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SEASONAL DEVELOPMENT OF HORSE-CHESTNUT LEAFMINER, *CAMERARIA OHRIDELLA* DESCHKA ET DIMIĆ 1986 (LEPIDOPTERA: GRACILLARIIDAE) IN THE GREEN STANDS OF KHARKOV

Мєшкова, В. Л. **Сезонний розвиток каштанового мінера, *Cameraria ohridella* Deschka et Dimić, 1986 (Lepidoptera: Gracillariidae) у зелених насадженнях Харкова [Текст] / В. Л. Мєшкова, І. М. Мікуліна // Вісті Харк. ентомол. т-ва. — 2013. — Т. XXI, вип. 2. — С. 29–37.**
Каштановий мінер в Харкові розвивається у трьох поколіннях. Початок вильоту метеликів із місць зимівлі збігається з феноіндикаторами — повним вкриттям листям дерев гіркокаштана та початком їх цвітіння (кінець квітня–початок травня). Тривалість розвитку гусениць залежно від температури становить 13–43 доби за суми ефективних температур 179.9–253.1 °С, тривалість розвитку лялечок — 11–15.3 доби за суми ефективних температур 105.3–299.4 °С. Середня тривалість періодів між появою метеликів I та II поколінь становила 51 добу, II та III — 40.6 доби, між появою мін I та II поколінь — 45 діб, II та III — 42.2 доби, між появою лялечок I та II поколінь 39.6 доби, II і III — 60 діб. Середня сума додатних температур для розвитку однієї генерації становить 979 °С, сума ефективних температур при порозі 10 °С — 516 °С. 5 табл., 7 назв.
Ключові слова: Lepidoptera, Gracillariidae, *Cameraria ohridella*, каштановий мінер, сезонний розвиток, сума температур, зелені насадження, Україна, Харків.

Мешкова, В. Л. **Сезонное развитие каштанового минёра, *Cameraria ohridella* Deschka et Dimić, 1986 (Lepidoptera: Gracillariidae) в зелёных насаждениях Харькова [Текст] / В. Л. Мешкова, И. М. Микулина // Изв. Харьк. энтомол. о-ва. — 2013. — Т. XXI, вып. 2. — С. 29–37.**
Каштановый минёр в Харькове развивается в трёх поколениях. Начало вылета бабочек из мест зимовки совпадает с феноиндикаторами — полным облиственением деревьев каштана конского и началом их цветения (конец апреля–начало мая). Продолжительность развития гусениц в зависимости от температуры составляет 13–43 суток при сумме эффективных температур 179.9–253.1 °С, продолжительность развития куколок — 11–15.3 суток при сумме эффективных температур 105.3–299.4 °С. Средняя продолжительность периодов между появлением бабочек I и II поколений составила 51 сутки, II и III — 40.6 суток, между появлением мин I и II поколений — 45 суток, II и III — 42.2 суток, между появлением куколок I и II поколений — 39.6 суток, II и III — 60 суток. Средняя сумма положительных температур для развития одной генерации составляет 979 °С, сумма эффективных температур при пороге 10 °С — 516 °С. 5 табл., 7 назв.
Ключевые слова: Lepidoptera, Gracillariidae, *Cameraria ohridella*, каштановый минёр, сезонное развитие, сумма температур, зелёные насаждения, Украина, Харьков.

Meshkova, V. L. **Seasonal development of horse-chestnut leafminer, *Cameraria ohridella* Deschka et Dimić, 1986 (Lepidoptera: Gracillariidae) in the green stands of Kharkov [Text] / V. L. Meshkova, I. M. Mikulina // The Kharkov Entomol. Soc. Gaz. — 2013. — Vol. XXI, iss. 2. — P. 29–37.**
Horse-chestnut leafminer develops in Kharkov in 3 generations. Moths after winter begin to swarm simultaneously with phenological indicators — total frondescence of *Aesculus hippocastanum* L. and beginning of its blooming (end of April–beginning of May). Duration of larvae development in dependence on temperature is 13–43 days at sum of effective temperatures over threshold 10 °C — 179.9–253.1 °C, duration of pupae development is 11–15.3 days at sum of effective temperatures over threshold 10 °C — 105.3–299.4 °C. Mean duration of intervals between appearance of moths of the 1st and 2nd generations is 51 days, 2nd and 3rd ones — 40.6 days, between appearance of mines of the 1st and 2nd generations — 45 days, 2nd and 3rd ones — 42.2 days, between appearance of pupae of the 1st and 2nd generations — 39.6 days, 2nd and 3rd ones — 60 days. Mean sum of positive temperatures for development of one generation is 979 °C, sum of effective temperatures over threshold 10 °C — 516 °C. 5 tabs, 7 refs.
Keywords: Lepidoptera, Gracillariidae, *Cameraria ohridella*, horse-chestnut leafminer, seasonal development, sum of temperatures, green stands, Ukraine, Kharkov.

