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ORIGINAL ARTICLE

Adventitious leaf miner *Parectopa robiniella* Clemens, 1863 and *Phyllonorycter robiniella* Clemens, 1859 on a black locust tree in the Kharkiv region

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The locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863) is a native species of North America and, in the 80s, it spread to Italy, Slovenia, Croatia, Austria, Slovakia, Romania, Hungary, and Ukraine. Black locust leaf miner (*Phyllonorycter robiniella* (Clemens, 1859)) is also of North American origin. In 1983, the black locust leaf miner was discovered in Switzerland, in 1988 in France, Germany, Italy, in 1990 in Austria, in 1992-in Slovakia, in 1994 in Slovenia, in 1996-in Hungary, 1999 in the Netherlands, in 2003-in Bulgaria. Currently, both types of locust leaf miners are distributed in 19 European countries. In Ukraine, these species appeared relatively recently and are not sufficiently studied. We have studied some bioecological peculiarities of the locust digitate leaf miner and black locust leaf miner under conditions of Kharkiv region: the density of mines of the black locust leaf miner population, pieces/leaf, the dynamics of flight, population of black locust leaves.

Keywords: Leaf mining insects, locust digitate leaf miner, black locust leaf miner, black locust, biological peculiarities, harmfulness, deciduous trees, lime tree, green plantations.

Introduction

The black locust (*Robinia pseudoacacia* L.) was introduced to Europe at the beginning of the XVII century as an ornamental type, and to Ukraine it was brought by V.N. Karazin at the end of the XVIII century. It is still considered an exotic species in Europe, although in some countries, particularly in Romania and Hungary, it has become an essential landscape element (Csóka, 2003; Rice, Westerman, & Federici, 2004). This type is used to protect the land from erosion and rehabilitate degraded areas, forest zones, hedges, and wood-in construction, furniture production, and parquet (Fodor & Hâruţa, 2009). It is proved (Rice, Westerman & Federici, 2004) that black locust, due to its symbiosis with nodule bacteria, enriches the soil of forest ecosystems with nitrogen, which is favorable for developing oak-pine forests. About 30 years ago, black locust leaf miner moths spread in Europe, which became dangerous to this plant in many countries (Wojciechowicz-ytko & Jankowska, 2004).

The locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863) is a native species of North America and, in the 80s, it spread to Italy, Slovenia, Croatia, Austria, Slovakia, Romania, Hungary, and Ukraine (Melika et al., 2006). The black locust leaf miner *Phyllonorycter robiniella* (Clemens, 1859) is also of North American origin. In 1983, the black locust leaf miner was discovered in Switzerland, in 1988 in France, Germany, Italy, in 1990 in Austria, in 1992-in Slovakia, in 1994 in Slovenia, in 1996-in Hungary, 1999 in Netherlands, in 2003-in Bulgaria (Csóka, 2003; Wojciechowicz-ytko & Jankowska, 2004). Currently, both types of locust leaf miners are distributed in 19 European countries. In Ukraine, these species appeared relatively recently and are not sufficiently studied. In the south of Hungary, the locust digitate leaf miner appeared in 1983 and spread throughout the country after 6-8 years. Due to damage to the leaves of black locusts by this insect, they fall off at the end of June (Melika et al., 2006). The locust digitate leaf miner has 2-3 generations per year, which can overlap each other. This insect feeds only on representatives of the genus *Robinia* (Antyuhova, 2010). Females of the locust digitate leaf miner lay eggs on the underside on the first-order's lateral rib at a distance of 0.3-1.0 cm from the central rib. Mines of irregular shape, with branches, include the primary rib. There is always one green larva in the mine.

After hatching, the caterpillars bite into the leaf from the underside. Larvae make a passage along the lateral rib to the central rib and then form a triangular cavity for excrement between the leaf ribs. After that, they gnaw through a small hole in the corner between the ribs on the upper side of the leaf and form a branched mine on both sides of the main rib. The mine on the bottom has a hole near the primary rib. Before pupation, the caterpillar leaves excrement near the upper side of the mine, and it spills out through a hole on the lower side. Because of this, the larvae of the last age leave the mines and pupate in the leaf litter (Csóka & Hirka, 2011) (Fig. 1, Fig. 2, Fig. 3, Fig. 4).

