a; Gordyeyeva, 2010b; Abramyk et al., 2010; Ivancova, 2010; Krasilovec, 2010; Yeshenko et al., 2010;. Kasyanov, 2011; Kyforuk et al., 2011; Fedorenko, V.P. & Lugovskij, 2011; Pysarenko, 2011; Lukomec et al., 2012).

The List of Pesticides and Agrochemicals Approved for Use in Ukraine in 2020 includes 17 seed dressers and 79 insecticides for spraying during the growing period to protect oilseed crops against *Phyllotreta spp.* flea beetles; of them, 32 insecticides (40,5%) are synthetic pyrethroids, 16 insecticides (20,3%) are neonicotinoids and 4 agents (5%) are organophosphorus compounds and 27 insecticides (34,2%) –combined insecticides.

An important role in protecting rapeseed from against *Phyllotreta spp.* flea beetles is assigned to resistant varieties and hybrids; therefore, in these modern days, breeding for resistance to diseases and pests is one of the main trends in the breeding of oilseeds of the genus *Brassica* (Gorshkov & Karpachev, 1988; Pilyuk, 2001). A number of pest-resistant varieties have been already created in Europe and the Russian Federation. Of spring rape varieties, according to figures provided by patent holders, Kris (All-Russian Research Institute of Oil Crops, Russia), Lira (All-Russian Research and Design Technological Institute of Rapeseed, Russia), Ribel (Svalof Weibull AB, Sweden), Ural (NPZ-Lembke KG, Germany), and Licolly Germany) are little damaged by *Phyllotreta spp.* flea beetles (Lychkovskaya, 2009). In Belarus (Pilyuk, 2001), *Phyllotreta spp.* flea beetles damage the following varieties to a lesser extent: k-330 (Antey), k-4217 (Russia), Liho (Germany), Karat, WW 1490 (Sweden).

Pheromone traps appear to be promising to control flea beetle numbers. Ye. Chonka (Csonka, 2008) suggested that allilisothiocyanate was the best attractant for many species of flea beetles of the genus *Phyllotreta* (*Ph. atra*, *Ph. nemorum*, *Ph. undulata*, *Ph. nigripes*, *Ph. armoraciae*, etc.).

Nowadays, transgenic rapeseed varieties containing the *Bacillus thuringiensis* (Bt) gene, which makes plants resistant to almost all phytophagous species, are becoming widespread in the world, but in southern China, even this gene does not confer resistance to *Ph. striolata*.

In Canada, rapeseed is bred to produce varieties that will have pubescence on stems and leaves, which would be similar to that in white mustard (white mustard is less populated with *Phyllotreta spp.* flea beetles than rapeseed).

The maximum use of their natural enemies is an important factor in limiting the *Phyllotreta spp.* flea beetle numbers. Hymenopterans, mites and nematodes infest flea beetles. Parasitic insects infest larvae and imagoes of flea beetles.

A braconid (family *Braconidae*, subfamily *Euphorinae* [species is unknown]) is mentioned as a parasitoid of beetles. This parasitoid infests imagoes of all species of the genera *Phyllotreta*, *Chaetocnema* and *Aphthona*. Bright red mite larvae (family *Trombidiidae*) can infest imagoes (Kostromitin, 1980).

Larvae are infested by two species of parasitoid wasps: *Diospilus morosus* Reinh (Hymenoptera: Braconidae) and *Eulophus* sp. (Hymenoptera: Eulophidae) (Tryapicyn, Shapiro & Shepetilnikova, 1982). Both species are ectozoans. In Germany, the parasitoid wasp *Tersilochus microgaster* and lots of nematodes infest *Phyllotreta spp.* flea beetles (Hoffman & Schmutterer, 1983).

Two species of nematodes (*Howardula phyllotretae* and *Hexamermis sp.*), 1 microsporidium species (*Nosema phyllotretae*) and 1 gregarine species (*Gregarina phyllotretae*), which parasitize on *Ph. undulate*, were detected Turkey (Yaman, Tosun & Aydin, 2009).

Conclusions

1. The analysis of the literary data indicates that despite the considerable number of the literary sources devoted to the flea beetles, theirs is still a number of its biological and ecological features which are in close connection with the protection measures for controlling it and these measures have not yet been completely clarified.

2. Modern systems of plant protection, consist in developing and implementing the integrated measures that preserve the crops from the harmful organisms while being the safest for the environment, animals and humans.

3. The transition to such integrated systems involves the application of a biological method of pest control, reducing the number of pesticide treatments, the ability to use the preparations of selective action together with the entomophages, etc. An important reserve in this program is the activation and use of natural resources of the beneficial insects (parasitoids and predators) which limit the number of harmful insect-phytophages.

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SECTION 2. QUARANTINE, INVASIVE AND ADVENTITIOUS ORGANISMS OF AGROCENOSES, URBOCENOSES AND FOREST PLANTATIONS

QUARANTINE PESTS OF TOMATOES IN GREENHOUSES

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It should be noted that the number of species of pests in greenhouses is much smaller than in open agrocenoses, the year-round use of such structures, constantly elevated air temperature and humidity, and the lack of natural regulatory factors contribute to the mass reproduction of phytophages and significantly increase their harmfulness. Insect pests are very dangerous for greenhouse tomatoes. They aren't only cause damage to various parts of the plant, but are also carriers of various diseases. Therefore, to prevent the emergence and reproduction of insect pests, preventive measures should be applied: compliance with the temperature regime and optimal humidity; application of fertilizers according to the recommended agrotechnical norms; enrichment of the soil with organic matter; soil loosening; timely destruction of weeds; compliance with crop rotation; joint landings. Getting rid of pests in a greenhouse is very difficult. It is much easier to prevent their occurrence. For this, the plants, and the greenhouse itself are subjected to mandatory preventive treatments.

Key words: *quarantine**,** greenhouse, tomatoes, insect, biological methods, complex system*

Modern greenhouse vegetable growing is one of the leading agro-industrial complexes of Ukraine, which provides the population with vegetable production year-round and allows getting the highest yield per unit area. But for this it's necessary to effectively protect plants from pests and diseases. The main vegetable crops in greenhouses are tomatoes, cucumbers, peppers, lettuce grown in film and glass greenhouses, both on the soil and on mineral substrates. The specific conditions of the closed ground are not favorable only for the development of vegetable plants, but also for many harmful organisms, affecting crops throughout the growing season. In closed soil conditions regular preventive measures before and after growing crops are mandatory, and also in the gaps between cultural cycles. Therefore, one of the most important elements of the technology of growing tomatoes in closed soil is protection plants from pests and diseases.

In complex systems of measures for the protection of vegetable crops considerable attention should be paid to biological methods, which are based on the use of bioagents against harmful organisms.

The success and profitability of growing greenhouse products is largely due to the modern system protection from harmful organisms. Among insects, one of the most dangerous pests of protected ground is quarantine species. Recently, such species dangerous for protected ground have appeared in Ukraine like western flower thrips, tobacco whitefly, which can significantly worsen the phytosanitary the state of greenhouses. A feature of these quarantine pests is that they have already acquired resistance to most insecticides, which makes them even more dangerous.

Western flower thrips – *Frankliniella occidentalis* . (Pergande, 1895) (Thysanoptera: Thripidae). Western flower thrips have a broad host range of more than 500 species in 50 plant families and are associated with many cultivated crops and ornamentals. Crops attacked by this pest include beans, burdock (gobo), capsicum, cucumber, eggplant, lettuce, onion, tomatoes and watermelon. Ornamental crops include carnation, chrysanthemum, orchids, pikake, rose and tuberose. Refer to Yudin *et al.*, (1986) for a listing of hosts in the vegetable-growing region of Kula, Maui.

Native to North America, the western flower thrips is widespread from sea level to sub-alpine altitudes. It is the most common thrips species of California and Arizona. This thrips has spread to the Canary Islands, Europe, Hawaii, New Zealand and northern South America. Although it has been intercepted in Guam on lettuce shipments from North America, it has not become established there as yet. This thrips was first reported in Hawaii on the island of Kauai in 1955 and has since spread to all major islands except Molokai. It did not become a serious pest until the mid-seventies when sporadic and economically significant outbreaks occurred, particularly on lettuce and chrysanthemums .

Western flower thrips in Ukraine was first discovered in 2001, in the city of Uzhgorod, Transcarpathian region, in the greenhouse of the State

Enterprise of Green Economy "AGRO- MIX". According to the phytosanitary service of Ukraine, as of 2021, the pest was widespread in Dnipropetrovsk, Poltava, Ternopil and Kherson regions on an area of 6.85 ha. Because diagnosis of this small species is difficult, it is probably found in Ukraine wider distribution.

Thrips puncture the leaves, flowers, or stems with their mouth parts and suck up the exuding sap. General thrips injury on foliage causes a characteristic silvery appearance, eventually browning and dying. Leaf tips wither, curl and die. The undersides of leaves are spotted with small black specks. Flowers become flecked, spotted, and deformed and many buds fail to open. Thrips can be found in greatest numbers between leaf sheaths and the stem. The western flower thrips is primarily a flower feeder that eats both the flower petals and pollen.

In addition to the direct feeding damage, extensive losses occur when this thrips vectors tomato spotted wilt tospovirus. Western flower thrips adults that have feed on diseased tissue as larvae may infect host plants with tomato spotted wilt virus (TSWV). It is a serious disease in several economically important crops worldwide (Cho *et al.*, 1988). TSWV disease affects the production of several economically important vegetables and ornamental crops. Tomato that have experienced losses of 50–90 %. TSWV is a unique virus in that it has one of the widest known host ranges of any plant virus. It is the only virus transmitted in a persistent manner by thrips/ Along with the western flower thrips *(Frankliniella occidentalis)*, TSWV is also vectored by other thrips species including yellow flower thrips *(Frankliniella schultzei)*, onion thrips *(Thrips tabaci)*, and chili thrips *(Scirtothrips dorsalis)*. The western flower thrips, however, is considered the most important vector.

Symptoms of TSWV disease are variable. Infections on the same host species vary according to the plant age, plant nutrition and environmental conditions such as temperature. Several strains of this virus exist with different symptoms and host ranges. The disease causes brown necrotic spots tissue, usually on one side of the plant. Two classes of hosts are known. Those characterized by localized sites of infection in tissues inoculated by the vector. The second type of host is called a systemic host. In this host, the virus spread systematically from the inoculation site to other parts of the plant. On tomato, early stages of the disease are characterized by chlorosis (yellowing) of leaves and terminal shoots that may develop into bronzing and necrosis. Tomato fruits are discolored with pale red or yellow areas that may be in the form of irregular mottling, blotches or distinct concentric rings.

Often thrips damage resembles damage to other invertebrates, such as ticks, or symptoms of diseases. The presence of thrips can be detected by the presence of characteristic excrement. The liquid excrement of thrips after drying has a dark green color and a conical shape; the petals are colored in other colors. The droppings of spider mites are black, dry grains that do not stick to the surface.

To detect and record the western flower thrips, 50 leaves are examined once a week in each greenhouse. Adhesives are used for early detection and control of population dynamics traps of blue, yellow, white colors. Attractive substances — geraniol, ethyl nicothionate increase catchability One trap is placed every 90–100 m^2, above the plants, near the ventilation holes, doors, corridors, traps are checked every 2–3 days. For early indicator plants can be used to detect thrips are very sensitive to the pest and are primarily inhabited by thrips, this saintpaulia and petunias.

Control the growth of the pest population in the outbreaks by using insecticides in accordance with the «List of pesticides and agrochemicals approved for use in Ukraine». It is possible to use biological methods by using entomophages, which are able to restrain the growth of the population of the western flower thrips: *Amblyseius cucumeris, Amblyseius barkeri, Orius majuscus*, *Orius iqaevigatus*.

The best way to deal with western flower thrips is prevention – it is important to prevent the harmful organism from entering the greenhouse.

Tobacco whitefly – *Bemisia tabaci* (Gennadius, 1889) (Homoptera, Aleirodidae). This species has been described many times, thanks to which it exists more than 20 synonymous names. It started as a dangerous pest in 1980 create problems not only for agriculture, but also for decorative crops in many countries of the world. Is a wide polyphagus, carries more than 110 viral infections, especially from the genus *Begomovirus*, as a result of which 20–100 % crop loss is possible.

The homeland of the tobacco whitefly is still not known for sure. For the first time this species was brought to America and Europe from Africa. In recent years there is a rapid spread of tobacco whiteflies in many countries. Great plasticity, omnivorousness, high reproduction rate make it one of the most harmful species. The tobacco whitefly has a cosmopolitan range. In greenhouses, greenhouses, the view penetrates far north

Bremisia tabaci was first discovered in Ukraine in 2007, in one of the private farms greenhouses near Ivano-Frankivsk on Hibiscus plants. The infected area was then 0.7 hectares. All plants were infected were destroyed, others were treated with insecticides against sucking insects. In 2008, *Bremisia tabaci* was no longer detected. However, already in 2010, they were again wilted cells in the greenhouses of the Lviv region — on cucumbers and on decorative plants of the greenhouse of tropical plants of the Lviv Botanical Garden the garden The total area of infection was slightly more than 6 ha. In all cases, infected plants were destroyed, and in greenhouses they were introduced a set of quarantine measures, including using an insecticide. However, in the same year, infection with this quarantine pest was recorded moved in the Kherson region. In 2019, new tobacco center whiteflies were found in the Kremenchutsk district of the Poltava region on area of 1.6 ha. In general, the area under quarantine in the country today is tobacco whitefly is 1.75 ha.

Insects can be found both on the outside and on the inside of plant leaves. If the plant is shaken, a swarm of small butterflies will immediately fly in all directions.

Females are quite sensitive to the quality of the fodder plant, its physical condition and air humidity. At a temperature of 20°C, females live up to 60 days, males – up to 20. Fertility – up to 160 eggs. In a year, 11–15 generations of tobacco whiteflies can develop in greenhouses (about 30–33°C).

Considering the climatic conditions in Ukraine, this pest can cause great damage to plants grown in closed soil conditions. Due to the high level of harmfulness, the tobacco whitefly is included in the List of regulated harmful organisms as a quarantine organism that is not available in Ukraine (list A–1).

The whitefly is a dangerous pest of agricultural crops, characterized by unique omnivorousness (polyphagy), high population growth rate, phenomenal survivability and resistance to pesticides. Currently, the species has spread widely across all continents. In greenhouses and greenhouses, the whitefly penetrates far to the north.

Economic losses from the whitefly are quite large, as it not only destroys and suppresses cultivated plants, reducing their productivity by up to 70 %, but is also a carrier of many dangerous diseases.

The pest can damage more than 600 types of plants. Favorite crops of whiteflies are pepper, cucumber, lettuce, tomato, as well as numerous flower plants (rose, gerbera, poinsettia, fuchsia, pelargonium, azalea and others). The harmful stage of development is the larva, which feeds on the sap of plants, which leads to yellowing, drying and falling of leaves. An adult insect carries more than 60 viruses, the causative agents of dangerous plant diseases, many of which can cause crop losses from 20 to

100 %. Insects do not fly very well, but they can be carried by the wind over long distances.

As a rule, whiteflies hide on the underside of leaves. On the upper side of the lower leaves, a shiny coating (honeydew, or fall) appears - the secretion of insects, on which sooty fungi («blackheads») develop, which suppress the development of plants. In addition, these allocations have a negative impact on the process of photosynthesis.

However, the most dangerous insect is in greenhouses, greenhouses and greenhouses, where, as a rule, there is an increased level of humidity and high air temperature. Working together, fungi, whitefly adults and larvae kill plants quickly and irreversibly. And if take into account that each new generation of whiteflies appears every 25–28 days, then in 3–4 months you will have several generations of whiteflies living in your greenhouse, which are equally harmful to plants.

It is very difficult to destroy the whitefly – for example, in a greenhouse, several stages of the pest live and reproduce at the same time, so among them there are stages that calmly tolerate the use of chemical preparations.

Given the special vitality of whiteflies, you can get rid of insects only with the help of complex measures, which should include preventive and quarantine measures, mechanical destruction of pests, as well as the mandatory use of chemical and biological means of plant protection. Since the whitefly shows quick adaptation and good resistance to insecticides, it is advisable to alternate pesticides to avoid habituation in insects.

The tobacco whitefly is a dangerous quarantine object, therefore the import of plants inhabited by the tobacco whitefly into the territory of Ukraine is prohibited. Phytosanitary control measures include banning the importation of plants with leaves, bulbs, tubers, cuttings, flowers, and fruits infested with pests; cut flowers and buds, fresh leaves, branches for making bouquets, fresh fruits: cabbage, cauliflower, broccoli and other edible vegetables from the genus *Brassica*, salads and other greens inhabited by tobacco whiteflies.

In case of detection of plants or their parts that are inhabited by *Bemisia tabaci* Gen., all products are subject to destruction or return to the shipper. There is a non-quarantine very similar pest of the tobacco whitefly – it is a greenhouse whitefly *Trialeurodes vaporariorum* , it is very easy to confuse it with the quarantine *Bemisia tabaci* . Their exact identification is carried out only by a specialist of the phytosanitary laboratory for puparia and only in laboratory conditions.

In order to prevent the spread of these pests and to localize their foci, it is necessary to observe organizational and economic and quarantine measures, to carry out constant monitoring and their timely detection. To prevent the appearance of pests or their spread in a greenhouse or greenhouse, it is necessary to carry out a set of preventive measures. During the growing season and at the end of the season, all plant remains are carefully removed so that whitefly adults and other pests do not lay eggs on them. The greenhouse and soil must be disinfected in the fall. Strictly follow the agrotechnical measures provided by the technology.

The use of pheromone traps and yellow glue traps is effective for detecting the pest.

It is easier to prevent whitefly on plants than to fight it. That is why phytosanitary measures are becoming extremely important. It is prohibited to import into Ukraine rooted plants with leaves, tubers, bulbs, rosettes of roots in the state of vegetation, cut flowers, cuttings, seedlings, fresh vegetables, greens infested with tobacco whiteflies. Since it is quite difficult to detect the pest in plant consignments, the best guarantee of eliminating the risk of introduction would be its absence in the places where the products are grown. In case of detection of plants or their parts that are inhabited by *Bremisia tabaci*, all products are subject to return or destruction.

The South American tomato moth (*Tuta absoluta* Meyr.) is distributed in the countries of South America, and according to the information service of the EPPO, the first information about its discovery on the European continent came from Spain in 2006. In 2010, the tomato moth was already discovered in Bulgaria, Cyprus in Germany, Spain, Hungary, Israel, Kosovo, Turkey; in the same year, it was discovered on the territory of Ukraine in tomatoes from Spain and the Netherlands. In 2011, the pest was officially recorded for the first time in Greece, Lithuania, and Great Britain; it also continues to spread in the countries of the Mediterranean basin, North Africa and the countries of the Middle East.

The tomato moth is the «major limiting factor for tomato production in South America». Damaged fruits are poorly stored, rot and lose their marketable quality. There are reports of losses from 50 to 100 % of the tomato crop. This pest is considered one of the most dangerous lepidopteran pests of tomatoes in Brazil.

The South American tomato moth was brought to Ukraine in 2010 with infected shipments of tomatoes from Turkey and Syria. At that time, outbreaks of the pest were found in the Autonomous Republic of Crimea and Odesa Region. The pest is gradually conquering new territories and, as of January 1, 2021, the affected area is more than 1,190 hectares. This is facilitated by the "softening" of the climate, which provokes the emergence of new generations of pests that have adapted to the natural conditions of our country.

The main host plants of the South American tomato moth are tomatoes. In addition to them, the moth can damage all types of plants from the nightshade family (*Solanaceae):* eggplants, potatoes, peppers, tobacco, and wild nightshade plants such as dahlia, nightshade , and nightshade.

The tomato moth is an oligophagous plant that feeds on nightshade crops. It can complete its development (from egg to adult stage) on such crops as tomatoes, potatoes, eggplants, etc. PATM is an insect with a high reproduction rate, it can have a full 12 generations per year depending on environmental conditions. The pest completes one generation in 28 days. Since the tomato moth damages plants even in closed soil conditions (greenhouses), it is necessary to take into account its rapid reproductive potential.

This pest is able to destroy from 60 % to 100 % of the crop in a very short time. In South America, it is considered one of the most important pests of tomatoes, both in the field and in greenhouses. In Spain, a year after the first detection (in 2007), almost 100% losses of the tomato crop was recorded in several winter months due to damage caused by caterpillars. And today, the damage caused to tomato fruits due to the feeding of the pest represents a potential threat to all Spanish producers of tomatoes and other nightshades.

Caterpillars of the South American tomato moth feed on all parts of tomato plants (except underground) and damage plants at all stages of their growth. They form large tunnels-mines on leaves, gnaw long tunnels in stems and shoots, green and ripe fruits. With significant damage, especially in the conditions of the closed space of the greenhouse, the leaves wither, eventually dry up and fall off. After the caterpillars damage the fruits, pathogenic fungi enter the latter, the fruits quickly lose their quality and appearance.

Biological features, the ability to quickly multiply and adapt to the South American tomato moth contribute to the rapid spread of the pest in Ukraine. In addition, greenhouse farms in all regions of the country that grow nightshade crops are at risk, especially those that do not grow seedlings themselves, but import them, as well as those that use containers that were previously used to transport imported tomatoes. Cargoes of fresh tomatoes, eggplants, peppers, as well as planting material of host plants (seedlings, decorative *Solanaceae* in pots) of imported origin are considered the main routes of penetration of the South American tomato moth. All vegetables imported into Ukraine, as well as those in transit and re-export undergo phytosanitary control, state phytosanitary inspectors select samples for examination. Imported vegetable products can be brought to the territory of Ukraine only after carrying out all the necessary procedures and receiving the conclusion of the phytosanitary examination certifying the phytosanitary status of the cargo.

It is necessary to apply biological and methods of protection. When applying biological protection of plants, parasitic insects or predators are used, which are natural enemies of these pests and destroy them at various stages of development. Among the predators that destroy several types of harmful insects at different stages of development, the most common are thrips bugs from the *Heteroptera subgenus*, especially *Macrolophus pygmaeus*, *Macrolophus fuliginosus*, *Dicyphus spp.* and *Nesidiocoris tenuis*. These insects are extremely active entomophages of tomato moth larvae. The tiny size and high mobility of these bugs allow them to move intensively in damaged plants in search of not only eggs, but also caterpillars, which are usually attacked outside the boundaries of mines. Other predators of the *Heteroptera* subspecies, which are periodically detected, also include hunting bugs, which are usually larger than the above-mentioned predators (7–10 mm), and therefore are able to prey on more developed larvae and pupae. *Amblyseius* mites have also started eating tomato moths, particularly eggs. As for parasitoids (parasites that complete their development at the expense of one host and attach to one or more similar species), among them there are often some *Hymenoptera* trichogrammatids from the genus *Trichogramma* , which most likely feed on the eggs of the tomato moth. Other identified parasitoids are some eulophids of the species *Necremnus*, *Hemiptarsenus* and *Pnigalio*, as well as, more rarely, *Ichneumonidae (Diadegma*).

Therefore, the application of an integrated system of protection of vegetable crops with the predominant use of biological means of protection against a complex of major pests in combination with the implementation of preventive, agrotechnical and organizational and economic measures makes it possible to collect planned crops of vegetable crops during each crop rotation.

Research on the use of biological means to combat pests of vegetable crops in closed soil indicates that scientific assets in this direction are significant, and their practical use opens up the possibility of full biologicalization of plant protection in greenhouse farms and in the conditions of private greenhouses.

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MISSING POTENTIALLY DANGEROUS PESTS FRUIT CROPS AND GRAPES IN UKRAINE

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The article provides information about the potentially dangerous pests of fruit crops and grapes that are absent in Ukraine and included in the EPPO Alert List 2023-03. *Apple buprestid (Agrilus mali Matsumura: Buprestidae: Coleoptera) wood borer insect, a dangerous pest of cultivated and wild species of apple trees, has a quarantine status in a number of countries in Europe and Asia. Brown winged cicada (Pochazia shantungensis Chou & Lu: Ricaniidae: Hemiptera) invasive species identified in the European part of Turkey 2018 by 2022 registered in four countries European and Mediterranean Plant Protection Organization (EPPO). Red-banded thrips (Selenothrips rubrocinctus Giard: Thripidae: Thysanoptera), being a polyphage, it damages a large number of fruit and ornamental crops, and grapes were repeatedly detected in EPPO countries in regulated plant products and greenhouses (Poland), in 2015 it was registered in Italy.*

Key words: *plant quarantine, Apple buprestid (Agrilus mali), Brown winged cicada (Pochazia shantungensis) , Red-banded thrips (Selenothrips rubrocinctus).*

Accelerated processes of biological invasions, active intrusion of alien species into new conditions, which has been taking place recently, leads to negative consequences for local species and ecosystems. The main reasons for this are anthropogenic factors: an increase in transportation, the intensive development of trade and tourism, the transformation of natural ecosystems (regulation of water bodies, deforestation or unjustified afforestation of the steppes, artificial drainage or watering of territories), as well as climate change. In order to avoid the introduction or spread of regulated pests, each country has the sovereign right to regulate the importation of plants, plant products and other regulated items in accordance with relevant international agreements. Timely detection of alien species, preventing their penetration and spread on the territory of the country is important in the conservation of plant resources and is the main task of the Quarantine and Plant Protection Department of the State Service of Ukraine for Food Safety and Consumer Protection.

The measures that this service takes in relation to pests are determined by the List of National Organizations and depend on whether the pest belongs to Lists A1 or A2. Therefore, the formation or editing of the National List is a top priority in order to prevent dangerous pests from entering the country and their spread, and is carried out based on the results of pest risk analysis (PRA).

In addition to the A1 and A2 Lists of pests recommended for regulation, the EPPO has an Alert List. The purpose of its creation in 1999 is to draw attention to pests that pose a potential threat to plant resources. The EPPO Alert Lists are intended to notify about the detection of previously absent pests in the member countries of the organization, as well as to alert National PPC organizations of a potential pest risk and recommendations on the selection of a pest as the subject of pest risk analysis. Pests, plant pathogens, missing plants that have recently been introduced into regions new to them, have given unusual outbreaks of mass reproduction, or have otherwise shown their aggressiveness, which indicates a potential pest risk for the region, are included in the EPPO Alert List.

Revision of the EPPO Alert List will make it possible to determine the feasibility of establishing a quarantine status for the subsequent submission of a proposal for amendments to the current "List of regulated pests of Ukraine".

The purpose of the research was to analyze the EPPO Alert List 2023-03 and identify pests potentially dangerous for Ukraine for the subsequent determination of the feasibility of conducting a pest risk analysis (PRA).

Updated in 2023, the Alert List includes a number of pests, some of which pose a potential threat to fruit crops and grapes, which are host plants for species absent in Ukraine (EPPO Alert List 2023-03).

Below is information on species that pose a potential threat to the plant resources of Ukraine.

Apple buprestid *Agrilus mali* Matsumara *(Coleoptera: Buprestidae)* – wood borer insect, a dangerous pest of cultivated and wild species of apple trees *Malus* spp.: *Cydonia oblonga, Malus baccata, M. domestica, M. prunifolia, M. sieversii, M. spectabilis, Prunus armeniaca, P. persica.* The species is distributed in the eastern part of Asia (Northeast China, the Korean Peninsula, the Far East and Eastern Siberia of Russia). The EPPO Phytosanitary Measures Panel recommended the inclusion of the pest on the EPPO Alert List (2020-07), taking into account the potential damage *A. mali* could cause to *Malus species*. The quarantine status of the pest has been determined in a number of countries in Asia and Europe, as well as national plant protection organizations (NPPO): Kazakhstan (A1 list_2017), Uzbekistan (A1 list_2008), Azerbaijan (A1 list_2007), Belarus (Quarantine pest_1994), Moldova (Quarantine pest_2017), EAEU (A2 list_2016), EPPO (Alert list_2020).

The body of the adult *Agrilus mali* is 8–10 mm long, shiny metallic green, copper or bronze, often with copper-red elytra. Large eyes almost in contact with the pronotum. The larvae are creamy white, 18–20 mm long, and go through five instars in their development. Pupae 10 mm long, whitish-yellow. The eggs are oblong, creamy white at first, then gradually turn yellow. The adults of the beetle feed on leaves, the larvae make extensive passages under the bark, damaging the phloem, cambium, and outer xylem tissues and disrupting the vascular system of the plant. This can lead to defoliation, branch dieback and eventually the death of the tree (*Agrilus mali…,*2022). It was noted that the affected trees were more susceptible to fungal infections (*Valsa mali*), which accelerates the wilting of trees. External symptoms of damage: gnaws on leaves as a result of additional feeding of beetles, typical D-shaped flight holes in the bark; drying of individual branches, cracking of the bark, the presence of twisted larval passages filled with drill flour under the bark and in the outer layer of wood (Fig. 1).

In China (Xinjiang Province) *A. mali* has a monovoltine life cycle and usually hibernates as young larvae inside galleries. From late July to early

September, adult females lay 60–70 eggs on young branches or new shoots. Hatching larvae, feeding on the core of the shoot, bore holes by the spring

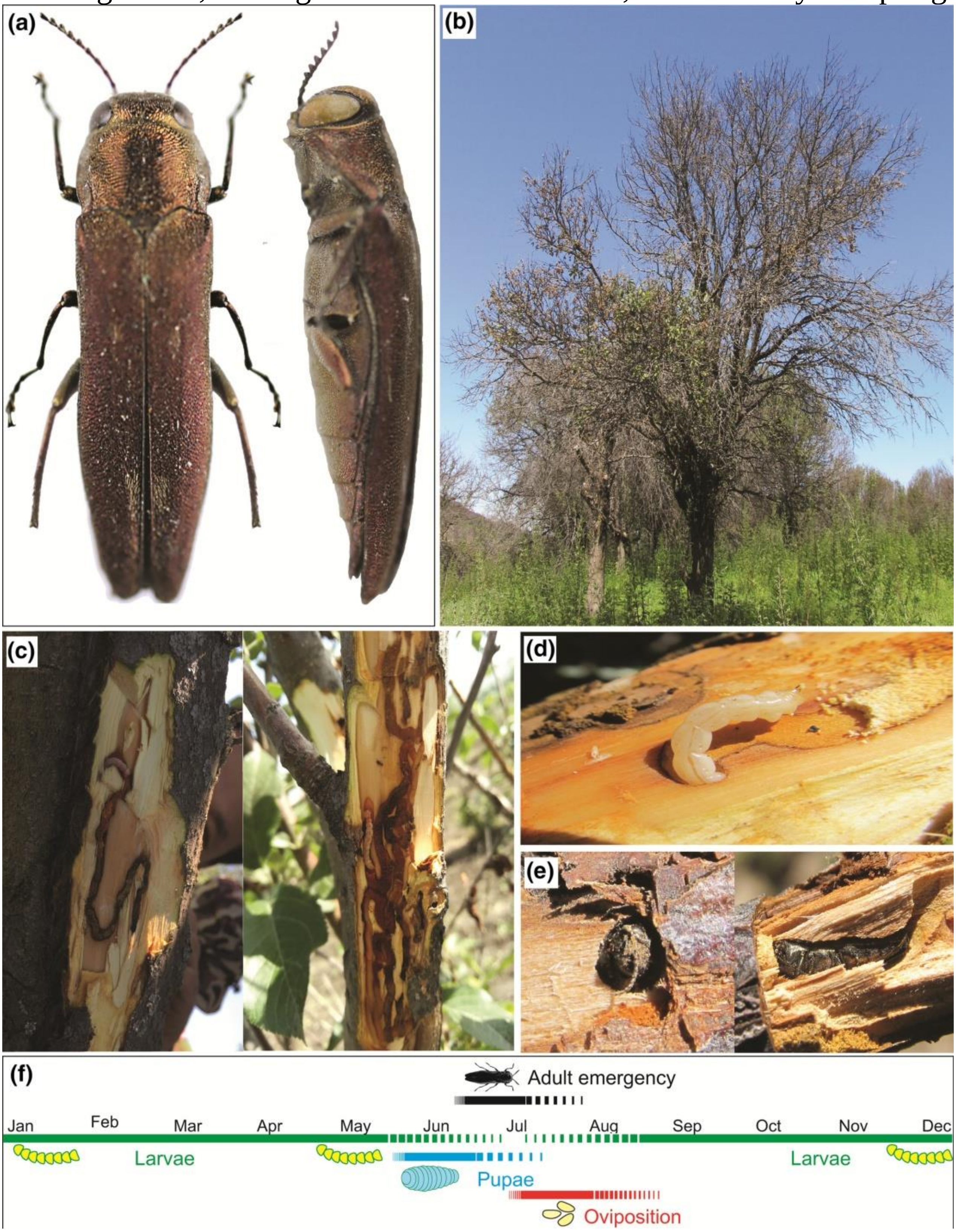

Figure 1. ***Agrilus mali:*** **a – imago, b – wild apple tree heavily infested with, c – typical serpentine galleries caused by larvae, d – mature larva in the young stem, e – adult in the stem and D-shaped adult emergence hole, f – Summary of the life cycle of** ***A. mali*** **in the wild**

apple forests of Tianshan Mountains,

(https://doi.org/10.1002/ece3.4804**)**

of next year. From the end of April to the end of June, the pest pupates, which, depending on the environmental conditions and the age of the trees, lasts for 2-3 months. Departure of adults takes place from the beginning of June to the end of July, flights are carried out over short distances (Cui, et al., 2019).

The spread of the pest occurs due to the movement of infected planting material of *Malus spp*., with untreated apple wood. Possible accidental unintentional importation with vehicles.

The main method for identifying apple borers is a thorough visual inspection. Under the bark in the passages, it is possible to identify larvae, and in the surface layers of wood - pupae in cradles. It is more difficult to detect egg layings in cracks in the bark and the beetles themselves, feeding in sunny weather on sunlit foliage.

A possible risk of introducing *A. mali* is that the apple tree (*Malus domestica*) is widely grown in the EPPO region for both fruit and ornamental purposes and is of great economic importance. *M. sieversii* is native to Central Asia (Kazakhstan, Kyrgyzstan, Tajikistan, Uzbekistan, and northeastern Afghanistan), is considered the main ancestor of all domesticated apple species, and is an important breeding resource due to its rich genetic diversity. There are no data on cultivation of *M. sieversii* in the EPPO region, but the plant is available for online sale from a number of nurseries. *M. sieversii* is listed as vulnerable by the International Union for Conservation of Nature (IUCN). In Ukraine, horticulture is one of the key areas of agriculture. A significant place in the production of fruit products is occupied by apple orchards. According to the "Sectoral Program for the Development of Horticulture in Ukraine until 2025", the area of annual plantings is planned to be increased to 20 thousand hectares. The total area of fruit-bearing apple plantations will be 144.8 thousand hectares. About 40% of plantings should be placed in the western Forest-Steppe, 40% - in the central Steppe and Crimea, and the rest - in other regions of the country (On Approving…, 2008).

Given that *A. mali* spends most of its life cycle inside trees, pest control is difficult and involves pruning of infested branches, insecticide treatment, and biological control. Research to identify biological control agents that may regulate *A. mali* populations is underway in China (Cao, et al., 2019).

The final conclusion about the quarantine status of *Agrilus mali* is possible after studying the information about the economic side of the problem, the likelihood of acclimatization of the pest in Ukraine outside its natural range, and measures to prevent the introduction of the pest.

Brown winged cicada *Pochazia shantungensis* Chou & Lu *(Hemiptera: Ricaniidae)* – invasive species, rapidly spreading to new regions. *P. shantungensis* was first described in 1977 in China, in 2010 it was introduced to the Republic of Korea, where the population of this pest in agricultural areas annually increases by more than 100% and causes serious economic damage (Baek, Kim, and Lee, 2019).

