Assessment of Biological and Ecological Characteristics of Sievers Apple Tree Pests in Trans-Ili Alatau, Kazakhstan

Roman Jashenko 1,2, Gulzhanat Tanabekova 1,3,* and Zhaozhi Lu 4

1 Institute of Zoology RK, 93 al-Farabi Str., Almaty 050060, Kazakhstan; roman.jashenko@zool.kz
2 Tethys Scientific Society, 93 al-Farabi Str., Almaty 050060, Kazakhstan
3 UNESCO Chair on Sustainable Development, Al-Farabi Kazakh National University, 71 al-Farabi Str., Almaty 050040, Kazakhstan
4 College of Plant Health and Medicine, Qingdao Agricultural University, Qingdao 266109, China; zhaozhi_lv@sina.com
* Correspondence: stat.stat2016@yandex.ru

Abstract: This research aimed to evaluate the occurrence of three significant pests, namely the apple ermine moth (Y. malinellus Zell.), the rosebush leaf roller (A. rosana L.), and the hawthorn leaf roller (C. crataegana Hb.), commonly found in Sievers apple trees. The research was conducted within the Ili-Alatau state national natural park, focusing on populations of the Sievers apple tree on the northern slope of the Trans-Ili Alatau mountain range. The study revealed varying pest abundances across different monitoring sites within the park. The apple ermine moth (Y. malinellus Zell.) exhibited lower occurrence compared to A. rosana L. and C. crataegana Hb. The Aksai and Kuznetsov Gorge populations of the Sievers apple tree showed higher susceptibility to the ermine moth. The rosebush leaf roller (A. rosana L.) was dominant in the Aksai and Oi-Zhailau populations, while the hawthorn leaf roller (C. crataegana Hb.) exhibited higher abundance in several monitoring sites. Phenological studies revealed that Y. malinellus Zell. have a life cycle of one year, the developmental stages of A. rosana L. last for approximately 9–10 months, and the life cycle of C. crataegana Hb. is also one year. The data obtained allowed us to assess pest status, which will hopefully help in developing protective measures for suppressing their outbreak in the region.

Keywords: Malus sieversii; insect pests; phenology; Yponomeuta malinellus Zell.; Archips rosana L.; Cacoecia crataegana Hb.

1. Introduction

Ile-Alatau State National Nature Park was established in 1996 with an area of 202,292 ha located near to the city of Almaty, Kazakhstan. Later, the area was gradually reduced. The boundaries of the Park have undergone multiple changes, and now the area of Ile-Alatau State National Nature Park is 186,400.2 ha [1]. Ile-Alatau State National Nature Park is located along the northern slope of the Zailiisky Alatau Mountains from the Shamalgan River in the west to the Sholak River in the east. Its length from west to east is 120 km, and its cross-section is 30 km. The southern boundary of the park runs along the main ridge of the Zailiiskiy Alatau and partly borders on the state border between Kazakhstan and the Kyrgyz Republic from the southwest. The northern boundary of the park runs along the foothills of the Zailiisky Alatau, covering wild forests. The main protected wealth of Ile-Alatau State National Nature Park is forest land. They cover an area of 75,207 ha, including a forested area of 62,262 ha and non-forested area of 10,969 ha. Thus, the forest cover of the protected area is 37.7% [2].

Apple and apricot forests are represented by massifs of different sizes, small groups, and individual trees throughout the territory of the national park. The Sivers apple tree is distributed practically in all gorges of the national park, namely Issyk, Mikushino, Soldatsay, Talgar, Kobyrbulak, Big and Small Almaty, Aksay, Kaskelen, and Turgen, at an...
altitude of 800 to 1800 m above sea level. The largest massifs of apple trees are located in the Belchabdar gorge, as well as in the “Kuznetsov slit” selection and a genetic site of about 200 ha located in the Taldy-Bulak tract of the Malovodnensk forestry of the Turgen area [3,4].

In terms of the implementation and preparation of reforestation measures, a lot of work is carried out by the department of forest protection and reproduction, as well as all areas of the national park. There are seven temporary forest areas (nurseries), including three in the Turgeni area, two in the Aksai area, and one each in the Medeu and Talgar areas. The total area of nurseries is 6.5 ha. For the creation of cultures of wild fruit plantations for the next 25 years, an area of 2265.0 hectares is defined, including apple Sivers (1409.0 ha), apricot (826.0 ha), and hawthorn (30.0 ha). Since 2008, on the territory of Ile-Alatau, SNNP has already created forest cultures for two main breeds: apple (81.1 ha) and apricot (115.2 ha). At the time of writing, the condition of the plantings is satisfactory (rooting rate 50% or higher) [5].