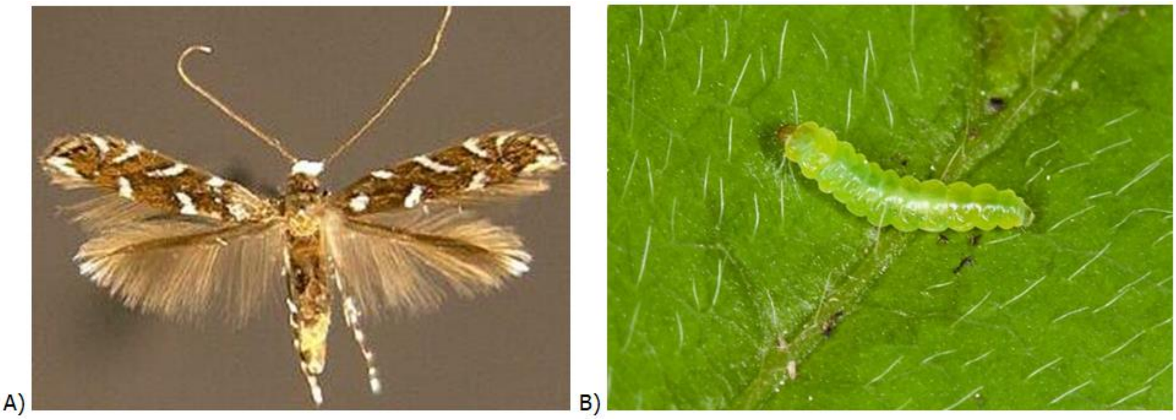

Fig. 1. Butterfly (A) and caterpillar (B) of the locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863).

Fig. 2. Mines of the locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863).

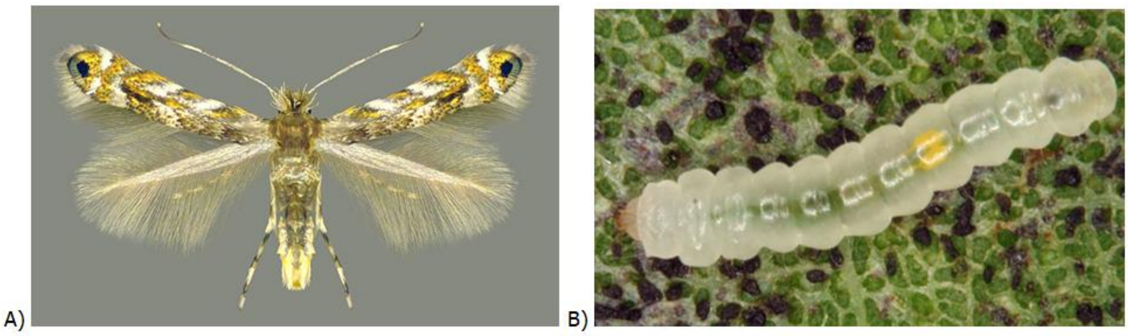

Fig. 3. Butterfly (A) and caterpillar (B) of the black locust leaf miner (*Phyllonorycter robiniella* (Clemens, 1859)).

Fig. 4. Mines of the black locust leaf miner (*Phyllonorycter robiniella* (Clemens, 1859)).

Caterpillars of locust digitate leaf miners of different ages can form new mines after leaving the primary mine. This does not form a cavity for excrement. Primary mines always grow from the base of the leaf base to its top, and secondary mines are often directed in the opposite direction. In the leaf development process, the caterpillars of the locust digitate leaf miner go through 5 ages.

Prepupa is formed in a cocoon in places of pupation (Ivinskis & Rimsaite, 2008). At the beginning of the growing season, the locust digitate leaf miner mines are found in the lower parts of the crown and in subsequent generations in the middle of the crown in the middle parts of the branches (Sefrova, 2002).

Another species, the black locust leaf miner (*Phyllonorycter robiniella*), can also develop in 2-3 generations, which overlap between June and October. Depending on the environmental conditions, butterflies start flying from late April to mid-May, after the first leaves appear on black locust trees. The lay of eggs by females of the first generation occurs during the black locust flowering period of black locust (the second half of May) and lasts until mid-June. Females lay their eggs on the lower surface of the leaf blade. The egg develops from 6 to 10 days, depending on the ambient temperature (Csóka, 2003). The caterpillar develops in 5 ages: in I-III, the larva feeds only on the spongy leaf parenchyma, and in IV and V-also columnar. After hatching, the caterpillars bite into the leaf from the underside. Initially, the caterpillar forms a narrow passage with a central line of excrement under the leaf epidermis on the underside; during the development of caterpillars of the II and III ages, it resembles a white spot. From the IV age, the larva tightens the leaf. During the development of V-age individuals, the mine is visible from the upper side of the leaf, and excrement is collected in the center of the mine. Mines do not cross the central rib. Caterpillar development is uneven and lasts 20 to 50 days, depending on ambient temperature. The black locust leaf miner mines appear a little earlier than the locust digitate leaf miner mines, but in both cases, the leaves of the intensively populated branches may fall prematurely at the end of June. There may be several mines on the same leaf, which often merge. Caterpillars of the last age pupate in mines in white oval cocoons. Butterflies fly out 7-10 days in summer and 10-20 days in autumn, depending on the temperature. Complete development of individuals lasts 5-11 weeks (Sefrova, 2002).