Introduction. Horse-chestnut leafminer, *Cameraria ohridella* Deschka et Dimić, 1986 (Lepidoptera: Gracillariidae) has recently spread in Europe (Sefrova, 2001; Csóka, 2003; Antyukhova, 2008), where it develops in 2–5 generations per year and damages horse-chestnut (*Aesculus hippocastanum* L.). Much attention was paid to investigation of this pest, but some data on the dates of development of different generations, their number and temperature conditions are contradictory. Horse-chestnut leafminer was found in Kharkov region for the first time in 2007 (Meshkova, Mikulina, 2008, 2009, 2012), and phenological investigations are carried out for the first time. Results of such investigations are important for determination the

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dates of effective protection of stands, optimizing the assessment (Meshkova, Mikulina, 2008) and prediction of population dynamics of this pest (Meshkova, Mikulina, 2012).

The aim of this study was investigation the peculiarities of seasonal development of horse-chestnut leafminer in chestnut trees in the green stands of Kharkov and comparison the results with data from other regions.

Materials and methods. Investigations were carried out during vegetation periods of 2008–2012 in 100 survey plots in different parks and street plantings of horse chestnut in Kharkov (dendrological park of Kharkiv National Agrarian University named after V. V. Dokuchajev, park named after T. G. Shevchenko, park named after M. Gor'ky, Botanical garden of Kharkov National University named after V. N. Karazin etc.).

Temperature data from meteorological station Kharkov were used. Phenological events of chestnut were registered twice a week using method of N. P. Sakharov (Sakharov, 1961).

The dates of swarming of horse-chestnut leafminer were determined by inspecting the trees in survey plots. In each of them 100 leaves were inspected randomly every week in different sides of crown. The presence and number of mines, larvae, pupae and exuviae were registered on each leaf.

Results of our investigations on seasonal development of horse-chestnut leafminer were compared to data on temperature conditions in the dates of registration of respective stages of horse-chestnut leafminer. Mean temperature during development of certain stages of horse-chestnut leafminer, sums of positive, active and effective (at threshold 10 °C) temperatures, as well as the dates of the stable transition of air temperature over 10 °C were calculated by method of V. Meshkova (Meshkova, 2009).

Results of our investigations in Kharkov (50 °00'00" N; 36 °13'45" E) were compared to data obtained in Kyiv (50 °27'00" N; 30 °30'00" E) in 2003–2006 (Kashtanovaja miniruyushchaya mol' …, 2007) and in Tiraspol (46 °50'23" N; 29 °36'23" E) in 2005–2009 (Antyukhova, 2008). The authors of these publications calculated the sums of temperatures for every stage of development of horse-chestnut leafminer from the beginning of the year. Therefore, we calculated from their data the differences of respective sums of temperatures to determine the necessary sums of temperatures for development of each stage or generation of this insect and to compare with our results.

Results and discussion. The dates of seasonal development of horse-chestnut leafminer are timed to its host plant — horse chestnut, and the dates and rate of development both host plant and miner depend on air temperature of the season.

By long-term data of N. P. Sakharov (Sakharov, 1961), in the 50th years of XX century in Kharkov the beginning of budding of horse chestnut trees was registered on April 11, and bud breaking on April 23. The beginning of frondescence was registered on May 1, and total frondescence on May 14 (Table 1).

Table 1. The earliest dates of phenological events in horse chestnut development in Kharkov

Phenological events	Dates by years					
	by N. P. Sakharov, 1961	2008	2009	2010	2011	2012
Budding	11.04	—	—	—	—	—
Bud breaking	23.04	04.04	10.04	01.04	14.04	02.04
Beginning of frondescence	01.05	09.04	14.04	12.04	26.04	13.04
Total frondescence	14.05	05.05	10.05	25.04	03.05	25.04
Appearance of blossom clusters	—	30.04	20.04	18.04	30.04	22.04
Beginning of blooming	12.05	05.05	07.05	03.05	08.05	27.04
End of blooming	27.05	20.05	26.05	18.05	25.05	16.05
Beginning of fruits development	—	26.05	31.05	22.05	30.05	20.05
End of fruits development	—	04.10	27.09	24.09	28.09	22.09
Beginning of foliage yellowing	01.08	20.07	22.06	10.07	12.07	08.07
Curling of damaged leaves	—	25.07	29.06	14.07	19.07	10.07
Total foliage yellowing	09.10	—	—	—	—	—
Beginning of leaf fall	19.08	27.07	15.07	15.07	17.07	12.07
Total leaf fall	18.10	16.10	20.10	26.09	08.10	25.09
Beginning of new foliage development	—		20.09	13.08	—	03.08
Autumn blooming	—		27.09	19.08	—	09.08

Our investigations show that the earliest bud breaking of horse chestnut occurred in 2010 (on April 1), in other years it was somewhat later, and in 2011 it was the latest — on April 14 (see Table 1). In all years the dates of this event were earlier than 50 years ago. Beginning of frondescence of horse chestnut trees was registered on April 9 in 2008, and in 2009, 2010 and 2012 it was April 14, 12 and 13 respectively, the latest in 2011 (on April

26). The total frondescence of horse chestnut trees was also observed earlier in the years of our investigations. It occurred on May 5, 10 and 3 in 2008, 2009 and 2011, on April 25 in 2010 and 2012 (see Table 1).