The main natural heritage of Ile-Alatau Park is coniferous forests consisting of Shrenka spruce and deciduous plantings of relict Sivers apple and wild apricot, aspen, birch, mountain ash, hawthorn, shrubs, and herbaceous plants [6]. It is important to note that the Sivers apple tree is recognized as the progenitor of the entire modern assortment of this fruit species in the world. The Almaty State Complex Reserve occupies 542,400 hectares and serves as a protection zone along the northern, eastern, and southern borders. The area of wild populations of this apple tree species has decreased by 75–80% in the last 100 years since the active development of lowlands in the vicinity of settlements.

The lower border of apple trees has risen by 200 m. The conditions for M. sieversii were noted on slopes of northern expositions at altitudes of 1300–1600 m. Wild apple forests exist as massifs of various sizes, small groups, and single trees, located mainly in the gorges of Issyk, Mikushino, Soldatsai, Talgar, Kotyrbulak, and the Big and Small Almatinka [7].

The area of Sivers apple trees has decreased due to mass felling for economic purposes, the ploughing of certain areas, grazing, grafting with cultivars, the development of slopes for summer houses, and a sharp decrease in natural regeneration as a result of excessive grazing.

At present, the unique intraspecific diversity of Kazakhstan’s wild apple populations is rapidly decreasing, resulting in a decline in the value of its gene pool. It is already difficult to restore these resources in a natural way as, in many local populations, there is practically no natural regeneration of apple trees. In addition, the proximity of cultivated apple orchards directly adjacent to wild populations of fruit forests is a serious problem. The buffer protection zone along natural populations is often not maintained. In addition to alien plant species, insect pests and diseases of wild apple trees and other wild fruit plant species threaten wild fruit forests [8,9].

Archips rosana, commonly known as the apple tree leaf roller moth, is a common pest of apple trees and other fruit trees. The larvae of this species feed on the leaves of fruit trees, rolling them up and webbing them together to create a shelter. This can cause damage to the leaves, which can reduce the tree’s ability to photosynthesize and produce fruit [10,11]. The rosebush leaf roller A. rosana L. has a high degree of contamination and abundance in all monitoring sites, except the Kuznetsov Gorge genetic reserve, where this leaf roller has an average occurrence. Yponomeuta malinellus, also known as the apple ermine moth, is another pest that can cause significant damage to apple trees. The larvae of this species spin a web around the apple tree branches, creating a ‘tent’ that they use for shelter. They then feed on the leaves and fruit of the tree, causing damage and reducing the yield [12,13]. Cacoecia crataegana, commonly known as the hawthorn leaf roller moth, is a species of moth that is a pest of hawthorn trees. The larvae of this species are known for feeding on the leaves of hawthorn trees, rolling the leaves, and webbing them together to create a shelter. This can cause significant damage to the tree and weaken it, making it more susceptible to other pests and diseases. These three dominant species can cause significant damage to wild populations of apple trees, reducing their yield and making them more vulnerable.
to other pests and diseases. Appropriate pest management practices, including cultural practices, biological controls, and chemical treatments, can help to manage and reduce the impact of these pests [14,15].

The early seasonal defoliation of trees is particularly hard on the organism of fruit trees, so the radial growth of trees can be significantly reduced for several years after the outbreak of insect pests. This reduction in tree growth facilitates the establishment of pathogenic fungi, bacteria, and insect pests on the tree, which, in turn, can further desiccate the trees [16,17]. For example, the outbreak of apple moths in 1998–2003 in the Dzhungar Alatau and in 2008–2011 in the Trans-Ili Alatau endangered priceless Sievers apple trees [18]. For 8 years in a row, during summer, the trees stood leafless, and after secondary leaf formation, they were weakened and subsequently dried out. Notably, the apple moth is also threatening the cultivated gardens and apple trees in the Trans-Ili Alatau, and some areas of apple orchards have been badly damaged by pests [19].

The ecological characteristics of pests are important to understand because they can help to identify the factors that contribute to pest outbreaks and the development of effective pest management strategies. To prevent widespread pest damage in apple forests, it is essential to establish regular scientific pest monitoring programs that track the dynamics of pest populations and their natural enemies and provide information on the phytosanitary status of a particular area during certain phenological periods. Such programs should be implemented alongside forest management and protective measures [20].