Materials and Methods

The study was carried out in parks and street plantations in Kharkiv (50º00' N, 36º15' E), in particular in Shevchenko Park (50º00' N, 36º14' E), Gorky Park (50º01' N, 36º14' E), Botanical Garden of V. N. Karazin KhNU (50º01' N, 36º13' E), street plantations on Pavlovo pole (Dzerzhinsk District of Kharkiv) (50º02' N, 36º13' E), Kharkiv Forest Park (50º03' N, 36º15' E) and in the Kharkiv region, in particular near V. V. Dokuchaiev Kharkiv National Agrarian University-in Veterans' Park and Dendrological Park of V. V. Dokuchaiev KhNAU (49º53' N, 36º27' E), in Danylivsky experimental state forest of Ukrainian Research Institute of Forestry and Forest Melioration named after H. M. Vysotsky (50º09' N, 36º31' E), in the village of Bereka, Pervomaisky district, Kharkiv region (49º28' N, 36º12' E). At the same time, several accounting points of accounting were laid in each plantation, which differed in environmental conditions.

The distribution and biological peculiarities of the leaf miner of locust digitate leaf miner, black locust, and leaf miner were studied on plants of black locust (*Robinia pseudoacacia* L.). The entomological object of the research was a pest of black locust-locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863) and the black locust leaf miner *Phyllonorycter robiniella* (Clemens, 1859).
The plantation survey was carried out according to generally accepted methods (Meshkova, 2006; Meshkova, 2009; Meshkova & Mikulina, 2010; Mikulina, 2011; Meshkova & Mikulina, 2012). The dates of the beginning of the phenological phenomena of the studied tree species were recorded by observations twice a week according to the method of MP. Sakharov (Sakharov, 1961). Once a week, from the beginning of leaf development to its falling (May-September), 100 leaves of the studying breeds were plucked at each accounting point, having been randomly selected randomly from different parts of the crowns, and placed in separate packages with labels. Tree and leaf sample volumes were determined on the results of preliminary statistical analysis. The population of trees by moth was defined as the proportion of populated leaves to the total number of leaves analyzed leaves as a percentage.

In model trees, in order to study the distribution of leaf miners settlements by layers, leaves were selected from the upper, middle, and lower layer of crowns-at a height of up to 2 m with pruning shears, from the middle and upper layers-with a knot cutter. In the areas where the planned cutting of trees of the studying species was carried out, a complete analysis of the distribution of leaf miners by the crown layers was carried out. The insects caught and collected were determined in the laboratory using a binocular microscope and determinants (Bednova & Belov, 1999; Zerova et al., 2010) and compared with samples from the collection of the Forest Protection Laboratory of the Ukrainian Research Institute of Forestry and Forest Melioration named after H. M. Vysotsky and the Kharkiv Entomological Society. To determine the species composition of caterpillars, moths were collected and stored in the laboratory in separate test tubes with labels (Melika et al., 2006). The age of leaf miners larvae was determined based on the length and appearance of mines, as well as the size of caterpillars (Sefrova, 2002).

Leaf miners moths were identified with the help of the senior researcher of the Museum of Nature of VN. Yu. A. Huhli, entomophages-with the help of the head of the Department of entomophagous taxonomy and ecological principals of biomethod of I.I. Schmalhausen Institute of Zoology of the National Academy of Sciences of Ukraine, A.V. Humovsky. The determination of individual species of the genus *Tilia* was carried out with the help of the head of the Department of dendrology V.I. Shatrovska (Botanical Garden of V.N. Karazin Kharkiv National University) and senior researcher T.V. Orlovska (Ukrainian Research Institute of Forestry and Forest Melioration named after H.M. Vysotsky).

During the cameral processing of the material, the number of mines, caterpillars, pupae, and exuviae of leaf miner on each leaf was determined. Taking into consideration that the damage by leaf miners up to 25% of the leaf surface is compensated by the tolerance of the host plant and has little effect on its productivity, and the damage over 75% of the surface is catastrophic for plants, we estimated the level of crown damage by a 4-point scale: 0 points-the area of the leaf is not damaged, 1-point the area of the damaged leaf from 0 to 25%, 2 points-from 25 to 50%, 3 points-from 50 to 75%, 4 points-the area of the damaged leaf exceeds 75% (Antyuhova, 2010).