In the 50th years of XX century the yellowing of horse chestnut foliage was registered on August 1, total yellowing on October 9, and leaf fall occurred from August 19 to October 18 (Sakharov, 1961). By our investigations, in 2008–2012 foliage yellowing of horse chestnut was registered already on June 22 in 2009, on July 8 and 10 in 2012 and 2010, and on July 12 and 20 in 2011 and 2008 respectively. Curling of leaves damaged by horse-chestnut leaf miner was first detected on June 29 in 2009, on July 10 and 14 in 2012 and 2010, on July 19 and 25 in 2011 and 2008. Damaged foliage fell before time in the 2nd (in 2009–2012) and 3rd (in 2008) decades of July. Total leaf fall of horse chestnut trees was registered in the 3rd decade of September (in 2010 and 2012) or in the 1st–2nd decades of October (in 2008, 2009, and 2011). Early yellowing and abscission of horse chestnut foliage was followed by development of new foliage and autumn blooming, which were registered in September 20–27 in 2009, in August 13–19 in 2010, and in August 3–9 in 2012 (see Table 1).

Blooming of horse chestnut was observed by N. P. Sakharov (Sakharov, 1961) in May 12–27, and the dates of fruits development were not registered by this scientist. We registered the beginning of horse chestnut blooming in the 1st decade of May in 2008–2011, and on April 27 in 2012 (see Table 1). The end of blooming of horse chestnut was also registered in 2008–2011 in almost similar dates, which almost do not differ from observations of N. P. Sakharov (Sakharov, 1961). This supports the known conclusion about low variability of the dates of summer events by years and locations (Meshkova, 2009).

Development of fruits of horse chestnut began in the 3rd decade of May in all years, and the fruits completed development both on branches with foliage or without it on the beginning of the 3rd decade of September in all years of investigation. Only in 2008 this event was registered on October 4 (see Table 1).

The pupae of horse-chestnut leafminer hibernate in fallen foliage. By our investigations, emergence of moths from locations of hibernation began the most often in the 1st decade of May, and in 2012 in the 3rd decade of April (Table 2). Mass swarming of adults of horse-chestnut leafminer began every year 4–7 days after beginning of emergence (see Table 2).

Table 2. Dates of phenological events in development of horse-chestnut leafminer in Kharkov

Phenological events	Dates by years				
	2008	2009	2010	2011	2012
Emergence of adults from hibernated pupae	05.05	04.05	28.04	04.05	22.04
Mass swarming of adults after winter	10–26.05	10–23.05	03–16.05	11–25.05	26.04–10.05
Appearance of mines of larvae of the 1st generation	29.05	23.05	19.05	20.05	10.05
Appearance of pupae of the 1st generation	19.06	14.06	09.06	15.06	31.05
Emergence of adults of the 1st generation	26.06	25.06	18.06	23.06	10.06
Mass swarming of adults of the 2nd generation	29.06–15.07	01.07–15.07	22.06–06.07	29.06–19.07	14.06 – 30.06
Appearance of mines of larvae of the 2nd generation	14.07	08.07	30.06	08.07	21.06
Appearance of pupae of the 2nd generation	28.07	24.07	17.07	25.07	11.07
Emergence of adults of the 3rd generation	06.08	04.08	27.07	04.08	21.07
Mass swarming of adults of the 3rd generation	09.08–24.08	06.08–19.08	03.08–17.08	10.08–24.08	26.07–09.08
Appearance of mines of larvae of the 3rd generation	20.08	21.08	15.08	16.08	05.08
Appearance of pupae of the 3rd generation	27.09	25.09	14.09	28.09	01.09
Appearance of mines of larvae of the 3rd generation on the foliage of autumn shoots	—	27.09	20.09	—	08.09

In Tiraspol (Antyukhova, 2008) the first moths of horse-chestnut leafminer appeared on April 13–16, in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the first moths appeared on April 24–May 4, and mass swarming was registered on May 12–27. Thereby, the dates of beginning of swarming of horse-chestnut leafminer after winter in Kharkov were close to such dates from Kyiv and later than in Tiraspol. Obtained data are connected with peculiarities of temperature accumulation in investigated regions: development of hibernated pupae began after stable transition of temperature over 10 °C, and duration of pupae development depended on temperature in the places of hibernation. Like this, in the years of researches of O. V. Antyukhova (Antyukhova, 2008) the stable transition of air temperature over 10 °C in Tiraspol was registered on April 7–12 and over 15 °C — on May 3–11. In Kharkov in 2007–2012 the stable transition of air temperature over 10 °C and 15 °C was registered on April 10–23 and May 5–24 respectively.

Mean air temperature in period of swarming of horse-chestnut leafminer after winter amounted in Kharkov from 11.5 to 18.4 °C in different years, average for 2008–2012 amounted 13.7 °C (Table 3). Sum of positive temperatures to the date of moths emergence in Kharkov amounted 339.6–569.5 °C (mean 399.5 °C), sum of active temperatures at threshold 10 ° C — 173.3 – 320.9 °C (216.4 °C), sum of effective temperatures at threshold 10 °C — 23.3–70 °C (50.4 °C) (see Table 3).