In 2018, the pest was found in the European part of Turkey and in the south of France, in 2021 in Germany, in 2022 in Italy and Russia (Sochi). The species was added to the ERRP Alert List in 2021 (EPPO Alert List, 2021).

P. shantungensis - a polyphage that infects more than 200 plant species from 81 families. Economic damage is caused to fruit and ornamental crops. The greatest economic damage among host plants is caused by fruit (apple, peach, plum, quince, blueberry, persimmon, black raspberry, Chinese lemongrass) and ornamental crops (chestnut, magnolia, acacia, etc.).

The body length of *P. shantungensis* varies depending on the sex of the pest; females are larger than males.

The body coloration of *P. shantungensis* varies from dark brown to black, crown, forehead and eyes from brown to dark brown. Pronotum and mesoscutum black together with thorax. The forewings are dark brown, with an elliptical white spot near the costal margin. The posterior margin of the abdominal segments is yellow (Fig. 2).

a b

Figure 2. Imago *Pochazia shantungensis* (a – female, b – male),
(https://gd.eppo.int/taxon/POCZSH/photos)

In South Korea, one generation of the pest per year is noted, in China - two. The pest hibernates in the egg stage on the inner branches of the tree.

Larvae hatch in May, nymphs prefer herbaceous plants. Adults appear from July (Kühn and Schrader, 2021).

Until the end of August - beginning of September, a new laying of eggs by females occurs. Zigzag masonry, on average, 28 pieces, covered with white wax threads (Fig. 3).

Figure 3. Oviposition *Pochazia Shantungensis*
(https://en.jadam.kr/news/articlePrint.html?idxno=9447)

The rate of development of the stages depends on the temperature. The optimal conditions for the development of eggs and nymphs of the first–fifth instars are temperature from 18 to 27°C, relative air humidity 40–70%, and 14-hour illumination. The higher the temperature, the shorter the development period. The lower development threshold was 9.3°C, and the sum of effective temperatures was 693.3 degree-days (Choi et al., 2016).

There is no information on the natural distribution of P. shantungensis, despite the fact that adults have the highest mobility of all developmental stages and can fly. Over long distances, the pest is carried in the egg stage with planting material from the countries of the modern range. Wood cannot be a vector as the pest lays its eggs on young branches (EPPO Alert List, 2021).

The most effective way to control the pest population is to use synthetic pesticides during the hatching period of the nymphs. Environmentally friendly materials (sophora, lily extract and other natural plant extracts) in the fight against nymphs and adults can show pest mortality above 80%. It is advisable to use yellow glue traps around oviposition sites.

Considering that *P. shantungensis* has a wide range of hosts, including economically important fruit crops for the EPPO region and in particular for Ukraine, as well as the naturalization of the species in two EU countries, the pest may pose a threat to Ukraine, where, according to the "Sectoral

Horticulture Development Program Ukraine until 2025", the area of annual plantings is planned to be increased to 20 thousand hectares. The final conclusion about the quarantine status of *Pochazia shantungensis* is possible after studying the probability of acclimatization of the pest in Ukraine outside the natural range, measures to prevent the introduction of the pest, and the economic side of the issue.

Red-banded thrips *Selenothrips rubrocinctus* Giard (*Thripidae : Thysanoptera)* – is a dangerous pest species native to the northern part of South America or Africa. In 2022, it was registered for the first time in the EPPO region (Italy) (EPPO RS 2022/106). Taking into account the harmfulness, the wide range (Americas, Africa, South Asia), the wide range of host plants and its distribution in international trade, the EPPO Secretariat has added the species to the EPPO Alert List 2022 **(**EPPO Alert List (2023-03).

Being a polyphage, *S. rubrocinctus* damages a large number of fruit and ornamental crops and shrubs *(Persea Americana, Mangifera indica, Anacardium occidentale, Carica papaya, Psidium guajava, Garcinia mangostana, Nephelium lappaceum).* In Brazil, thrips is recognized as a pest of vineyards (*Vitis vinifera*), it reduces the quality of fruits and, in case of intense infection, causes partial or complete defoliation of plants. Grapes in Ukraine are one of the promising and economically important crops of agricultural production, aimed at meeting the demand of the population and providing the food industry with raw materials for processing. Currently, the total area of vine plantations of all categories of agricultural enterprises in Ukraine is 93.3 thousand hectares, of which 13.6 thousand hectares are table varieties (14.6%). "The Program for the Development of Viticulture and Winemaking in Ukraine for the period up to 2025", provides for an additional 13.7 thousand hectares of vineyards in the southern regions of Ukraine by 2025 (On Approving…, 2008).

S. rubrocinctus repeatedly detected by the European protection and quarantine services of the Netherlands on regulated plants Codiaeum from Sri Lanka and Togo (1980 to 1995), on *Garcinia sp*. from Thailand (2005), on *Codiaeum sp*. from Suriname (2011) and from Costa Rica (2011–2014) as well as in the UK on *Psidium guajava* from Jamaica (2003) and on *Garcinia sp*. from Thailand (2005) in 2005. In 2009 it was found in a greenhouse in Poland on *Codiaeum variegatum*. In July 2015, the pest was registered in Italy on some trees *Liquidambar styraciflua* и *Koelreuteria paniculata*) (Taddei et al., 2021).

Symptoms of *S. rubrocinctus* infestation result from the feeding of adults and nymphs. When heavily infested, the leaves take on a brown, sunburned appearance, chlorotic spots form, leading to premature leaf drop. The skin of the fruit is covered with silvery or brown scars, turning reddish-brown with cracking and rotting, making them unsuitable for sale (Fig. 4). Honeydew secreted by thrips causes the development of black soot fungus (Brown and Chin, 2013).

Figure 4. Damage symptoms of *Selenothrips rubrocinctus*, (https://www.inaturalist.org/taxa/271215-Selenothrips-rubrocinctus)

The body of *S. rubrocinctus*, about 1.2 mm long, is blackish brown with a reddish tint on the first three abdominal segments and anal segments. Tarsi and apices of tibiae yellow, segments of antennae yellow. Males are smaller than females. Both sexes are winged. Forewings uniformly dark with long black setae. Nymphs and pupae are yellow or pale orange, the first three abdominal segments and the tip of the abdomen are bright red. Adult nymphs measure about 1 mm (Fig. 5) (Hoddle, Mound and Paris, 2012).

Figure 5. Imago (male on the left, female on the right) and nymphs *Selenothrips rubrocinctus* (https://gd.eppo.int/taxon/SLENRU)

Red-banded thrips females live for about a month, during which time they can lay up to fifty eggs, formed by parthenogenesis. Each egg is laid on the underside of a leaf and covered with a drop of liquid that hardens into a protective black disc. After about four days, nymphs emerge from the eggs. The nymph stage lasts about nine days, followed by the prepupal and pupal stages (Denmark Anderson Denmark and Wolfenbarger, 2008).

The life cycle takes about three weeks. The number of generations of Red-banded thrips depends on the climatic conditions of the habitat; in Florida, thrips develop in 3 generations, in South China - 8.

The spread of *S. rubrocinctus* over short distances is carried out by active or passive flights. The main way the pest spreads to new, free areas is the import of infected planting material of trees and shrubs, potted ornamental crops, cut flowers, and fruits of tropical crops, on which the pest can be present at all stages of development.

Pest control does not always require the use of chemical protection. The use of the biological method is quite effective, since *S. rubrocinctus* is the prey of predatory insects such as spiders, mites, lacewings, beetles and other types of predatory thrips. These natural controls are effective in most cases. When chemical control is required, perethroids and other officially registered insecticides are used (Baker, 2022).

Although tropical in origin, *S. rubrocinctus* has adapted to more temperate zones, which may pose a threat to the southern part of the EPPO region, as well as to growing seedlings in greenhouses.

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MODERN DISTRIBUTION AREA OF *HYPHANTRIA CUNEA* DRURY

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Hy*phantria cunea Drury is a polyphagous quarantine pest, which is not evolutionarily tied to the territory of Ukraine. We have analyzed data from literary sources on the geographical spreading of Hyphantria cunea Drury, indicated the current area of the pest and noticed factors that influence the acclimatization of a pest. The motherland of Hyphantria cunea Drury is North America; in 1770, an entomologist Druri first described this species. The first indications of the harmfulness of Hyphantria cunea Drury are noted in the USA in 1899 and on the European continent Hyphantria cunea Drury was found near the city of Budapest (Hungary) on the island of Chepel in August 1940. By 1948, the pest had spread throughout Hungary and began to occupy the tree plantations of neighbouring countries, such as the Czech Republic, Slovakia, Yugoslavia, Romania, and Austria. At present, the pest is widespread in Europe, Asia, and North America. In Europe Hyphantria cunea Drury was found in countries such as: Austria, Azerbaijan, Bulgaria, Greece, Georgia, Italy, Moldova, Germany, Russia, Romania, Serbia, Slovakia, Slovenia, Turkey, Hungary, Ukraine, France, Croatia, and the Czech Republic. In 1945 Hyphantria cunea Drury was found in Japan, in the parks of Tokyo. In 1979 – in China in Liaoning Province and in Southern Korea it was first described in 1958. In 2003, small foci of caterpillars of Hyphantria cunea Drury were found in Wellington (New Zealand). In Russia, the first foci of mass reproduction of Hyphantria cunea Drury were discovered in the forests of Krasnodar Krai*

in Krasnodar and Abinsk forest enterprises in 1976 on an area of 270 hectares. In Ukraine, the first foci of Hyphantria cunea Drury were found in Transcarpathia in 1952, in June, virtually all over the lowlands of the region. In the Northeastern part of the Forest-Steppe of Ukraine, in Sumy region in particular, Hyphantria cunea Drury was first registered in 2010. In Kharkiv region Hyphantria cunea Drury was discovered at the beginning of 80s of XX century. This article highlights the peculiarities of spreading of Hyphantria cunea Drury and its harmfulness. We have also established the ways of penetration and the current area of pest spreading in Ukraine and in the world. We have carried out the analysis of spreading data of the regulated pest in the territory of Ukraine and in the world, including in the territory of Kharkiv region and the factors, which influence the pest acclimatization have been noted.
Key words: *Fall webworm; Hyphantria cunea Drury; Areal; Distribution area*

Introduction. Losses caused to agriculture by pests, weeds and plants diseases are extremely high. According to the Food and Agriculture Organization (FAO) of the United Nations, the world's losses because of them every year are around 20–25% of the world's potential food crop yield (Yemec, 2014).

During the period from 1920 to 2000 on the territory of the former USSR about 100 alien species of phytophagous insects acclimatized. A significant part of these species refers to a harmful category, and 8 – to dangerous quarantine species. In other regions of the world the number of acclimatized alien insect species is significantly higher (Severin, 1921; Izhevskij, 1990, 2002). Biological invasions of different organisms have caused enormous changes in ecosystems (Kuznecov, 2010). Scientists in their studies note that one of these species is Hyphantria cunea Drury – polyphagous quarantine pest, one of the most common in Ukraine. Numerous researches on the biology and ecology of Hyphantria cunea Drury show that since penetration it has taken an important place not so much in anthropogenic as in natural biocenosis. This is confirmed by a significant number of predators, parasitoids and diseases that limit its number in Ukraine (Sikura, 2000; Movchan, 2002; Trigob'yuk, 2005; Stankevych, 2015; Lezhenina, 2016).

The population of Hyphantria cunea Drury is characterized by high viability due to its polyphagia (Boguleunu, Nica & Petresen, 1976; Greenblatt, Calvert & Barbosa, 1978; Hidaka, 1979; Yemec, 2014).

Mezentseva L.L. (1989) states that Hyphantria cunea Drury damages about 230 plant species, including grapes. But according to other scientists' data (Davidenko, 2008; Zapolovskij, 2013; Chumak 2013; Tokar, 2014; Bondarenko, 2015), the caterpillars of Hyphantria cunea Drury can feed on 636 species of fruit, ornamental, forest and other crops, among which phytophagous damages 200 species in North America, 234 in Europe, and more than 300 plant species in Asia (Hukuhara & Hashimoto, 1966; Hirai, 1977; Jaenike & Selander, 1980; Jarfas, 1986).

At present, in Ukraine the nutrition of Hyphantria cunea Drury is recorded on more than 250 species of fruit and ornamental breeds, and therefore it is characterized as extremely aggressive and dangerous harmful organism which causes great damage to perennial plantations. This pest causes the greatest damage to ash-leaved maple, mulberry tree, apple tree, pear tree, plum, quince-tree, bird-cherry, walnut (Morris & Futtion, 1970; Morris, 1972; Jarfas. & Viola, 1986; Morris, 1987; Timchenko, 1988; Morgun, 2001). One of the main signs that diagnoses Hyphantria cunea Drury in the plantations is the presence of spider's web nests in the trees. Caterpillars of 1-2 ages form nests of several leaves, which are densely enlaced with spider's web. At the end of 5th age of caterpillars the nest can reach the size of 1.0–1.5 m. Coarse leaves eating is typical during the development of caterpillars of older ages. According to scientists' studies damage to trees by Hyphantria cunea Drury leads to defoliation of plantations, namely the violation of metabolic processes in the plants and their weakening. As a result, yield, protective, ornamental and aesthetic function of plantations is reduced; conditions for the fauna existence deteriorate. Individual plants become weaker and with repeated damage can die. Fruit and berry crops decrease the yield or don't bear fruit at all, not only in the year of severe damage but also the next year. Trophic relations play one of the main roles in the development of pests. Depending on the state of population and meteorological conditions of the vegetative period the caterpillars of Hyphantria cunea Drury, like other polyphagous, prefer certain species and cultivars of plants which they feed on. The presence of sufficient forage base determines the duration of development, viability, mass of caterpillars and pupae, as well as the fertility of butterflies ((Nady, Rcichart & Ubrizsy, 1953; Nordin, Rennels & Maddox, 1972; Shestopalov, 2012, Stankevych, 2017).

Methods. The purpose of the article is to analyze the data of literature sources as to geographical spreading of Hyphantria cunea Drury, to indicate the current area of the harmful organism and note the factors, which influence pest acclimatization.

The research data is based on literature sources and analysis of the dynamics of the quarantine organism spreading since its penetration into Europe. Our research was carried out during 2014-2019 in Kharkiv region (neighborhood of the village Mala Rogan, 49°56’19’’N, 36°29’26’’E) according to generally accepted methods during the vegetative period – we recorded the number of trees with caterpillars’ nests, estimated the degree of trees settlement, counted the total area of foci of the infection, and identified the forage plants.

Results and Discussion. According to research data, the motherland of Hyphantria cunea Drury is North America (Ignatyuk, 2013; Nakonechna, 2019). In 1770 this species was described by an entomologist Druri. The primary area of Hyphantria cunea Drury is located on the North American continent from the Pacific to the Atlantic coast, and in the latitudinal direction – from the southern border of coniferous forests of Canada (extending between 54 and 58 north latitude) to the state border of the USA and Mexico. The first indications of the harmfulness of Hyphantria cunea Drury are noted in the USA in 1899 (Howard, 1899). Outbreaks of mass reproduction were noted in 1921 p. (Severin, 1921) and 1969 (Warren, 1970).

On the European continent the first specimens of Hyphantria cunea Drury were found near the city of Budapest (Hungary) on the island of Chepel in August 1940. There is evidence to think that the pest was brought to the island with some cargo. And in 1945 – in Japan, where it quickly began to cause significant damage to fruit crops, mulberry tree, ornamental plants and field protective plantations and was included in the list of quarantine objects (Ito & Miyashita, 1968, Yasyukevich, 2013). According to other data (Hirai,1969), for the first time the pest was found in Japan in 1947 in the parks of Tokyo.

In 1979, the pest was discovered in China in Liaoning Province (State Environmental Protection Administration of Chine, 2001). In Southern Korea Hyphantria cunea Drury was first described in 1958 (Kind, 1991).

By 1948, the pest had spread throughout Hungary and began to occupy the tree plantations of neighboring countries, such as the Czech Republic, Slovakia, Yugoslavia, Romania and Austria. At present, the pest is widespread in Europe, Asia and North America.

In Europe Hyphantria cunea Drury was found in countries such as: Austria, Azerbaijan, Bulgaria, Greece, Georgia, Italy, Moldova, Germany, Russia, Romania, Serbia, Slovakia, Slovenia, Turkey, Hungary, Ukraine, France, Croatia, the Czech Republic (Figure 1, see Movchan, 2002).

In Bulgaria in 1962 one spider's web nests with caterpillars of Hyphantria cunea Drury was discovered for the first time and in 1963 there were 880 of them (Boehrn, 1976). In France Hyphantria cunea Drury was first found in 1977 (Jarfac, 1986). In Absheron Region of Azerbaijan Hyphantria cunea Drury was found in 1991–1992 (Gaziyev, 1999). At the beginning of the XXI century Hyphantria cunea Drury penetrated from the territory of Azerbaijan into Iran and began to spread in the northern provinces of the country (Gninenko, 2005).

Figure 1. Distribution area of *Hyphantria cunea* Drury in Europe

The first signals of damage to tree and shrub vegetation by caterpillars of the pest came from Northern Kyrgyzstan in 2005. During the route surveys, the foci of Hyphantria cunea Drury were found on the territory of Issyk-Altin and Alamedyn districts of Chui region including in 22 inhabited settlements along the by-pass highway and “Bishkek-Torugart” highway and in green plantation of the cities of Kant and Bishkek (Morkovkina, 2006). In 2003, small foci of caterpillars of Hyphantria cunea Drury were found in Wellington (New Zealand) (Kean, 2007).

In Russia, the first foci of mass reproduction of Hyphantria cunea Drury were found in the forests of Krasnodar Krai in Krasnodar and Abinsk forest enterprises in 1976 on an area of 270 hectares. Gradually the foci spread in the forests of Adygea. The total area of foci of Hyphantria cunea Drury in the forests of Kuban in 1982 was 794 hectares. During the next years, the area of foci was reduced and in 1986, the area was 531 hectares. Since 1987, there wasn't any information on foci of mass reproduction of Hyphantria cunea Drury in the forests of Krasnodar Krai and Adygea in reporting data of forest management until 1995, when the foci were found again on an area of 100 hectares (Gninenko, 2005). In Ukraine the first foci of Hyphantria cunea Drury were found in Transcarpathia in 1952, in June, virtually all over the lowlands of the region (Figure 2, see Shumov, 2018).

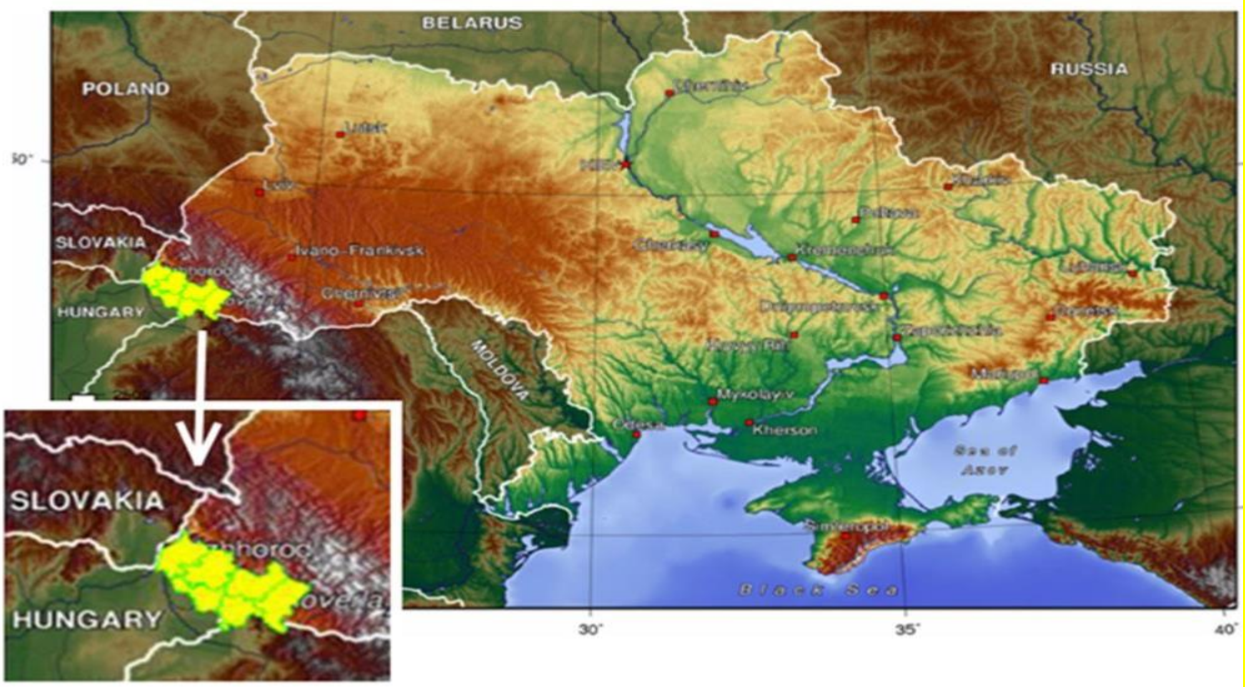

Figure 2. Areas of Transcarpathia Region, where *Hyphantria cunea* Drury was recorded for the first time (1952) (the fragment below is increased) (Shumov, 2018)

Over the next two years, the pest moved northward by 10-15 km and in the valleys of the Latorica, Borzhava and Tisza rivers individual foci were found in the depth of the foothills. The further spreading of Hyphantria cunea Drury, as I.A. Churayev believed (1962), was suspended as a result of extraordinary measures, taken to fight against them. He believed (Churayev, 1958), that through the flight of Hyphantria cunea Drury the penetration of a pest from Transcarpathia is possible into Lviv, Ternopil and IvanoFrankivsk regions. Although I.A. Churayev suggested that the Carpathians are a temporary obstacle on the way of natural settling of Hyphantria cunea Drury from Transcarpathia in the eastern direction.

M.P. Umnov (1955) and K.K. Fasulati (1957) pointed out the importance of the Carpathian massif as an obstacle to the settling of the harmful organism. At the same time, M.P. Umnov (1955) wrote that Hyphantria cunea Drury is exceptionally plastic species to the climatic conditions and that the zone of its possible acclimatization should be considered almost the entire European part of the USSR (except northern regions) and all the republics of Central Asia and Transcaucasia. K.K. Fasulati (1957) considered this thought as incapable, pointing out that the area will be determined not only by temperature and humidity, but by the whole complex of landscape and ecological conditions. Concerning Transcarpathia, in 1957 K.K. Fasulati (1957) wrote that Hyphantria cunea Drury in Transcarpathia occupied everything that it could occupy – all natural biotopes in the plain part. Researchers A.Y. Sikura (1962) and V.Yu. Dulo (1978) believed that in the foothills climatic conditions play only an indirect role in restriction of number of Hyphantria cunea Drury, and the main role belongs to entomophages of the butterfly (Sikura, 2000).

According to V.A. Bykovsky's data (1998) Hyphantria cunea Drury refers to species in which the outbreak of mass reproduction is replaced by many years depression. This is inherent and to some other Lepidoptera. The reasons for this phenomenon have not been determined but probably a number of factors causes them. According to the scientist's observations if the number of Hyphantria cunea Drury rises in one part of area, in another it can reduce. Outbreaks and depressions of number are described for Transcarpathia and Odessa regions.

As of 2013, Hyphantria cunea Drury was found in 20 regions of Ukraine on an area of 50098.627 hectares, which is 1389.8 hectares less compared to 2012. In 2014 the area of pest settling increased by 21.9 as a result of revealing of new and expansion of old pest foci in Zhytomyr, Ivano-Frankivsk and Sumy regions. For the first time, quarantine regime for Hyphantria cunea Drury was introduced in Zhytomyr district of Zhytomyr region on an area of 20 hectares and in Tlumatsky district of Ivano-Frankivsk region on an area of 0.7 hectares. At the same time, because of the absence of cases of pest detection during the observations of many years, quarantine regime was cancelled in 7 districts of Kherson region on the total area of 1411.7 hectares (Bazikina, 2015). In the North-Eastern part of the

Forest-Steppe of Ukraine, in Sumy region in particular, Hyphantria cunea Drury was first registered in 2010 (Yemec, 2014). In Zhytomyr region the pest was first discovered in Ruzhyn district in 2011, quarantine regime in the urbantype settlement of Ruzhyn was introduced on an area of 1.72 hectares (Ignatyuk, 2013). According to the State service of Ukraine on Food Safety and Consumer Protection as of 01.01.2019 Hyphantria cunea Drury was found in 20 regions. The total area of spreading at the end of 2018 decreased by 12959 hectares and makes 36417 hectares.

Combining the maps of Eco regions of Ukraine and the administrative districts where Hyphantria cunea Drury was recorded, since 1952 to the present, a map of pest spreading in the steppe and forest-steppe zones of Ukraine has been obtained, which according to the basic provisions corresponds to biological characteristics of the harmful organism (Shumov, 2018) (Figure 3).

Figure 3. The administrative districts of Ukraine where *Hyphantria cunea* Drury has been discovered since 1952 vs Eco regions of Ukraine (Shumov, 2018)

In Kharkiv region Hyphantria cunea Drury was discovered in the early 80[s] of XXI century (Stankevych, 2016, 2017, 2018; Stankevych, 2017). According to the data of the State service of Ukraine on Food Safety and Consumer Protection in 2017 the pest was registered in 24 districts of Kharkiv region on the total area of 2429.5 hectares. A significant part of the inhabited territory falls on homestead lands – 57.4%, on the territory of farms of all forms of ownership – 19.2% and on other lands – 24.4% (Figure 4).

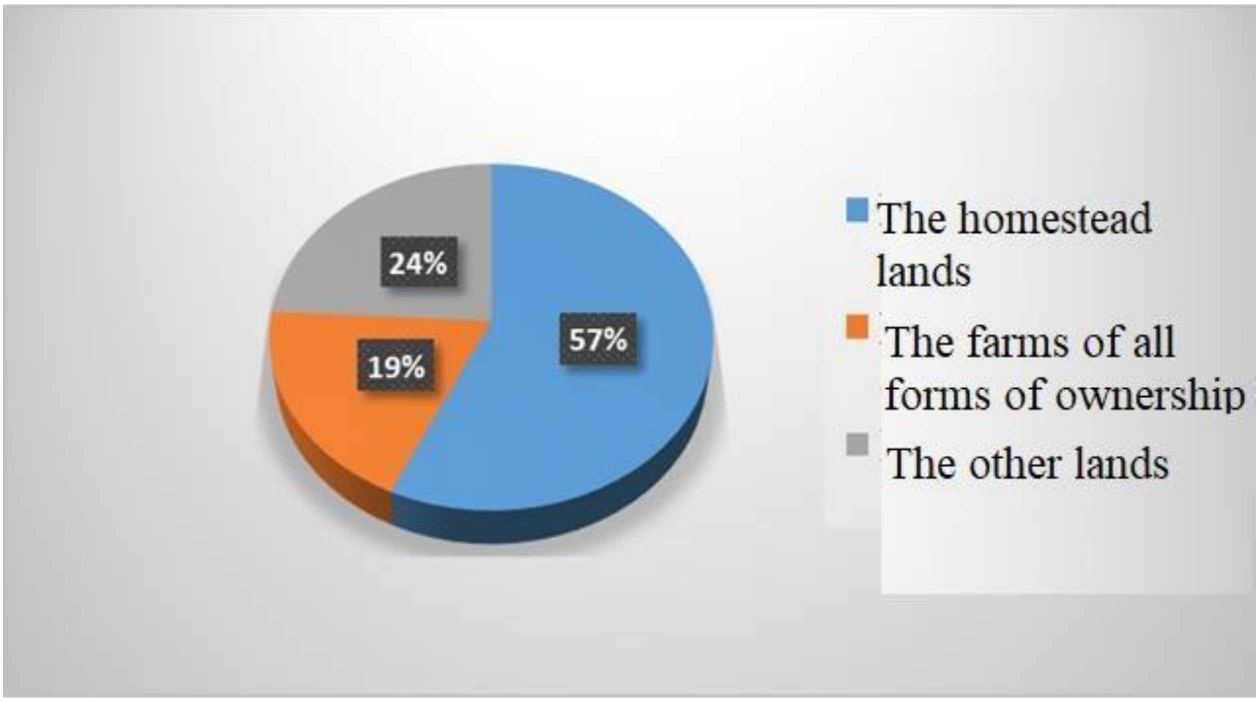

Figure 4. Habitat distribution of *Hyphantria cunea* Drury in Kharkiv region, 2017

The most common pest was in Lozova (810 hectares), Blyzniuky (518.5 hectares) and Barvinkove (249.9 hectares) districts, the least – in Izium district – 0.3 hectares. According to the data of control surveys in 2017, a new focus of Hyphantria cunea Drury was discovered on the territory of Bohodukhiv district with the total area of 18 hectares.

In 2014 we discovered a new focus on the territory of Kharkiv district where our research was being conducted during 2014– 2019 (the neighborhood of the village of Mala Rogan, 49' 56´19´´N, 36´29´26´´E). In the course of conducted research it was determined that in 2014 on the territory of Village Council of Mala Rogan Hyphantria cunea Drury fed only on ash-leaved maple, which grows along the road that connects the village of Mala Rogan and the highway Kharkiv-Rostov. The length of this section of the road is 1.7 km (Figure 5).

In 2014 during the accountings, 11 nests of the pests were counted, in 2015–83 nests and 496 nests in 2016. In 2016, the caterpillars developed not only in ash-leaved maple, but also in wild pear tree and sloe. Besides, in 2016 the first nest was noted on the territory of Rogan Village Council, which borders Village Council of Mala Rogan of Kharkiv district.

In the spring of 2017 ashleaved maple along the road that connects the village of Mala Rogan and the highway Kharkiv-Rostov, was cut down by almost 50%. However, in the course of accountings it turned out that it did not have a negative impact on the number of the pest.

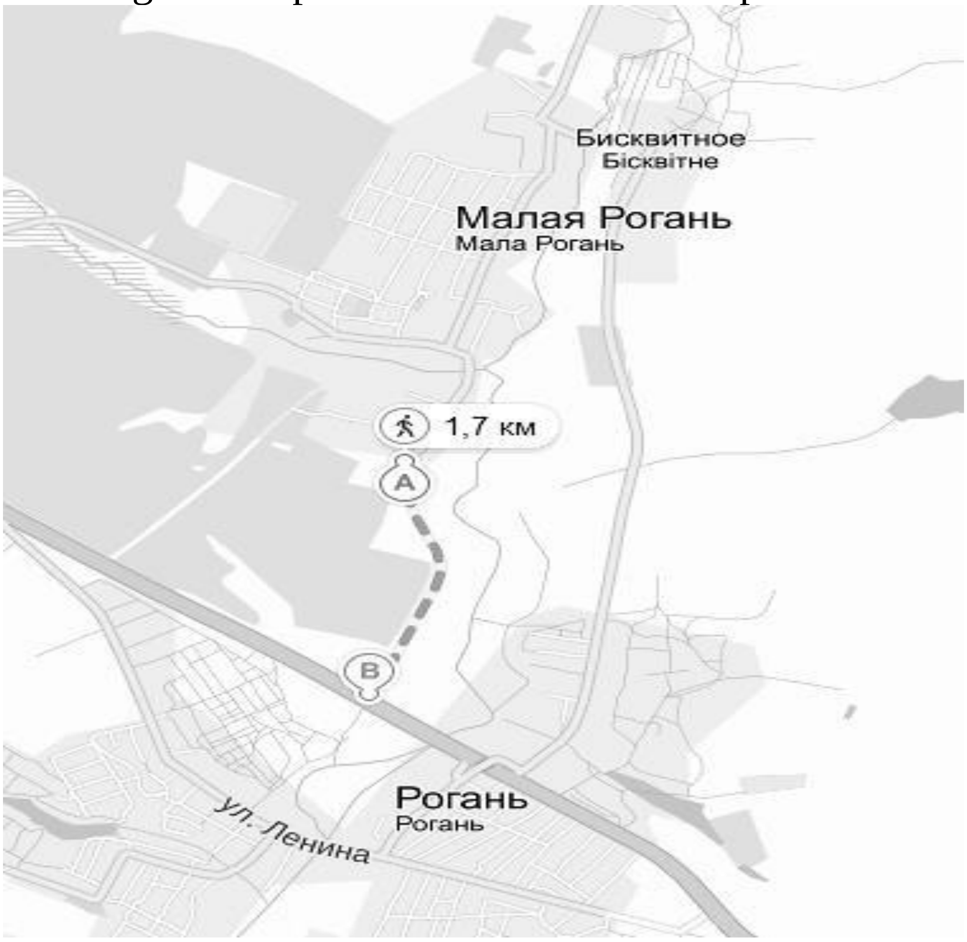

Figure 5. The concentration of *Hyphantria cunea* Drury in the territory of Village Council (Mala Rogan, 2014-20198)

Hyphantria cunea Drury began settling in maple trees that grow in an abandoned garden of chokeberry that, borders the highway. At the same time, not a single nest was noted in chokeberry. In total 681 of spider's web nests of the pest were counted in the course of accountings in 2017. It is also interesting that not a single nest was found on annual shoots of ash-leaved maple that grow on the place of cutting. All nests were concentered on shoots at the age of two years and older. In 2018, the focus continued to grow. During the route surveys 762 spider's web were discovered. In 2018, the pest along with the forage plant (ash-leaved maple) spread into adjacent to the road garden of chokeberry, which is almost completely littered with the plants of ash-leaved maple. The nutrition of caterpillars of Hyphantria cunea Drury was not revealed on chokeberry itself. In addition, the first spider's webs were noted in ash-leaved maple on Lermontov Street (Mala Rogan) at a distance of 1500 km from the main location, which allows expecting for further growth of the pest number and the expansion of its focus. As we can see, over the five years, the number of pest's nests has increased almost 70 times.

Our research shows that Hyphantria cunea Drury has a high reproduction coefficient, but it remains economically insignificant pest in Kharkiv district, because it is focused only in ash-leaved maple. Nevertheless, as the experience of other countries in which this species has spread testifies it should be systematically monitored and, if necessary, localize the focus and apply extermination measures.

Conclusion. The penetration of the pest into new territories happens with the help of airflows, as well as inobservance of quarantine and phytosanitary measures. The average speed of spreading of Hyphantria cunea Drury on the territory of Ukraine is 30-40 km per year. Thus, despite the quarantine and extermination measures, which to some degree inhibit the activity of Hyphantria cunea Drury spreading, its expansion into new suitable for existence territories is continuing. The world's area of Hyphantria cunea Drury has not stabilized up to now and continues to broaden, mainly due to meridional settling. The data of our research shows that of Hyphantria cunea Drury has a high reproduction coefficient, but it remains economically insignificant pest in Kharkiv district, because it is focused only on ash-leaved maple. However, as the experience of other countries in which this species has spread testifies it should be systematically monitored and, if necessary, localize the focus and apply extermination measures.