Results

The black locust leaf miner and the locust digitate leaf miner feed only on members of the genus *Robinia* (Seljak, 1999) and have 2-3 generations per year, which can overlap each other (Seljak, 1999; Antyuhova, 2010). At the same time, locust leaf miners differ in phenology, some biological peculiarities, and the shape of the mines. The mines of the locust digitate leaf miner have an irregular shape, with branches, and always include the main vein. There is always one green caterpillar in the mine. Caterpillars of the last age leave mines and pupate in leaf litter (Fodor, 2009). The black locust leaf miner mines looked like white spots on the underside of the leaves and do not cross the main vein. There may be several mines on the same leaf, which often merge. Caterpillars of the last age pupate in mines in white oval cocoons (Sefrova, 2002; Wojciechowicz-Zytko & Jankowska, 2004; Fodor, 2009).

The locust digitate leaf miner dominates in Transdniestria (Antyuhova, 2010), while Romania is dominated by one or another type of leaf miner in some years (Fodor, 2009). In the same plantations, the first generation locust digitate leaf miner mines are found several weeks later than the black locust leaf miner mines (Ivinskis & Rimsaite, 2008; Antyuhova & Meshkova, 2011). Literature data on the phenology of locust leaf miners are mainly devoted to the locust digitate leaf miner (Csoka, 2003; Antyuhova, 2010), detailed data on the phenology of the black locust leaf miner are known only for the Czech Republic (Seljak, 1999), fragmentary for Poland (Wojciechowicz-Zytko & Jankowska, 2009), Slovenia (Seljak, 1999), Lithuania (ivinskis & rimsaite, 2008). In the Kharkiv region, locust leaf miners were discovered in 2007 and the black locust leaf miner dominated. Taking into account the importance of black locust in decorative and protective plantations in the green city zone, the lack of study of this pest in Ukraine, and the need to develop protective measures, we have conducted our research.

Black locust leaf miner (*Phyllonorycter robiniella* (Clemens, 1859))

When studying the peculiarities of the seasonal development of the black locust leaf miner on the black locust in the green plantations of Kharkiv, we took into account that the timing of insect development is usually consistent with the seasonal development of the feed plant, which is timed to the course of the temperature in the area and season (Meshkova, 2009; Beleckij, 2011). As we calculated (Mikulina, 2011), during our research period, 2010 was characterized by the largest amounts of positive, active and effective temperatures at thresholds of 5, 10, and 15°C. In terms of the sum of temperatures in the summer period (the period with temperatures through 15°C), the second place was occupied by 2011, the third by 2009 and the last-by 2008. The most stable temperature transition through 5°C and 10°C was in 2008 (March 15 and 10 April). At the same time, summer began most early in 2010 and 2011 (the dates of a stable transition of air temperature through 15°C-May 5 and 8, respectively), while in 2008 this phenomenon was registered only on May 24.

According to long-term data obtained by M.P. Sakharov in the 1950s of the last century (Sakharov, 1961), in Kharkiv region, buds of black locust began to swell on April 26, and open on April 30. The beginning of covering with leaves was registered in the 1950s of the last century on 10 May, and complete cover with leaves was on 26 May. According to our research, the first buds of black locust began to open in 2008, on April 20, in other years a little later, on April 23-26 (Table 1).

Table 1. Phenology of black locust (Kharkiv).

Index	Dates by Years				
	Saharov, 1961	**2008**	**2009**	**2010**	**2011**
Opening of the buds	30.04	20.04	26.04	25.04	23.04
The beginning of covering with leaves	10.05	7.05	4.05	3.05	5.05
Complete cover with leaves	26.05	26.05	22.05	21.05	24.05
The beginning of flowering	25.05	25.05	26.05	15.05	24.05
The end of flowering	6.06	14.06	16.06	2.06	12.06
The beginning of fruit and seed ripening	6.09	12.09	15.09	10.09	14.08
The end of fruit and seed ripening	25.09	1.10	30.08	25.09	24.09
The beginning of turning yellow of leaves	31.08	23.08	19.08	13.08	25.08
Complete turning yellow of leaves	11.10	22.10	21.10	17.10	15.10
The beginning of leaves falling	4.09	15.09	24.08	20.08	20.09
Complete leaves falling	29.10	25.10	5.11	29.10	20.10
Complete fruit falling down	21.10	22.10	2.11	27.10	23.10

In all years, this phenomenon occurred after a stable transition of air temperature through 10°C and was somewhat earlier than 50 years ago. We registered the beginning of cover with leaves of black locust in 2008 and 2009 on May 7 and 4, and in 2010 and 2011-on April 24 and 26, respectively. The complete cover of the black locust with leaves occurred in the third decade of May (Table 1). At the same time, even in one year, the terms of phenological phenomena differed in the areas of research. Complete cover of black locust with leaves according to M.P. Sakharov (Sakharov, 1961) and according to our data occurred in 2008, 2009 and 2011 in the third decade of May, while in 2010 a week earlier. This may be due to the higher temperature in May 2010 (17.7°C with a long-term average temperature of 15.3°C). The air temperature passed 15°C in 2010 on May 5, 2008 and 2009-on May 24 and 18, respectively, in 2011 and on May 8.