Table 3. Indices of heat accumulation to the of dates of adults emergence from hibernated pupae in Kharkov

Years	Dates of emergence	Date of stable transition of air temperature over 10 °C	Mean air temperature, °C	Sum of temperatures, °C		
				positive	active at threshold 10 °C	effective at threshold 10 °C
2008	05.05	10.04	11.5	569.5	320.9	50.9
2009	04.05	23.04	13.3	424.1	205.1	55.1
2010	28.04	15.04	12.7	339.6	173.3	23.3
2011	04.05	22.04	18.4	357.7	200.0	70.0
2012	22.04	8.04	12.6	306.5	182.6	52.6
Average	01.05	16.04	13.7	399.5	216.4	50.4

By the data of Kyiv researchers (Kashtanovaja miniruyushchaya mol' …, 2007), the sum of effective temperatures at the beginning of emergence of horse-chestnut leafminer after wintering amounted from 68 to 132 °C, which is close to upper limit of this index in Kharkov (see Table 3). Data on positive and active temperatures for development of horse-chestnut leafminer in Kyiv are not presented.

In Tiraspol (Antyukhova, 2008), the sum of positive temperatures in the dates of beginning of swarming by horse-chestnut leafminer after winter amounted 473.4–530.8 °C, the sum of effective temperatures at threshold 10 °C amounted from 0 to 3.6 °C in different years. Sum of positive temperatures to the beginning of swarming of horse-chestnut leafminer is rather close in Kharkov and Tiraspol, but the sum of effective temperatures is much lower in Tiraspol. Obtained results are connected with the absence of data on threshold of pupae development after hibernation and with variability of microclimate in the places of hibernation. Therefore we suggest predicting the dates of emergence of horse-chestnut leafminer after hibernation using phenological indicators, that is the total frondescence of horse chestnut trees and beginning of their blooming (see Table 1).

From 16 to 25 days passed in different years from emergence of the first moths to appearance of the first mines on the leaves of horse chestnut. Mean air temperature made up 13.9–19.9 °C at this period, sum of positive temperatures amounted 248.4–376 °C (average 321.4 °C), sum of active temperatures at threshold 10 °C — 239–376 °C (average 309.0 °C), sum of effective temperatures at threshold 10 °C — 78.5–185.6 °C (average 127 °C) (Table 4).

Table 4. Sums of positive, active and effective temperatures at threshold 10 °C, accumulated during development of different stages of horse-chestnut leafminer in Kharkov

Period	Year	Duration of period, days	Mean air temperature, °C	Sum of temperatures, °C		
				positive	active at threshold 10 °C	effective at threshold 10 °C
From moths emergence after winter to appearance the mines of larvae of the 1st generation	2008	25.0	13.9	348.6	305.7	115.7
	2009	19.0	14.1	267.9	258.5	78.5
	2010	21.0	17.9	376.0	376.0	166.0
	2011	16.0	15.5	248.4	239.0	89.0
	2012	18.0	19.9	365.9	365.9	185.6
	Average	19.8	16.3	321.4	309.0	127.0
From appearance the mines of larvae of the 1st generation to appearance the pupae of the 1st generation	2008	22.0	18.0	396.8	396.8	176.8
	2009	23.0	19.3	424.2	424.2	204.2
	2010	21.0	18.5	388.4	388.4	178.4
	2011	27.0	20.6	473.3	473.3	243.3
	2012	21.0	22.1	424.7	424.7	214.7
	Average	22.8	19.7	421.5	421.5	203.5
From appearance the pupae of the 1st generation to emergence the moths of the 2nd generation	2008	7.0	19.9	119.6	119.6	59.6
	2009	11.0	20.8	228.6	228.6	118.6
	2010	9.0	22.8	205.6	205.6	115.6
	2011	11.0	20.8	228.3	228.3	118.3
	2012	10.0	20.3	208.3	208.3	108.3
	Average	9.6	20.9	198.1	198.1	104.1