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QUARANTINE SPECIES OF LIST A1 NEMATODES IN UKRAINE

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In the article, the authors analyzed and systematized the results of research obtained during the processing of domestic and foreign information sources regarding the prevalence, harmfulness, and bioecological features of nematode species absent in Ukraine, which the State Production and Consumer Service includes in the A1 list. There are three such species in Ukraine: Globodera pallida (Stone) Behrens, Meloidogyne chitwoodi Golden, O'Bannon, Santo & Finley and Meloidogyne fallax Karssen. The main host plant of the G. pallida is the potato. Tomatoes, eggplants, other species and hybrids of the nightshade family (Solanaceae) are also affected. The nematode causes especially great damage in temperate climates. There are no specific signs of plant disease with globoderosis. Diseased plants with a strong degree of potato nematode infection can be easily distinguished from healthy ones by the color of the leaves (premature yellowing), growth retardation, "beardiness" of the root system, densely covered with cysts, depressed state of the plants as a whole. In an infected plant, the level of photosynthesis decreases and, as a result, its biomass decreases. The marketability of newly formed tubers decreases (ratio of marketable and small fraction), their quality deteriorates – the content of dry matter, starch, protein, vitamin C decreases. As of 2022, the Globodera pallida (Stone) Behrens is widespread in many countries of Europe, Asia, Africa, North, Central and South America and New Zealand. M. chitwoodi can affect a wide range of cultivated plants and weeds. Potatoes and tomatoes are the best feeders, while barley, corn, oats, sugar *beets, wheat, and other members of the cereal family can only support the population. As a result of damage to plants by M. chitwoodi, the yield of crops decreases, their market value is lost. The latter, in particular, is due to browning, necrotization of the tissues of potato tubers, the formation of ugly calluses and ulcers on their surface. The species was first described in the USA in 1980. On the European continent, the species was first described in the Netherlands in the 80s of the last century. As of 2022, M. chitwoodi is common in many European countries, in Mozambique, South Africa, the United States, Mexico, Argentina, and Chile. The only true host plant of the M. fallax is the potato (Solanum tuberosum), but the possibility of feeding on other plants has also been experimentally proven. The external signs of defeat by M. fallax of potatoes and carrots are similar to those caused by M. chitwoodi (halo formation, necrotization of internal tissues immediately under the skin. Currently, there is no information on economic losses from M. fallax. Since in natural conditions there are mixed centers of M. fallax and M. chitwoodi, it is possible to predict the same economic losses from the first and second species.As of 2022, M. fallax is common in many European countries, in South Africa, Chile, Australia and New Zealand.*

Key words: *nematodes, plant quarantine, A1 list, prevalence, harmfulness, phytosanitary risk.*

Formulation of the problem. The problem of the invasion of numerous harmful organisms from abroad into new territories attracts the attention of society and every year becomes more and more urgent due to the development of processes of globalization, climate change, pollution and degradation of ecosystems. The main channels of their distribution are also rapidly developing – international trade and tourism. In particular, in the period from 1979 to 2004, the volume of import-export of agricultural products on a global scale increased from 224.1 to 604.3 million dollars. США, and the annual flow of air passengers only in EU countries during the same period increased from 200 to 600 million people.

Having penetrated into new territories, foreign species of organisms can acclimatize, occupy new ecological niches and successfully compete with local species, sometimes causing serious irreversible processes in the environment at the genetic, species and ecosystem levels. It has been proven that during each subsequent decade, at least 3–5 alien (adventive) pathogens of plant diseases and 5–10 plant pests are introduced (penetration of a harmful organism, accompanied by its acclimatization). As a result, damage caused by alien species is registered not only in the agricultural sector and forestry, but also in the economy as a whole (as a result of the introduction of restrictions on the movement of goods and cargo, the spread of allergic diseases in the population, a decrease in the level of biodiversity, etc.). According to recent estimates, these losses are estimated at almost 9 billion euros annually for the EU countries alone, a quarter of which is caused by terrestrial invasive plants. In particular, in the early 2000s, the annual medical costs associated with the spread of ragweed in Germany tripled and amounted to 50 million euros.

There are various ways of spreading quarantine organisms, they are divided into two main groups – active and passive. The active migration of insects contributes to their settlement at considerable distances from the primary site: today it has been proven that the seas and high mountains are not an obstacle for the active migration of insects, especially Lepidoptera or Lepidoptera (in some cases they are detected even thousands of kilometers from the primary habitat). The passive spread of harmful organisms is associated with biotic factors (transfer with a vector organism, on animal fur or bird feathers), abiotic factors (air and water currents) and human activity (economic activity, movement of goods, transport, etc.).

Quarantine species of nematodes deserve special attention, because due to their small size and hidden way of life, it is very difficult to prevent their spread and penetration into new territories. In this article, the authors considered three species of nematodes absent in Ukraine, which the State Production and Consumer Service includes in the A1 list: *Globodera pallida* (Stone) Behrens, *Meloidogyne chitwoodi* Golden, O'Bannon, Santo& Finley and *Meloidogyne fallax* Karssen.

Materials and research methods. Domestic and foreign information sources were analyzed, as well as the current databases of the EPPO regarding the prevalence, harmfulness, and bioecological features of nematode species absent in Ukraine, which the State Production and Consumer Service includes in the A1 list [1–12].

Results and discussion.

Globodera pallida (Stone) Behrens (KKB - HETDPA). Synonyms: *Heterodera pallida* Stone, *H. rostochiensis* Wollenweber in partim. belongs to the type Roundworms – Nematoda, order Tylenchida – Tylenchida, family Heteroderidae – Heteroderidae

The main host plant of *G. pallida* is the potato. Tomatoes, eggplants, other species and hybrids of the nightshade family (Solanaceae) are also affected. The nematode causes especially great damage in temperate climates: in fields with reduced specialized crop rotation, where potatoes are grown unchanged and returned to the previous place in the second or third year, the average yield losses from globoderosis (a disease caused by parasitism of *G. pallida*) are 30 %, but with a high number of nematodes in the soil, the complete death of plants is possible. It is believed that due to the presence of 20 eggs in 1 g of soil, 2 tons of potatoes are lost from 1 ha. In addition to the mentioned direct losses, there are also indirect losses due to the prohibition or restriction of the transportation of plant products from the affected areas.

Populations of pale Globodera are heterogeneous and consist of pathotypes (Ra1, Ra2, Ra3), which differ in their virulence (ability to affect certain genotypes of the main host - potatoes). Identification of pathotypes is carried out according to the international scheme, according to which selective hybrids of wild potato species are used as differentiating plants.

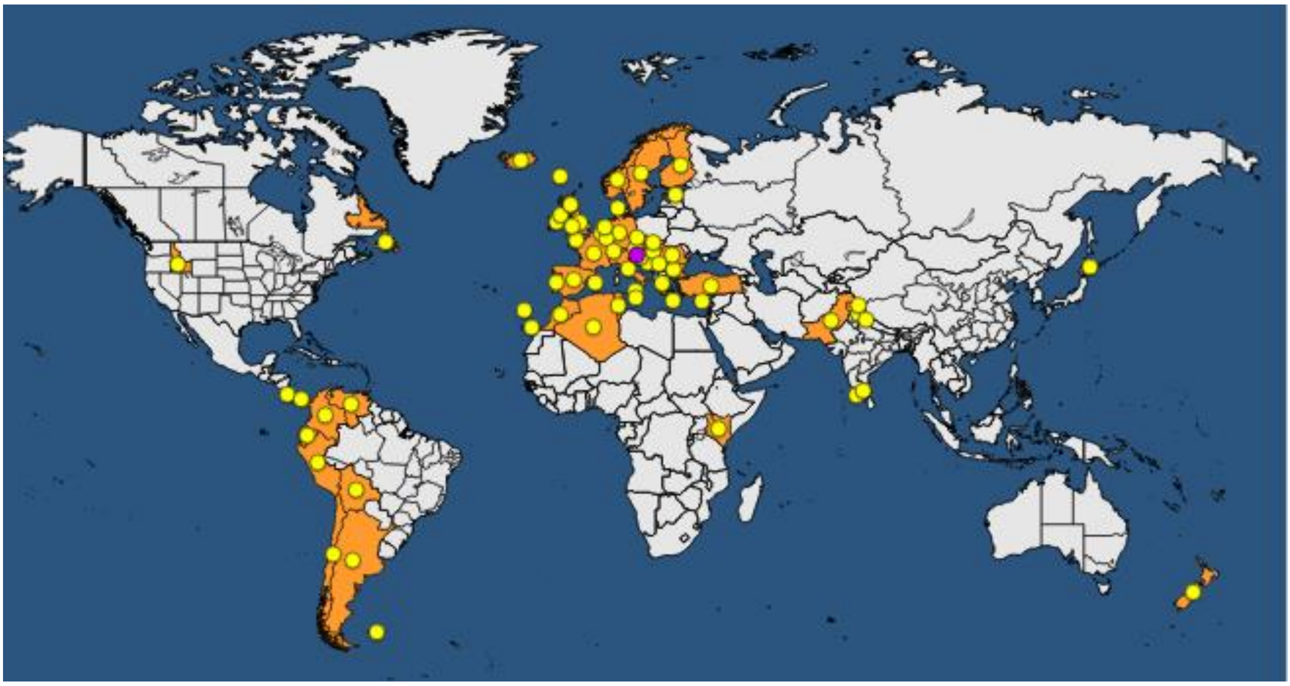

Fig. 1. World range of *Globodera pallida* (Stone) Behrens

As of 2022, G. pallida is common in many European countries: Austria, Belgium, Bulgaria, Bosnia and Herzegovina, Great Britain, Greece (Crete), Denmark, Estonia, Ireland, Iceland, Spain (Balearic Islands, Canary Islands), Italy (the island of Sicily), Cyprus, Luxembourg, Malta, the Netherlands, Germany, Norway, Portugal (the island of Madeira), Romania, Serbia, Slovakia, Slovenia, Turkey, Hungary, the Faroe Islands, Finland, France, Croatia, the Czech Republic , Switzerland, Sweden; Asia: India, Pakistan, Japan; Africa: Algeria, Kenya, Morocco, Tunisia; North America: Canada (island of Newfoundland), USA (state of Idaho); Central America and the Caribbean: Costa Rica and Panama; South America: Argentina, Bolivia, Venezuela, Ecuador, Colombia, Peru, Falkland Islands, Chile; Australia and Oceania: New Zealand (Fig. 1).

Eggs and larvae hibernate under the protective cover of the cyst, the number of which can vary widely. The first larval stage ends with molting in the egg. In the spring, under favorable weather conditions and under the influence of the stimulating action of the root secretions of the host plant, second-instar larvae emerge from the cyst and penetrate the roots, where they molt twice more and turn into adults. At the same time, the females swell up, break through the epidermis, and their rear end appears outside the root; at the front end, they remain attached to the root. Worm-like males migrate into the soil, fertilize the females and die. After fertilization, the females swell even more under the pressure of the eggs that are formed inside. At the end of the growing season, the female dies, her shell darkens (without going through the golden phase) and she turns into a cyst filled with eggs. Cysts fall from the roots and remain in the soil. Eggs in cysts remain viable for many years. Usually, G. pallida has one generation per growing season, sometimes under favorable conditions – two.

The potato nematode has a pronounced sexual dimorphism.

The female is motionless, almost round (sometimes pear-shaped) in shape with a more or less elongated head end (neck), the length of which is slightly longer in the pale globedera than in the golden one. The vulva (circumfenestral type - without a vulvar bridge) and anus are located at the back end of the female body, together they form the perineal region, the structure of which is an important cinematic feature. The most typical features of *G. pallida* are a rounded shape, a larger (compared to *G. rostochiensis*) size of the fenestra in a mature female, the number of folds of the cuticle between the anus and the fenestra is usually less than 14, the Granek index is less than 3. An additional criterion in determining the species of potato globodera is color females in the period of their transformation into cysts (chromogenesis) – the absence of a "golden" phase indicates that the studied population belongs to the species *G. pallida*, and if it is present, to the species *G. rostochiensis*.

The invasive second-instar larva is mobile, distinguished by a rectangular outline of the mouth disc and lips (vs. oval in *G. rostochiensis*). Its stylet is larger in size than that of golden globedera, with basal tubercles pointed anteriorly. In the caudal part of the larva's body, the lateral lines are crossed by the lumbar ridges of the cuticle (they do not cross in the case of golden globedera).

The male is colorless, mobile, worm-shaped, 900–1200 µm long, 31–46 µm wide. Spicules and shanks are located near the short and oval tail (Fig. 2).

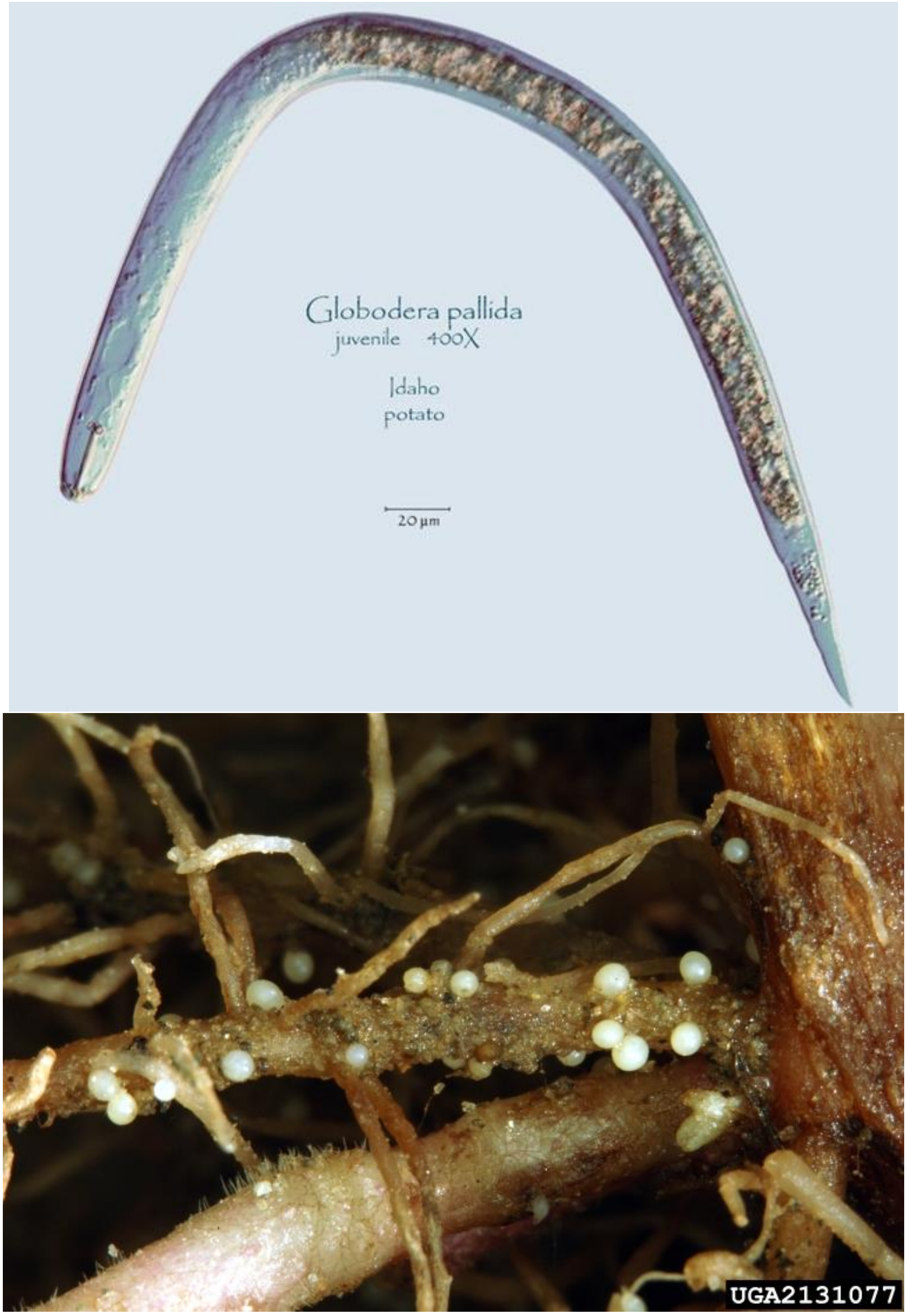

Fig. 2. *Globodera pallida* (Stone) Behrens

Taking into account the morphological and morphometric kinship of the species of potato cyst-forming nematodes, various biochemical methods are also used for their identification (EOKZR standard – PM 7/40 (1) *G. rostochiensis* and *G. pallida*).

Table 1

Main morphological characteristics of *G. pallida* and *G. rostochiensis*

Stage of developme nt of the	Sign	*G. pallida*	*G. rostochiensis*
Cyst	length, µm	579 ± 70	445 ± 50
	width, µm	534 ± 50	382 ± 61
	diameter of the fenestra, µm	24,5 ± 5,0	18,8 ± 2,2
	anus-fenestra distance, µm	49,9 ± 13,4	66,5 ± 10,3
	Granek's index	2,1 ± 0,9	3,6 ± 0,8
	the number of cuticle folds on the axis of the anus-fenestra	12,5 ± 3,1	216 ± 3,5
	color during ripening	white or creamy	golden
Larvae of the 2nd instar	length, µm	486 ± 23	469 ± 20
	stylet, micron	23,8 ± 1,0	21,8 ± 1,7
	basal tubercles	загострені	заокруглені
Males	stylet, micron	27,5 ± 1,0	25,8 ± 0,9
	length of spicules, µm	10,3 ± 1,5	35,5 ± 2,8
	shank length, µm	11,3 ± 1,6	36,3 ± 4,1

There are no specific signs of plant disease with globoderosis. Diseased plants with a strong degree of potato nematode infection can be easily distinguished from healthy ones by the color of the leaves (premature yellowing), growth retardation, "beardiness" of the root system, densely covered with cysts, depressed state of the plants as a whole (Fig. 3). In an infected plant, the level of photosynthesis decreases and, as a result, its biomass decreases. The marketability of newly formed tubers decreases (ratio of marketable and small fraction), their quality deteriorates - the content of dry matter, starch, protein, and vitamin C decreases.

Potato globe borers are not able to move over significant distances on their own, so the main way of spreading nematodes is with potato tubers, affected soil attached to the tubers, root crops, bulbs, rooted planting material, decorative and other plants, as well as containers, equipment, on people's feet and animals Cysts can be carried by rainwater, wind, and birds.

It is prohibited to import affected planting material and soil from the infection zones of countries where the disease is widespread.

Quarantine inspection of potato plantings (route inspections) should be carried out during the period of mass flowering of plants: they note the centers of suppression, plant fall, inspect the root system of chlorotic bushes, determine the degree of the disease on a 9-point scale. Soil samples are taken for further nematological analysis (you can take them at any time of the year when the soil is not frozen).

Fig. 3. Potato plants affected by globoderosis (above) and cysts of G. pallida on potato tubers

Quarantine regime is introduced in detected centers: mandatory destruction of crops and plantings by a radical method with immediate burning of excavated plants and disinfection of equipment. Export of products of plant origin from this zone is carried out in compliance with the established requirements. It is prohibited to export planting material from farms that are under quarantine.

An effective anti-nematode measure is the observance of agricultural techniques – the use in crop rotation of crops that are not affected by potato nematodes (legumes, cereals, technical crops, perennial grasses, and others), the application of fertilizers, the destruction of weeds, and the cultivation of nematode-resistant potato varieties. There should be spatial isolation of seed plantings from production and home plots (1 km).

Meloidogyne chitwoodi Golden, O'Bannon, Santo & Finley (KKB – MELGCH) belongs to the type Roundworms – Nematoda, order Tylenchida – Tylenchida, family Heteroderidae – Heteroderidae

M. chitwoodi can affect a wide range of cultivated plants and weeds. Potatoes and tomatoes are the best feeders, while barley, corn, oats, sugar beets, wheat, and other members of the grass family (Roaceae) (grasses and weeds) can only support the population. Plants of the cabbage (Brassicaceoe), pumpkin (Cucurbitaceae), leguminous (Fabaceae), licorice (Lamiaceae), lily (Liliaceae), umbrella (Umbelliferae) and grape (Vitaceae) families are inhabited to the smallest degree by nematodes of this species. Capsicum pepper and tobacco (Nicotiana tabacum) are not affected at all.

Certain differences have been established in the parasitization of different physiological races of the pathogen: in particular, carrots are colonized only by the first race of the species, while alfalfa is colonized by the second. In the Netherlands, the most vulnerable are carrots, cereals, corn, field peas, potatoes, sugar beets, tomatoes, common beans, and Spanish chickpeas.

As a result of damage to plants by *M. chitwoodi*, the yield of crops decreases, their market value is lost. The latter, in particular, is due to browning, necrotization of the tissues of potato tubers, the formation of ugly calluses and ulcers on their surface. If only 5 % of potato tubers have necrotic spots caused by meloidogenosis, then the entire harvested crop loses commerciality. It was established that in the absence of protective measures, the annual loss of potatoes in the North-Eastern states of the USA could amount to 40 million dollars. USA. There are no similar economic calculations for European countries, but there are known cases of a significant decrease in grain yields (wheat, barley, oats, corn). Recently, isolated foci of the disease in potatoes and some vegetables were first registered in the Netherlands – on sandy soils, in areas with warm summer months.

The species was first described in the USA in 1980. Its name is associated with the Columbia River, which is located between the states of Oregon and Washington. On the European continent, the species was first described in the Netherlands in the 1980s, but a review of archival drawings and specimens of Meloidogyne collections suggests that the introduction could have taken place much earlier – in the 1930s. It is likely that *M. chitwoodi* has a wider distribution on the European continent than was believed until recently. Taking into account the tolerance of the species to low soil temperatures and the fact that the pathogen can cause the greatest damage to potato plantings, it is possible to predict the geographical distribution of *M. chitwoodi* in the same regions where potato cyst-forming nematodes are also widespread.

As of 2022, *M. chitwoodi* is common in many European countries: England, Belgium, Spain, the Netherlands, Germany, Portugal, Turkey, France, Sweden, and Switzerland; Africa: Mozambique and South Africa; North America: USA; Central America: Mexico; South America: Argentina, Chile (Fig. 4).

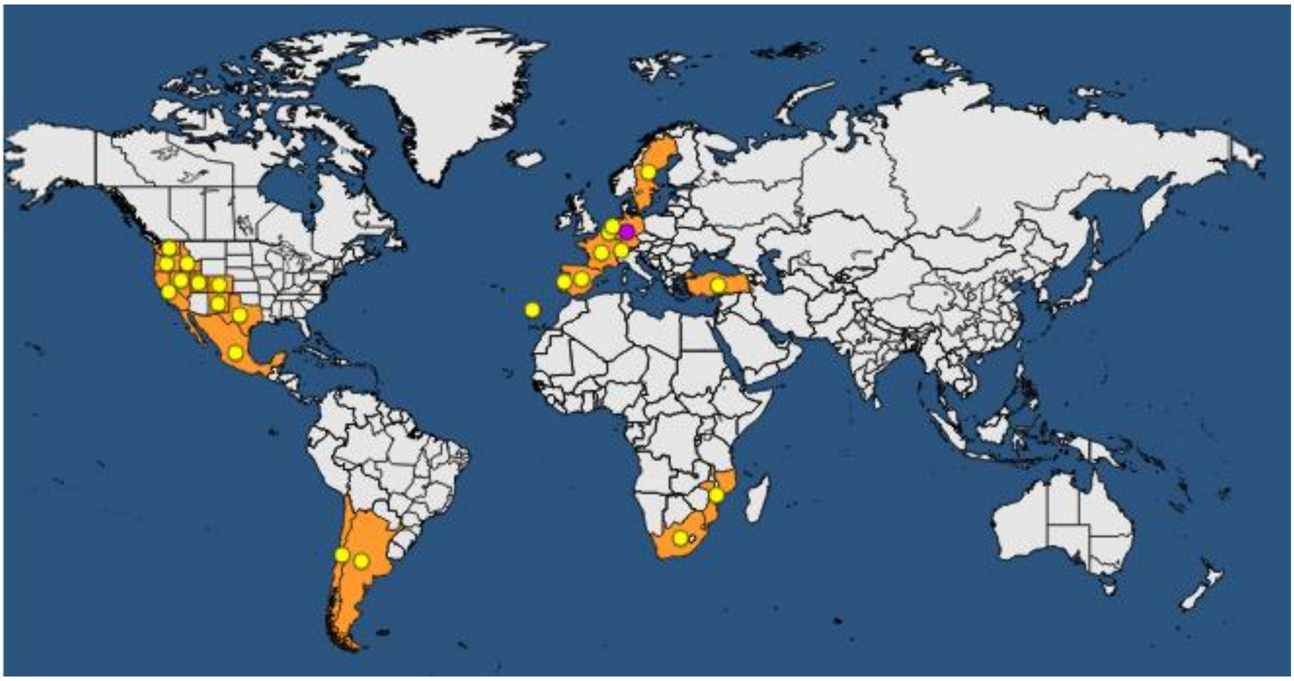

Fig. 4. World range *Meloidogyne chitwoodi* Golden, O'Bannon, Santo& Finley

M. chitwoodi overwinters in the stage of eggs or larvae, which are able to tolerate long periods of frost. In the spring, when the soil temperature is above 5 °C, invasive larvae of the second age are born from the eggs (the development of another species of M. hapla begins only when the soil temperature is above 10 °C. The larvae search for a young root and with the help of a stylet dig into it near the point of growth, and then they migrate towards the cortex (on the contrary, tubers are settled mainly through the eye). It is here that giant food cells are formed under the influence of nematode waste products, and later galls are formed. As a result of intensive nutrition, the larvae increase in size and acquire a pear-shaped shape. At this stage their feeding ceases, and they rapidly undergo three more molting stages, becoming mature females and males.The adult males leave the root, emerge into the soil, and seek out females for fertilization (however, as with other species of the genus Meloidogyne, the development of the Colombian roundworm may be parthenogenetic.) Females lay eggs in a jelly-like sac near the surface of the root. If this process takes place in potato tubers, the plant cells crust around the egg masses, turn brown and form a protective "basket". As a result of this process, characteristic brown pustules or galls similar to warts appear on the surface of the tubers, and necrotic spots appear on the skin and pulp.

In the case of favorable conditions for growth and development, the life cycle of *M. chitwoodi* lasts about 3–4 weeks. Based on the results of the phytosanitary risk analysis conducted for European countries, it is possible to predict the development of 2 generations of *M. chitwoodi* per year in the south of Finland, 3 generations in Great Britain and even 4 generations in the south of Europe.

Several races of *M. chitwoodi* are known, which differ in host plants. Yes, the first race is able to parasitize carrots, the second – only on alfalfa. A third race was first described in California, another race discovered in the Netherlands is now known as an independent species – *M. fallax*.

The high morphological affinity of round nematodes greatly complicates the diagnosis of the species.

The female is motionless, pear-shaped (length 430–740 nm and width 344–518 nm), pearl-white in color.

The male has a filamentous body 887–1268 nm long and 22–37 nm wide, the tail is short (4.7–9.0 nm), rounded.

The invasive second instar larva is 336–417 nm long and 12.5–15.5 nm wide. Its body tapers slightly at both ends, has a short tail (39–47 nm) with a blunt rounded tip, and a well-defined hyaline part of the tail. The species *M. chitwoodi* and *M. hapla* are very similar externally, they can be distinguished by the structure of the perineal plate of mature females and specific structures in the middle bulb of *M. chitwoodi* (Fig. 5).

Damage symptoms vary depending on the host plant species, nematode population density, and environmental conditions (Fig. 6).

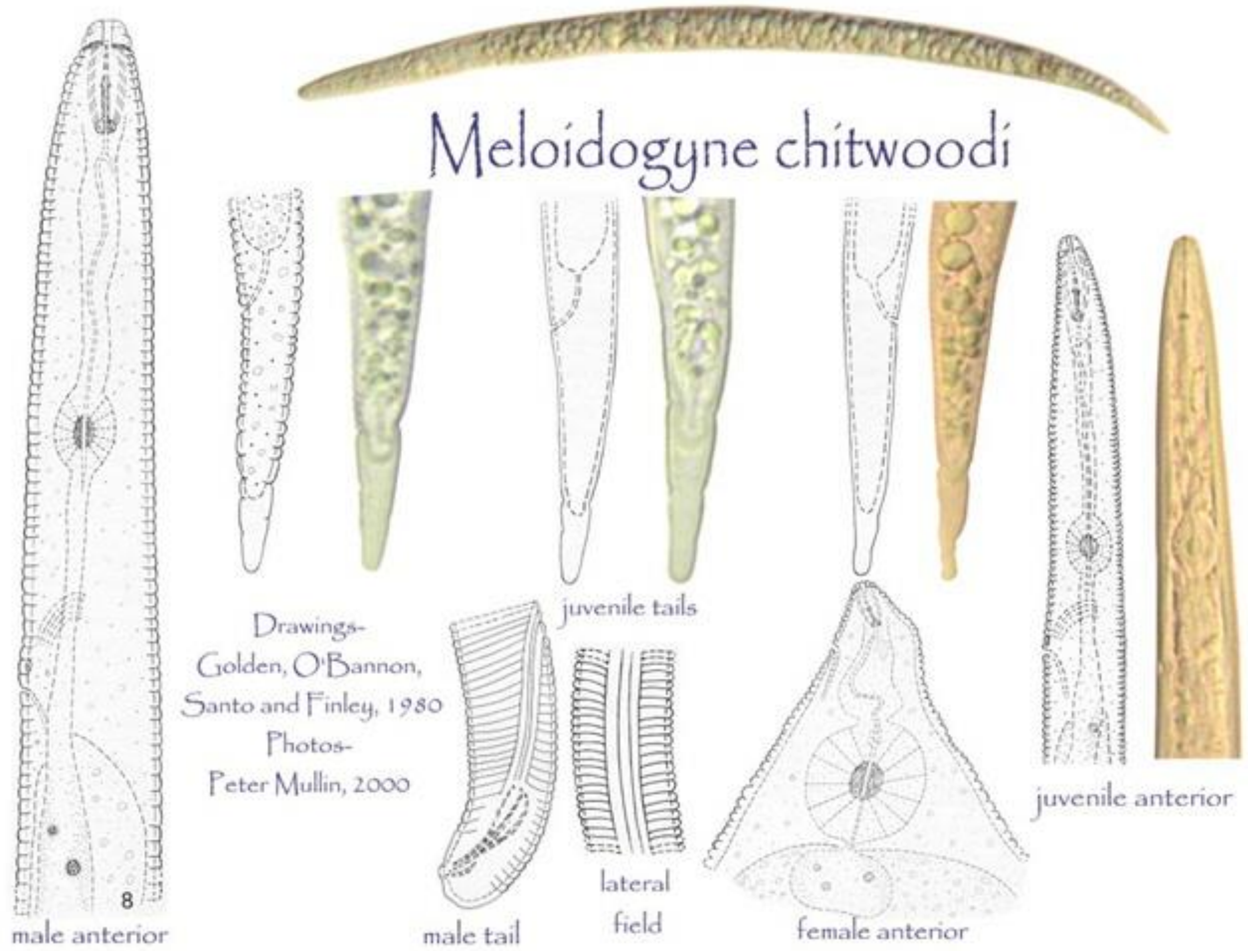

Fig. 5. Morphology *Meloidogyne chitwoodi*
Golden, O'Bannon, Santo& Finley

The symptoms of plant damage are not always obvious, the most typical are suppression of the condition of plants as a whole, weakening of turgor and premature drying in conditions of moisture deficiency, which ultimately leads to a decrease in plant yield. Galls that form on the surface of potato tubers as a result of *M. chitwoodi* colonizing them are significantly different from those that arise from parasitism of other species of the genus Meloidogyne. *M. hapla*, for example, induces the formation of small detached galls from which lateral roots are formed, while *M. incognita* (Kofoit et White) Chitwood forms large, easily visible galls. In the case of *M. chitwoodi* colonization of potato tubers, galls are not always visible, in some cases they are invisible even with a strong degree of plant damage. If galls are formed, they are more like small swellings above the site of nematode development, which are mostly concentrated in one part of the tuber. Single galls may form near eyes or necrotic areas. Sometimes the external symptoms are similar to signs of tuber damage by powdery scab. If a tuber with weak symptoms of internal damage is put into storage, then over time, due to the

Fig. 6. Symptoms of damage to the underground organs of plants by *Meloidogyne chitwoodi* Golden, O'Bannon, Santo& Finley

progression of the disease process, these symptoms become more pronounced not only from the middle, but also from the outside of the tuber. The inner tissue of the tuber, below the formed gall, is usually necrotic and has a brown tint. Against such a background, adult female nematodes are easily distinguished by the shiny white color of their plum-like body.

The roots of plants can also be inhabited by nematodes, but in this case it is not possible to detect the disease without a magnifying glass, because even with a high degree of damage, galls are mostly not formed. The spherical bodies of females can break through small roots, and they can then be seen under a binocular magnifying glass. Over time, females form an egg sac that gradually darkens. The formation of galls is also observed on many cereals: on wheat and oats they are more noticeable than on barley or corn. The same is true for tomatoes: galls are visible on some varieties, and completely absent on others.

Only the invasive larvae of *M. chitwoodi* are able to actively move in the soil, but for small distances (several tens of centimeters), so the main source of infection is infected planting material (including tubers, bulbs), as well as agricultural equipment and soil. Distribution of nematodes can also occur with sewage, birds, etc.

Specific quarantine measures against *M. chitwoodi* of the EPPO have not yet been developed, those measures directed against potato cyst-forming nematodes can be taken as a basis (prohibition of importation of affected rooted planting material and soil from countries where the nematode is distributed, certification of seed potatoes, etc.

<u>Meloidogyne fallax Karssen (KKB – MELGFA) belongs to the type Roundworms – Nematoda, order Tylenchida – Tylenchida, family Heteroderidae – Heteroderidae.</u>

The only true host plant of *M. fallax* is the potato (*Solanum tuberosum*). However, experimentally, in greenhouse conditions, the ability of the species to parasitize carrots (*Daucus carota*), Spanish goat's cheese (*Scorzonera hispanica*) and tomatoes (*Lycopersicon esculentum*) was proven. Since in most cases the range of host plants of *M. fallax* and *M. chitwoodi* coincides, the following types of plants can be used as differentiating plants: for *M. chitwoodi* it is common bean (*Phaseolus vulgaris*), valerian medicinal (*Valeriana officinalis*), corn (*Zea mays*), gray Erica (*Erica cinerea*) and bush foxglove (*Potentilla fruticosa*); while for *M. fallax* it is *Oenothera erythrosepala*, *Phacelia tanacetifolia*, *Daylilies* (Hemerocallis) and *Dicentra spectabilis*.

The external signs of damage by *M. fallax* of potato tubers and carrots are similar to those caused by *M. chitwoodi* (halo formation, necrotization of internal tissues immediately under the skin. At the moment, there is no information on economic losses from *M. fallax*. Since in natural conditions there are mixed centers of *M. fallax* and *M. chitwoodi*, it is possible to predict the same economic losses from the first and second species.

As of 2022, *M. fallax* is common in many European countries: England, Belgium, the Netherlands, Germany, France, Sweden, and Switzerland; Africa: South Africa; South America: Chile; Australia and Oceania: Australia and New Zealand (Fig. 7).

M. fallax overwinters in the egg or larva stage. Under favorable conditions, invasive larvae of the second age are born from the eggs, which search for a young root and, with the help of a stylet, plunge into it near the point of growth, and then migrate towards the cortex, where, under the influence of nematode waste products, giant food cells are formed, and later galls are formed.