In the 1950s of the last century, the turning yellow of black locust leaves began on August 31, complete yellowing was recorded on October 11, and the falling leaves falling lasted from September 4 to October 29 (Sakharov, 1961). According to our research, in 2008-2011, black locust leaves yellowed was recorded already in the second decade of August, complete yellowing in the third decade of October, after the date of a stable transition of air temperature through 10°C down. The fall of leaves began in 2009 on August 24 and in 2010-on populated trees on August 16, which is associated with damage by locust leaf miners. Complete fall in leaves was registered in late October to early November.

The flowering of black locust during the years of research by M.P. Sakharov (Sakharov, 1961) occurred from May 25 to June 6, with fruit ripening-from September 6 to September 25. The beginning of flowering in the years of our research was registered in close terms, with the exception of 2010 (15 May), when a stable spring temperature transition through 15°C occurred at the earliest. In 2010 flowering ended 10-14 days earlier than in all the years of our research and 4 days earlier than according to M.P. Sakharov (Sakharov, 1961). In other years of our research, flowering ended on June 12-16. Fruit ripening was recorded in the third decade of September, after a stable air temperature transition from 15°C to below. The dates of black locust fruit falling in all the years of our research were very close to the dates of complete leaf fall (Table 1), although some of the fruit remains in the trees. The black locust leaf miner overwinters at the pupal stage in the litter. Butterflies that overwinter fly out from pupae after the black locust is fully covered with leaves. The first butterflies were discovered on 9-11 May 9-11 (Table 2), that is, during the leaf growth period. Therefore, most mines are located on leaves at the base of a compound black locust leaf, which coincides with O. V. Antyukhova data of (Antyuhova, 2010).

Table 2. Phenology of the black locust leaf miner *Phyllonorycter robiniella.*

Index	**Dates by years**			
	2008	**2009**	**2010**	**2011**
Imagoes of wintering generation	13.05	11.05	10.05	9.05
Eggs of I generation	25.05	23.05	15.05	14.05
Mines of I generation	8.06	5.06	24.05	8.06
Pupae of I generation	30.06	25.06	18.06	23.06
Imagoes of II generation	5.07	1.07	25.06	2.07
Eggs of II generation	7.07	4.07	28.06	3.07
Mines of II generation	16.07	14.07	8.07	14.07
Pupae of II generation	30.07	29.07	25.07	5.08
Imagoes of III generation	7.08	6.08	8.08	12.08
Eggs of III generation	7.08	10.08	8.08	14.08
Mines of III generation	13.08	20.08	10.08	20.08
Pupae of III generation	15.09	20.09	12.09	6.09

Due to the variety of microclimatic conditions in the overwintering grounds of pupae and the different rates of their warming, the flight of butterflies is stretched for two to three weeks. Butterflies lay their eggs on the lower surface of the leaves. Several eggs of the black locust leaf miner were counted on one leaf. In this case, the mines merged (Fig. 5). The first mines were detected 6-10 days after eggs lay, depending on the temperature. The first earliest mines were discovered in 2010-on May 24, and in other years-on June 5-8. The appearance of the first-generation mines coincided with the flowering of the black locust. The caterpillars chewed through narrow passages 2-3 mm long, in which excrement was placed in the center.

Fig. 5. Mines of the black locust leaf miner *Phyllonorycter robiniella.* (On the left-mines with larvae of I age, on the right-several mines with larvae of I-II ages on the leaf; July 2010, photo by the author).

Caterpillars, like most leaf miners (Gerasimov, 1952), went through 5 ages of development. During the same period with the increase in the age of the caterpillars, not only the size, but also the appearance of the mines changed. After molting at the II age, the mines began to flatten and by the end of development, the caterpillars of the III age resembled white spots. At ages I-III caterpillars damaged only the spongy parenchyma of the leaf, and beginning from IV age, they pulled the leaf together and gnawed out the palisade parenchyma in a shape of islands. During the development of individuals of V age, the mine was also visible on the upper side of the leaf, it occupied almost half of it but did not cross the main vein (Fig. 6).

Fig. 6. Mines of the black locust leaf miner *Phyllonorycter robiniella* (July 2010, photo by the author; left mine from the upper side of the leaf; right larva and pupa cocoon).