This study aimed to assess the occurrence of three major pests (Yponomeuta malinellus Zell., Archips rosana L., and Cacoecia crataegana Hb.) that are commonly found in Sievers apple trees. Additionally, it aimed to investigate the life cycle characteristics of these pests in order to provide preventive recommendations. By understanding the phenological aspects of these pests in the Northern Tien Shan region, it becomes possible to enhance the survival of trees and effectively manage their harmful populations.

2. Materials and Methods
2.1. Distribution and Study Area

Our research involved examining multiple populations of the Sievers apple tree within Ili-Alatau state national park, specifically on the large northern slope of the Trans-Ili Alatau mountain range. All studied wild natural populations are located at altitudes of 900–1500 m above sea level, though on slopes of southern exposition, they may rise up to 1500–1700 m (Figure 1). Samples were taken from monitoring sites of Ile-Alatau State National Park, such as the Aksai forestry, the Soldatsai forestry, the Issyk forestry, the Small Almatinka gorge, the Oi-Zhailau gorge, the Kuznetsov gorge breeding-genetic reserve (Figure 2).

In the Soldatsai population of the Talgar area national park, M. sieversii are found in the form of small massifs, groups, and individual trees, predominantly of yellow fruit forms. In the Issyk River gorge population, the Sievers apple trees are found individually and in groups at altitudes of 1200–1800 m above sea level on slopes of northern exposition and along the river bed.

In the Alma-Arasan gorge population of the Medeu area of the national park, the Sievers apple tree grows in small groups or individual trees. In the Aksai area of the national park, the apple trees are found as individual trees amidst other trees and shrubs [21].

2.2. Sampling Methods

The extent of the spread of harmful organisms was identified by completing a route survey of the monitoring sites and catching insect pests with an entomological net. In each monitoring site, 10 trees of different ages were selected. Sampling was carried out in April, during daylight hours, as the post-embryonic development of these pests begins in this month. The caterpillars begin to hatch in April, and they damage the leaves of trees.
In the Soldatsai population of the Talgar area national park, *M. sieversii* are found in the form of small massifs, groups, and individual trees, predominantly of yellow fruit forms. In the Issyk River gorge population, the Sievers apple trees are found individually and in groups at altitudes of 1200–1800 m above sea level on slopes of northern exposition and along the river bed.

In the Alma-Arasan gorge population of the Medeu area of the national park, the Sievers apple tree grows in small groups or individual trees. In the Aksai area of the national park, the apple trees are found as individual trees amidst other trees and shrubs [21].

2.3. Pests Counting

Pests were counted by methods generally accepted in entomology. Thus, leaf damage by leaf rollers (hawthorn and rosebush leaf) per 10 model trees were accounted by damage degree as follows:

1: Weak, 2: Medium, and 3: Severe. Damage to leaves by apple moth was determined per 10 model trees on a four-point scale, which was as follows: 0—no damage, 1—damaged leaves on single branches, 2—leaves damaged by 10–25%, 3—leaves damaged by 50–75%, and 4—completely damaged.

One hundred leaves per tree were assessed three times between April and July. The prevalence of the dominant pest species was investigated according to the “Methodological guidelines for monitoring pests, weeds and crop diseases” [22].
The results of studying the species composition of pests were recorded using the following scale:
- 0—species in the collection is absent;
- +—a rare occurrence of species (5–10% of leaves, generative and axial parts of the tree are infested or damaged);
- ++—average occurrence of species (10–25% of leaves, generative and axial parts of the tree are infested or damaged);
- +++—high occurrence (25–50% of the surface of analysed tree organs are infested and damaged).

2.4. Pests Types and Identification

The pests that were most relevant to our research objectives were apple ermine moth *Yponomeuta malinellus* Zell., hawthorn leaf roller *Cacocia crataegana* Hb., and rose leaf roller *Archips rosana* L. The first item we inspected were leaves contaminated by pests at different stages of their development, including larvae of different ages, pupae, and adults [23,24]. Various identification tables that have been widely referenced in the scientific literature were used. All collected insects were thoroughly studied under a microscope and photographed.

2.5. Phenological Characterization of Pests

The phenological characteristics of the three dominant pests were studied both in the field and in the laboratory via artificial cultivation of all development stages in cages (2018–2019, the Institute of Zoology of the RK National Academy of Sciences). The collected moths and larvae were placed in 0.5 L glass jars or glass tubes together with their host *M. sieversii* leaves. Infested leaves were also kept separately in other test tubes. These artificial cages were marked with serial numbers, and a register, which listed their respective details, was made; these details included entry number, place and time of collection, information on the plant and the nature of its damage, etc. Subsequently, the larvae were transplanted into separate tubes for shedding and keeping [24,25].