Continuance of the Table 4

Period	Year	Duration of period, days	Mean air temperature, °C	Sum of temperatures, °C		
				positive	active at threshold 10 °C	effective at threshold 10 °C
From emergence the moths of the 2nd generation to appearance the mines of larvae of the 2nd generation	2008	18.0	19.6	352.9	352.9	172.9
	2009	13.0	21.9	284.7	284.7	154.7
	2010	12.0	24.2	289.8	289.8	169.8
	2011	13.0	19.5	253.7	253.7	123.7
	2012	11.0	23.2	269.9	269.9	159.9
	Average	13.4	21.7	290.2	290.2	156.2
From appearance the mines of larvae of the 2nd generation to appearance the pupae of the 2nd generation	2008	14.0	23.2	185.3	185.3	105.3
	2009	16.0	24.6	343.9	343.9	203.9
	2010	17.0	23.8	380.5	380.5	220.5
	2011	17.0	23.6	329.8	329.8	189.8
	2012	20.0	23.0	459.5	459.5	259.5
	Average	16.8	23.6	339.8	339.8	195.8
From appearance the pupae of the 2nd generation to emergence the moths of the 3rd generation	2008	9.0	20.9	460.0	460.0	240.0
	2009	11.0	22.1	287.2	287.2	157.2
	2010	10.0	26.1	287.0	287.0	177.0
	2011	10.0	22.6	338.9	338.9	188.9
	2012	10.0	22.9	226.8	226.8	126.8
	Average	10.0	22.9	320.0	320.0	178.0
From emergence the moths of the 3rd generation to appearance the mines of larvae of the 3rd generation	2008	14.0	26.5	185.8	185.8	115.8
	2009	17.0	17.8	303.4	303.4	133.4
	2010	19.0	28.0	532.6	532.6	342.6
	2011	12.0	23.5	282.3	282.3	162.3
	2012	15.0	26.1	393.8	393.8	243.8
	Average	15.4	24.4	339.6	339.6	199.6
From appearance the mines of larvae of the 3rd generation to appearance the pupae of the 3rd generation	2008	38.0	15.7	708.2	642.6	262.6
	2009	35.0	18.1	596.9	596.9	266.9
	2010	30.0	18.8	563.2	563.2	263.2
	2011	43.0	18.4	479.5	479.5	219.5
	2012	27.0	21.3	569.4	569.4	299.4
	Average	34.6	18.5	583.4	570.3	262.3

The first mines of this pest were found on the beginning of the 2nd decade of May in 2012, at the end of the 2nd decade of May in 2010 and 2011, on the 3rd decade of May in 2008 and 2009 (see Table 2). This event coincided with the dates of the completing blooming of horse chestnut (see Table 1). In Tiraspol the first mines were found on May 10–15 (Antyukhova, 2008), in Kyiv — on May 5–18 (Kashtanovaja miniruyushchaya mol' …, 2007), that is earlier, than in Kharkov.

From 21 to 27 days (average 22 days) passed in different years from appearance of the first mines (larvae) to appearance of the first pupae. Air temperature amounted 18–22.1 °C (average 19.7 °C), sum of positive temperatures and active temperatures at threshold 10 °C amounted 388.4–473.3 °C (average 421.5 °C), sum of effective temperatures at threshold 10 °C — 176.8–243.3 °C (average 203.5 °C) (see Table 4). In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the sum of effective temperatures at threshold 10 °C for larvae development amounted 375–492 °C (average 432.3 °C). In Tiraspol (Antyukhova, 2008) the sum of positive temperatures for larvae development amounted 258.6–291.3 °C and was closer to our data obtained in Kharkov.

The first pupae of the 1st generation were found in Kharkov at the end of May and in the 1st decade of June in 2012 and 2010, and in the 2nd decade of June in 2008, 2009 and 2011 (see Table 2). In Tiraspol (Antyukhova, 2008) the first pupae were found on May 24–29, and in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) on June 7–17.

Adults of the 2nd generation were found in Kharkov in the 2nd–3rd decades of June of 2008–2012. Mass swarming was registered up to the middle of July, only in 2010 and 2012 — up to the 1st decade of July (see Table 2). In Tiraspol the swarming of adults of the 2nd generation was registered in the 1st decade of June (Antyukhova, 2008), in Kyiv in the 2nd–3rd decades of June (Kashtanovaja miniruyushchaya mol' …, 2007).

From 7 to 11 days (average 9.6 days) passed in different years from appearance of the first pupae to emergence of the first adults of the 2nd generation in Kharkov at temperature 19.9–22.8 °C (average 20.9 °C). Sum of positive temperatures and active temperatures at threshold 10 °C amounted 119.6–228.6 °C (average 198.1 °C), sum of effective temperatures at threshold 10 °C amounted 59.6–118.6 °C (average 104.1 °C) (see Table 4). In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the sum of effective temperatures at threshold

10 °C for pupae development in the 2nd generation amounted 98–122 °C (average 104.5 °C). In Tiraspol (Antyukhova, 2008) the sum of positive temperatures for pupae development amounted 199.5–320.7 °C, the sum of effective temperatures at threshold 10 °C amounted 109.5–130.7 °C.

The mines of the 2nd generation of the horse-chestnut leafminer were found in Kharkov the earliest in 2012 (June 21), in the 1st decade of July in 2009 and 2011, and the latest in 2008 (July 14) (see Table 2). In Tiraspol (Antyukhova, 2008) the mines of the 2nd generation were found on June 9–20, the pupae were found on July 4–9. In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the mines of the 2nd generation were found on June 23–July 4, the pupae were found on July 15–31.

Duration of period between emergence of moths and appearance of mines of horse-chestnut leafminer of the 2nd generation amounted in Kharkov 11–18 days (average 13.4 days), mean temperature for this period was 19.5–24.2 °C (average 21.7 °C) (see Table 4). In Tiraspol (Antyukhova, 2008) mean temperature for this period amounted 21.2–24.4 °C.