In the case of laying several eggs on a single leaf, the mines merged, starting with the appearance of II-age caterpillars. The caterpillars pupated in a thick, silky cocoon, which was clearly visible in the mine (Fig. 7). The first pupae of the first generation of black locust leaf miner were discovered by us at the earliest in 2010 (June 18), somewhat later in 2011 (June 23), and at the latest in 2009 and 2008 (June 25 and 30, respectively).

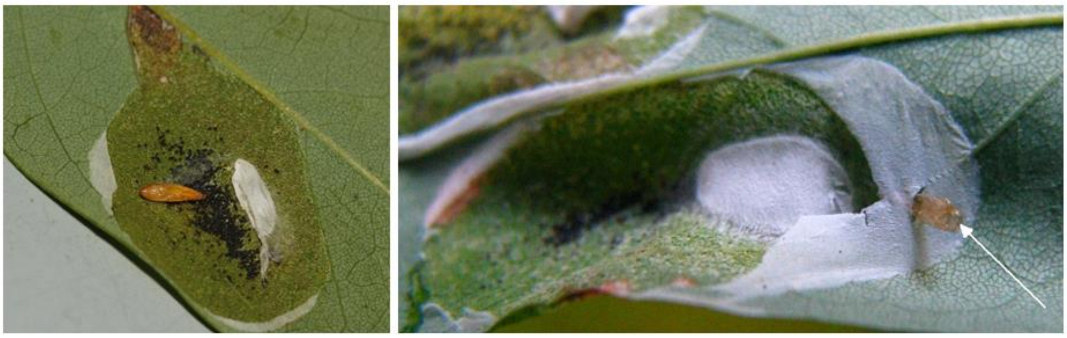

Fig. 7. Pupa (left) and exuvium (right) of the black locust leaf miner (July 2009, photo by the author).

Imagoes of the II generation flew out the most late in 2008 (July 5), the most early in 2010 (June 25). Almost in the same terms, the first eggs were discovered (Table 3). Mines of I-generation caterpillars were detected most early in 2010 (May 24), and in the remaining years-in early June.

Eggs of the second generation were detected on 28 June 28, 2010, and in the remaining years-in the first decade of July. The first mines of the second generation were registered in early July 2010 and in the middle of the same month for other years of research. Pupae of II generation were detected most late in 2011 (5 August), in the remaining years-in the third decade of July. Butterflies of were found III generation in all years were found in the first decade of August (Table 3). The first mines of III-generation caterpillars of the black locust leaf miner were discovered on August 10, 2010, August 13, 2008, August 20, 2009, and 2011, as can be seen from Fig. 6 and Fig. 8, the development periods of caterpillars and pupae of II and III generations overlapped in all years of research Fig.

When comparing the pupation dates of caterpillars of the III generation of black locust leaf miner with the dates of a stable air temperature transition through 15°C, it can be seen that these phenomena were recorded in all years in close terms that were close to the dates of the beginning of black locust leaf fall (Fig. 8).

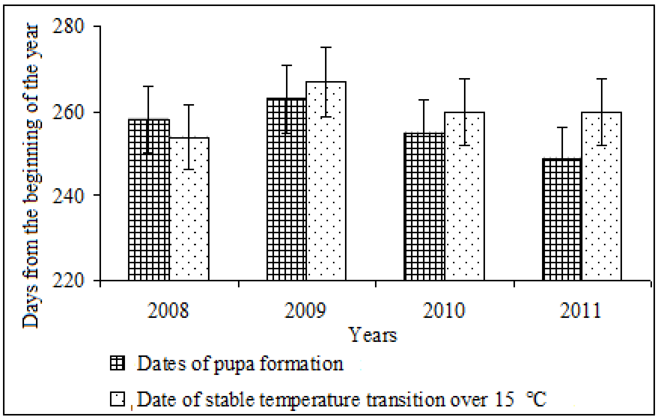

Fig. 8. Comparison of the dates of pupa formation of the third generation black locust leaf miner with the dates of a stable air temperature transition through 15°C.

Analysis of active and effective temperature sums at a threshold of 10°C accumulated during the development of caterpillars of individual generations shows that the highest values of these indicators correspond to the third generation (Table 3).

Table 3. The duration of caterpillar development of individual generations of black locust leaf miner and sums of temperatures (average 4 years).