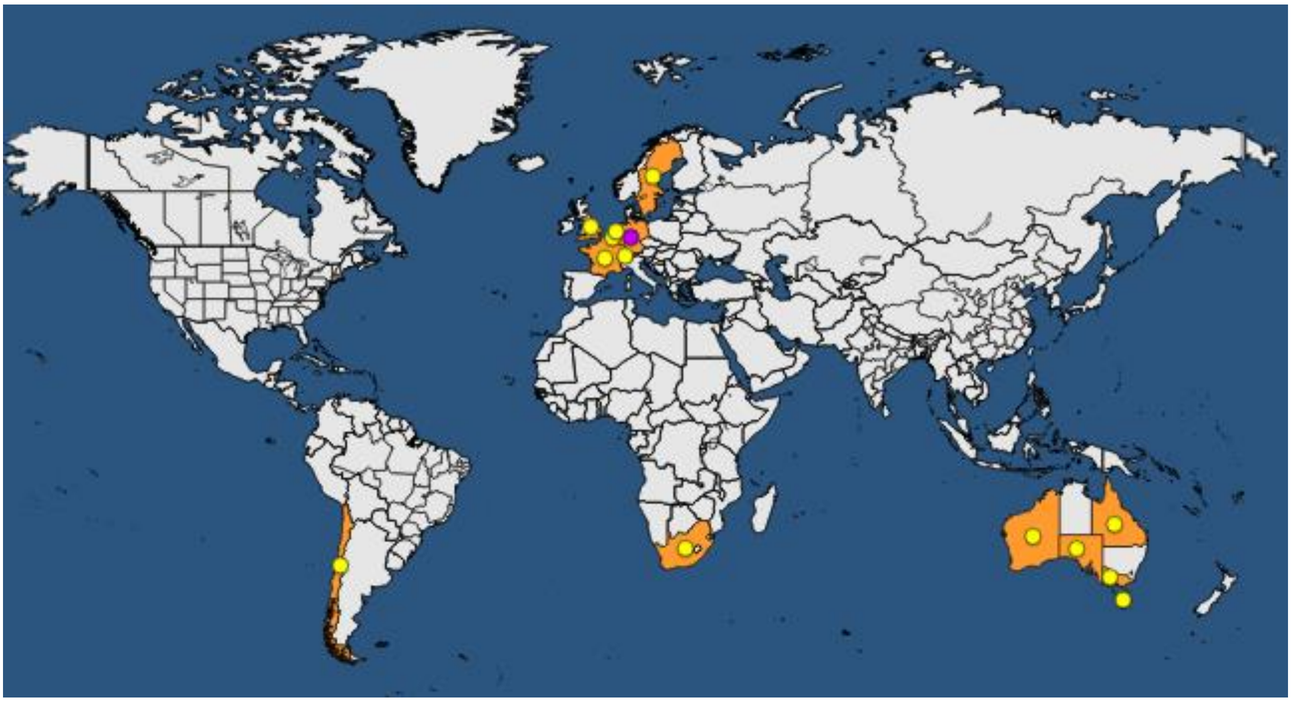

Fig. 7. World range *Meloidogyne fallax* Karssen

As a result of intensive feeding, the larvae increase in size and acquire a pear-shaped shape. At this stage, their feeding stops and they quickly go through three more stages of molting, turning into mature females and males. Adult males leave the root, go into the soil and look for females for fertilization (parthenogenetic development is also possible). Females lay eggs in a jelly-like sac near the surface of the root. So, the life cycle of *M. fallax* is generally similar to that of *M. chitwoodi*, this primarily concerns the mechanisms of plant settlement, halo formation, disease symptoms, the number of molts, and parthenogenesis. At the same time, there are still no results of comparative studies on mechanisms of regeneration, survival strategies, and the number of degree days required to complete the life cycles of these species. Based on preliminary results, it was established that the life cycle of *M. fallax* when parasitizing potatoes is shorter than that of *M. chitwoodi*. It was shown that when both species were crossed, the first generation was viable, while the second was not, partly due to morphological changes in the structure of the invasive larvae.

Identification by morphological features is complicated by the relatedness of the species *M. fallax* and *M. chitwoodi* (EPPO standard 7/41).

The female *M. fallax* leads a sedentary lifestyle, has a rounded or pear-shaped pearl-white body, 400–720 µm long and 250–460 µm wide. Stylet slightly curved dorsally, 13.9–15.2 µm long, with rounded or ovate basal tubercles that are slightly bevelled posteriorly. Females of *M. fallax* and *M. chitwoodi* have certain differences in the structure of the perineal plate, in particular, the first species is characterized by a higher dorsal arch and thickened cuticular folds (Fig. 9).

The migrating male has a slender body covered with cuticular rings, 735–1520 µm long and 27–44 µm wide, the anterior end of the body is slightly blunt, while the posterior end is slightly rounded. The labial disk is raised, the stylet is 18.9–20.9 µm long with large rounded basal tubercles (it should be noted that the stylets of females and males of *M. fallax* are longer, and their basal tubercles are more convex and rounded than those of *M. chitwoodi* (Fig. 8, 10).

The invasive second-instar larva is worm-shaped, covered with cuticular rings, 380–435 µm long and 13.3–16.4 µm wide. The body of the larva is somewhat blunted at both ends, the tail is 46–56 µm long, the hyaline part of which is 12.2–15.8 µm (the indicated parameters in *M. fallax* exceed similar parameters in *M. chitwoodi*). The hemisonid of invasive larvae is at the same level as the excretory pore, while in *M. chitwoodi* it is located in front of the latter (Figs. 8, 11).

Differentiation of species is possible with the use of a bioteg. A higher diagnostic accuracy is achieved by molecular methods (EPPO standard RM 7/41 *M. chitwoodi* and *M. fallax*).

In the experimental plots, plants affected by *M. fallax* (potatoes, carrots) had the same symptoms of the disease as in the case of their infection with *M. chitwoodi*, namely the formation of galls and tissue necrosis immediately under the skin (Fig. 8).

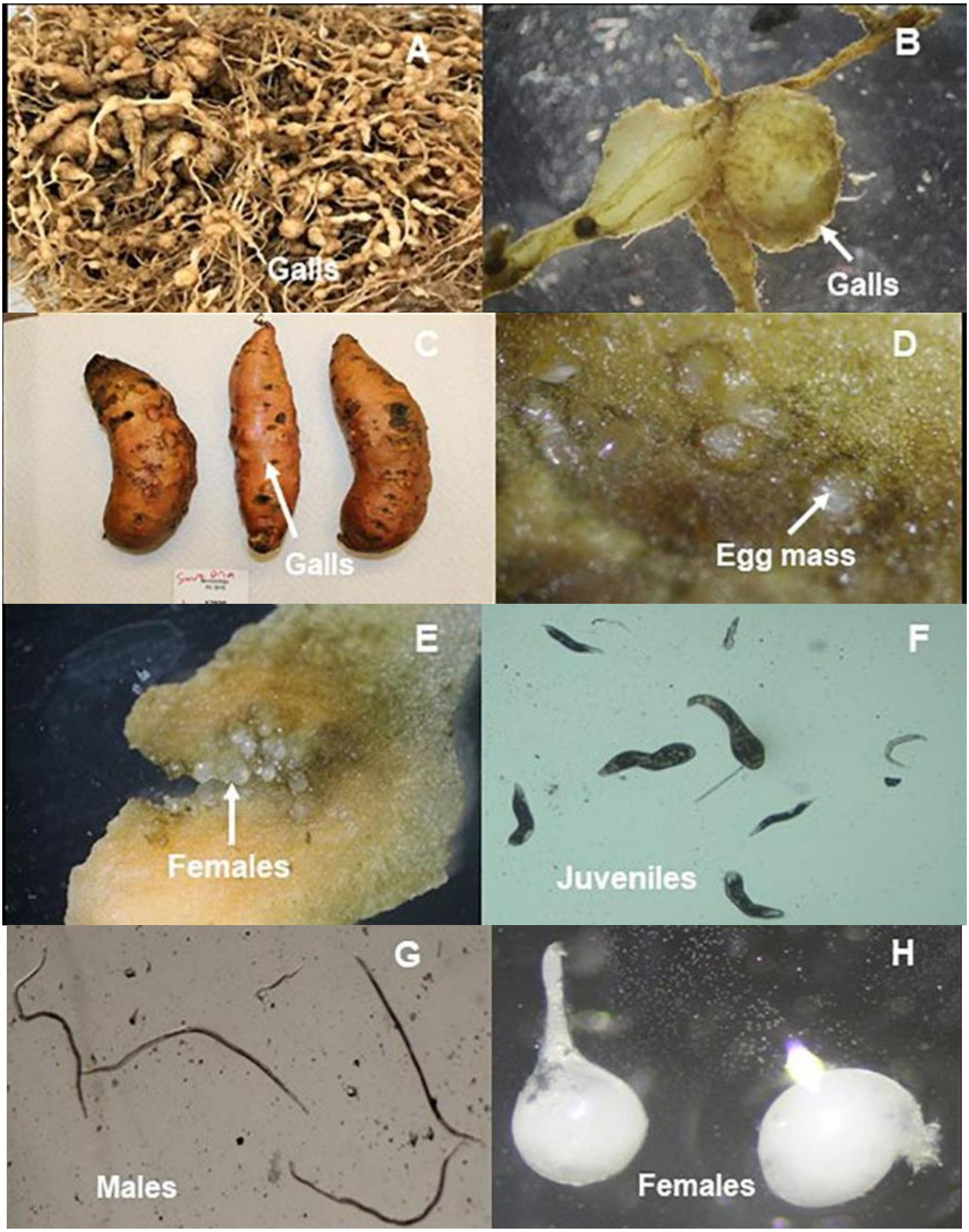

Fig. 8. Morphological features and symptoms of plant damage by *Meloidogyne fallax* Karssen:

A) large galls and massive swellings on the roots of tomatoes; C) galls on soybeans; C) galls on sweet potatoes; D) egg mass on sweet potatoes; E) adult females on sweet potatoes; F) invasive larvae of the second stage (J2) on soybeans; G) males on soy; H) females on sweet potatoes

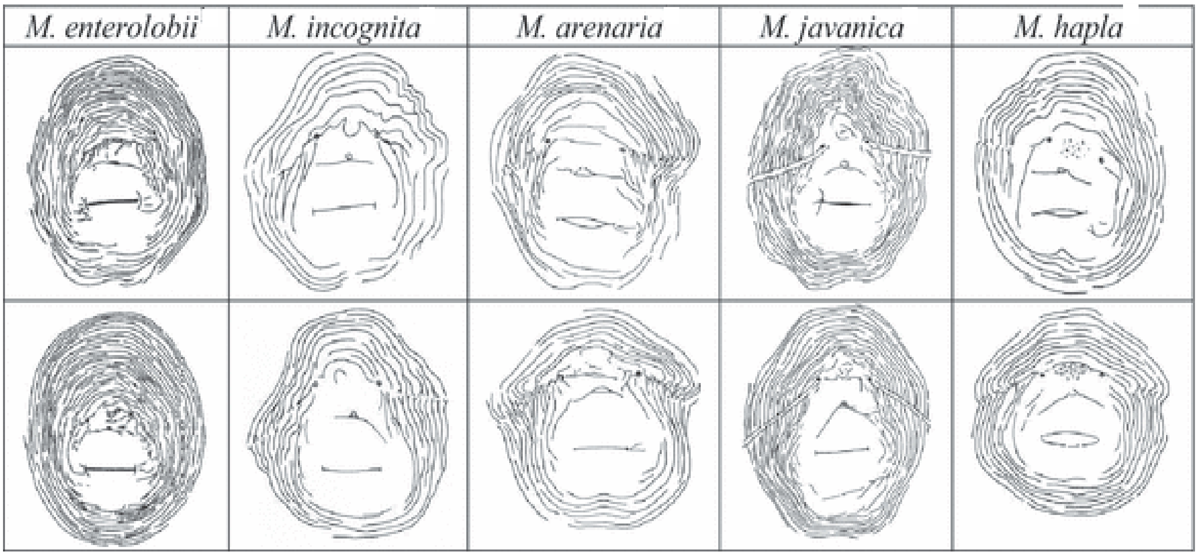

Fig. 9. Drawings of intermediate patterns of nematodes from the genus *Meloidogyne* (different drawings illustrate variability)

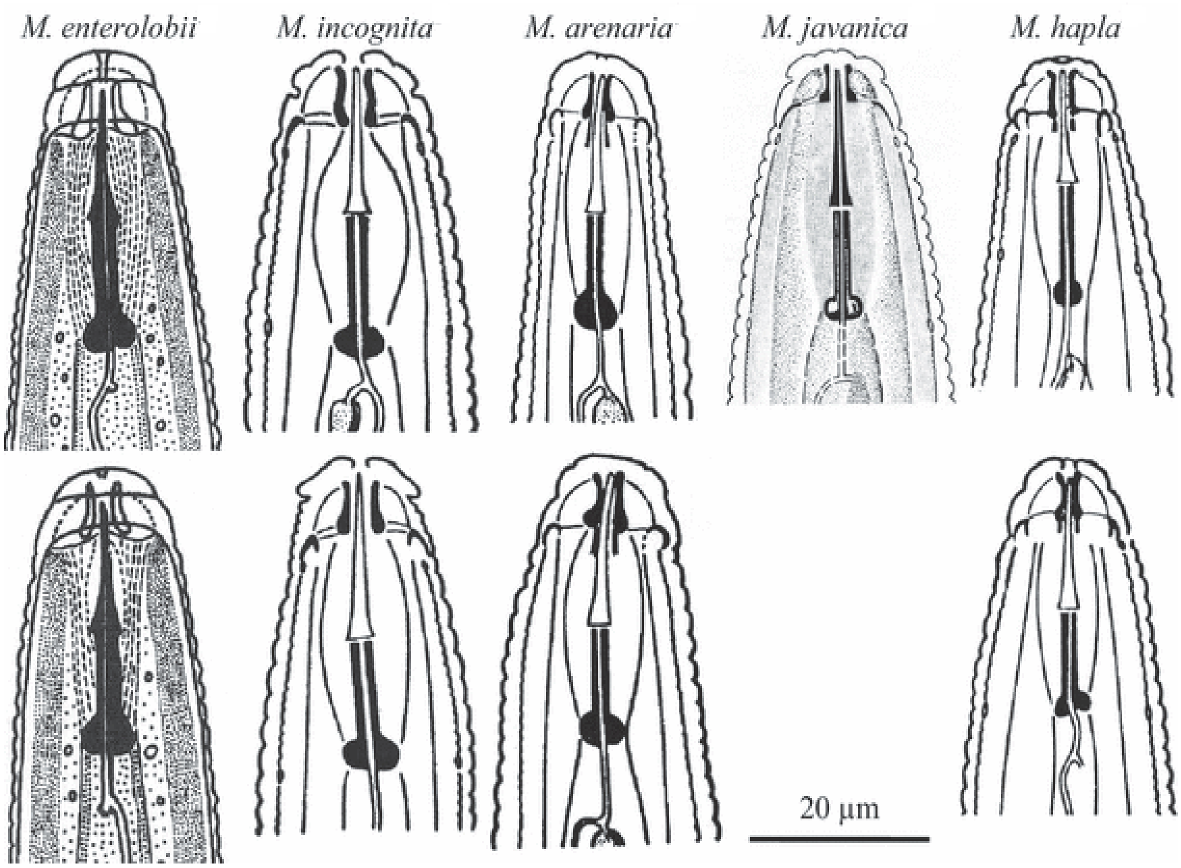

Fig. 10. Drawings of labial regions of male nematodes from the genus *Meloidogyne* (different drawings illustrate variability)

They are the same as for *M. chitwoodi* – the main source of infection is infected planting material (including tubers, bulbs), as well as agricultural equipment and soil. The spread of nematodes can also occur with sewage, birds, etc.

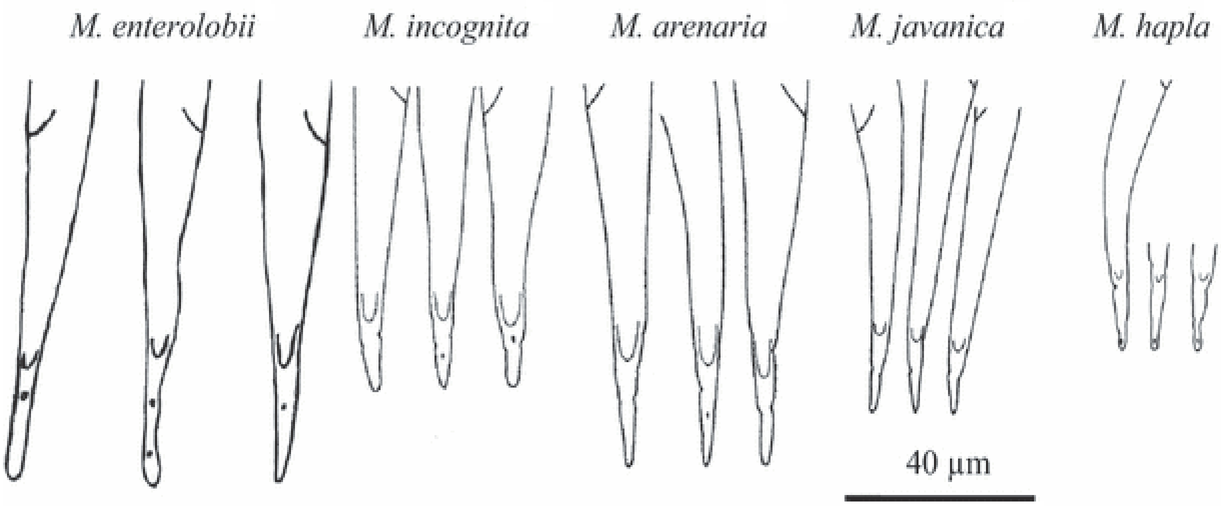

Fig. 11. Drawings of the tail of second-instar larvae of nematodes from the genus *Meloidogyne* (different drawings illustrate variability)

Table 2

Morphological and morphometric variations of nematodes from the genus *Meloidogyne*, µm

	M. enterolobii	***M. incognita***	***M. arenaria***	***M. javanica***	***M. hapla***
♀ stylet	13,2–18,0 (15,1)	13–16 (14)	14,4–15,8 (15,5)	14–18 (15)	10–13 (11)
♂ stylet	21,2–25,5 (23,4)	23,0–32,7 (25,0)	20,7–23,4 (21,6)	20,0–23,0 (21,2)	17,3–22,7 (20,0)
J2 body	405,0–472,9 (436,6)	337–403 (371)	450–490	387–459 (417)	312–355 (337)
J2 tail	41,5–63,4 (56,4)	38–55 (46)	52,2–59,9 (55,8)	36–56 (49)	33–48 (43)
J2 hyaline part of the tail	5–15	6,3–13,5 (8,9)	10,8–19,8 (14,8)	9–18 (13,7)	11,7–18,9 (15,7)

Since the species was described recently, a clear system of plant protection against this species of nematodes has not yet been developed. Initial exploratory studies have shown that the introduction of black steam can reduce the population density of *M. fallax* in the soil by 95%, but it has not been proven that growing the plants in the following season will allow obtaining a quality harvest that will meet the standards. For sugar beets and carrots, the effectiveness of such an anti-nematode measure as late spring sowing has been proven.

It is not recommended to grow catch crops on nematode-infected soils, as they can serve as host plants for *M. fallax* and in this case will contribute to the accumulation of infectious agents in the soil. Anti-nematode crop rotations are recommended to include weakly affected crops, such as corn and cereals. Screening (diagnostics) of resistance made it possible to establish that Phaseolus vulgaris is the only culture resistant to M. fallax, some potato genotypes – *S. bulbocastanum, S. hougasii, S. cardiophyllum, S. fendleri* and *S. brachistotrichum* – were also highly resistant to the pathogen.

Conclusions

1. According to the results of the analysis of domestic and foreign professional information sources, it was established that there are three types of nematodes from list A1 in Ukraine as quarantine species: *Globodera pallida* (Stone) Behrens, *Meloidogyne chitwoodi* Golden, O'Bannon, Santo& Finley and *Meloidogyne fallax* Karssen.

2. The main host plant of *G. pallida* is potato. Tomatoes, eggplants, other species and hybrids of the nightshade family (Solanaceae) are also affected. The nematode causes especially great damage in temperate climates. There are no specific signs of plant disease with globoderosis. Diseased plants with a strong degree of potato nematode infection can be easily distinguished from healthy ones by the color of the leaves (premature yellowing), growth retardation, "beardiness" of the root system, densely covered with cysts, depressed state of the plants as a whole. In an infected plant, the level of photosynthesis decreases and, as a result, its biomass decreases. The marketability of newly formed tubers decreases (ratio of marketable and small fraction), their quality deteriorates – th content of dry matter, starch, protein, vitamin C decreases. As of 2022, *G. pallida* is widespread in many countries of Europe, Asia, Africa, North, Central and South America and New Zealand.

3. *M. chitwoodi* is able to affect a wide range of cultivated plants and weeds. Potatoes and tomatoes are the best feeders, while barley, corn, oats, sugar beets, wheat, and other members of the cereal family can only support the population. As a result of damage to plants by *M. chitwoodi*, the yield of

crops decreases, their market value is lost. The latter, in particular, is due to browning, necrotization of the tissues of potato tubers, the formation of ugly calluses and ulcers on their surface. The species was first described in the USA in 1980. On the European continent, the species was first described in the Netherlands in the 80s of the last century. As of 2022, *M. chitwoodi* is common in many European countries, in Mozambique, South Africa, the United States, Mexico, Argentina, and Chile.

4. The only true host plant of *M. fallax* is the potato (*Solanum tuberosum*), but the possibility of feeding on other plants has been experimentally proven. The external signs of defeat by *M. fallax* of potatoes and carrots are similar to those caused by *M. chitwoodi* (halo formation, necrotization of internal tissues immediately under the skin. Currently, there is no information on economic losses from *M. fallax*. Since in natural conditions there are mixed centers of *M. fallax* and *M. chitwoodi*, it is possible to predict the same economic losses from the first and second species.As of 2022, *M. fallax* is common in many European countries, in South Africa, Chile, Australia and New Zealand.

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SECTION 3. MONITORING AND PROTECTION OF BIODIVERSITY OF AGROCENOSES, URBOCENOSES AND FOREST PLANTATIONS

THE PHYTOSANITARY STATUS OF MAIN AGROCENOSES IN WESTERN REGION OF UKRAINE

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The main crops in western region of Ukraine are cereal, technical, oil crops and corn. The structure of species of causal organisms of diseases and structure of pests' species on winter wheat, soybean, oilseed rape in 2016–2022 in western regions of Ukraine (Lviv, Volyn, Ternopil, Khmelnytsk and Ivano-Frankivsk) were detected. Sowing plots of corn and sunflower were observed in 2020–2022 in Lviv region. The most common diseases of main crops are mycosis, and the biggest parts in structure of pests have insects.

Key words: *sown area, gross harvests, diseases, pests, winter wheat, soybean, oilseed rape, corn, sunflower.*

Ukraine is the largest country in Europe with total area 603 549 square km. The relief of Ukraine is represented by plains (about 95 % of total area) and mountains — Carpathians and Crimean. The climate is mostly temperate, exception of southern coast of Crimea with subtropical climate. The average year temperature is from +5…+7 ºC on north to +11…+13 ºC — on south of country. The average summer temperature is +17…+23 ºC and winter temperature is –8…+2 ºC. The amount of rainfall decreases from north and northwest to south and southeast of Ukraine. The highest amount of year rainfall is in Ukrainian Carpathian (about 1500 mm), the least amount — on Black Sea coast (about 300 mm). The average of year rainfall in Ukraine is about 400–650 mm. In winter precipitation falls in the form of snow or rain. The height of snow may reach 10–30 sm (Geographical location of Ukraine).

The landscapes of Ukraine are represented by three zones: Forest zone, Forest-Steppe zone and Steppe zone. There are big areas of fertile black soil in Ukraine. Their square is about third part of the world reserves. They have about 44% of Ukraine territory or about 17 million hectares. In comparison their area is only 6% in the world. The content of humus in fertile black soil is range from 3 to 9%. Except fertile black soil (so-called chernozems) in Ukraine occur gray forest soils (so-called alfisols), turf-podzolic soils, kastanozems and their varieties.

The combination of fertile soils and favorable climate facilitate to the growth of agriculture of Ukraine.

Ukraine has significant potential of land resources. Now land fund is 60,3 million hectares. Agricultural land in Ukraine is about 19 % of total Europe land and arable land is about 27%.

Total area of agriculture land is 42,7 million hectares or 70 % of all Ukraine territory. Arable land area is 32,5 million hectares or 78,4 % of all agricultural land.

Above 92% of Ukrainian territory is involved to economic use. The amount of arable land is extremely high and is above 54% while in developed Europe countries its low than 35% (Ukraine-2016; State Service of Ukraine for geodesy, cartography and cadaster).

Land users in Ukraine are agricultural enterprises and households. Agricultural enterprises are represented by agroholdings and private farms. Land fund of agroholdings is 5,7 million hectares or 28% (data are valid before 2022). The highest number of agroholdings (20 and more) is in central and north regions of Ukraine. But the largest land area that is controlled by agroholdings (300 and more thousand ha) concentrate in central and west regions.

We analyze statistical data in 1990–2021 by State Statistic Service of Ukraine (Plant Growing in Ukraine, 2021; State Statistic Service of Ukraine). In structure of sown area in Ukraine in 2021 the main crops were cereals (wheat, corn and barley), oil crops (sunflower, oilseed rape), technical crops (soybean, sugar beet), potato and vegetables (fig. 1). Cereal, oilseed rape, soybean, corn, and sunflower are the main crops that sowing in agroholdings. The producing of vegetables, fruit, potato, and sugar beet is concentrated in big and small private farms. The households are producing the agricultural products mainly for themselves.

Analyzing of dynamic of main crops production in Ukraine during 1990–2021 we detected increasing of sown areas under the main crops except sugar beet. Sown area significantly increased under soybean (more than 20 times) and under oilseed rape — more than 10 times (fig. 2). Decreasing of sown areas under sugar beet can be explained by difficult agrotechnologies. Now sugar beet production concentrated in specialized agrarian enterprises that have special agrotechnics and lays near sugar factory and have agreement with it. Despite of this situation gross harvest of sugar beet leaves on the same level.

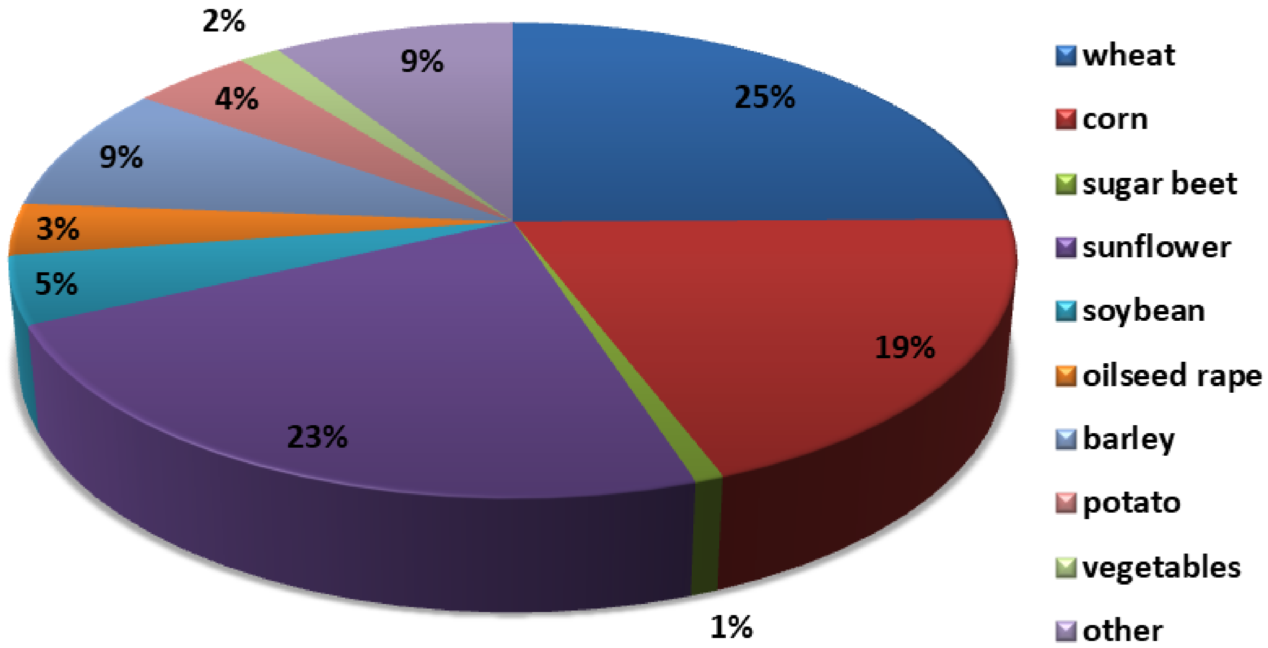

Fig. 1. Structure of sown area in Ukraine, 2021 (data by State Statistic Service of Ukraine)

In comparison 1990–2000 now we have new innovation agrotechnologies that allow obtaining the higher yields of these crops. Thus, in Ukraine in 2021, the average yield of wheat was 45,3 c/ha, corn — 76,8 c/ha, sugar beet — 479,1 c/ha, soybean — 26,4 c/ha, sunflower — 24,6 c/ha and oilseed rape — 29,3 c/ha. But agroholdings obtained significantly higher yields of these crops. For example yield of wheat reached 90 c/ha and more at average indexes — 60–80 c/ha and oilseed rape — above 40 c/ha.

Since 2000 till now we are observed increasing of gross harvests of majority crops, except buckwheat and sugar beet (fig. 3). So, the highest gross harvest was obtained from wheat, corn and potato — above 21–42 mln t. Level of gross harvests increasing of the main crops is range from 1,1 to 54 times. The highest rates were for sunflower (almost 5 times), corn (11 times), oilseed rape (22 times) and soybean (almost 55 times).

Our research was monitoring of phytosanitary status of main crops in western region of Ukraine in 2016–2022 (Kosylovych & Korol, 2016; Lykhochvor & Kosylovych, et al., 2017; Kosylovych & Holiachuk, 2017, 2019, 2020; Holiachuk & Kosylovych, 2019, 2020; Stankevych, Zabrodina, et al., 2021). Research included route observes of plots of winter wheat, soybean, oilseed rape in three locations in each region: Lviv, Volyn, Ternopil, Khmelnytsk and Ivano-Frankivsk. In laboratory were detected species of causal organisms of diseases and species of pests. In Lviv region we also observed sowing plots of corn and sunflower in 2020–2022.

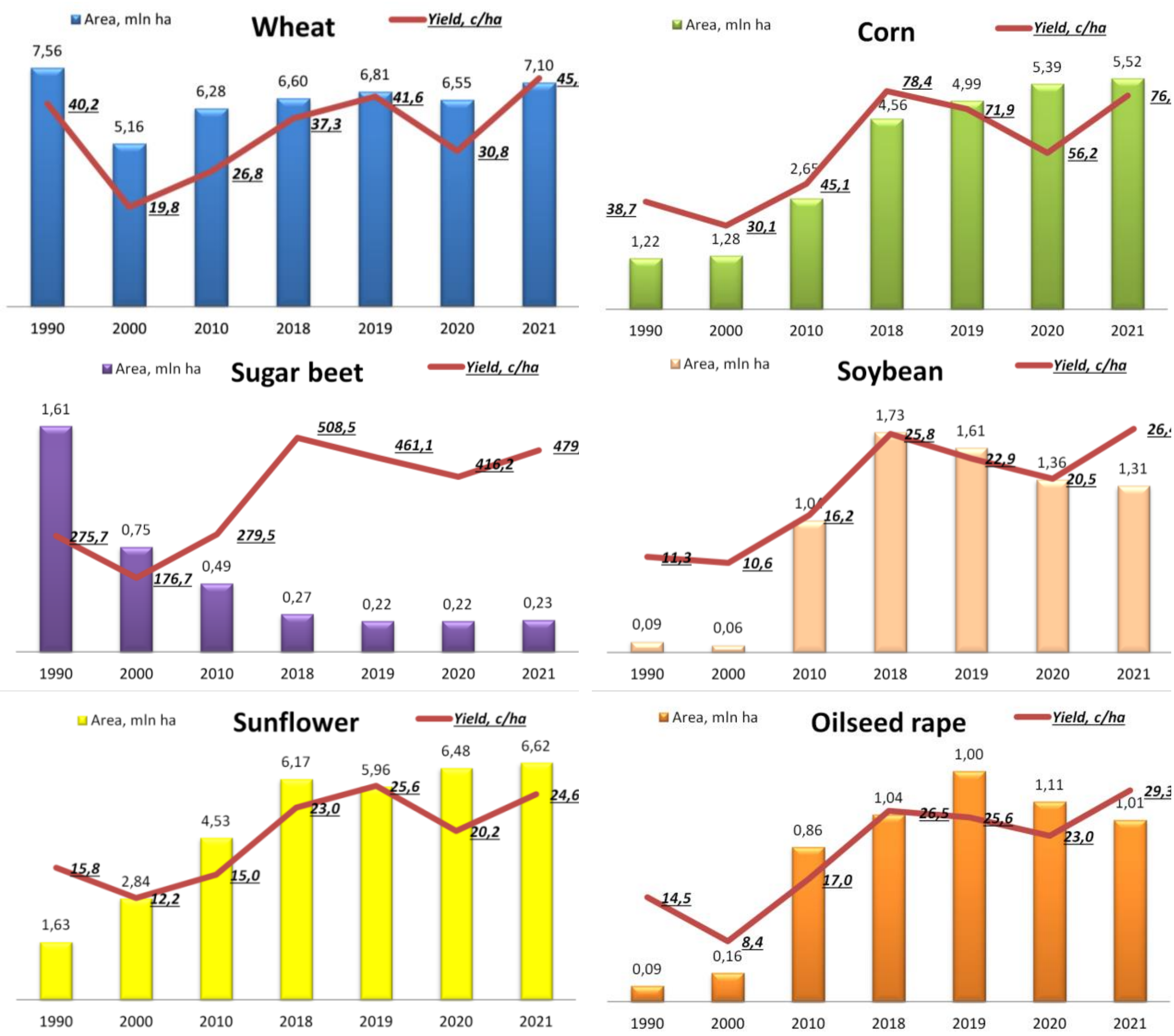

Fig. 2. Dynamics of main crops in Ukraine
(data by State Statistic Service of Ukraine)

During last 7 years on wheat plants we detected such fungal diseases as powdery mildew (*Blumeria graminis* (DC.) Speer), *Septoria* leaf and head blotch, brown and yellow rusts, *Pyrenophora* leaf spot, complex of *Helminthosporium* leaf spots, *Fusarium* ear blight and complex of root and stem rots and others (fig. 4).

He biggest parts in winter wheat diseases' structure in 2016–2022 have powdery mildew (20%) and *Septoria* leaf and head blotch (21%). Traditionally rusts have significant part, especially brown leaf rust

(*Puccinia recondita* f. sp. *tritici* Rob. ex Desm) — 14%. But during last 7 years among them we observed the increasing of yellow stem rust (*Puccinia graminis* Pers.) development. Besides increasing of tan spot (*Pyrenophora tritici-repentis* (Ptr)) ratio was detected among leaf spots, and *Fusarium* head blight among ear diseases (fig. 5).