The sum of positive temperatures and active temperatures at threshold 10 °C for period from moths emergence to appearance of mines of the 2nd generation of horse-chestnut leafminer amounted in Kharkov 253.7–352.9 °C (average 290.2 °C), sum of effective temperatures at threshold 10 °C amounted 123.7–169.8 °C (average 156.2 °C). In Tiraspol (Antyukhova, 2008) the sum of positive temperatures for this period amounted 183.4–208.6 °C, sum of effective temperatures at threshold 10 °C amounted 103.4–108.6 °C. In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the sum of effective temperatures at threshold 10 °C amounted 114–161 °C.

Pupae of horse-chestnut leafminer were found in Kharkov in the 2nd decade of July in 2010 and 2012, and in the 3rd decade of July in 2008, 2009, 2011 (see Table 2). In Tiraspol (Antyukhova, 2008) pupae were found on July 4–9, in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) — on July 15–31. Duration of larvae development in the 2nd generation of horse-chestnut leafminer amounted in Kharkov 14–20 days (average 16.8 days) at mean temperature 23.2–24.6 °C (average 23.6 °C). In Tiraspol (Antyukhova, 2008) larvae developed 20–26 days at mean temperature 21–23.3 °C. The sum of positive temperatures for development of larvae of the 2nd generation amounted in Kharkov 185.3–459.5 °C (average 339.8 °C), in Tiraspol (Antyukhova, 2008) — 426.2–602.7 °C. The sum of effective temperatures at threshold 10 °C amounted in Kharkov 105.3–259.5 °C (average 195.8 °C), in Tiraspol (Antyukhova, 2008) — 236.2–352.7 °C, in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) 386–400 °C (average 393.8 °C).

Emergence of the first adults of the 3rd generation was registered in Kharkov in 2012 and 2010 on July 21 and 27, in 2008, 2009 and 2011 — on August 6 and 4. Mass swarming of adults of the 3rd generation began few days after beginning of swarming. It continued up to the 1st decade of August in 2012, to the end of the 2nd decade of August in 2009 and 2010, to the beginning of the 3rd decade of August in 2008 and 2011 (see Table 2). The first adults of the 3rd generation was registered in Kyiv on July 22–August 8 (Kashtanovaja miniruyushchaya mol' …, 2007), in Tiraspol — on Jult 14 (Antyukhova, 2008). In Kharkov pupae developed 9–11 days (average 10 days) at 20.9–26.1 °C (average 22.9 °C). In Tiraspol (Antyukhova, 2008) pupae developed 10–11 days, in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) pupae developed 7–17 days. Sum of positive temperatures for development of pupae made up 287–460 °C (average 320 °C) in Kharkov (see Table 4) and 112.2–225.8 °C in Tiraspol (Antyukhova, 2008). Sum of effective temperatures at threshold 10 °C made up in Kharkov 126.8–240 °C (average 178 °C), in Tiraspol 62.3–126.7 °C (94.5 °C) (Antyukhova, 2008), in Kyiv 56–153 °C (average 109.8 °C) (Kashtanovaja miniruyushchaya mol' …, 2007).

Mines of larvae of the 3rd generation of horse-chestnut leafminer were found in Kharkov on August 5, 15 and 16 in 2012, 2010 and 2011 and a bit later (in August 20 and 21) in 2008 and 2009 (see Table 2). In Tiraspol (Antyukhova, 2008) the mines were found on July 21–28, in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) — on July 28–August 23. The mean temperature for period from moths' emergence to mines appearance (12–19 days) amounted 17.8–28 °C (average 24.4 °C) in Kharkov. The sum of positive temperatures for this period amounted in Kharkov 185.8–532.6 °C (average 339.6 °C) (see Table 4), in Tiraspol (Antyukhova, 2008) 153.6–400.5 °C (average 277.1 °C). The sum of effective temperatures at threshold 10 °C made up in Kharkov 115.8–342.6 °C (average 199.6 °C), in Tiraspol (Antyukhova, 2008) 83.6–260.5 °C (172.5 °C), in Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) 78–229 °C (average 156.5 °C).

Pupae of the 3rd generation of horse-chestnut leafminer were registered in Kharkov in the 3rd decade of September in 2008, 2009, 2011 and a bit earlier in 2010 and 2012 (on September 14 and 1 respectively) (see Table 2). In Tiraspol the first pupae were found on August 30–September 11 (Antyukhova, 2008), in Kyiv on August 20–September 23 (Kashtanovaja miniruyushchaya mol' …, 2007). In Kharkov development of larvae of the 3rd generation lasted 30–43 days (average 34.6 days) at 15.7–21.3 °C, in Tiraspol 24–40 days at 25.2–27.4 °C (Antyukhova, 2008). The sum of positive temperatures for period of larval development in the 3rd generation in Kharkov amounted 479.5–708.2 °C (583.4 °C) and in Tiraspol 928.3–1042.6 °C (985.5 °C) (Antyukhova, 2008).

In Kharkov the sum of effective temperatures at threshold 10 °C made up 219.5–299.4 °C (average 262.3 °C), in Tiraspol 528.3–592.6 °C (average 560.5 °C) (Antyukhova, 2008), in Kyiv 294–448 °C (average 375.8 °C) (Kashtanovaja miniruyushchaya mol' …, 2007).