Generation	Duration, days	T average,°C	Sums of temperatures, °C	
			Active (over 10°C)	Effective at the threshold 10°C
I	21.0	21.2	446.5	231.5
II	17.0	23.2	404.6	234.6
III	28.5	19.5	559.3	274.5
Average	21.7	21.7	463.8	244.9

The data obtained may be connected with a slowing in caterpillars development in late summer under the influence of the photoperiod, as is known for other species with several generations and species developing in the second half of summer (Meshkova, 2009). Comparison of the development of the terms and rates of black locust leaf miner caterpillars development with data on air temperature during the development periods of individual generations shows that the caterpillars of the first generation developed on average for 21 days at an average air temperature of 21.2°C, the second generation-17 days at 23.2°C, and the third-28.5 days at 19.5°C. The connection between the duration of caterpillar development and temperature was characterized by a correlation coefficient of -0.9 ($P < 0.05$), which confirms the dependence of the rates of caterpillar development of the black locust leaf miner on air temperature. By the totality of data on the duration of caterpillar development in individual generations (n, days), it was determined that the rates of development of individuals in percentage are 100/n (Meshkova, 2009). It allowed determining the 10°C caterpillar development threshold from the coordinates of the intersection point of the graph of the dependence of the caterpillar development rate on the temperature of the corresponding periods with the X axis (Fig. 9).

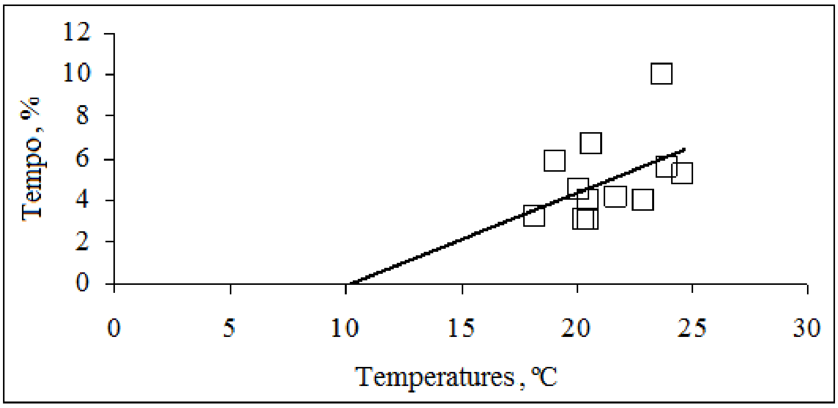

Fig. 9. Dependence of the development rates of black locust leaf miner caterpillars on air temperature and graphical determination of the development threshold of this stage.

Table 4 shows data on active (at thresholds of 10 and 15 °C) and effective at thresholds of 10°C sums of temperatures accumulated during the periods between the appearance of butterflies of the previous and next generations and between the appearance of mines of the previous and next generations, as well as on the duration of the corresponding periods. Calculations for the development period of the third generation are not given since it is interrupted by diapause and overwintering of pupae.
The duration of the development period of the first generation of the black locust leaf miner, determined by the terms of butterflies flying out, turned out to be longer in all years (on average 51 days) than the duration of development of the second generation (38.5 days). This phenomenon can be explained by differences in the rates of warming of pupae's wintering grounds and the flight of butterflies.

Table 4. The sums of active and effective temperatures at the 10°C threshold of 10°C accumulated during the development of individual generations of the black locust leaf miner.

Periods	**Years**	**Duration of the period, days**	**T average,°C**	**Sums of temperatures, °C**		
				Active at the threshold 10°C	**Active at the threshold 15°C**	**Effective at the threshold 10°C**
From the flying out of butterflies from wintering grounds to the beginning of flight of second-generation butterflies (development of the first generation)	2008	53	17.7	929.5	830.2	419.5
	2009	51	18.9	956.9	839.6	456.9
	2010	46	19.9	917.5	888.7	457.5
	2011	54	19.5	1054.1	1001.8	514.1
	Average	*51.0*	*19.0*	*964.5*	*890.1*	*462.0*
From the beginning of flight of the second generation butterflies to the beginning of flight of the third generation butterflies (development of the second generation).	2008	33	21.3	704.3	704.3	374.3
	2009	36	22.6	812.4	812.4	452.4
	2010	44	25.5	1123.5	1123.5	683.5
	2011	41	22.8	933.6	933.6	523.6
	Average	*38.5*	*23.1*	*893.5*	*893.5*	*508.5*
From the appearance of mines of the first generation to the appearance of mines of the second generation (development of the first generation)	2008	38	20.1	765.6	765.6	385.6
	2009	39	21.7	844.6	844.6	454.6
	2010	45	21.9	984.8	956	534.8
	2011	36	20.6	740.4	740.4	380.4
	Average	*39.5*	*21.1*	*833.9*	*826.7*	*438.9*
From the appearance of mines of the second generation to the appearance of mines of the third generation (development of the second generation)	2008	28	21.3	596.7	596.7	316.7
	2009	37	21.1	782.5	754.8	412.5
	2010	33	26.4	872.3	872.3	542.3
	2011	37	23.1	856.1	856.1	486.1
	Average	*33.8*	*23.0*	*776.9*	*770.0*	*439.4*
Overall average		*40.7*	*21.5*	*868.3*	*845.0*	*462.2*