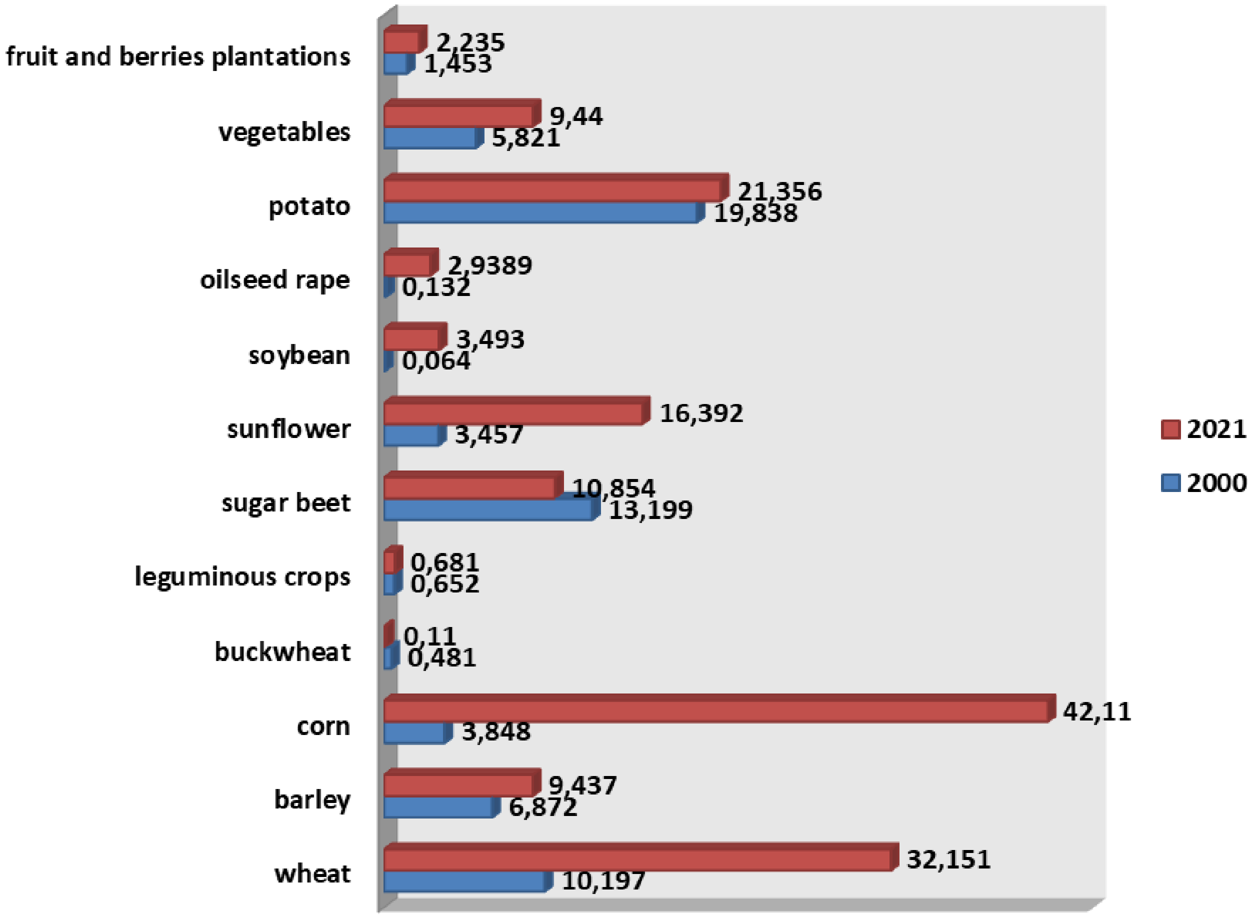

Fig. 3. Gross harvests of main crops in Ukraine, mln t (data by State Statistic Service of Ukraine)

Among pests on winter wheat the most spread were cereal flies (*Mayetiola destructor* Say., *Oscinella frit* L., *Oscinella pusilla* Mg., *Opomyza florum* Fabr., etc), flea beetles (*Phyllotreta vittula* Redt., *Chaetocnema hortensis* Geoffr.), cereal leaf beetles (*Oulema melanopus* L., *Oulema lichenis* Voet.) and cereal aphids (*Schizaphis graminum* Rond., *Sitobion avenae* F., *Brachycolus noxius* Mordv., *Rhopalosiphum padi* L.) with parts 13–24% in structure of pests of winter wheat (fig. 6). In recent years, the number of grain beetles (*Anisoplia agricola* Poda, *Anisoplia austriaca* Hrbst.) and bread bugs (*Eurygaster integriceps* Puton, *Aelia rostrata* Boh.) has increased to 5% and 8%, respectively. We also detected grain sawflies (*Cephus pygmaeus* L.), thrips (*Haplothrips tritici* Kurd.) and cereal ground beetles (*Zabrus tenebrioides* Goeze.) in winter wheat fields.


a
b
c
d
e
f

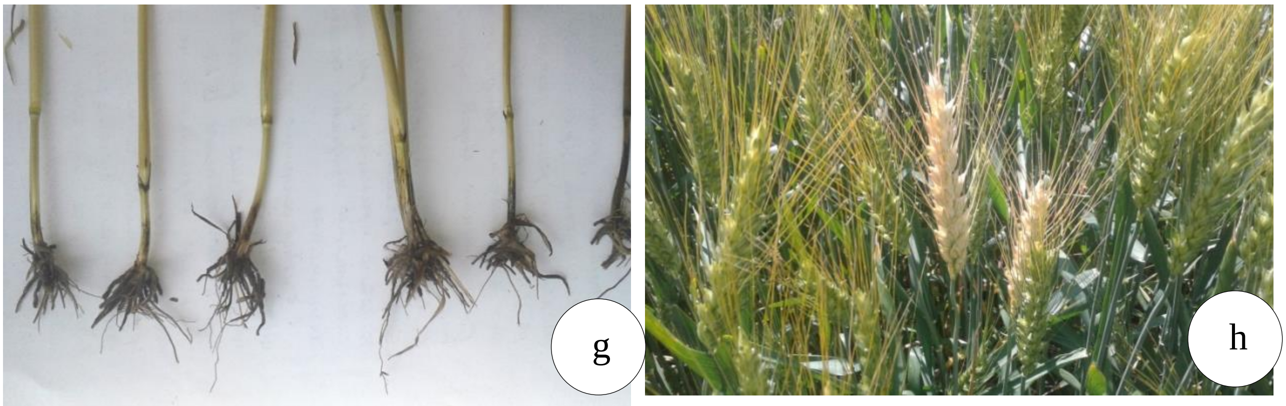

Fig. 4. Main diseases of wheat: a — powdery mildew; b — brown leaf rust; c — Septoria leaf blotch; d — tan spot; e — Fusarium head blight; f — Septoria head blotch; g — root rot; h — white ear as result root rot lesions (photo by Yulia Holiachuk)

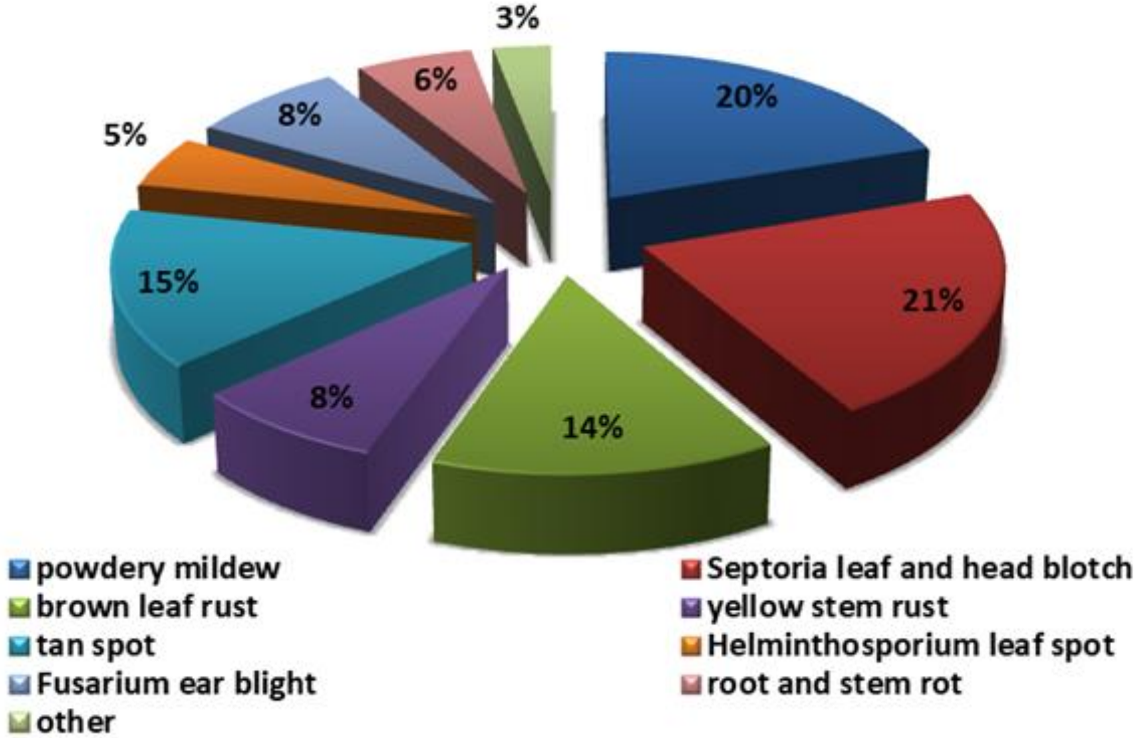

Fig. 5. Structure of main diseases of winter wheat in western region of Ukraine in 2016–2022

On soybean plant we detected such mycoses as powdery (*Erysiphe diffusa* (Cooke & Peck) U. Braun & S. Takam.) and downy mildew (*Peronospora manshurica* (Naum) Syd.), brown spot (*Septoria glycines* Hemmi.), frogeye leaf spot (*Cercospora sojina* Hara), white rot (*Sclerotinia sclerotiorum* (Lib.) de Bary), rust (*Phakopsora pachyrhizi* Syd. & P. Syd.) and others (fig. 7). Bacteria diseases of soybean causing by *Pseudomonas syringae* van Hall has significant mean. Thus, downy mildew and frogeye leaf spot have the highest indexes of diseases — 22% and 19%, respectively. It should be noted more spreading of *Sclerotinia* white rot than in previous years.

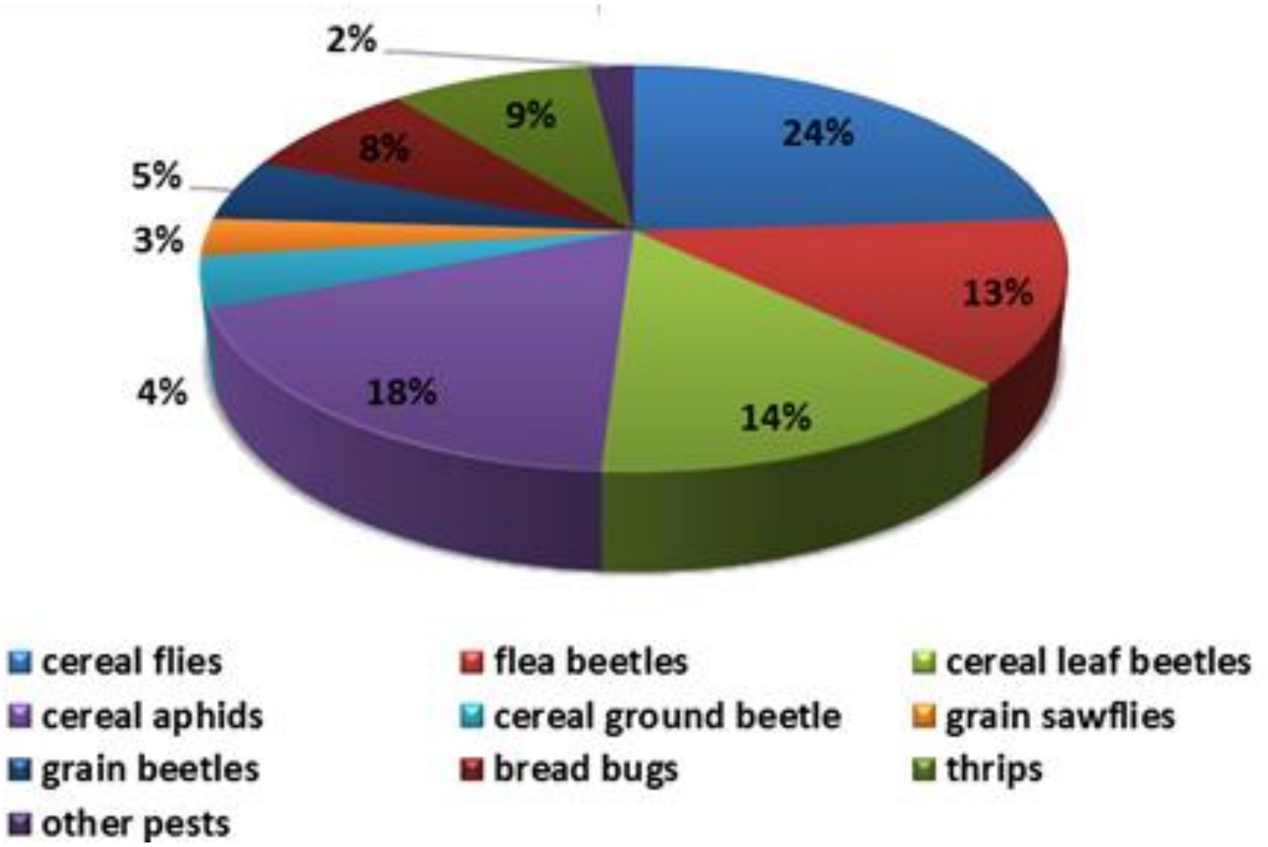

Fig. 6. Structure of harmful entomocomplex of winter wheat in western region of Ukraine (2016–2022)

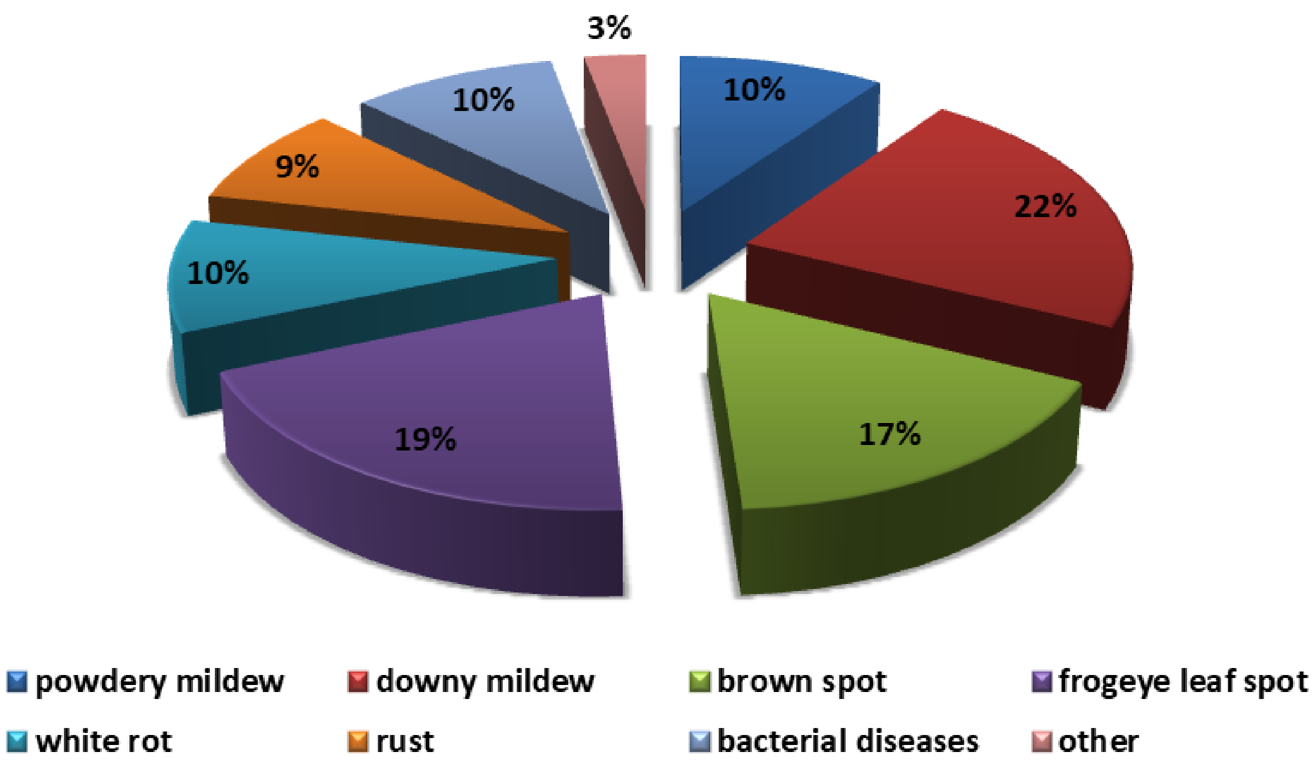

Fig. 7. Structure of main diseases of soybean in western region of Ukraine in 2016–2022

Among pests of soybean the most spreading were pea leaf weevils (*Sitona lineatus* L., *Sitona macularius* Marsham and etc), aphids *(Aphis fabae* Scop. and etc), twospotted spider mite (*Tetranychus urticae* Koch), thrips (*Thrips tabaci* Lind. and etc). Their parts in structure of pests were 13–19% (fig. 8). In recent years, we detected cotton bollworm (*Helicoverpa armigera* Hbn.), silver-Y moth (*Autographa gamma* L.), pea pod borer (*Etiella zinckenella* Tr.), seedcorn maggot (*Delia platura* (Meigen)) and in 2019 painted lady butterfly (*Vanessa cardui* L.) on soybean plants (fig. 8).

On oilseed rape we detected downy mildew (*Peronospora parasitica* (Pers.) Fr.) and powdery mildew (*Erysiphe cruciferarum* Opiz ex L.Junell), blackleg and stem cancer causing by *Leptosphaeria maculans* Ces. & De Not. (anamorph — *Phoma lingam* Desm.), dark leaf spot (*Alternaria* spp.) (fig. 9), light leaf spot or scorch (*Pyrenopeziza brassicae* Sutton & Rawlinson), white rot (*Sclerotinia sclerotiorum* (Lib.) de Bary) and snow mold (*Fusarium* spp. and *Typhula* spp.) in recent years.

The biggest parts in diseases' structure of oilseed rape in 2016–2022 were downy mildew and blackleg and stem cancer — 21–27% (fig. 10). The rising of sown area of oilseed rape has led to wide spreading of *Leptosphaeria* disease and white rot. In the recent five years we observed the increasing of snow mold development.

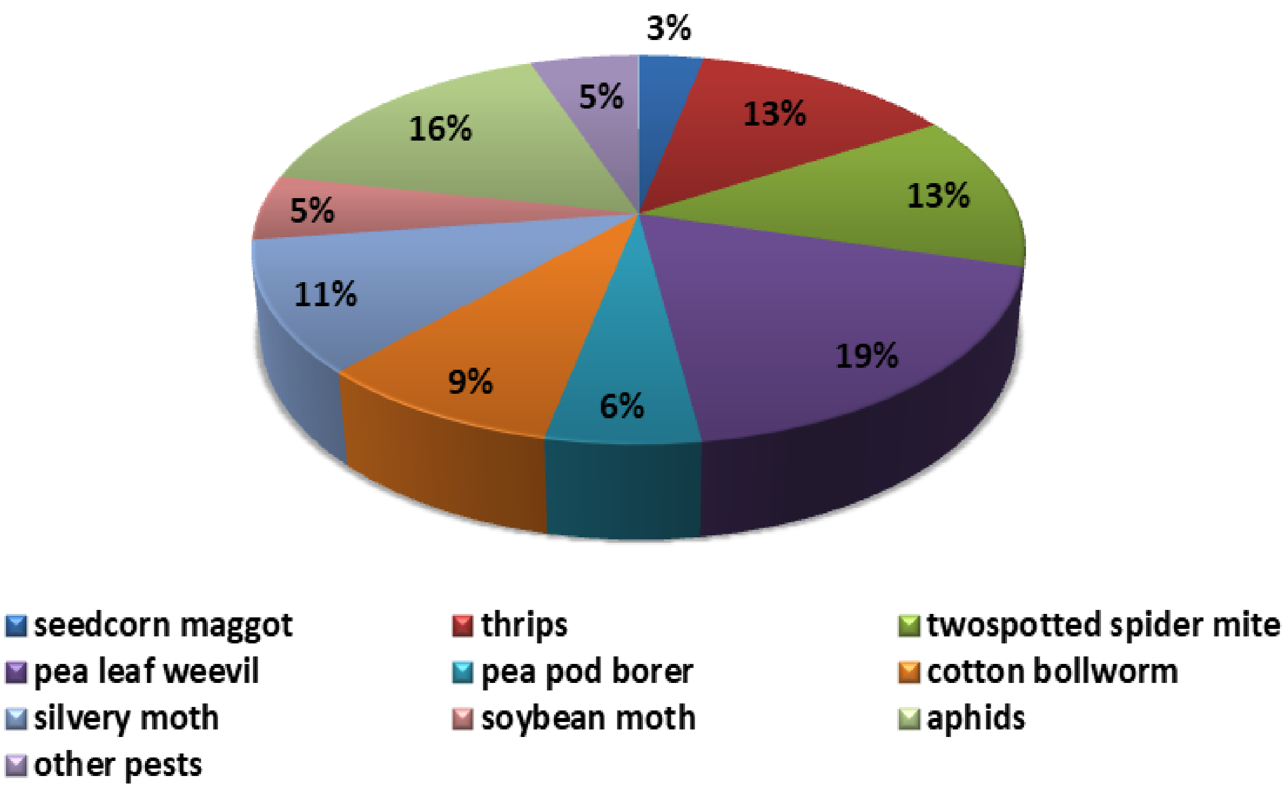

Fig. 8. Structure of harmful entomocomplex of soybean in western region of Ukraine (2016–2022)

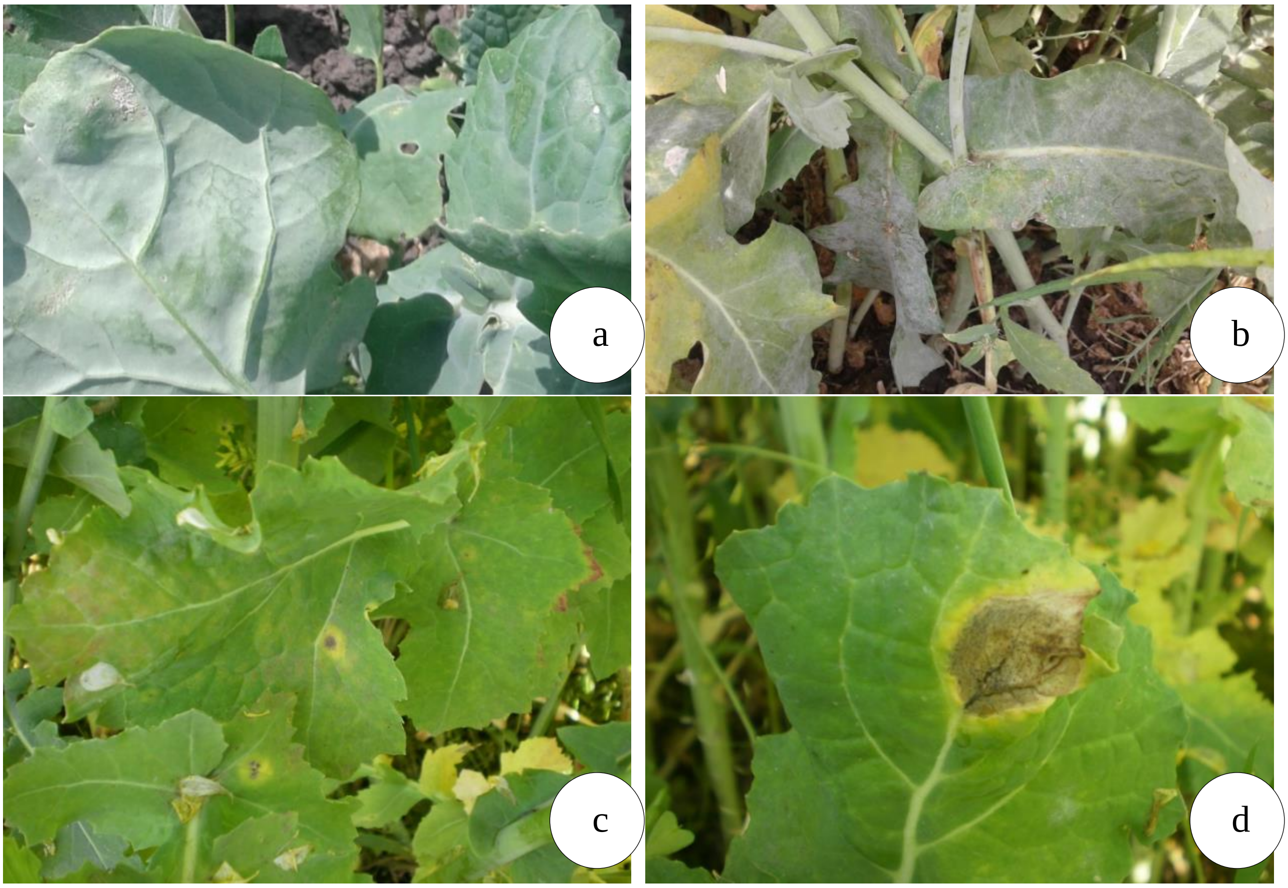

Fig. 9. Diseases of oilseed rape: a — downy mildew; b — powdery mildew; c — dark leaf spot; d — *Phoma* leaf spot (photo by Yulia Holiachuk)

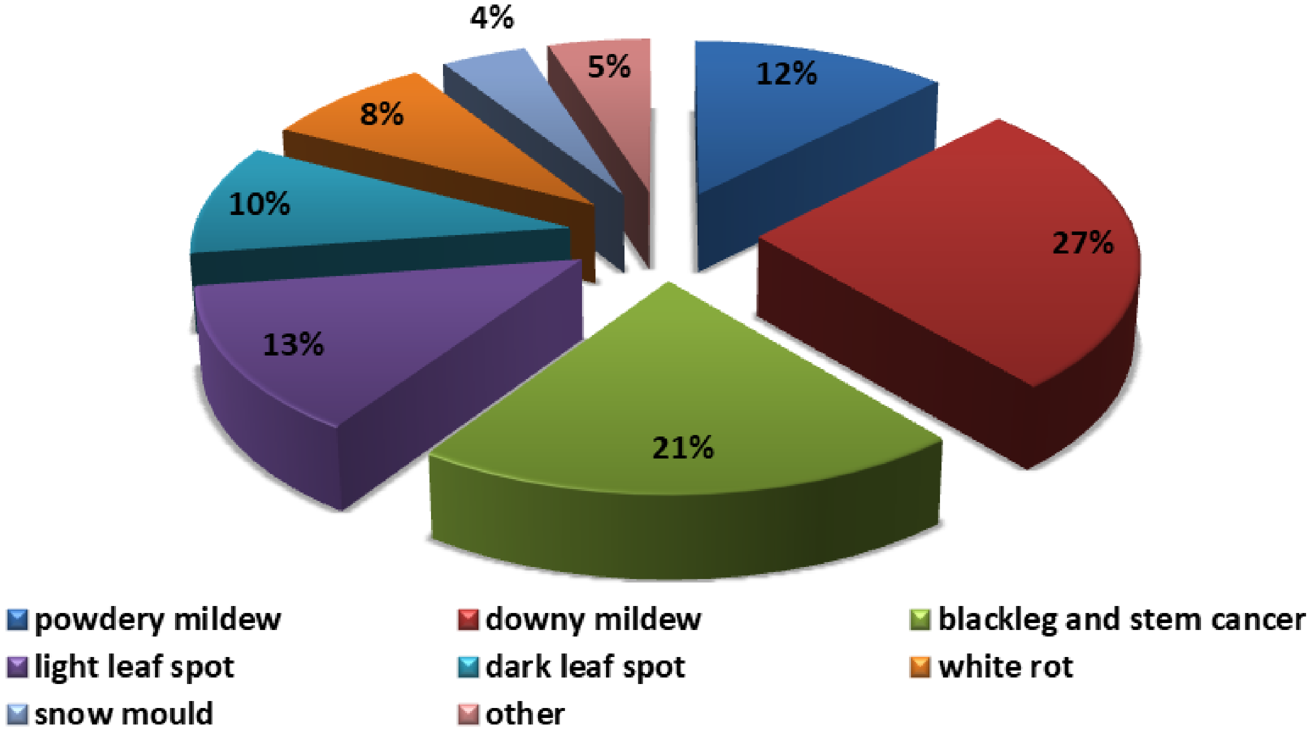

Fig. 10. Structure of main diseases of oilseed rape in western region of Ukraine in 2016–2022

Among pests we observed the most prevailing species, as cabbage stem weevils (*Ceutorhynhus napi* Gyllenhal, *Ceutorhynhus picitarsis* Gyllenhal, *Ceutorhynchus quadridens* Germar and etc), seedpod weevil (*Ceutorrhynhus assimilis* Payk.), rape blossom beetle (*Meligethes aeneus* F.), brassica pod midge (*Dasyneura brassicae* W.), aphids (*Brevicoryne brassicae* L.), rape sawfly (*Athalia colibri* Christ.), flea beetles (*Phyllotreta* spp.) and in the last years — blossom feeder (*Epicometis hirta* Poda.) (fig. 11). The biggest parts in pests' structure have stem and seedpod weevils and rape blossom beetle — 34% and 23%, respectively.

The most spread diseases of corn in western region in Ukraine are *Drechslera* leaf spot, corn smut (*Ustilago maydis* (DC.) Corda), root and stem rot causing by *Fusarium* spp., *S. sclerotiorum*, *Sclerotium bataticola* Taub., and bacteria. On the ear of corn *Fusarium* blight prevails, sometimes head smut (*Sorosporium reilianum* (Kuehn) McAlp) was detected.

Among pests of corn except polyphagous pests dominant species in western region of Ukraine is the western corn rootworm (*Diabrotica virgifera virgifera* le Conte) that is the quarantine pest from A–2 List in Ukraine. The big number of corn stem moth (*Ostrinia nubilalis* Hbn.) were detected on corn plants. Cereal aphids and beet webworm (*Loxostege sticticalis* L.) have sporadic development.

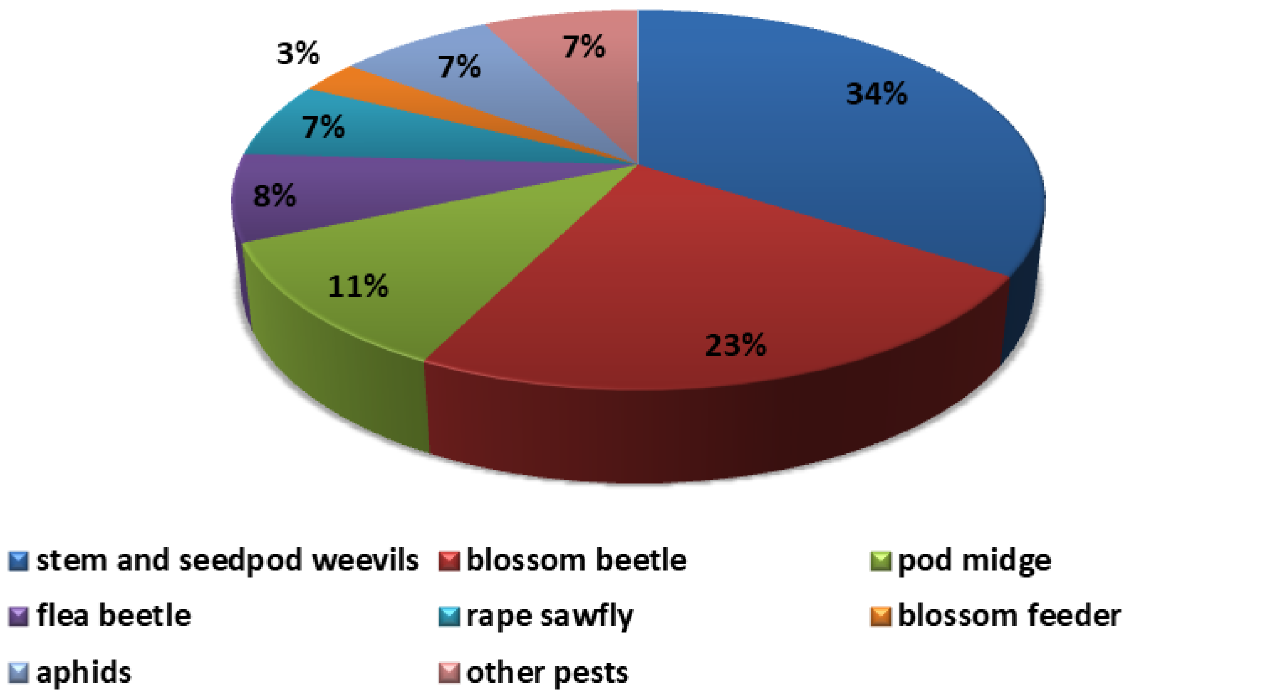

Fig. 11. Structure of harmful entomocomplex of soybean in western region of Ukraine (2016–2022)

The sunflower is new crop for western region of Ukraine. Sowing area of this crop in western region to 2010 was not significant, but climate change, increasing of air temperature and wide spreading early and middle-early hybrids and varieties allowed to increasing of sunflower fields to the west of country. So, if in 2010 there were 0,1 thousand hectares in Lviv region, than in 2018 — 34,1 thousand ha of sunflower. Now on sunflower plants we detected significant development of downy mildew (*Plasmopara halstedii* (Farl.) Berl. et de Toni.), stem black spot (*Phoma oleracea* f. sp. *helianthi-tuberosi* Sacc.), *Phomopsis* stem cancer (*Phomopsis helianthi* Munt.-Cvetk, Mihljc. & M. Petrov.), white mold (*S. sclerotiorum*) and grey mold (*Botrytis cinerea* Pers. ex Fr.).

Among pests on sunflower we detected polyphagous pests, sunflower long-horned beetle (*Agapanthia dahli* Richt.), mordellid beetle (*Mordellistena parvula* Gyll.), aphids (*Brachycaudus helichrysi* Kalt. and etc), twospotted spider mite. Last two years on sunflower plants in western region detected big number of broomrape (*Orobanche cumana* Wallr.).

The research shows that the most common diseases of wheat, oilseed rape, soybeans, corn and sunflower are mycoses caused by fungi or fungus-like organisms. Pests of crops are represented by a wide range of species, and they damage plants throughout their growing season. Monitoring of phytosanitary status of crops is an important task, both for science in the study of biological diversity of agrocenoses, and for modern agricultural production in the development of plant protection systems against diseases and pests, in particular in the selection of effective fungicides and insecticides.

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TECHNICAL HARMFULNESS OF XYLOPHAGOUS INSECTS IN POPLAR AND ASPEN STANDS OF THE LEFT-BANK FOREST STEPPE

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The aim of this research was to evaluate the technical damage for Populus spp. caused by xylophagous insects and to reveal the most dangerous insect species. Technical harmfulness of 72 species was evaluated according to scores of colonized stem part, depth, and diameter of galleries, as well as colonized sapwood surface. Most of the species gnaw galleries in the lower stem part, which has the greatest economic value. The highest score of technical harmfulness was estimated for six longhorn beetles, one jewel beetle, one horntail and all analyzed Lepidoptera.

Key words: *colonized stem part, depth of galleries, diameter of galleries, as colonized sapwood surface.*

Introduction. Poplars and aspens (*Populus* spp.: Salicaceae) have many valuable characteristics including fast growth, ease of propagation, and propensity to hybridize (Poplars and Willows, 2014). They provide board, fiber, plywood, match, paper, biofuel, and bioenergy, rehabilitate degraded lands, restore forest landscapes, and mitigate climate change (Vysotska, Tkach, 2016).

Dozens of insect species feed by leaves and buds of these plants, suck sap, induce galls, bore into shoots and stems, attack roots, and transmit pathogens (Ostry et al., 1989; Lieutier et al., 2004; Steed, Burton, 2015). At least 300 species of phytophagous insects are known in North America (Mattson et al., 2001), and over 500 species in Europe (Charles et al., 2014).

However, only a relatively small number of insect species regularly cause severe physical damage to trees that reduce their economic or environmental value.

Xylophagous insects colonize the stems, branches, and/or roots of the trees (Lieutier et al., 2004). These insects are characterized by physiological and technical harmfulness. Some species are dangerous for the health of trees, while others cause a deterioration in the quality of wood, however, some species are characterized by a high degree of both physiological and technical harmfulness (Meshkova, 2017).

The main indicators of physiological harmfulness of insects are the ability to colonize trees of different health (healthy, weakened, severely weakened, drying up, or dead), to damage and weaken trees during maturation feeding of adults with foliage or phloem and as a result of the introduction of pathogenic organisms during maturation feeding or inhabiting a tree (Mozolevskaya, 1974; Ostry, Anderson, 1995; Davydenko et al., 2014; Zeps et al., 2017). The galleries of xylophagous larvae can cross the vessels, which prevents the flow of water and nutrients from the roots to the crowns, weakens the trees, and can cause their death (Lieutier et al., 2004).