The most of pupae of horse-chestnut leafminer of the 3rd generation stayed in diapause up to spring. At the same time in 2009, 2010 and 2012 the mines of the 4th generation were found (see Table 2) on the foliage, which developed in autumn in damaged trees (see Table 1). Development of these larvae could not completed in result of autumnal frosts, lowering the temperature below 10 °C in the 3rd decade of October and stopping the vegetation of horse chestnut trees.

In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) the moths emerged from the pupae of the 3rd generation in September, the larvae of the 4th generation developed in the middle-end of September and pupated in October. In Tiraspol the individuals of the 4th generation of horse-chestnut leafminer were not revealed.

Comparison of development of different generation shows (see Table 4), that in Kharkov the period between emergence of moths after winter and appearance of mines amounted averagely 19.8 days at 16.2 °C, for 2nd generation it made up 13.4 days at 21.7 °C, for 3rd generation — 15.4 days at 24.4 °C. Obtained data are agreed with knowledge about acceleration of insect development with increase of temperature. The sum of positive temperatures for development of moths and eggs of these generations amounted 321.4, 290.2 and 339.6 °C. The sum of effective temperatures at threshold 10 °C amounted 127, 156.2 and 199.6 °C and had a trend to increase from 1st to 3rd generation.

Development of larvae of the 1st, 2nd and 3rd generations lasted 22.8, 16.8 and 34.6 days at mean temperature 19.7, 23.6 and 18.5 °C. Development of larvae was the most rapid in the 2nd generation, because the air temperature was the highest. The sums of positive temperatures during development of larva of the 1st, 2nd and 3rd generations amounted 421.5, 339.8 and 570.3 °C, and the sums of effective temperatures amounted 203.5, 195.8 and 262.3 °C.

Duration of larvae development in the 1st and 2nd generations amounted 9.6 and 10 days at mean air temperature 20.9 and 22.9 °C. A bit longer development of pupae in the 2nd generation comparing to the 1st one in spite of higher temperature can be connected with overlapping of generations. The sums of positive temperatures during development of pupae of the 1st and 2nd generations amounted 198.1 and 320 °C, and the sums of effective temperatures amounted 104.1 and 178 °C. Increase of these indices for the 2nd generation can be also explained by overlapping of generations (see Table 4).

We calculated duration of development of different generations of horse-chestnut leafminer and respective temperature indices using data of moth emergence, larvae and pupae appearance in adjacent generations (1st and 2nd, 2nd and 3rd) (Table 5). Length of period between moth emergence after winter and in the 2nd generation amounted in Kharkov 49–53 days (average 51 days), between moth emergence in the 2nd and 3rd generations — 39–42 days (average 40.6 days). Calculated by Kyiv data (Kashtanovaja miniruyushchaya mol' …, 2007), this index amounted 55 and 46 days, by Tiraspol data (Antyukhova, 2008) — 46–58 and 34–43 days respectively.

Table 5. Sums of positive, active and effective temperatures at threshold 10 °C, accumulated during development of different generations of horse-chestnut leafminer in Kharkov

Period	Year	Duration of period, days	Mean air temperature, °C	Sum of temperatures, °C		
				positive	active at threshold 10 °C	effective at threshold 10 °C
From beginning of emergence the moths after winter to beginning of emergence the moths of the 2nd generation (development of the 1st generation)	2008	53.0	16.3	865.0	822.1	352.1
	2009	52.0	17.7	920.7	911.3	401.3
	2010	51.0	19.0	970.0	970.0	460.0
	2011	50.0	19.0	950.0	940.6	450.6
	2012	49.0	20.2	998.9	998.9	508.6
	Average	51.0	18.4	940.9	928.6	434.5
From beginning of emergence the moths of the 2nd generation to beginning of emergence the moths of the 3rd generation (development of the 2nd generation)	2008	41.0	20.8	998.2	998.2	518.2
	2009	40.0	22.9	915.8	915.8	515.8
	2010	39.0	24.5	957.3	957.3	567.3
	2011	42.0	22.0	922.4	922.4	502.4
	2012	41.0	23.5	956.2	956.2	546.2
	Average	40.6	22.7	950.0	950.0	530.0
From appearance the mines of larvae of the 1st generation to appearance the mines of larvae of the 2nd generation (development of the 1st generation)	2008	46.0	18.9	869.3	869.3	409.3
	2009	46.0	20.4	937.5	937.5	477.5
	2010	42.0	21.0	883.8	883.8	463.8
	2011	49.0	20.3	955.3	955.3	485.3
	2012	42.0	23.2	902.9	902.9	482.9
	Average	45.0	20.8	909.8	909.8	463.8