The duration of the development period of both generations that was determined by the terms (39.5 and 33.8 days, respectively) was less than that determined by the dates of flight of butterflies. The duration of development of the corresponding generations of individual years varied slightly. On average, it was the smallest (38 days) in 2008, and in the remaining years it was 41-42 days, and in all cases the development of the first generation was the longest when calculating in terms of the appearance of butterflies of the second and wintering generations (Table 4). Slightly higher values of the average air temperature were recorded during the development of the second generation of the black locust leaf miner (19-21.1°C and 23.0-23.1°C for the first and second generations, respectively). Due to the fact that the development of all generations of the black locust leaf miner continued at temperatures above 15°C, the sums of active temperatures required for the development of individual generations turned out to be quite close-an average of 868.3 and 845.0°C, respectively. The sum of effective temperatures at the threshold of 10°C for the development of one generation was on average 462.2°C (Table 4).

Based on average research data for 2008-2011, a phenological calendar was constructed for the development of the black locust leaf miner (Table 5).

Table 5. Phenological calendar of the development of black locust leaf miner development based on average long-term data in green plantations (Kharkiv, 2008-2011).

		Months-decades														
Generation	**Wintering**	**May**			**June**			**July**			**August**			**September**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
I	O	O	O													
		+	+	+												
			•	•	•											
				—	—	—	—									
						O	O	O								
II							+	+	+							
							•	•	•	•						
								—	—	—	—					
									O	O	O	O				
III											+	+	+			
											•	•	•			
												—	—	—	—	
														O	O	O

Reference designation • egg, -larva, O-pupa, +- imagoes.

Locust digitate leaf miner (*Parectopa robiniella* Clemens, 1863)

Another locust leaf miner-locust digitate leaf miner was found in the region of our research in much smaller numbers than the black locust miner, and therefore we have identified only some peculiarities of its seasonal development. We have registered three periods for flight of this butterfly, which indicates the presence of three generations per year. According to data obtained in Tiraspol (Antyuhova, 2010), this species has three generations, according to data obtained in Hungary (Csoka, 2003), two generations. According to the above data on the temperature in the region of our research in 2008-2011, the conditions for the development of this pest were closer to those recorded in Tiraspol. At the same time, it is possible that in years with lower temperatures during the development of the locust digitate leaf miner, the number of generations may be smaller. Mines of the locust digitate leaf miner were detected several weeks later than mines of the black locust leaf miner (Table 6).

Table 6. Phenological calendar of the development of locust digitate leaf miner based on average long-term data in green plantations (Kharkiv, 2008-2011).

		Months-decades														
Generation	**Wintering**	**May**			**June**			**July**			**August**			**September**		
		1	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**	**1**	**2**	**3**
I	O	O	O	O	O	O										
					+	+	+									
					•	•	•									
						—	—	—								
								O	O	O						
II									+	+	+					
									•	•	•					
										—	—	—				
											O	O	O			

III	+	+	+		
	•	•	•		
		–	–	–	
				O	O

Reference designation • egg, -larva, O-pupa, +- imagoes.

Unlike the mines of the black locust leaf miner (Fig. 10 left), the mines of the locust digitate leaf miner had an irregular shape, branching and always included the main vein (Fig. 10 on the right). There was always one larva in the mine.

Fig. 10. Mines of the black locust leaf miner (left) and the locust digitate leaf miner (right) (July 2010, photo by the author).

Unlike the black locust leaf miner, whose caterpillars pupate inside mines, the caterpillars of the locust digitate leaf miner pupated in cocoons outside the mine, in particular on the forest floor.

Conclusion

Butterflies of the black locust leaf miner that overwinter fly out of pupae during the development of black locust leaves (in the third decade of May). The dates of pupation of the third generation caterpillars are close to the dates of a stable air temperature transition through 15°C and the dates of the beginning of the black locust leaves falling (II-III decades of September). The threshold for the development of caterpillars is 10°C, and the sum of effective temperatures at the threshold of 10°C for the development of a generation is 462.2°C.

The maxima of mine density was registered in the I-II decades of June, the III decade of July, the I decade of August, and the III decade of August, the I decade of September. Mines of the locust digitate leaf miner were detected several weeks later than those of the black locust leaf miner. The caterpillars of the black locust leaf miner pupate inside mines, while the locust digitate leaf miner pupates in cocoons outside the mine, in particular on the forest floor. The maximum leaf population with the black locust leaf miner reached 40% in the KhNU Botanical Garden of KhNU, in Gorky Park, and in the street plantings of Pavlovo pole.

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