The main indicators of the technical harmfulness of xylophages are the colonized part of the tree, the depth of the gallery's location and their diameter, as well as the surface of the sapwood covered by the galleries (Mozolevskaya, 1974).

The scoring of the harmfulness of xylophagous insects was developed by Mozolevskaya (1974) on the example of Scots pine (*Pinus sylvestris* L.) pests. An approach was subsequently applied to pests of English oak (*Quercus robur* L.) (Meshkova, Kukina, 2011; Bieliavtsev, Meshkova, 2019), Norway spruce (*Picea abies* Karst.) (Kukhta et al., 2014), Scots pine

(Skrylnik, 2013), Silver birch (*Betula pendula* Roth.) (Skrylnik et al., 2019), European ash (*Fraxinus excelsior* L.) and elms (*Ulmus* spp.) (Meshkova, 2020) with some modifications. For example, the population density of these insects (Meshkova, 2017), and additional factors of plantings weakening (Skrylnik et al., 2019) were taken into account.

During research in the Left-bank Forest Steppe of Ukraine, we have found 72 species of poplar and aspen xylophages (Skrylnyk et al., 2023), representing the orders Coleoptera (66 species, or 92%), Lepidoptera (5 species, or 7%) and Hymenoptera (1 species, or 1%). Polyphagous insects prevailed, and single and rare species dominated. The periods of swarming and indicators affecting the physiological harmfulness of these insects were determined.

The aim of this research was to evaluate the level of technical damage for *Populus* spp. in the Left Bank Forest-steppe of Ukraine caused by xylophagous insects and to reveal the most dangerous insect species.

Materials and methods. Our research was carried out in 2019–2022 in the forest fund of Myrhorodsky and Lubensky forest enterprises of Poltava region, Trostyanetsky, Okhtyrsky, and Shostkynsky forest enterprises of Sumy region, Zmijivsky, Gutyansky, Vovchansky, Zhovtnevy forest enterprises of Kharkiv region, at the archive plantation of poplar clones in the Pivdenne Forestry of the Kharkiv Forest Research Station of Ukrainian Research Institute of Forestry & Forest Melioration named after G.M. Vysotsky, in the arboretum of the State Biotechnological University, as well as in the field and road protective forest shelter belts of Zmievsky (since 2020 Chuguevsky), Krasnokutsky (since 2020 Bogodukhovsky), and Kharkivsky districts of Kharkiv region. The collection of Yu. Skrylnyk since 2006 and published data of these regions with his participation were also included in the analysis (Skrylnik, Terekhova, 2011; Terekhova, Skrylnyk, 2014).

Insects were collected by mowing, manual collection, using window traps, an inspection of trees, collection of preimaginal stages under the bark and in the wood of trees as well as insect rearing in the sections of stems and branches in an insectarium with inserted nets or ventilation holes respectively (Meshkova et al., 2009). After the adults' emergence, all insects were identified. Then the sections were debarked, and galleries were examined to evaluate the parameters which were necessary for damage rating.

In the analysis, only those insect species were used, for which the development in the stems and branches of *Populus* spp. (*P. tremula* L., *P. nigra* L., *P. alba* L. and their hybrids and clones) was proved by our research (Skrylnik et al., 2019, 2023, Zhupinska 2019; Meshkova et al., 2022) and/or supported by publications (Bily, 2002; Yanitsky, 2007; Bartenev, 2009; Prokhorov, 2010; Nikulina et al., 2015; Danilevsky, 2020).

A general score of timber destruction was evaluated for each insect species as a sum of points that evaluate the depth of gallery location (1.2 points for the depth of gallery location below 1 cm, 1.7 points for 1–4 cm, and 4.3 points for more than 4 cm), their diameter (0 points for diameter up to 0.3 cm, and 0.1 points for diameter over 0.3 cm) and colonized sapwood surface (0 points for surface up to 1 dm^2, 0.1 points for 1–2 dm^2, and 0.2 points for over 2 dm^2).

The technical harmfulness of each species was evaluated as a product of the scores of a general of timber destruction, colonized stem part (1 point for upper stem part and branches with thin bark; 1.3 points for middle stem part and branches with transition bark; 1.5 points for lower stem part and branches with rough bark), and timber value of damaged tree species (the last coefficient for *Populus* spp. is 1.7, considering its price compared to other tree species).

Results. Among 72 xylophagous insects colonizing *Populus* spp. in the region of our research, Coleoptera species belong to the families Cerambycidae (longhorn beetles), Buprestidae (jewel beetles), and Curculionidae (Table 1).

Family Curculionidae is represented by Cryptorhynchinae (weevils) and Scolytinae (bark beetles), and the last subfamily includes the tribe Xyleborini having an obligate nutritional symbiosis with xylophagous fungi. Order Hymenoptera is represented by one horntail species (Siricidae). Order Lepidoptera is represented by two families: clearwing moths (Sesiidae) and goat moths (Cossidae).

An analysis of 72 xylophagous insects colonizing *Populus* spp. shows that the depth of their larval galleries varies from a few millimeters (in the phloem under the bark) to over 4 cm (when placed in the sapwood and even in the heartwood). The galleries expand as the larvae develop and their maximum diameter ranges from 1 to 25 mm. The surface occupied by galleries may exceed 2 dm^2.

Table 1

A score of technical harmfulness of xylophagous insects in *Populus* spp. in the Left-bank Forest Steppe, points

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Coleoptera: Cerambycidae						
Aegosoma scabricornis (Scopoli, 1763)	4.3	0.1	0.2	4.6	1.5	11.7
Prionus coriarius (Linnaeus, 1758)	4.3	0.1	0.2	4.6	1.5	11.7
Rhamnusium gracili-corne Thery, 1894	4.3	0.1	0.2	4.6	1.5	11.7
Rhagium mordax (Degeer, 1775)	1.7	0.1	0.1	1.9	1.5	4.8
Dinoptera collaris (Linnaeus, 1758)	1.2	0.1	0	1.3	1	2.2
Rutpela maculata (Poda, 1761)	1.7	0.1	0.1	1.9	1.5	4.8
Leptura aurulenta Fabricius, 1792	1.7	0.1	0.1	1.9	1.5	4.8
Leptura quadrifasciata Linnaeus, 1758	1.7	0.1	0.1	1.9	1.5	4.8
Lepturalia nigripes (Degeer, 1775)	1.7	0.1	0.1	1.9	1.5	4.8
Strangalia attenuata (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1.5	4.8
Stenurella melanura (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1.5	4.8

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Necydalis major Linnaeus, 1758	4.3	0.1	0.2	4.6	1.3	10.2
Trichoferus campestris (Faldermann, 1835)	1.7	0.1	0.1	1.9	1.3	4.2
Purpuricenus kaehleri (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1.3	4.2
Cerambyx scopolii Fuesslins, 1775	4.3	0.1	0.2	4.6	1.5	11.7
Aromia moshata (Linnaeus, 1758)	4.3	0.1	0.2	4.6	1.5	11.7
Obrium cantharinum (Linnaeus, 1767)	1.7	0.1	0.1	1.9	1.3	4.2
Ropalopus clavipes (Fabricius, 1775)	1.2	0.1	0.1	1.4	1.3	3.1
Ropalopus macropus (Germar, 1824)	1.2	0.1	0.1	1.4	1	2.4
Chlorophorus figuratus (Scopoli, 1763)	1.7	0.1	0.1	1.9	1.3	4.2
Chlorophorus varius (Müller, 1766)	1.7	0.1	0.1	1.9	1	3.2
Xylotrechus arvicola (Olivier, 1795)	1.2	0.1	0.1	1.4	1.5	3.6

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Xylotrechus rusticus (Linnaeus, 1758)	1.7	0.1	0.2	2	1.5	5.1
Mesosa curculionoides (Linnaeus, 1761)	1.2	0.1	0.2	1.5	1.5	3.8
Mesosa nebulosa (Fabricius, 1781)	1.2	0.1	0.2	1.5	1.5	3.8
Lamia textor (Linnaeus, 1758)	1.7	0.1	0.2	2	1.5	5.1
Anaesthetis testacea (Fabricius, 1781)	1.2	0.1	0	1.3	1	2.2
Pogonocherus hispidus (Linnaeus, 1758)	1.2	0.1	0	1.3	1	2.2
Pogonocherus hispidulus (Piller et Mitt., 1783)	1.2	0.1	0	1.3	1	2.2
Aegomorphus clavipes (Schrank, 1781)	1.2	0.1	0	1.4	1.5	3.6
Leiopus punctulatus (Paykull, 1800)	1.2	0.1	0	1.3	1.5	3.3
Tetrops praeusta (Linnaeus, 1758)	1.2	0	0	1.2	1.5	3.1
Saperda populnea (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1.5	4.8
Saperda octopunctata (Scopoli, 1772)	1.7	0.1	0.1	1.9	1.5	4.8

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Saperda perforata (Pallas, 1773)	1.7	0.1	0.1	1.9	1.5	4.8
Saperda scalaris (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1.5	4.8
Saperda carcharias (Linnaeus, 1758)	4.3	0.1	0.2	4.6	1.5	11.7
Stenostola ferrea (Schrank, 1776	1.7	0.1	0.1	1.9	1	3.2
Menesia bipunctata (Zoubkoff, 1829)	1.2	0	0	1.2	1	2.0
Oberea oculata (Linnaeus, 1758)	1.7	0.1	0.1	1.9	1	3.2
Coleoptera: Buprestidae						
Acmaeoderella flavofas-ciata (Piller & Mitterpacher, 1783)	1.2	0.1	0	1.3	1	2.2
Dicerca aenea (Linnaeus, 1766)	4.3	0.1	0.1	4.5	1.5	11.5
Dicerca alni (Fischer von Waldheim, 1824)	4.3	0.1	0.1	4.5	1.3	9.9
Poecilonota variolosa (Paykull, 1799)	4.3	0.1	0.1	4.5	1.3	9.9
Eurythyrea aurata (Pallas, 1776)	4.3	0.1	0.1	4.5	1.3	9.9

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Eurythyrea austriaca (Linnaeus, 1767)	4.3	0.1	0.1	4.5	1.3	9.9
Trachypteris picta (Pallas, 1773)	1.2	0.1	0	1.3	1.5	3.3
Agrilus lineola Kiesenwetter, 1857	1.2	0	0	1.2	1	2.0
Agrilus viridis (Linnaeus, 1758)	1.2	0	0	1.2	1	2.0
Agrilus convexicollis Redtenbacher, 1849	1.2	0	0	1.2	1	2.0
Agrilus cyanescens (Ratzeburg, 1837)	1.2	0	0	1.2	1	2.0
Agrilus auricollis Kiesenwetter, 1857	1.2	0	0	1.2	1	2.0
Agrilus pratensis (Ratzeburg, 1837)	1.2	0	0	1.2	1	2.0
Agrilus pseudocyaneus Kiesenwetter, 1857	1.2	0	0	1.2	1	2.0
Agrilus subauratus (Gebler, 1833)	1.7	0.1	0	1.8	1	3.1
Agrilus roscidus Kiesenwetter, 1857	1.2	0	0	1.2	1	2.0
Agrilus ater (Linnaeus, 1767)	1.7	0.1	0	1.8	1.5	4.6

Insect species	Depth of gallery locatio n score	Diame -ter of galler y score	Coloniz ed sapwood surface score	Gener al score of timber destru c-tion	Stem part score	Techni -cal harm-fulness score
Agrilus guerini Lacordaire, 1835	1.7	0.1	0	1.8	1.5	4.6
Agrilus suvorovi Obenberger, 1935	1.2	0.1	0	1.3	1.5	3.3
Coleoptera: Curculionidae: Cryptorhynchinae						
Cryptorhynchus lapathi (Linnaeus, 1758)	1.7	0.1	0	1.8	1.5	4.6
Coleoptera: Curculionidae: Scolytinae						
Anisandrus dispar (Fabricius, 1792)	1.7	0	0	1.7	1.5	4.3
Anisandrus maiche Kurentzov, 1941	1.7	0	0	1.7	1.5	4.3
Xyleborinus saxesenii (Ratzeburg, 1837)	1.7	0	0	1.7	1.5	4.3
Xyleborus cryptogra-phus (Ratzeburg, 1837)	1.7	0.1	0	1.8	1.5	4.6
Trypodendron signatum (Fabricius, 1787)	1.7	0	0	1.7	1.5	4.3
Trypophloeus granulatus (Ratzeburg, 1837)	1.2	0	0	1.2	1.5	3.1
Lepidoptera: Sesiidae						
Paranthrene tabanifor-mis (Rottemburg, 1775)	4.3	0.1	0.1	4.5	1.5	11.5
Sesia apiformis (Clerck, 1759)	4.3	0.1	0.1	4.5	1.5	11.5

Insect species	Depth of gallery location score	Diame-ter of gallery score	Colonized sapwood surface score	General score of timber destruc-tion	Stem part score	Techni-cal harm-fulness score
Lepidoptera: Cossidae						
Zeuzera pyrina (Linnaeus, 1761)	4.3	0.1	0.1	4.5	1.5	11.5
Cossus cossus (Linnaeus. 1758)	4.3	0.1	0.1	4.5	1.5	11.5
Acossus terebra (Denis & Schiff., 1775)	4.3	0.1	0.1	4.5	1.5	11.5
Hymenoptera: Siricidae						
Tremex fuscicornis (Fabricius, 1787)	4.3	0.1	0.1	4.5	1.5	11.5

Notes: The score of technical harmfulness of xylophagous insects is the product of the general score of timber destruction, a score of stem part, and a score of the timber value. A general score of timber destruction is the sum of points for depth of destruction, gallery width, and colonized sapwood surface. Depth of gallery location score: 1.2 – up to 1 cm (Low); 1.7 – 1–4 cm (Moderate); 4.3 – over 4 cm (High). Diameter of gallery score: 0 – up to 0.3 cm (Low); 0.1 – over 0.3 cm (High). Colonized sapwood surface score: 0 – up to 1 dm^2 (Low); 0.1 – 1–2 dm^2 (Moderate); 0.2 – over 2 dm^2 (High). A score of stem part: colonizing lower stem part with rough bark – 1.5 points; middle stem part with transition bark – 1.3 points; upper stem part and branches with thin bark – 1 point. The timber value index for *Populus* sp. is 1.7.

The correlations between the parameters of the galleries are significant ($p<0.001$). However, it is weak for depth with diameter ($r=0.35\pm0.012$) and moderate for surface area with depth ($r=0.57\pm0.010$) and diameter ($r=0.55\pm0.010$).

According to the scoring, 40.3% of the detected xylophagous species are characterized by a moderate depth of gallery location, i.e. from 1 to 4 cm (Fig. 1).

The predominant location of galleries at such a depth is characteristic of Scolytinae. The galleries of a significant part of longhorn beetles are nearer to the bark (32.5%) or in the deep wood layers (17.5%). The galleries of most jewel beetles (57.9%) are located at a depth of up to 1 cm, and only in 5 species, at a depth of more than 4 cm.

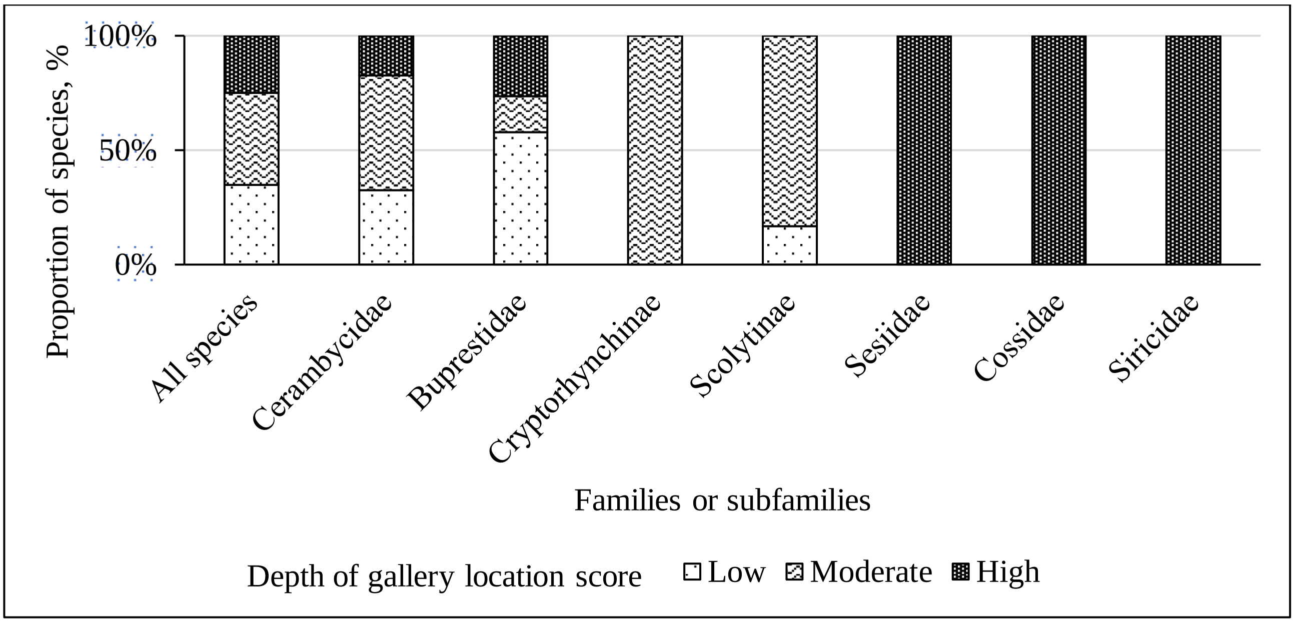

Figure 1. Distribution of xylophagous insects damaging *Populus* spp. by the depth of gallery location score (see Notes to Table 1)

Seven longhorn beetle species (*Aegosoma scabricornis*, *Prionus coriarius*, *Rhamnusium gracilicorne*, *Necydalis major*, *Cerambyx scopolii*, *Aromia moshata*, *Saperda carcharias*), five jewel beetles (*Dicerca aenea*, *Dicerca alni*, *Poecilonota variolosa*, *Eurythyrea aurata*, and *Eurythyrea austriaca*), all analyzed Lepidoptera and horntail *Tremex fuscicornis* have the deepest galleries.

The diameter of galleries of most analyzed xylophages (79.2%) exceeds 0.3 cm (Fig. 2). Thinner galleries were found for five out of six analyzed species of bark beetles, in 8 out of 19 jewel beetles and in two out of 40 analyzed longhorn beetles.

Colonized sapwood surface score is low and moderate for 40.3 and 44.4 % of analyzed xylophages, respectively, and is high only for 15.3 % of species, all of which belong to longhorn beetles (see Table 1, Fig. 3). This parameter is low for all analyzed bark beetles, and moderate for all analyzed Lepidoptera and for horntail. Most jewel beetles (73.7%) have a low colonized sapwood surface score, and the rest of this family have a moderate score.

A general score of timber destruction by xylophagous insects damaging *Populus* spp. varied from 1.2 to 4.6 points (Table 2). All analyzed Lepidoptera and a horntail *Tremex fuscicornis* have the maximum value of this indicator, and Scolytinae species have the minimum value. Longhorn beetles have the widest range of the general score of timber destruction, and jewel beetles have a slightly smaller value of it.

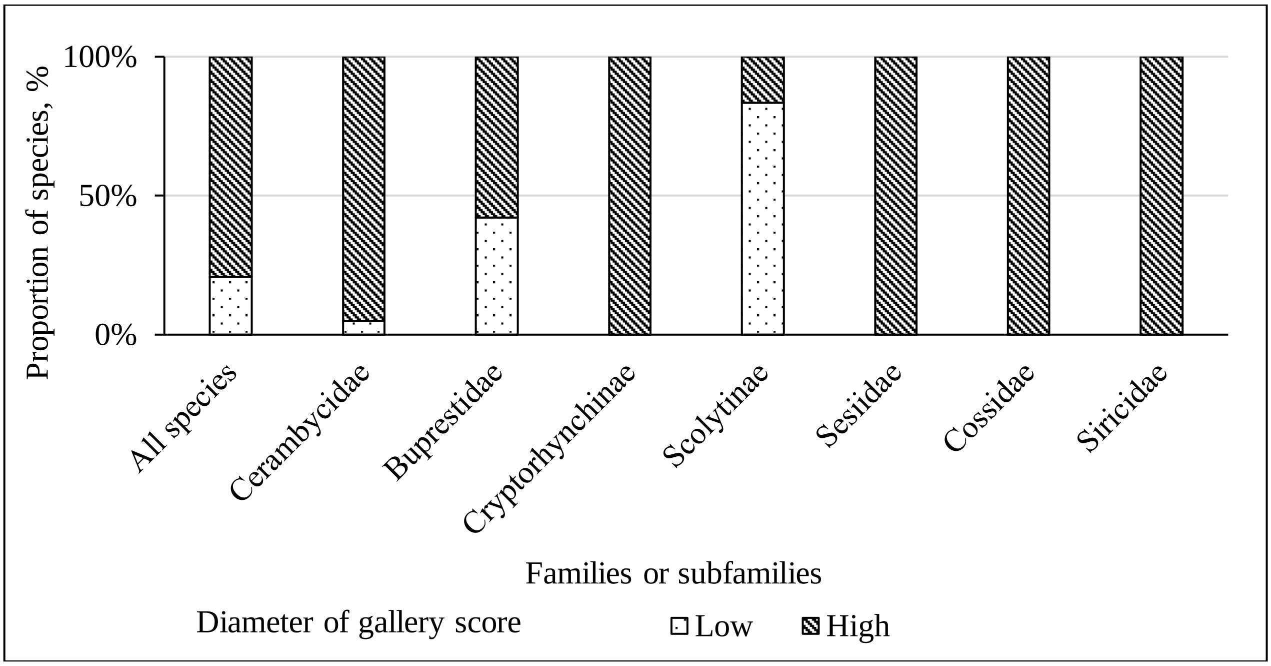

Figure 2. Distribution of xylophagous insects damaging *Populus* spp. by the diameter of galleries score (see Notes to Table 1)

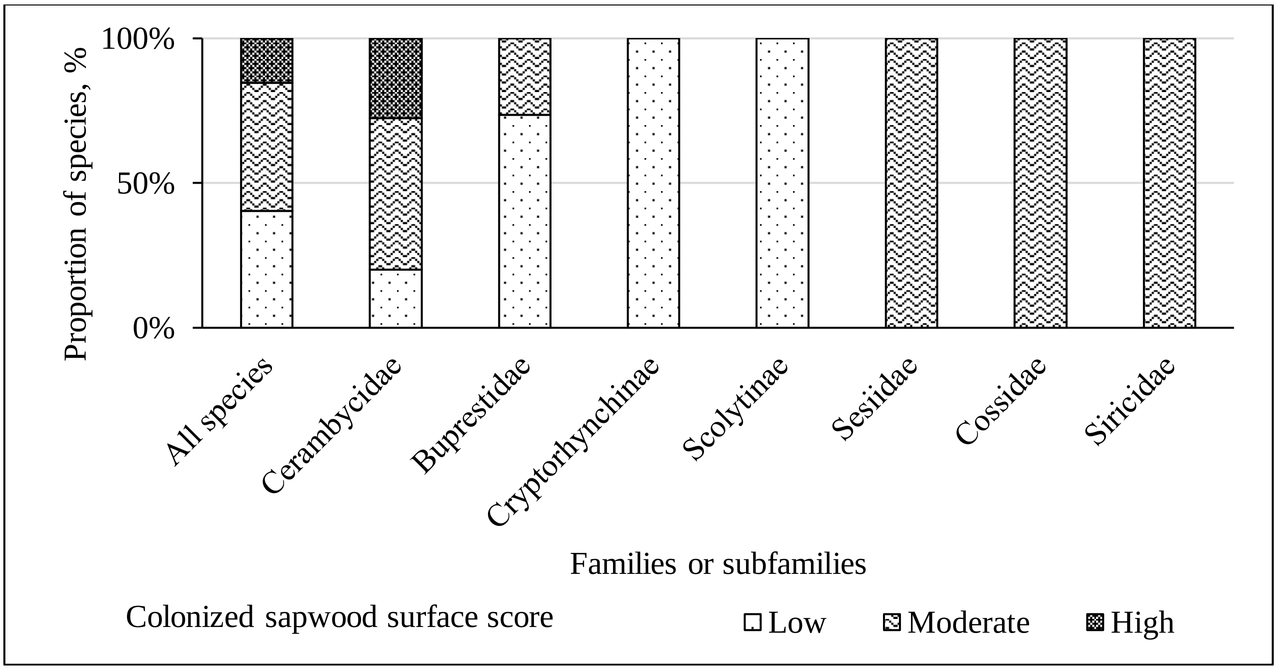

Figure 3. Distribution of xylophagous insects damaging *Populus* spp. by colonized sapwood surface score (see Notes to Table 1)

The harmfulness of xylophagous insects is dependent also on the colonized stem part. Most of the xylophagous species (59.7%) gnaw galleries in the lower stem part of poplars (Fig. 4), which has the greatest economic value (Meshkova, 2017). However, stem pests' galleries at the lower part of the stem decrease the output of saw timber, furniture, and veneering and have no impact on paper, pulp, or match production (Poplars and Willows, 2014).

Table 2

A general score of timber destruction by xylophagous insects damaging *Populus* spp.

Para-meters	All species	Cera m-bycid ae	Bupr es-tidae	Cryptorhy n-chinae	Scol y-tinae	Sesi-idae	Coss-idae	Siric -idae
Mean± St. error	2.3± 0.15	2.2± 0.18	2.2± 0.33	1.8± 0.00	1.6± 0.22	4.5± 0.00	4.5± 0.00	4.5± 0.00
Min – Max	1.2– 4.6	1.2– 4.6	1.2– 4.5	1.8 – 1.8	1.2– 1.8	4.5– 4.5	4.5– 4.5	4.5– 4.5
Number of species	72	40	19	1	6	2	3	1

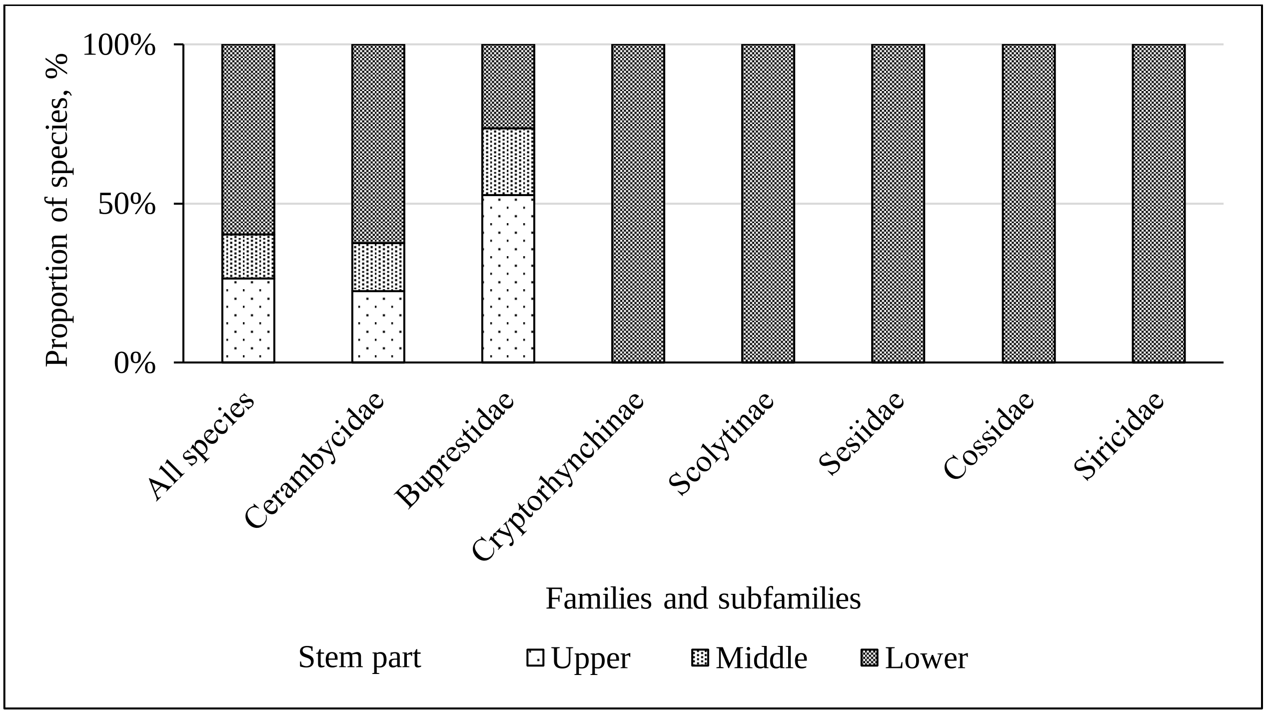

Figure 4. Distribution of xylophagous insects damaging *Populus* spp. by colonized stem part

Scolytinae, Lepidoptera, and horntail *Tremex fuscicornis* inhabited trees mainly in the lower stem part (see Table 1). These species can also inhabit branches, but this has less effect on both the health condition of trees and wood quality. An exception includes the cases when these insects vector the pathogens or wood-destroying fungi into the tree (Ostry, Anderson. 1995; Zeps et al., 2017). However, the issue of the influence of this phenomenon on the poplar wood quality has not yet been sufficiently studied.

Jewel beetles were found more often (52.6% of the analyzed species) in the stem part and branches with thin bark, while a greater number of longhorn beetles (62.5%) preferred the lower stem part with rough bark.

A technical harmfulness score of xylophagous insects damaging *Populus* spp. ranged from 2 to 11.7 points (Table 3). Longhorn beetles and jewel beetles have the greatest variability of technical harmfulness because these families are represented by the largest number of species. The highest score of technical harmfulness (11.7 points) was estimated for six longhorn beetles colonizing the lower stem part and gnawing galleries in the deep sapwood layers, particularly, *Aegosoma scabricornis*, *Prionus coriarius*, *Rhamnusium gracilicorne*, *Aromia moshata*, *Cerambyx scopolii*, and *Saperda carcharias*. The first four species are polyphagous and are rather rare, the last two species are polyphagous but common.

Table 3

A technical harmfulness score of xylophagous insects damaging *Populus* spp.

Para-meters	All species	Ceram-bycidae	Bupres-tidae	Cryptorhyn-chinae	Scoly-tinae	Sesi-idae	Cossi-dae	Siric-idae
Mean± St. error	5.5± 0.41	5.2± 0.49	4.7± 0.81	4.6± 0.00	4.2± 0.22	11.5 ± 0.00	11.5± 0.00	11.5 ± 0.00
Min – Max	2.0–11.7	2.0–11.7	2.0–11.5	4.6 – 4.6	3.1–4.6	11.5–11.5	11.5–11.5	11.5 – 11.5
Number of species	72	40	19	1	6	2	3	1

Among jewel beetles, the highest technical harmfulness score (11.5 points) was estimated for *Dicerca aenea*, which is not common. Another three jewel beetles (*Poecilonota variolosa*, *Eurythyrea aurata*, and *E. austriaca*) have got 9.9 points. They all are polyphagous and rather rare.

The technical harmfulness score of the analyzed Lepidoptera species is 11.5 points. Among them, *Paranthrene tabaniformis* and *Acossus terebra* are monophagous species. The rest three species (*Sesia apiformis*, *Zeuzera pyrina* is common, and *Cossus cossus*) are polyphagous. The technical harmfulness score of the only Hymenoptera species (*Tremex fuscicornis*) is

11.5 points. This species is polyphagous and usually rare but can be common or even abundant in some stands.

The correlation between colonized sapwood surface score and colonized stem part is significant ($p<0.001$), but low ($r=0.37\pm0.012$; $t=30.4$). The correlation between colonized stem part and technical harmfulness score is significant ($p<0.001$), but moderate ($r=0.51\pm0.01$; $t=48.9$). The correlation between colonized sapwood surface score and technical harmfulness score is significant ($p<0.001$) and high ($r=0.98\pm0.001$; $t=1757.1$).

Conclusions. Seventy-two species of xylophagous insects, belonging to Coleoptera (Cerambycidae, Buprestidae, and Curculionidae), Hymenoptera (Siricidae), and Lepidoptera (Sesiidae, and Cossidae) colonize poplars and aspens in the Left Bank Forest-steppe of Ukraine. Larval galleries of most of them are in the lower stem part of a tree, which has the greatest economic value.

The highest score of technical harmfulness was estimated for six longhorn beetles (*Aegosoma scabricornis*, *Prionus coriarius*, *Rhamnusium gracilicorne*, *Aromia moshata*, *Cerambyx scopolii*, and *Saperda carcharias*), a jewel beetle *Dicerca aenea*, horntail *Tremex fuscicornis* and all analyzed Lepidoptera species.

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BRIEF ECOLOGICAL AND FAUNISTIC CHARACTERISTICS OF SOLITARY BEES IN THE-NORTH-EASTERN UKRAINE

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An analysis of the history of the study of solitary bees in northeastern Ukraine over a century and a half, their fauna, assemblages, habitat distribution, trophic relationships, and phenology is presented. From Northeastern Ukraine, 360 solitary bee species belonging to 53 genera of 6 families were recorded. Among them, 103 species were new to the regional fauna, 170 species were found in singletons, and 8 species were the most numerous. Most species (69.4%) were found in all habitats. About 40% of species prefer steppe or forest habitats, indicating a zonal character (forest-steppe) of the fauna. By trophic relationships, 71 species (19.7%) are kleptoparasites, and 67.8% are polylectic. The bees with midsummer flight activity (131 species.) are the most numerous.

Key words*: fauna, assemblages, habitat distribution, trophic relationships, phenology.*

State of the problem

The north-east of Ukraine and the south-west of the Central Black Earth region is considered one of the most studied in terms of insect fauna. However, only a few publications are devoted to studying the fauna of solitary bees. At the end of the nineteenth century, a short list of species recorded from the environs of Kupyansk was published by P. Ivanov (1872). N. Beletsky (1873) published a list of species inhabited in the environs of Kharkiv. The most complete list was presented by V. Yaroshevsky (1881), it included 108 species of solitary bees from the Kharkiv Province. This list also included the species not found by V. Yaroshevsky, but cited in the works of P. Ivanov and N. Beletsky.

Further, the study of bees in the region was associated with the name of S.I. Malyshev, who worked fruitfully for a long period on the study of bee nesting biology at the biological station in Borisovka, Belgorod region, now the Les na Vorskle Nature Reserve. During the period from 1912 to 1937, he published 20 works on nesting, nesting biology, parasites, and food relationships of 16 bee genera (Malyshev, 1923; 1924; 1926; 1947). At the same time, the work of E. Pesotskaya (1929) on the role of the glandular apparatus in the instinctive activity of bees was published, where several solitary bee species from Borisovka were mentioned. The next important stage in bee research in the region is U-Yan-zhus's, work on legume pollinating bees in Borisovka. In the fifth chapter of her thesis (U-Yan-zhu, 1960), she lists 227 species of 48 genera for the Borisovka vicinity (including 22 species of bumblebees – the genus *Bombus*). The thesis indicates the dates of bee flight activity in 1957–1959, the number of collected specimens, and fodder crops. She also provides a comparative zoogeographic analysis of the bee fauna of Borisovka, Kyiv region (Lebedev, 1933), and Bashkiria (Nikiforuk, 1957) – the areas with the most thoroughly studied fauna of the solitary bees at that time.