Continuance of the Table 5

Period	Year	Duration of period, days	Mean air temperature, °C	Sum of temperatures, °C		
				positive	active at threshold 10 °C	effective at threshold 10 °C
From appearance the mines of larvae of the 2nd generation to appearance the mines of larvae of the 3rd generation (development of the 2nd generation)	2008	37.0	22.5	831.1	831.1	461.1
	2009	44.0	21.2	934.5	934.5	494.5
	2010	46.0	26.1	1200.1	1200.1	740.1
	2011	39.0	23.2	951.0	951.0	541.0
	2012	45.0	21.5	1080.1	1080.1	630.1
	Average	42.2	22.9	999.4	999.4	573.4
From appearance the pupae of the 1st generation to appearance the pupae of the 2nd generation (development of the 1st generation)	2008	39.0	20.6	657.8	657.8	337.8
	2009	40.0	22.6	857.2	857.2	477.2
	2010	38.0	23.7	875.9	875.9	505.9
	2011	40.0	21.4	811.8	811.8	431.8
	2012	41.0	22.7	937.7	937.7	527.7
	Average	39.6	22.2	828.1	828.1	456.1
From appearance the pupae of the 2nd generation to appearance the pupae of the 3rd generation (development of the 2nd generation)	2008	61.0	18.3	1354.0	1288.4	618.4
	2009	63.0	18.8	1187.5	1187.5	557.5
	2010	59.0	23.0	1382.8	1382.8	782.8
	2011	65.0	20.8	1100.7	1100.7	570.7
	2012	52.0	22.9	1190.0	1190.0	670.0
	Average	60.0	20.8	1243.0	1229.9	639.9
Total average		46.0	21.0	979.0	974.0	516.0

Duration of period between appearance of mines of the 1st and 2nd generation amounted in Kharkov 42–49 days (average 45 days), of the 2nd and 3rd generation — 37 – 46 days (average 42.2 days) (see Table 5). By Tiraspol data (Antyukhova, 2008) this index amounted 25–60 and 31–49 days respectively.

Duration of period between appearance of pupae of the 1st and 2nd generation amounted in Kharkov 38–41 days (average 39.6 days), of the 2nd and 3rd generation — 59–65 days (average 60 days). By Tiraspol data (Antyukhova, 2008) this index amounted 41 and 52–69 days respectively. In all cases the 2nd generation developed faster due to highest temperatures during its development (see Table 5).

Sum of positive temperatures for development of one generation of horse-chestnut leafminer, calculated by the dates of moths emergence in 1st and 2nd generations, and 2nd and 3rd generations, in Kharkov amounted 940.9 and 950 °C, calculated by the dates of mines appearance — 909.8 and 999.4 °C, calculated by the dates of pupae appearance — 828.1 and 1243 °C, average for all mentioned intervals amounts 979 °C (see Table 5). For Tiraspol data (Antyukhova, 2008) this index amounts 821 and 880 °C at calculation by the dates of moths emergence, 664 and 961 °C calculated by the dates of mines appearance, 918.6 and 1432 °C calculated by the dates of pupae appearance, average for all mentioned intervals amounts 516 °C.

Sum of effective temperatures for development of one generation of horse-chestnut leafminer in Kharkov, calculated by the dates of moths emergence in 1st and 2nd generations, and 2nd and 3rd generations, made up 434.5 and 530 °C, calculated by the dates of mines appearance — 463.8 and 573.4 °C, calculated by the dates of pupae appearance — 456.1 and 639.9 °C. Average for all mentioned intervals amounts 505.1 °C (see Table 5). For Tiraspol data (Antyukhova, 2008) this index makes up 296.7 and 495 °C at calculation by the dates of moths emergence, 335 and 561 °C by the dates of mines appearance, 508.6 and 827 °C by the dates of pupae appearance, average for all mentioned intervals amounts 503.8 °C. In Kyiv (Kashtanovaja miniruyushchaya mol' …, 2007) average sum of effective temperatures for development of one generation of horse-chestnut leafminer makes up 505 °C.

Conclusions. Horse-chestnut leafminer develops in Kharkov in three generations. The most of pupae of the 3rd generation stay in diapause up to spring. Some pupae develop to the moths, and the larvae of the 4th generation begin consume the foliage, which appear in autumn after fall of damaged leaves, but never complete development.

Beginning of moth emergence from locations of hibernation is registered at the end of April–beginning of May and coincides with phenological indicators — total frondescence of horse chestnut trees and beginning of their blooming. Foliage damaged by horse-chestnut leafminer falls in the 2nd–3rd decades of July and is followed by development of young foliage and autumnal blooming.

Duration of development of larvae of horse-chestnut leafminer lasts 13–43 days depending on temperature, sum of effective temperatures at threshold 10 °C amounts 105.3–299.4 °C; pupae develop 7–11 days, and sum of effective temperatures amounts 103–240 °C.

Interval between emergence of moths of the 1st and 2nd generations averages 51 days, 2nd and 3rd ones — 40.6 days, between appearance of mines of the 1st and 2nd generations — 45 days, 2nd and 3rd ones — 42.2 days, between appearance of pupae of the 1st and 2nd generations 39.6 days, 2nd and 3rd ones — 60 days. Average sum of positive temperatures for development of one generation of horse-chestnut leafminer amounts 979 °C, sum of effective temperatures at threshold 10 °C amounts 516 °C.

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