In subsequent years, information on the solitary bees in the region can be found in publications devoted to pollinators of some plant species or groups of plants. The vast majority of publications are about pollinators of seed alfalfa. In particular, the works of V. V. Zharinov (1975, 1982); Zharinov, and Osychnyuk (1976), B. S. Zinchenko and L. A. Korbetskaya (Zinchenko, Korbetskaya, 1980; Zinchenko, 1982), in the Poltava and the south of Sumy regions, and V. N. Gramma et al. (1979), M. A. Filatov (1996) in the Kharkiv region.

The researches of L. A. Antonova (1979), and K. V. Skuf'in (1979) were conducted in the southwest of the Central Black Earth region of Russia.

Another large group of publications that provide information about the bees in the region is dedicated to the protection of insects and the increase in their numbers. The number of these works especially increased after the appearance of the “Red Book of the USSR” in 1978, and then the regional Red Books (1983; 1994). These publications can be subdivided into two main groups:

a) the works listed the solitary bee species that require protection in a given region. First of all, most works concern frequent, but economically important pollinators of alfalfa and other forage plants (Skuf'in, 1958; Rabinovich et al., 1975; Zinchenko, 1975; Medvedev et al., 1977; Zagovora et al., 1979; Bilenko, Zharinov, 1978; Zharinov, 1980; Litvinov, Oparenko, Filatov, 1984).

b) publications on the organization and functioning of micro-reserves and micronational parks for useful entomofauna, including solitary bees (Gramma et al, 1980, 1982).

This group of publications includes methodical works: information leaflets, guidelines, and posters for agricultural workers, students, and schoolchildren on the protection and attraction of the local solitary bee species (Zharinov, 1981; Radchenko, 1982 a; Litvinov et al., 1987; Grishchenko et al., 1989; Babiy et al., 1994).

Since 1960, only two faunistic works (Tseitgamel, Chernov, 1978; Filatov, 1984) listed the solitary bees of the Central Black Earth State Nature Reserve have been published. The latter work presents a list of 96 bee species from the Yamskaya Steppe segment of the Reserve, which has not been given in the publication of 1978.

The study of fauna and some aspects of solitary bee biology in the adjacent regions was much more intensive. Thus, for the south-east of Ukraine (steppe zone, Donetsk region), V. G. Radchenko indicated 374 species (1982 b). He also published many works on the fauna and nesting biology of some solitary bee species (Radchenko, 1980; 1989; 1993; 1994). 348 species are known (Pesenko, 1973b) from the Lower Don region. Additional information on the bee fauna of the Central Black Earth region of Russia, in the areas not covered by our research, can be found in the works of V. K. Zavgorodnya (1952), A. A. Zhuravlev (1956), E. K. Greenfeld (1956), and S. G. Bogoyavlensky (1966).

In the middle part of the Lower Volga region, which is adjacent to the Central Black Earth region of Russia, 551 species of solitary bees were recorded (Mukhin, 1979). In the Right-Bank Ukraine, A. Z. Osychnyuk (1959, 1960) studied the fauna of solitary bees in the steppe regions. She listed 339 species. In the Forest-Steppe of the Right-Bank Ukraine, solitary bees are poorly studied. Only a work of A. G. Lebedev (1933) in the south of Kyiv region and two works in the Kanivskyi Nature Reserve (Osychnyuk, 1963; Romasenko, 1980) are known.

The fauna of the forest zone of the Right-Bank Ukraine and the Ukrainian Carpathians has been studied much more thoroughly. A total of 132 species of solitary bees of 31 genera are indicated in Polissia (Osychnyuk, 1961 a), and 265 species of 44 genera in the Carpathians and Transcarpathia (Osychnyuk, 1961 b). For certain areas of this large region, the information on the bee fauna is found in the works of A. Z. Osychnyuk (1967 a, b; 1975) and the Polish apidologist Noskiewicz (Noskiewicz, 1937/1938). The information on the fauna of Colletidae and Andrenidae in Ukraine and some adjacent territories is given in the monographs of A. Z. Osychnyuk (1970, 1977).

A characteristic feature of most of the cited faunistic studies is the high proportion of surveys in natural habitats, despite the fact that these areas and regions are the zones of intensive industrial and agricultural development. Up to 70% of the area is made up of agricultural land. The rest is occupied by towns, villages, rivers, and forests. The area of sites with varying degrees of protection does not exceed 10-14%. This means that there are practically no natural, undisturbed habitats left. We can speak of natural biotopes only if we consider territories of natural reserves. In fact, the fauna of natural biotopes accounts for a much larger number of publications than that of transformed ones, and it is not possible to compare the richness of the fauna of natural and secondary cenoses. The exception is the ecological and faunistic works of Yu. A. Pesenko (1971; 1972; 1975; 1978) for the Lower Don region, considering the area of the surveyed biotopes.

In addition to the information on the species composition, many listed works provide data on phenology, daily and seasonal dynamics, fodder crops, nesting biology, and parasites. Phenology most fully elucidates such issues as the last dates of flight of solitary bee species, and for many species, the bivoltine cycle has been known.

Ecological and faunistic characteristics of the solitary bees in the study area

Fauna and assemblages of solitary bees

During the collection period in the studied area of the north-east of Ukraine and two adjacent regions of Russia, as well as on the basis of publications, we provide a list of 360 solitary bee species belonging to 53 genera of 6 families. The genus and species richness of the families is shown in Table 1.

Table 1

Species composition of solitary bees in the study area

Family	Number of genera	Number of species	The proportion of species in the fauna, %
Colletidae	2	28	7.8
Andrenidae	5	75	20.8
Halictidae	9	91	25.3
Melittidae	3	11	3.1
Megachilidae	16	71	19.7
Apidae	18	84	23.3
Total	53	360	100

The largest number of species is represented by the Halictidae family – 91 species, 25.3% of the fauna. A slightly smaller number of species was registered in the Apidae family – 84 species (23.3%) and the Andrenidae – 75 species (20.8%). In general, the representatives of these three families make up 69.4% of the bee fauna in the region. A similar proportion is observed as for the bees in the south-east of Ukraine (Radchenko, 1982) and the Lower Don region (Pesenko, 1973 b).

Of the 360 bee species listed, 54 species were not present in our collection but were recorded in the literature sources (see above): Colletidae – 3 species, Andrenidae – 3 species, Halictidae – 11 species, Megachilidae – 20 species, and Apidae – 15 species.

On average, this is 15% of the total list. For the first time in the region, we recorded 103 species of solitary bees: Colletidae – 9 species of 2 genera; Andrenidae – 19 species of 1 genus; Halictidae – 33 species of 2 genera; Melittidae – 3 species of 2 genera; Megachilidae – 12 species of 7 genera; Apidae – 25 species of 10 genera.

According to a five-point logarithmic abundance scale (Pesenko, 1982), the solitary bees presented in the collections are distributed into the following groups (Table 2). Only bees collected during the quantitative sampling were evaluated.As can be seen from Table 2, more than half of the species – 170 (57.8%), are found as singletons, represented by no more than 6 specimens in the collection. 71 species are relatively rare (24.4%), 45 species are regular (15.3%) and 8 species (*Andrena flavipes* Panzer, 1799, *A. dorsata* Kirby, 1802, *Lasioglossum malachurum* (Kirby, 1802), *L. pauxillum* (Schenck,1853), *L. calceatum* (Scopoli, 1763), *L. albipes*

(Fabricius, 1781), *Rophitoides canus* (Eversmann, 1852)) are frequent, accounting for 2.7% of the total number of species but more than half – 53.8% (8556 specimens) of the total number of bees collected. Among the frequent species, *Andrena flavipes* (1403 individuals) and *A. dorsata* (1337 individuals) are the most abundant. They represent 17.2% of the total number of bees.

Table 2

Classes of relative abundance of the solitary bees of the study area (15903 individuals of 294 species)

Point	Verbal description of relative abundance	Class interval	Number of species	Proportion of collected individuals, %
1	Single (rare)	1-6	170	57.8
2	Few (relatively rare)	7-47	71	24.2
3	Medium (regular)	48-340	45	15.3
4	Many (frequent)	341-2400	8	2.7
5	A lot (abundant)	> 2401	–	–
	TOTAL		294	100

Habitat distribution of bees

We analyzed the habitat preferences of solitary bees in the area in question based on a long-term quantitative assessment. We calculated bees on flowering mellittophilous vegetation without taking into account their nesting sites, which is accepted in the apidological studies (Pesenko, 1982).

In natural cenoses, we identified three main habitats that differ in the moisture degree and associated natural vegetation cover, the food base of the solitary bees:

1. Xerophytic “STEPPE” habitats – steppe areas of natural reserves, chalk, and steppe slopes.

2. Mesophytic “FOREST” habitats are forest edges and clearings.

3. Meso- and hygrophytic “FLOODPLAIN” habitats – floodplain areas.

Of the 294 bee species collected in quantitative samples, 204 species (69.4%) did not reveal a certain preference and were evenly distributed in all the named areas (Table 3).

The steppe areas are preferred by: *Colletes inexpectatus* Noskiewicz, 1936, *C. nasutus* Smith, 1853, *Hylaeus bisinuatus* Foerster, 1871, *H. clypearis* (Schenck, 1853), *H. brevicornis* Nylander, 1852, *Andrena anatolica* Alfken, 1935, *A. chrysopus* Pérez, 1902, *A. enslinella* Stoeckhert, 1924, *A. stoeckhertella* Pittioni, 1948, *A. transitoria* Morawitz, 1871, *Camptopoeum friesei* Mocsáry, 1894, *C. Frontalis* (Fabricius, 1804), Mocs., *Halictus patellatus* Morawitz, 1873, *Sphecodes schenkii* Hagens, 1882, *Nomioides minutissimus* (Rossi, 1790), *Dasypoda argentata* Panzer, 1809, *D. aurata* Rudow, 1881, *Lithurgus cornutus* (Fabricius, 1787), *Trachusa byssina* (Panzer, 1798), *Tr. interrupta* (Fabricius, 1781), *Icteranthidium laterale* (Latreille, 1809), *Megachile apicalis* Spinola, 1808, *Ammobates vinctus* Gerstaecker, 1869, *A. opacus* Popov, 1951, *Ammobatoides abdominalis* (Eeversmann, 1852), *Pasites maculatus* Jürine, 1807, *Tetraloniella graja* (Eversmann, 1852), *Tetraloniella scabiosae* (Mocsáry, 1881), *Eucera velutina* (Morawitz, 1874), *Amegilla ochroleuca* (Pérez, 1879), *Anthophora puescens* (Fabricius, 1781), *Anthophora bimaculata* (Panzer, 1798), *Thyreus scutellaris* (Fabricius, 1781), *Th. truncatus* (Pérez, 1883).

Table 3

Habitat preference of the families of solitary bee species

Family	Habitats			
	Steppe	Forest	Floodplain	Total
Colletidae	5 / 62.5 *	2 / 25.0	1 / 12.5	8 / 100
Andrenidae	7 / 25.0	8 / 28.6	13 / 46.4	28 / 100
Halictidae	4 / 25.0	11 / 68.8	1 / 6.2	16 / 100
Melittidae	2 / 33.3	3 / 50.0	1 / 16.7	6 / 100
Megachilidae	5 / 33.3	10 / 66.7	– / –	15 / 100
Apidae	13 / 76.4	2 / 11.8	2 / 11.8	17 / 100
TOTAL	36 / 40.0	36 / 40.0	18 / 20.0	90 / 100

Note: * – number of species/proportion in the fauna of the family, %

In the forest areas, we have found:

Colletes succinctus (Linnaeus, 1758), *Hylaeus annulatus* (Linnaeus, 1758), *Andrena aberrans* Eversmann, 1852, *A. lathyri* Alfken, 1899, *A. proxima* (Kirby, 1802), *A. rufizona* Imhoff, 1834, *A. simillima* Smith, 1851, *A. susterai* Alfken, 1914, *A. tarsata* Nylander, 1848, *A. wilkella* (Kirby, 1802), *Lasioglossum brevicorne Schenck, 1870*, *L. convexiusculus* (Schenck, 1853), *L. leucopus* (Kirby, 1802), *L. minutissimus* (Kirby, 1802), *L. nigripes* (Lepeletier, 1841), *L. pallens* (Brullé, 1832), *Halictus smaragdulus* Vachal, 1895, *H. setulellus* (Strand, 1909), *Dufourea minuta* Lepeletier, 1841, *D. inermis* (Nylander, 1848, *Ceylalictus variegatus* (Olivier, 1789, *Macropis fulvipes* (Fabricius, 1804., *M. europea* Warncke, 1973, *Melitta tricincta* Kirby, 1802, *Chelostoma distinctum*

(Stoeckhert, 1929), *Ch. florisomne* Linnaeus, 1758, *Ch. mocsaryi* Schletterer, 1889, *Ch. proximum* Schlettere, 1889, *Ch. ventrale* Schletterer, 1889, *Osmia leiana* (Kirby,1802), *O. niveata* (Fabricius, 1804), *O. cornuta* (Latreille, 1805), *Epeolus schumelli* Schilling, 1849, *Anthophora furcata* (Panzer, 1798).

The floodplain areas are characterized by *Colletes cunicularius* (Linnaeus, 1761), *Andrena apicata* Smith, 1847, *A. barbilabris* (Kirby, 1802), *A. caranthonica* Perez, 1902 *A. coitana* (Kirby, 1802), *A. fulvago* (Christ, 1791), *A. gelriae* v. d. Vecht, 1927, *A. helvola* (Linnaeus, 1758), *A. praecox* (Scopoli, 1763), *A. sericata* Imhoff, 1863, *A. vaga* Panzer, 1799, *A. varians* (Kirby, 1802), *A. ventralis* Imhoff, 1832, *Lasioglossum corvinum* (Morawitz, 1877), *Melitta nigricans* Alfken, 1905, *Tetraloniella salicariae* (Lepeletier, 1841), *T. fulvescens* (Giraud, 1863).

In the generalized data on the bees' habitat preference, the habitat-specific species in the steppe and forest areas are represented by 36 species each, accounting for 80% of the total number of species, which indicates a zonal (forest-steppe) nature of the fauna; 18 species (20%) prefer the floodplains, that is and intrazonal habitat.

The proportion of ecological groups (steppe/forest/floodplain) varies between families. The largest number of steppe species, more than half, is in the families Colletidae (62.5%) and Apidae (76.4%). The smallest number is in the families Andrenidae and Halictidae (25.0% each). More forest species are in the families Halictidae (68,8%) and Megachilidae (66.7%). The family Melittidae includes 50% of the forest species. Almost half of the species (46.4%) of Andrenidae prefer floodplain habitats. In general, the whole Andrenidae family is characterized by a preference for humid places, forests, and floodplains (75% of family members).

Trophic relationships

One of the main tasks of ecological and faunal studies of solitary bees is to recognize the features of trophic relationships of the bees in a given region. Using literature data, as well as personal data obtained during bee collection on the mellitophilous flowers, we analyzed the trophic relationships of solitary bees in various natural and agricultural habitats.

Of the six bee families collected in the study area, three included kleptoparasites. In the family Halictidae, we recorded one genus (*Sphecodes* Latr.) and 13 species. In the family Megachilidae, there are three genera and 14 species: *Stelis* Pz. – 6 species, *Dioxoides* Popov – 1 species, *Coelioxys* Latr. – 7 species.

Kleptoparasites of the family Apidae were represented in 9 genera: *Nomada* F. – 28 species, *Ammobates* Latr. – 2 species, *Pasites* Jur. – 1 species, *Ammobatoides* Rad. – 1 species, *Biastes* Pz. – 3 species, *Epeolus* Latr. – 4 species, *Triepeolus* Robertson – 1 species, *Melecta* Latr. – 2 species, *Thyreus* Pz. – 2 species.

Thus, 13 genera and 71 species (19.7% of the fauna) are kleptoparasites. More than half of these species (44.62%) belong to the family Apidae. Moreover, the genus *Nomada* in terms of the number of species (28) yields only such large genera of bees as *Andrena* and *Halictus.*

The periods of flight activity of kleptoparasites coincide with the flight activity of their hosts. Many of them (*Nomada* spp. and *Sphecodes* spp.) have two generations per season, like their hosts from the genera *Andrena* and *Halictus*. Most often we observed kleptoparasites near the nests of their hosts, especially near the complex multi-species nest aggregations. For example, in 1985, near the Village of Rogan, Kharkiv region, we saw 48 individuals of kleptoparasitic bees of the genera *Sphecodes, Nomada, Biastes,* and *Triepeolus* in a complex nest aggregation of their hosts *Andrena* (1 species), *Halictus* (3 species), *Systropha* (1 species), and *Tetralonia* (1 species) in one hour. In addition to the hosts' nest aggregation, the kleptoparasites occur on the mass flowering plants with a non-specialized flower and easily accessible nectar, such as Loesel's walker (*Sisymbrium loeselii* Linnaeus, 1755), Jacob's ragwort (*Senecio jacobaea* Linnaeus, 1753), and common milfoil (*Achillea millefolium* Linnaeus, 1753). The exception is *E. schummeli*, whose specimens were collected only on the food plant of its host (*Colletes nasutus*) – the common bugloss (*Anchusa officinalis* Linnaeus, 1753), a flower with a long corolla and hard-to-reach nectary.

Following the terminology proposed by Robertson (925, 1928), the pollinating bees are divided into groups according to the nature of their trophic relationship with the flowering plants:

1. Polylectic bees collect pollen from plants of many families.
2. Wide oligolectic bees collect pollen from plants of the same family.
3. Narrow oligolectic bees collect pollen from plants of related genera.
4. Monolectic bees collect pollen from plants of one species (genus).

The distribution of pollinating bees in the study area by the trophic group was as follows (Table 4).

Oligolectic bees, divided into separate groups by Robertson, we combined into one general group – oligolectic bees. It includes 93 species. Of these, we found 14 species only on one plant species, that is, they behaved like typical monolectics: *C. nasutus on A. officinalis; C. succinctus* (Linnaeus, 1758) on *Calluna vulgaris* (L.) Hull, 1808*; Andrena aberrans* Eversmann, 1852 on *Chamaecitisus ruthenicus* (Fisch. Ex Wol.) Klask., 1958*; A. florea* Fabricius, 1793 on *Bryonia alba* Linnaeus, 1753, *A. hattorfiana* (Fabricius, 1775) on *Knautia arvensis* (Linnaeus, 1753) Coult, *Systropha curvicornis and S. planidens* on *Convolvulus arvensis* Linnaeus,1753, *Melitta nigricans* Alfken, 1905 and *T. salicariae* on *Lythrum salicaria* Linnaeus 1753, *M. fulvipes and M. europea on Lysimachia vulgaris* Linnaeus, 1753, *Hoplitis adunca* (Panzer, 1798) on *Echium vulgare* Linnaeus, 1753, *Tr. interrupta* and *Tetraloniella scabiosae* (Mocsary, 1881) on *Scabiosa ochroleuca* Linnaeus, 1753.

Table 4

Distribution of pollinating solitary bees by trophic groups

Family	Trophic groups				
	polylectic bees		oligolectic bees		Total
	number of species	% in the family	number of species	% in the family	number of species
Colletidae	20	71.4	8	28.6	28
Andrenidae	51	68.0	24	32.0	75
Halictidae	62	79.5	16	20.5	78
Melittidae	–	–	11	100.0	11
Medachilidae	39	68.4	18	31.6	57
Apidae	24	60.0	16	40.0	40
Total	196	67.8	93	32.2	289

Monolectic bees account for 4.8% of the total number of pollinating species. In general, as is already mentioned, the oligolectic bees of the different groups are represented by 93 species (32.2%), which is one-third of the fauna of the pollinating bees.

For comparison, the proportion of oligolectic bees in the fauna of the Lower Don region is 41.6% (Pesenko, 1974, 1975), which is almost half of the species. There is a clear tendency towards a decrease in the proportion of oligolectic bees in the bee community when moving to the north. Of the eight most numerous bee species in the region, only *Rophitoides canus* is widely oligolectic and associated with the pollination of plants of the legume family. The other seven species are polylectic bees, visiting plants of many families.

Phenology

Systematic quantitative calculations, as well as individual collections of solitary bees throughout the season over many years of the study, made it possible to analyze the phenology of different groups of bees. According to the flying activity period, all bees can be divided into five main groups:

a) spring
b) spring and summer
c) summer
d) late summer
e) flying all season (many of them are bivoltine).

In spring, the first bees were recorded from the willow flowers on the 3rd of April. Fourteen species begin their flight activity before 20 April. Of these, one species (*Colletes cunicularis)* belongs to the family Colletidae; eight species (*Andrena apicata, A. caranthonica,* Eversmann, 1852, *A. labiata* Fabricius, 1802, *A. precox, A. vaga, A. varians, and A. ventralis*) to Andrenidae; two species (*Lasioglossum griseolum* (Morawitz, 1872), *Sphecodes ferruginatus* Hagens, 1882) to Halictidae, and three species (*Anthophora plumipes* (Pallas, 1772), *A. aestivalis* (Panzer, 1801) and *Melecta albifrons* (Foerster, 1771)) to Apidae. Eight species out of 14 are the representatives of the family Andrenidae. The predominance of bees from this family among spring species is typical of many areas of the Palaearctic (Pesenko, 1972). Most spring species end their flight in early June.

The group of spring and summer species starts flying on 10 May and finishes in late June or early July. It includes 20 species of solitary bees from four families: *Andrena enslinella* Stochert, 1924, *A. haemorrhoa* (Fabricius, 1781), *A. humilis* , *A. labialis* (Kirby, 1802), *A. lathyri* Alfken, 1899, *A. truncatilabris* Morawitz, 1878, *Halictus xanthopus* (Kirby, 1802), *Osmia aurulenta* (Panzer, 1799), *O. cornuta*, *O.bicornis* (Linnaeus, 1758), *Eucera clypeata* Erichson, 1835, *E. interrupta* Bar, 1850, *E. longicornis* (Linnaeus, 1758), *A. retusa* (Linnaeus, 1758), *Melecta luctuosa* (Scopoli, 1770), *Xylocopa valga* Gerstaecker, 1872.

Summer species appear in mid-June and finish flying in late July – early August. This group includes 131 species of families: Colletidae – 14 species, Andrenidae – 17 species, Halictidae – 14 species, Melittidae – 11 species, Megachilidae – 45 species, Apidae – 30 species. In our conditions, all 11 species of the Melittidae family are summer species, and their flight period does not exceed one and a half months. Forty-five species out of 71 or 63.4% of the total species composition of the family Megachilidae belong to the summer group.

Late summer species begin their flight in mid-July and end in late August – early September. We include the following 17 species into this phenological group: four species of the family Andrenidae (*Andrena marginata, A. simillima* Smith, 1851*, A. rufizona* Imhoff, 1834*, Panurgus calcaratus* (Scopoli, 1763)); three species of the Halictidae (*Lasioglossum ageratum* (Kirby,1802)*, Sphecodes schenckii* Hagens, 1882*, Rophites hartmanni* Friese, 1902); three species the Megachilidae (*Icteranthidium laterale* (Latreille, 1809)*, Stelis punctulatissima* (Kirby, 1802)*, Megachile pilidens* Alfken, 1924); seven species of the Apidae (*Biastes emarginatus* (Schenck, 1853)*, B. truncatus* (Nylander, 1848)*, Epeolus variegatus* (Linnaeus, 1758)*, Amegilla ochroleuca* (Perez, 1879)*, Am. quadrifasciata* (Villers, 1789)*, Thyreus scutellaris* (Fabricius, 1781)*, Th. truncatus* (Perez, 1883)). Half of the species begin their flight in the second half of summer, they are kleptoparasites of the bees that have two generations per season or of late summer species.

It has been found that 88 species of solitary bees appear in spring and continue to fly until early autumn. Many of these have two generations per season. For the remaining 94 bee species on the list, flight periods have not been recognized.

Conclusions:

1. During our study, 360 solitary bee species belonging to 53 genera of 6 families were recorded from Northeastern Ukraine.

2. One hundred and three species were new to the regional fauna.

3. Eight species of the fauna were the most numerous: *Andrena flavipes, A. dorsata, A. ovatula, Lasioglossum malachurum, L. pauxillus, L. calceatum, L. albipes, Rophitoides canus*, while 170 species (57.8%) were found in singletons.

4. Most bee species (204 and 69.4% of the fauna) in the region were found in all habitats.

5. In terms of habitat distribution, an equal number of species (36 species and 40% of the fauna) prefer steppe or forest habitats, indicating a zonal character (forest-steppe) of the fauna.

6. 71 species (19.7%) of solitary bees in the region are kleptoparasites.

7. More than half of the bees (67.8%) are polylectic species visiting the flowers of plants of many families.

8. The group of midsummer flying bees is the most numerous – 131 species.

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SECTION 4. RESISTANCE OF PLANTS TO BIOTIC AND ABIOTIC FACTORS

MAJOR CUCUMBER DISEASES AND THE CROP IMMUNITY

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In Ukraine, cucumber (Cucumis sativus Linneus) annually occupies about 20 % of the total area of all vegetable crops sown in the open ground or 52.6 thousand hectares. The main reason that significantly reduces the quantitative and qualitative indicators of this vegetable crop's main valuable economic traits is the high incidence of commercial crops with diseases, especially downy mildew (Pseudoperonospora cubensis (Berk & M.A. Curtis) Rostovtsev). Since 1985 in Ukraine, this cucumber disease in the open ground on nonresistant varieties has continuously had intense development, in some years the development – by the type of epiphytotic. Simultaneously, the shortage of commercial yield of this vegetable crop due to the defeat of this disease under the field conditions can reach the level of 50–80 % or more, seed loss – 25–70 %. One of the main reasons for significant losses of commercial yield and seeds of gherkin cucumber under the conditions of its cultivation in the open ground is recognized as the high susceptibility of samples to some diseases, particularly downy mildew (Pseudoperonospora cubensis (Berk. & M.A. Curtis) Rostovtsev). Unfortunately, this problem has remained relevant for Ukraine over the past few decades. So, obtaining the initial material of a gherkin cucumber with a harmonious combination in the genotypes of a complex of various

valuable economic characteristics (yield, quality, resistance to diseases, chemical substances content, suitability for various types of processing) and creating a modern competitive, innovative product (variety, hybrid) on its basis remains a relevant and priority task for domestic agricultural science at present. At the same time, scientists have proved that introducing complex (integrated) systems into production, which expect the biologization of protection with its transfer to an ecological and economic basis, is recognized as the most promising today. We suggested using resistant varieties (hybrids) in such integrated systems that provide the highest economic effect.

Keywords: *cucumber, diseases, prevalence, harmfulness, phytopathological complex, immunity, signs of long-term stability*

Introduction

Cucumber (*Cucumis sativus* Linneus) belongs to the genus cucumber (Cucumis) of the pumpkin family (Cucurbitaceae Juss.). In the world, the area where this vegetable crop is grown annually occupies up to 9 million hectares (Sanwen Huang et al., 2009). In Ukraine, cucumber is also one of the main crops among vegetables, which is grown annually in both open and frame areas in various soil and climatic zones on areas of up to 50 thousand hectares (Bolotskih, 2002; Yarovij, 2006). When developing the cucumber classification, scientists considered the similarity of different samples by morphological traits, suitability for growing in specific climatic zones, and several other botanical (approbatory) traits (Sokolov, 2003).

Developed by A.I. Filov (Gorova & Yakovenko, 2001), the classification of this vegetable crop is divided into seven subspecies:

Wild-growing subspecies (*C. sativus* ssp. *agrestis* Gab.). Small leaves with sharply marked lobes, small fruits, incredibly green color, cylindrical, very bitter. It grows in the northern regions of India in a wild state.

Himalayan subspecies (*C. sativus* ssp. *himalaicus* Fil.), including Indian Bohairic and Himalayan hollow. They have tiny branched stems, small spherical fruits up to 5 cm in diameter. Plants are almost bush-shaped, early ripening, fruits turn yellow very quickly.

Indo-Japanese subspecies (*C. sativus* ssp. *indo-japonicus* Fil.), which was formed under conditions of tropical and subtropical climates. The plants are solid, dark green, the fruits are large, with small or medium tubercles and complicated pubescence, with black (Indian) or white (Japanese) spikes. Varieties of this subspecies, especially Japanese ones, demand breeding as carriers of a complex of resistance genes to the most common diseases.

Chinese subspecies (*C. sativus* ssp. *chinensis* Fil.). Plants are solid, with long runners and large leaves. The fruits are long, often curved, sickle-formed and serpentine. This subspecies is used in breeding when creating greenhouse varieties, early ripening and cold-resistant forms.

West-Asian subspecies (*C. sativus* ssp. *occidentaliasiaticus* Fil.), varieties of which have solid plants, large stems, small or medium-sized leaves. This ecotype is characterized by high adaptability to the continental climate conditions; plants combine heat and cold resistance in their genotype, fruits with thick skin can only be used in salads.

European-American subspecies (*C. sativus* ssp. *europaeo-americanus* Fil.). Plants of medium strength, with medium or small leaves. The fruits are small or medium-sized, with tubercles or rough. This subspecies includes most cucumber varieties grown in Ukraine and other regions of the world.

Hermaphrodite-flowered subspecies (*C. sativus* ssp. *hermafhroditus* Fil.), which is characterized by the formation of hermaphrodite flowers instead of female ones. The ovary is half-low, a turban is formed on the fruit. Pubescence is simple. Varieties of this subspecies are widely used in hybrid breeding.

According to the botanical description, cucumber is an annual herbaceous plant. The fruits of this vegetable crop are valued for their high taste, aroma, and various enzymes that promote digestion. They contain (in terms of 100 g of raw matter): sugar 1.5– 2.0 %, protein – about 1 %, vitamin C – 10–16 mg, vitamin PP – 0.2 mg, carotene – 0.1 mg. Cucumbers are superior to radishes in thiamine – red beet and common onion in terms of riboflavin content. Besides, cucumbers' iodine content is higher than that of potatoes, onions, and most other vegetable crops. Fruits are consumed in fresh, canned, and salted forms (Autko, 2004). Cucumber fruits' consumption improves appetite and the absorption of other foods due to the enzymes necessary for better absorption of B1 group vitamins. These alkaline salts reduce the acidity of gastric juice and are recommended for kidney and liver diseases. Cucumber juice is useful for rheumatic diseases, strengthens heart and blood vessels, has an antisclerotic effect, improves memory, and the high potassium content helps remove water from the human body, regulates and facilitates the work of the heart. Also, cucumber (juice) is widely used in cosmetology (Mamchur, 1988).

By weight, cucumber fruits are divided into tiny (weight less than 50 g), small (from 50 to 100 g), medium (101–200 g), large (201–400 g), and huge (over 400 g). The taste qualities of the fruit (good, medium, bad) depend not only on the chemical composition but also on the consistency of the pulp (crunching, semi-dense, dense, coarse), the thickness of the skin (thin, thick), the bitterness content in the fruit (strong, absent) and the specific aroma (strong, weak or absent). By the duration of the growing season, cucumber varieties and hybrids are divided into early ripening, which begins to bear fruit 32–48 days after sowing in the open ground (Gherkin type), medium early ripening (50–55 days), and late-ripening (56–70 days) (Blinova, 2005; Nalobova, 2005).

Due to the global climate changes, the cultivation of varieties and hybrids of gherkin cucumbers (early ripening) has become attractive in commercial vegetable growing in Ukraine. Their main advantages, in comparison with samples of the semi-late and medium ripening group, is the genetically controlled size of the Gherkin fruit – no more than 12 cm, the compact habitus of the plant (with short runners), the maximum commercial yield on irrigation –19–23 t/ha (with twice-repeated crop rotation), with drip irrigation – 45–50 t/ha (Avtorskie semena…., 2008).

We aimed to review the long-term resistance of gherkin to major diseases under different conditions and cultivation technologies, features of a phytopathological complex of gherkin, and gene complex (immunity) for resistance to major diseases.

Results

The theoretical and practical significance of protracted resistance trait of gherkin cucumber to the main diseases under various conditions and growing technologies.

Cropping capacity and quality of gherkin cucumbers strongly depend on the technology of its cultivation – varieties (hybrids) do not tolerate large doses of mineral fertilizers, need stable soil moisture supply, are severely damaged by pests and diseases, and significantly reduce productivity in case of late harvesting. Simultaneously, varieties and hybrids of gherkin-type cucumber over the past 7–10 years still took a leading position in the rating of domestic producers of fresh and processed vegetable production. Their main advantage is many ovaries and gherkins, small fruits-gherkins with high pickling qualities and high commercial cropping capacity (Avtorskie semena…., 2008).

One of the essential measures to increase the production of this vegetable crop is to increase its yield by breeding new highyielding varieties and hybrids, developing more advanced industrial cultivation technologies, one of the basic elements of which is a comprehensive system for protecting commercial crops from diseases, pests, and weeds (Alekseeva, 1984; Autko, 2004; Nalobova, 2008). Until 1985, the sowing area under cucumber in Ukraine was about 70 thousand hectares, but today, due to the substantial annual spread of downy mildew, they have decreased to 40 thousand hectares (Mihajlov, 1992; Litvinov, 2011). Under the conditions of the research region, downy mildew of cucumber acquired an epiphytotic character in 1989–1990, when only 2.07–2.36 t/ha of this crop was obtained from spring-summer film greenhouses in July, and summer commercial crops completely died from the disease (Chaban, 1993).

A sharp increase in losses of cucumber's commercial products due to losses from diseases became very relevant for many countries of the world during this period (Babadoost et al., 2004). As noted by G.I. Yarovyj, A.V. Kuleshov, and O.M. Batova (Yarovij et al., 2010), who analyzed the data of 1995–2005, downy mildew on cucumber under the conditions of the region of conducting research had a spread of 9–55 % (on average for years at the level of 27.8%) with the degree of plant damage of 2– 27 % (on average for years at the level of 14.5 %). Thus, in 1996, producers of commercial cucumber in the United States spent more than 120 million dollars on means for crops protection against downy mildew, which sharply reduced production profitability (Ojiambo, Paul & Holmes, 1997). Earlier, back in the 80–90 years, scientists from different regions of the world found that downy mildew and cucumber affect more than 70 different plant species of the genus *Cucumis*. The disease became widespread in central Europe on cucumbers in 1984, virtually destroying this crop's crops (Grinko & Zherdeckaya, 1991).

Spores of the pathogen showed a high ability to survive at relatively low soil temperatures in winter and active mycelium – the ability to be preserved in nature for quite a long time, which is established by systematic studies for many regions of the world (Efimov et al., 1978; Shetty, 2002; Rai, 2008). Up to 80 % of all cucumber crops in Ukraine were varieties of Nezhinsky local and Nezhinsky 12 of Nezhinsky variety type (Petrenko & Poznyak, 2007). The most distinct and precious consumer difference of varieties selected on the genetic basis of this variety type were very high pickling qualities and morphological and biometric traits of the commercial product: small (11-12 cm long) green fruit, thin, tender skin of green fruit, dense pulp with small cells, complicated black pubescence, thoughtful expression of ribs and furrows in young fruits, medium or small seed case, high taste qualities of processed products (Gorova & Yakovenko, 2001; Bolotskih, 2002). Despite significant breeding achievements, after 1985, the disease's global epiphytotic spread made cucumber cultivation in the former USSR unprofitable. Since this period that breeding work began in Ukraine, Belarus, Moldova, and other republics of the USSR to create varieties and hybrids of open ground cucumber of a new generation – primarily with protracted high resistance to the primary diseases, especially downy mildew, on the background of the maximum possible genetic improvement of several other valuable traits (Efimov et al., 1978; Prosalkova, 1994).

At the same time, breeders were faced with the task of combining as much as possible in the newly created varieties (hybrids) such characteristics as a friendly yield, a long period of fruiting (gherkins), high pickling fruits qualities, early ripening, resistance to the main diseases, in particular downy mildew (Gavrish, 2001).

Therefore, for further work with resistance trait to some diseases, particularly to downy mildew, samples of cucumber of Far Eastern selection were involved in the breeding process, where work was already carried out to create initial resistant forms of cucumber (Vitchenko & Meleshkina, 1991). This happened by introducing cucumber's genetic potential originating from Japan, China, Vietnam, and India resistant to downy mildew and other diseases into domestic breeding (Gorova & Yakovenko, 2001; Skripnik & Lopotun, 2003).

In cucumber breeding for resistance to the primary diseases, it was found out that the focus on creating varieties and hybrids of cucumbers only to improve the yield indicators and quality of gherkins significantly limits the choice of sources and donors of resistance to the main diseases. Without the introduction of a sufficient variety of small genes (gene complexes) into the newly created genotype, which makes it possible to control resistance to the main diseases under the field conditions as much as possible, breeding in this direction is ineffective or doomed to failure (Nalobova, 2005). As a summary, it was stated that such a limited number of cucumber samples resistant to this disease led to a high uniformity of mass crops in the former USSR, which contributed to the rapid and intensive development of some phytopathogens, in particular the causative agent of downy mildew in significant areas (Gorohovskij, 2002; Blinova, 2005; Nalobova, 2005).

As noted above, in Ukraine, downy mildew has been registered annually on commercial crops for many years. According to various literary sources, the shortage of yield ranges from 50 to 100 % in individual years (Sergiyenko, 2003). Thus, according to the State Plant Protection Inspectorate of the Ministry of Agrarian Policy and Food of Ukraine (Markov, 2010) in 2008, downy mildew on cucumber was recorded in June on more than a third of commercial crops. Only dry, hot weather in the second half of the growing season restrained its development in most areas where this vegetable crop is grown. At the same time, it was found that the most favorable weather conditions for the development and spread of downy mildew on cucumber crops annually develop in Transcarpathian, Zaporizhzhia, Dnipropetrovsk, Poltava, Kharkiv, and some other regions, where the damage rates of grown samples ranged from 42–100 % with a degree of damage from 10 to 45 %.

Considering the problematic ecological situation in Ukraine and the fact that cucumbers of Gherkin type are widely used in nutrition in a fresh form, the use of chemicals on this vegetable crop starts from the period of mass fruiting prohibited. This proves that breeding in the direction of creating resistant varieties is recognized today as the most radical means of globally protecting cucumber plants from diseases. However, we need to have information about the composition of natural populations of pathogens, their space, and time changes to successfully solve such breeding programs' problems. This process is long and should be constant, but production already needs real effective measures to regulate the prevalence of diseases and reduce cucumber yield losses from them (Bailey et al., 1992; Prosalkova, 1994; Skripnik, 2000; Adam, 2010).

Today, world and domestic producers of vegetable products solve this problem with integrated protection systems. They represent an ideal combination of biological, agrotechnical, breeding-genetic, chemical and organizational, and economic measures aimed at the most effective and ecologically justified neutralization of the negative effects of biotic stress factors of various origins on plants (Chaban et al., 2000; Autko, 2004; Bilik & Kulyeshov, (2006). In the 90s, the scientific community admitted that humanity needs to learn how to organically manage agroecosystems by in-depth knowledge of general and specific rules of their formation and functioning. First of all, it was found out that both factors of immunity and methods for determining the necessity and timeliness of applying protection measures of different origins play a leading role in ensuring the natural self-regulation of artificial plant coenosis.

Simultaneously, it is primarily recommended to make changes in the ratio of varieties by increasing the share of sustainable varieties' growth (Chulkina & Chulkina, 1995; Kirichenko & Petrenkova, 2012). All protection measures should be carried out taking into account regional long-term and short-term forecasts, which will allow developing environmentally-oriented protection systems for each region of growing of a particular product (Chumakov, 1973). This harmonious combination of the above factors makes it possible to stop the increase in the use of pesticides, which will slow down the growth of pesticide environmental pollution (Kartashov & Kazakova, 1988; Stancheva, 2005). At the same time, scientists have proved that introducing complex (integrated) systems into production, which expect the biologization of protection with its transfer to an ecological and economic basis, is recognized as the most promising today (Robaka, 2001). It is separately noted that it uses resistant varieties (hybrids) in such integrated systems that provide the highest economic effect (Wu, 1994).

Peculiarities of the formation of a phytopathological complex of a cucumber of Gherkin type and gene complexes (immunity) by the resistance to the main diseases

The analyzed literature sources allowed us to establish a general and zonal list of open-ground cucumber diseases in the research region and globally (Yarovij et al., 2010). We determined that diseases such as downy mildew, powdery mildew, fusarium wilt, angular bacterial spot disease, and anthracnose are always present on cucumbers under open ground in the above list conditions (Mihajlov, 1992; Nalobova, 2004; Litvinov et al., 2011). At the same time, we noted that the selection of varieties resistant to these diseases is impossible without a thorough study of the long-term and seasonal peculiarities of their pathogenesis, biology of the main pathogens, and the nature of the formation of trophic connections with the plant, analysis of the influence of weather conditions on the intensity of these processes (Nalobova, 19984 Maryutin et al., 2010).

For the first time and most fully, the composition of many cultivated plants diseases, including cucumber, on the European part of the former USSR in 1929 was described by A.A. Yachevsky (Yachevskij, 1929).

Analysis of domestic literature has shown that the most common and harmful diseases of cucumber in the open and frame area are downy mildew, powdery mildew, anthracnose, fusarium wilt, and angular bacterial spot disease (Bondarenko, 2011; Bondarenko, 2012; Bondarenko, & Solodovnik, 2012; Bondarenko, 2013; Bondarenko, Chernenko, & Sergienko, 2013; Chernenko et al., 2013, Chernenko, Sergienko & Bondarenko, 2014).

Downy mildew or peronosporosis of cucumbers (English – Downy Mildew of Cucurbits). This disease's causative agent is the fungal organism *Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovtsev. It belongs to the kingdom *Chromista* (fungal organisms), the division *Oomycota*, the class *Oomycetes*, the order *Peronosporales*, the family *Peronosporaceae*, and the genus *Pseudoperonospora* (Garibova & Lekomceva, 2005). In the international mycological literature, this disease's causative agent's basic name is *Pseudoperonospora cubensis* (Berk. & M.A. Curtis) Rostovzev (Garibova & Lekomceva, 2005). The international universal disease code is PCU (Zitter et al., 1996).

In addition to this name, in the scientific literature, this cucumber disease's causative agent for specific diagnostic symptoms has been described at various times under such names – *Peronospora cubensis* Berk. & M.A. Curtis, in Berkeley (1868), *Plasmopara cubensis* (Berk. & M.A. Curtis) Humphrey (1891), *Peronospora atra* Zimm. (1902), *Pseudoperonospora tweriensis* Rostovzev (1903), *Pseudoperonospora cubensis* var. *tweriensis* Rostovzev (1903), *Plasmopara cubensis* var. *tweriensis* (Rostovzev) Sacc. & D. Sacc.(1905), *Plasmopara cubensis* var. *atra* (Zimm.) Sacc. & D. Sacc. (1905), *Peronoplasmopara humuli* Miyabe & Takah. (1905), *Pseudoperonospora celtidis var. humuli* Davis (1910), *Plasmopara humuli* (Miyabe & Takah.) Sacc. (1912), *Pseudoperonospora humuli* (Miyabe & Takah.) G.W. Wilson (1914), *Peronospora humuli* (Miyabe & Takah.) Skalický.According to the type of nutrition, this pathogen belongs to typical classical biotrophic organisms (Brunelli & Dawi, 1987; Gorohovskij, 2005). For the first time, downy mildew on cucumber in the open ground was discovered in Central America in Cuba in 1868, later (1888) – in Japan, and later, in 1889 – in North America. At the beginning of the twentieth century, downy mildew was recorded on cucumbers throughout Europe and East Africa, Brazil, and the Java Peninsula (Naumov, 1931).

Today, downy mildew of cucumber (pumpkin crops) in the open ground is widespread on all continents and geographical zones of cultivation – in the countries of Western, Central and Eastern Europe, Asia, Africa, North America, the Far and Middle East (Yakubickaya et al., 1987; Skripnik & Lopotun, 2003). At one time, for the first time, the mass defeat of cucumber crops by downy mildew, except for Ukraine and the former republics of the USSR, was simultaneously observed in significant, radically different soil and climatic conditions in different European countries (Czechoslovakia (Laser et al., 1988); Germany (Mende & Krumdein, 1986), Italy (Brunelli & Dawi, 1987), Hungary (Summer & Rhafar, 1987), Austria (Bedlan, 1986), Sweden (Forsberg, 1986), Switzerland (Varady & Ducort, 1985) and Greece (Jeorgopoulos & Skylakakis, 1986). According to literary reports, this disease mainly affects cucumber plants, melon, less often – watermelon, vegetable marrow, and other pumpkins. First, symptoms of downy mildew appear on cotyledon or real leaves. When plants in the field are affected, round or angular spots are formed on real cucumber leaves and quickly increase in size. With the angular shape of the spots, the disease is often mistaken for bacteriosis. In wet weather, spots on the leaf's underside are covered with a grey-purple coating of sporulation of the pathogen. Gradually, the spots increase in size and subsequently cover the entire leaf blade. Such leaves quickly turn brown, dry up and crumble (Kupalova & Bolotskih, 1989).

The harmfulness of this disease in the open ground is very high – within a few days, especially in the presence of favorable weather conditions for the pathogen's development, it can lead to the complete death of cucumber crops. In wet and relatively warm weather, the causative agent of the disease forms many zoospores that spread by air currents and in the presence of drip-liquid moisture on the surface of plants, within 4-6 hours (night dew, rain, fog, watering) germinate, damage and re-infect the plant (Skripnik & Lopotun, 2003; Nalobova, 2005; Walters et al., 2005).

Mathematical analysis of 10-year data under conditions of the region of conducting research revealed a negative connection between the amount of precipitation and the spread of the disease (B = -0.69) and the tendency to reduce its development. The result of these studies was the fact of establishing a significant negative effect of increasing air temperature (B = -1.57 and 2.59) and positive effect of air humidity (B = 0.68 and 2.07) on the dynamics of downy mildew development in agrocenoses (Yarovij, Kulyeshov & Batova, 2010). Different researchers associate the somewhat atypical dependence of this moisture-loving phytopathogen on the amount of precipitation with the nature of their falling out during the period when the disease develops rapidly. Light precipitation, downpours during the day, and high temperatures do not provide protracted moisture to plants, and, as a result, do not contribute to the spread of the disease (Zherdeckaya, 1990; Gorohovskij, 2002; Yarovij, Kulyeshov & Batova, 2010).

In contrast, it was found that excessive precipitation washes away the propagules of this phytopathogen from plants. So, for the development of downy mildew in cucumber agrocenosis, moderate precipitation, the presence of dew, air humidity of more than 70 % are favorable – because these factors ensure the preservation of moisture on plants for more than 4–5 hours, which is essential for activating and accelerating the pathological process. Other scientists also emphasize that the intensity of the spread and development of this disease is closely interrelated with hydrothermal conditions, in which the presence of drop moisture on the leaves is crucial.

The optimal air temperature for the fungus development is 18...22 °C (Zherdeckaya, 1990; Maryutin et al., 2010).

This phytopathogenic organism's development cycle in the natural environment is represented by endogenous mycelium and two types of spores: asexual (zoospores) and sexual (oospores). This pathogen's endogenous mycelium is branched, with eggshaped, pear-shaped haustoria, formed on cucumber plants throughout the growing season, causing their repeated reinfection. The type of lesion is passive. This phytopathogen is preserved during the inter-vegetation period: mycelium – in seeds, oospores – in infected plant remnants (Mihajlov, 1992; Garibova & Lekomceva, 2005). Asexual sporulation of the fungus – zoosporangiophores with zoosporangia (conidia), sexual – oospores. Zoosporangiophores are collected in bundles of 2–7 pieces, coming out through the torn cuticle with terminal branches extending at right angles. Zoosporangia are ellipsoidal, ovate, with a papillary tubercle at the apex, greyish or purple, sometimes brown, measuring 20–28 × 16–20 microns. Oospores are spherical, yellowish, 36–42 microns in diameter. Infection of plants occurs with the help of zoospores that come out of zoosporangia. Zoosporangia need drop moisture to germinate. Zoospores germinate by forming a tube through which this pathogen enters the plant through the stomata (Zitter, Hopkins, & Thomas, 1996). This phytopathogen forms several generations of conidial sporulation during the growing season, providing a high reproduction rate and rapid epiphytotic spread. At the same time, it is noted that the optimal temperature for germination of zoosporangia and oospores is 15 ... 20 °C (Dhillon et al., 1999). Some researchers also found that this disease is represented in field agrocenoses of cucumber by simple races or their combinative complex mixture in the world and Ukraine. However, research in this area has more general biological and evolutionary significance than practical or applied (Lebeda & Widrlechner, 2003; Mitchell et al., 2011; Cohen & Rubin, 2012). In the presence of drop moisture on the plants, the infection can pass within 2 hours. From the moment of penetration of the fungus into the host plant's tissues to the appearance of the first disease symptoms, an incubation period passes, depending on weather conditions and varietal characteristics, ranging from 3 to 13 days (Forsberg, 1986). Also, it was reported that losses from this disease directly depend on plant development stages: the earlier the infection process occurs, the higher the production loss (Markov, 2010).

The appearance of primary foci of downy mildew at the beginning of the flowering phase under local conditions most often led to plants' complete death in significant areas even before the first harvest of commercial products. Severely affected plants grew brown and dried up, and only the remains of leaf petioles were retained on the shoots. The absence of leaves delayed the setting and development of fruits, and fruits that managed to form to marketable sizes did not have a typical "cucumber" taste, became wilted, the color of their skin was pale green (Efimov, Sklyarevskaya & Olhovskaya, 1978; Timchenko & Mihajlov, 1989). Earlier, it was already noted that if weather and climatic conditions contribute to developing this disease, the commercial yield of commercial cucumber can decrease even by 80–100 % (Mihajlov, 1992). In Ukraine, due to the very strong (by the type of epiphytotic) nature of the development of this disease in 1985, the duration of the cucumber fruiting period was reduced to 1– 2 weeks, and in some places, the complete death of crops was recorded even before it began (Skripnik & Lopotun, 2003). This disease covers significant areas of crops and can cause mass death of plants as early as 8–10 days from the beginning of the pathological process, having an expression in severe damage to leaf apparatus, shedding of the ovary, yellowing, and partial or complete wilting of fruits (Alekseeva, 1984; Strajstar, 1991). So, first of all, the harmfulness of this disease is manifested in a significant decrease in the assimilation surface of the leaf apparatus. With a weak degree of damage, the amount of chlorophyll decreases to 53 %, with an average – to 42 %, with a strong – to 13.3 %. Simultaneously, irreversible changes occur in the plant's protein complex with a gradual decrease in the synthesis of protein nitrogen, monosaccharides, and its complete cessation of complex sugars synthesis (Granke & Hausbeck, 1995; Gorohovskij, 2005; Lindenthal, 2005).

From the literature sources, a complex of small (*minor*) genes that recessively control cucumber resistance to the disease is known: *dm* – (downy mildew resistance), *dm-1* (downy mildew resistance-1), *dm-2* (downy mildew resistance-2), *dm-3* (downy mildew resistance-3) (Gorbatenko, Holodnyak & Shvartau, 2011).

As scientists note, even today, the system of measures to protect cucumbers from downy mildew is very limited. The use of various methods, including crop rotations, fertilizers, and chemical and biological means of protection, to prevent limiting the spread of this disease is, unfortunately, ineffective (Zitter et al., 1996; Babadoost et al., 2004).

At the same time, it is necessary to consider that cucumber fruits (the main product of consumption) are used not only in processed form but also in fresh. Thus, the use of chemical means of plant protection in the critical, from a phytopathological point of view, a period of their development (fruiting period) is minimal (Efimov et al., 1978; Mihajlov, 1992; Colucci & Wehner, 2006; Celetti & Roddy, 2011).

The most effective method of protecting cucumber crops from downy mildew today is considered to be growing in field crop rotations an assortment of varieties and hybrids with protracted high resistance. At the same time, it is recognized that this type of resistance can reduce both the volume of use of chemical and biological protection products and the multiplicity of treatments for cucumber plants of Gherkin type, which will positively affect the increase in the profitability of commercial production of this vegetable crop (McGrath, 2001; Sergiyenko, 2003; Nalobova, 2005; Chaudhry et al., 2009). Some authors define such diseases as powdery mildew, angular bacterial spot disease, or bacteriosis, fusarium wilt, and anthracnose to the list of less common but annually potentially dangerous cucumber diseases when it is grown in the open ground of the designated region of Ukraine (Yurina, 1984; Yarovij, Kulyeshov & Batova, 2010). Cucumber powdery mildew (English – Powdery Mildew of Cucumber). The causative agent is the fungus *Erysiphe cichoracearum* DC. *f. cucurbitacearum* Poteb. It belongs to the class *Ascomycetes*, order *Erysiphales*, family *Erysiphaceae*, genus *Erysiphe* Link. The international universal disease code is Gc (ex Ec) (Zitter, Hopkins & Thomas, 1996).

The disease is widespread on cucumbers in protected and open ground in all regions of its cultivation. It also affects vegetable marrow, pumpkin, melon, and other pumpkin plants in all development phases, starting with cotyledon leaves. A sharp increase in infection 10–20 days after the appearance of the first symptoms of this disease significantly reduces the growing season of plants, which is accompanied by a noticeable shortage of general and commercial yield (Zitter et al., 1996; Babadoost et al., 2004).

The disease manifests itself in separate white powdery spots on the upper surface of the leaves and subsequently on the lower one. With a firm lesion, the leaves and stems are covered with a complete powdery coating – the mycelium of this fungus. The mycelium of the fungus forms haustoria, with the help of which it penetrates the plant cell. Conidiophores are formed on mycelium's hyphae, on the limbs of which chains of oval conidia are separated (Mihajlov, 1992; Sokolov, 2003). During the growing season of plants, the disease is spread by conidia. At the end of the growing season, small spots appear on the mycelium (powdery coating), first yellow, then brown – wintering fruit bodies of the fungus (cleistothecia). According to the description of cleistothecia *E. cichoracearum* f. *cucurbitacearum* – spherical, 80–150 microns in diameter with a simple or branched appendix apex. Bags of 5–15 pieces in cleistothecia size 58–90 × 30–50 microns, with a short leg. As a rule, the spores are ellipsoidal or rounded, measuring 20–30 × 10–20 microns, two per bag (Cohen, 1977; Zherdeckaya, 1990).

Spores that affect cucumbers in the current year's crop rotation germinate in late spring and summer from overwintered cleistothecia. Affected leaves and stems of plants quickly turn brown and dry out. The yield and quality of cucumber fruits are reduced very much (Wu, 1994; Lebeda & Urban, 2004). The development of the disease is promoted by sharp fluctuations in temperature and humidity and insufficient solar insolation of plants (Zitter, Hopkins & Thomas, 1996). At the same time, depending on the specific combinative combinations of weather and climatic factors, powdery mildew in agrocenoses of openground melons (cucumber, melon) acts as a direct antagonist of downy mildew, primarily due to various requirements for ecological factors that form the mechanisms of the harmfulness of these diseases (Wehner & Shetty, 1997). Conidia of the causative agent of this disease germinate best and infect plants at consistently high air humidity. The optimal temperature for plant damage by this pathogen is 16–20 °C. With an increase in temperature above 20 °C, the development of the disease is significantly inhibited. In some (cool and humid) years, powdery mildew can reduce the yield of cucumbers under open ground conditions by 30–45 % (Medany, Wadid & Abou Hadid, 1999). In the list of genes that control cucumber resistance to disease are noted the following: *pm-1* (powdery mildew resistance-1), *pm-2* (powdery mildew resistance-2), *pm-3* (powdery mildew resistance-3), and *pm-h* (*s*, *pm*) (powdery mildew resistance expressed by the hypocotyl) (Adam, 2010).

Today in the world and in Ukraine, there is an objective need to breed cucumber hybrids of open and especially frame areas with protracted complex resistance to diseases such as downy mildew (*Pseudoperonospora cubensis* Rostow) and powdery mildew (*Erysiphe cichoracearum* DC). This trait allows reducing the cost of growing them primarily by reducing the frequency of plant treatments with pesticides. Simultaneously, the created hybrids must be high-yielding and have high taste and technological qualities of fruits (Nalobova, 2008; Chistyakova, & Biryukova, 2012).

Fusarium wilt of cucumber (English – Rot of Cucumber; Wilt of Cucumber). The primary causative agent of the disease is a representative of fungi of the genus *Fusarium* (Schlechtend.: Fr.), namely the fungus *Fusarium oxysporum* (Schlechtend.:Fr.) f. sp. *cucumerinum* (Owen) Snyder & Hansen. This facultative parasite belongs to the division *Ascomycota*, subdivision Pezizomycotina, class Sordariomycetes, subclass Hypocreomycetidae, order Hypocreales, family Nectriaceae, genus *Fusarium* Link. The international universal disease code is FCU (Zitter et al., 1996). The pathogen affects cucumber plants in all stages of development. Infected seeds sown in the soil have low field germination. The hypocotyls of the affected sprouts rot, and they die even before coming out of the soil surface. The disease has a visual expression in two forms – directly wilting and rot of the root neck (Mihajlov, 1992). In the first form of disease symptoms, cotyledon leaves of the affected plant acquire a pale green color, lose turgor, wither and dry up within 2–3 days. In the second form of expression, root neck rot is most often observed in plants at excessive humidity and low soil temperature. With this course, the plant's root neck becomes thinner and rots, the stem becomes watery and translucent. In the future, such shoots break and fall (Yurina, 1984).

There are also two forms of damage in adult plants – direct wilting or growth inhibition (stunt, Gerlagh & Blok, 1988). In this case, adult plants wither in the same way as shoots. Often individual shoots of the plant wither. Sometimes the affected plants do not die, remain stunt, their internodes become short, and their leaves become small. Fruits from such plants are also small, or do not form, inedible (Egel & Martyn, 2007). The disease is spread through contaminated soil, plant remains, or seeds (Tkacheva, 2007).

Fusarium wilt causes especially great harm to cucumbers in frame area conditions with permanent cultivation (Gerlagh & Blok, 1988). One recessive gene (*Fcu*) has been identified in the cucumber genome, which controls resistance trait to races 1 and 2 of this pathogen in plants (Gorbatenko, Holodnyak & Shvartau, 2011). Considering that the cucumber crop in the frame area is the leading one, occupies significant areas and is often grown in a permanent crop, many pathogens accumulate in the soil, which inhibit the growth and development of plants negatively affect yields. The use of pesticides in the frame area leads to their accumulation in the soil and commercial fruits. Therefore, the creation of high-yielding cucumber hybrids of frame area with resistance to this disease is one of the world's essential modern tasks and domestic breeding (Yurina, 1984; Madamkin et al., 2010).

Bacteriosis, or angular bacterial spot disease of cucumber (English – Angular Leaf Spot of Cucumber). Pathogens – the bacterium *Pseudomonas syringae* pv. *lachrymans* (Smith & Bryan) Young Dye & Wilkie (синоніми – *Bacterium lachrymans* E.F. Smith and Bryan, *Bacillus lachrymans* (E.F Smith and Bryan) Holland, B. Burgeri Potebnia, *Phytomonas lachrymans*

(E.F Smith and Bryan) Bergey et al., *Pseudomonas lachrymans* (E.F Smith and Bryan) Carsner).It belongs to the section of Gram-negative aerobic bacilli and cocci of the class *Zymobacteria* of the order *Pseudomonadales* of the family *Pseudomonadaceae* of the genus *Pseudomonas* Migula. According to the type of nutrition – a typical facultative parasite (hemibiotroph). The international universal disease code is PSL (Zitter, Hopkins & Thomas, 1996). Bacterial spot disease is common in both open and frame area. Apart from cucumber, it can affect plants of melon. It appears on cotyledons (in light brown spots), leaves, stems, and fruits. On the leaves, oily angular spots first appear, limited by the small veins of the leaf. On the underside, when the air humidity is high, they are covered with yellowish droplets containing many bacteria. Later, the spots dry up, the tissue between the small veins falls out, the leaves become holey. With a firm lesion, the small veins themselves remain from the leaves. On the fruits, stems, and petioles of leaves, small watery spots first appear, which quickly increase in size and sink in the form of ulcers. Bacteria overwinter on plant remains in the soil (Agrios, 2005).

It is proved that the main infectious beginning from seed disease; its intensity is directly related to weather and climatic conditions. Usually, the first symptoms in the field are recorded from July to the end of the plants' growing season. During the growing season, bacteria are passively spread by wind, rain, irrigation water, and insects, in particular melon aphids, thrips, and spider mites, are the active vector of distribution (Kritzman & Zutra, 1983). Dry and hot weather can correct the intensity of its development and distribution in agrocenoses of open-ground cucumber (Bedlan, 1986; Rai, 2008).

One recessive psl (pl) gene has been identified in the cucumber genome, which monogenously controls the cucumber plant's resistance to angular bacterial spot disease (Bedlan, 1986; Rai, 2008). Thus, the analyzed literature sources have shown that the critical phase of this vegetable crop in the phytosanitary aspect is the phase of mass fruiting, when using chemical and biological plant protection products, without violating sanitary and hygienic standards, becomes extremely difficult. Cucumber is consumed fresh, usually unripe. Fruits are harvested every 2–4 days, while the minimum waiting time for most allowed using biological and chemical preparations ranges from 7 to 20 days (Sergiyenko, 2003).

As the main conclusion, we will note that taking into account global trends and trends in breeding theory and practice, the fundamental task for Ukrainian scientists today is to obtain initial material of cucumber resistant to downy mildew, including gherkin cucumbers, by working out schemes of immunological, statistical and hybrid analyses. This will allow selecting valuable resistant initial parental material (genotypes) for varietal and heterotic breeding, harmoniously combining a complex of valuable approbatory and economic characteristics, and effectively using it in the breeding process.

Conclusions

Due to the global climate changes, the cultivation of varieties and hybrids of gherkin-type cucumbers (early ripening) has become attractive in commercial vegetable growing in Ukraine. The main advantage of which, in comparison with samples of the semi-late and medium ripening group, is the genetically controlled size of the Gherkin fruit – no more than 12 cm, the compact habitus of the plant (with short runners), the maximum commercial yield on irrigation –19–23 t/ha (with twice-repeated crop rotation), with drip irrigation – 45–50 t/ha

At the same time, scientists have proved that introducing complex (integrated) systems into production, which expect the biologization of protection with its transfer to an ecological and economic basis, is recognized as the most promising today. We suggested that it is the use of resistant varieties (hybrids) in such integrated systems that provides the highest economic effect. The analyzed literature sources allowed us to establish a general and zonal list of the most common diseases of open-ground cucumber both in the research region and worldwide. We determined that diseases such as downy mildew, powdery mildew, fusarium wilt, angular bacterial spot disease, and anthracnose are always present on cucumbers under open ground conditions. Today, downy mildew of cucumber (pumpkin crops) in the open ground is widespread on all continents and geographical zones of cultivation – in Western, Central and Eastern Europe, Asia, Africa, North America, the Far, and the Middle East.

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GENETIC RESISTANCE OF POTATO VARIETIES TO BLACK LEG AND WET ROT

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Formulation of the problem. In recent years, pathogens of bacterial origin, which cause plant diseases during the growing season and rotting of tubers during storage, pose a great danger to the potato growing industry in Ukraine [5]. The development of rots is especially intensified by the mass use of mechanization in growing potatoes, which causes mechanical damage to the tubers and the subsequent development of rots on them [1].

It has been proven that when the host plant interacts with the pathogen, complex physiological and biochemical processes take place in the individual organs of the potato with a significant content of carbohydrates and water, which lead to wilting of the stems and rotting of the tubers [4].

As a result of evolutionary variability and adaptation of pathogens to the host plant in different conditions, new species and strains of harmful microorganisms appear, which greatly complicates their control when assessing resistance in agrocenoses.

Research materials and methods. Evaluation of the initial and breeding material of potatoes for resistance against wet rot and black leg was carried out by methods of infection of tubers cut from tuber patches and stems.

Wet rot and black tuber stem are caused by Pect bacteria. carotovorum subsp. carotovorum and Pect. carotovorum subsp. atrosepticum.

With the method of infecting whole tubers, the stability of potato samples was evaluated in the autumn-winter period. Before infection, the tubers of each sample were warmed up for 3–5 days at a temperature of 18–20 oC, and then the stolon part of each tuber was injected with a syringe with a modified needle to a depth of 15 mm, 0.2 mm of bacterial suspension at a bacterial concentration of 106 conidia/mm [2] . Infected tubers of each sample were placed in a polyethylene bag lined from the middle with moistened filter paper (to create a humidity close to 100% and kept for 5 days in an incubation chamber at a temperature of 22–25 °C, after which the degree of damage to the tubers of each sample by wet rot and resistance to it on a 9-point scale, where score 1 is the maximum degree of damage, and score 9 is the minimum (Table 1).

Table 1

Scoring scale for damage to tubers by wet rot

№	Affected tubers in the sample, %	Rating scale in points (9 points)	Degree of stability
1	0–10,0	9	relatively stable
2	10,1–20,0	7	moderately stable
3	20,1–40,0	5	slightly susceptible to damage
4	40,1–60,0	3	prone to damage
5	60,0	1	very susceptible to damage

In the method of infection of the patches removed from the tubers, 4–5 medium-sized tubers were taken from each variety sample, washed with water and cut into 20 patches up to 1 cm thick and the diameter of the whole tuber, which were laid out on a 25x35 cm glass lined with moistened filter paper. Patches were infected by injecting 0.1 mm of bacterial suspension with a concentration of 106 into the middle of each of them with a medical syringe [3].

Such 2–3 glasses with infected plasters of the samples were stacked one on top of the other and glass without plasters was placed on top, lining the upper and middle glasses from below with moistened filter paper and placing wooden cubes 1.5x1.5x1.5 cm in size between them on the edges [6]. These put together glasses with plasters of infected varieties were placed in a polyethylene bag and kept for 2 days in an incubation chamber at a temperature of 22–25 oC, after which the degree of damage to the plasters was assessed according to the scale (Table 2).

Table 2

Scale for assessing the degree of damage by wet rot of patches removed from potato tubers and the resistance of samples to it

№	Lesions of tubers in the sample, %	Rating scale in points (9 points)	Degree of resistance
1	0–10,0	9	relatively stable
2	10,1–20,0	7	moderately stable
3	20,1–40,0	5	slightly susceptible to damage
4	40,1–60,0	3	prone to damage
5	60,0	1	very susceptible to damage

With the method of infecting stems with black leg, the assessment of potato varieties for resistance against black leg was carried out when the plants reached a height of 18–20 cm, but no later than the budding phase. During this period, they are most prone to damage by pathogens of soft rot [7]. Each sample was cut off 5 stems, which were infected by injecting 0.1 ml of a bacterial suspension of virulent strains of Pect pathogens into them with a medical syringe at a height of 5 cm from the cut. carotovorum subsp. carotovorum and Pect. carotovorum subsp. atrosepticum at a concentration of 106, and sterile water was injected into the control stems and placed in cellophane bags lined from the inside with moistened filter paper [5]. Three days later, on the fourth day, the degree of damage to the stems of each sample by blackleg was assessed on a 9-point scale, where score 1 is the maximum damage to the stems, and score 9 is the minimum.

Research results. Starting the selection of potatoes for resistance against wet rot, we first of all set ourselves the task of finding out the possibility of obtaining resistant forms by means of various types of crossing high-yielding varieties with forms resistant to this pathogen.

For this purpose, during 2011–2014, we conducted testing and assessment of resistance against wet rot among 230 variety samples of potatoes of various origins and obtained hybrid crossings.

Testing and evaluation was carried out by the laboratory method, infecting whole tubers with virulent strains of Pect pathogens. carotovorum subsp. carotovorum and Pect. carotovorum subsp. atrosepticum with a medical syringe and keeping them in an incubation chamber. The damage was recorded and the resistance against it was assessed on a nine-point scale (point 1 – the maximum degree of damage with low resistance, point 9 – minimum damage with a high degree of resistance). At least 100 genotypes were analyzed for resistance to wet rot from the generation of each crossing combination.

Our research has established that relatively resistant hybrids can be obtained only when parental forms with a high level of resistance are involved in hybridization. The resistance of the hybrid generation against wet rot increased only when both parental forms were resistant to it (Table 3).

Table 3

Resistance of the hybrid generation against wet rot depending on the resistance of the parental forms (2011–2014)

Hybrid generation number	Parent form	The degree of resistance against wet rot in points (on a 9-point scale)				d
		parental forms		of the hybrid generation		
		♀	♂	average resistance score with	a resistance of 7 points	
77.602	Serpanok x Slov’yanka	7	7	5,7 ± 0,07	35	0
77.588	Serpanok x 40-4c/72	7	3	5,0 ± 0,08	15	0,7 ± 0,13
77.604	Serpanok x Teteriv	7	2	4,7 ± 0,6	11	1,0 ± 0,15
77.624	Teteriv x 40-4c/72	7	3	2,6 ± 0,10	0	3,1 ± 0,12

Thus, when crossing two relatively resistant to wet rot potato varieties, Serpanok and Slovianka, the degree of resistance to artificial infection with the pathogen is 7 points, the hybrid generation had an average resistance of 5.7 points, including 35% of hybrids had resistance of 7 points.

When crossing the relatively resistant Serpanok variety with the unstable hybrid 40-4s/72, the average resistance of the hybrid generation against wet rot was 5.7 points, and only 11% of the hybrids had resistance to it of 7 points.

When crossing two unstable parental forms - the Teteriv variety and the hybrid 40-4s/72, the average resistance of the hybrid generation when artificially infected with it was 2.6 points, and it completely lacked forms with a relative resistance to wet bacterial rot of 7 points.

As a result of the use of relatively resistant parent forms in the selection process, we bred new potato varieties characterized by significant resistance to wet rot - Borodyanska rozhova, Ukrainian rozhova, Kyiv Dawn, Lugovskaya with 6-7 points of resistance, while resistant standards had average resistance 6.5 points.

In our research, we also studied the degree of resistance to wet rot of regenerative plants obtained in vitro from potato protoplasts and anthers, and selected from them forms relatively resistant to this disease. From 2011 to 2014, we tested 122 regenerants for resistance to wet rot and identified among them forms with a higher degree of resistance to damage by wet rot than the original forms (Table 4).

Table 4

Resistance to wet rot of regenerated plants from potato protoplasts and anthers in comparison with the degree of resistance of the original forms (2011–2014)

Varieties from which regenerants were obtained	Number of regenerants plants	The degree of resistance to wet rot in points on a 9-point scale			Coefficient of variation	Dispersion
		original forms	regenerative plants: average resilience score	regenerative plants: % of plants with resistance of 7 points		
Slov'yanka	48	5-6	5,6 ± 0,15	64,5	14,7	0,81
Serpanok	23	6-7	4,3 ± 0,23	17,4	31,9	1,40

The selection of regenerants resistant to wet rot from protoplasts and anthers of the Slovianka variety was particularly effective. With 5–6 points of resistance of this variety to wet rot, the number of regenerants obtained from it with a resistance of 7 points was 64.5% of the total number. And the Serpanok variety, although it had the same and even slightly higher resistance to wet rot (6-7 points), but only 17.4% of the regenerants obtained from it had 7 points of resistance to wet rot.

All this should be taken into account in further work on cell selection for resistance against pathogens of various pathological origins.

Conclusions

1. The resistance of the hybrid generation against wet rot increases if both parental forms are resistant to this disease. If one of them is unstable, then there are few stable hybrids in their generation, and when two unstable parental forms are used in the hybrid generation, stable genotypes are completely absent.

2. With the help of cell selection, regenerating plants were obtained, which are characterized, along with economic and valuable traits, by significant resistance to wet rot.

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