Laboratory tests were carried out according to the method of Dobrovolsky [26] and Fasulati [27]. Insect pests were grown from April to July. Samples were kept in a growth chamber. The feeding ration was changed as required. The day–night cycle regime was kept the same as it would be naturally. The temperature regime and relative humidity were set close to natural conditions.

In the laboratory, the tubes with twisted leaves were covered with gauze and labeled. The keeping and feeding of larvae in test tubes were strictly controlled, constantly maintaining the appropriate moisture degree, which is necessary for the normal development of larvae [28]. To this end, the jars with the larvae were not kept long under the direct rays of the sun in order to avoid the tubs fogging up, since over-moistening and overheating would negatively affect the development of the larvae. Monitoring sites (Table 1) were laid in wild fruit forests of the Trans-Ili Alatau at various heights from 1345 to 1714 m.

Table 1. Geographic coordinates of the monitoring sites.

<table>
<thead>
<tr>
<th>Location</th>
<th>Easting</th>
<th>Northing</th>
<th>Elevation (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Aksai area, the Aksai forestry</td>
<td>76°47'58&quot;</td>
<td>43°7'23&quot;</td>
<td>1345</td>
</tr>
<tr>
<td>The Talgar area, the Soldatsai forestry</td>
<td>77°21'16&quot;</td>
<td>43°16'5&quot;</td>
<td>1538</td>
</tr>
<tr>
<td>The Issyk area, the Issyk forestry</td>
<td>77°29'05&quot;</td>
<td>43°15'11&quot;</td>
<td>1714</td>
</tr>
<tr>
<td>The Medeu area, the Small Almatinka gorge</td>
<td>77°01'31&quot;</td>
<td>43°09'59&quot;</td>
<td>1553</td>
</tr>
<tr>
<td>The Aksai area, the Ot-Zhaylau gorge</td>
<td>76°50'30&quot;</td>
<td>43°07'26&quot;</td>
<td>1453</td>
</tr>
<tr>
<td>The Turgen area, the Kuznetsov gorge breeding-genetic reserve</td>
<td>77°40'21&quot;</td>
<td>43°22'05&quot;</td>
<td>1595</td>
</tr>
</tbody>
</table>
2.6. Statistics

The data obtained from the study are the results of triplicate measurements. The resulting measurements were analyzed using XLStat 2020 (Addinsoft Inc., Lille, France). The differences between the samples were evaluated using one-way ANOVA; \( p < 0.05 \) was considered statistically significant.

3. Results and Discussion

3.1. Pest Infestation of Apple Tree

To date, more than 130 species of pests of wild Sievers apple tree populations and other fruit species have been recorded in the mountainous wild fruit forests of the Trans-Ili and Dzungar Alatau \[28,29\]. The pests that cause the most environmental damage are insects, among which the most significant (52%) are species of the order Lepidoptera (69 species of 57 genera). We identified three dominant species that cause significant damage to wild populations of apple trees (Table 2).

Table 2. Dominant species causing epiphytotic and economic loss, as well as their species breeding mass.

<table>
<thead>
<tr>
<th>Dominant Pest</th>
<th>Kuznetsov</th>
<th>Soldatsai</th>
<th>Small Almatinka</th>
<th>Aksai</th>
<th>Issyk River</th>
<th>Oi-Zhailau</th>
</tr>
</thead>
<tbody>
<tr>
<td>Archips rosana L.</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
<tr>
<td>Yponomeuta malinellus Zell.</td>
<td>+++</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>++</td>
<td>+++</td>
</tr>
<tr>
<td>Cacoecia crataegana Hb.</td>
<td>++</td>
<td>++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>

Note: +++—strong degree of infestation; ++—medium.

Meanwhile, the hawthorn leaf roller \( C. crataegana \) Hb. has an average occurrence and contamination degree in the Kuznetsov and Soldatsai gorges, but at other monitoring sites, it has a high degree of abundance and contamination. There was a moderate distribution of \( A. rosana \) L. and \( C. crataegana \) Hb. in the Kuznetsov Gorge genetic reserve, although apple ermine moths are abundant here (as in the Aksai and Oi-Zhailau gorges). It was found that, in the Trans-Ili Alatau, the occurrence of \( Y. malinellus \) Zell. is lower than \( A. rosana \) L. and \( C. crataegana \) Hb.

The Sievers apple tree of the Aksai and the Kuznetsov Gorge populations is more affected by the ermine moth compared to the trees growing in other monitoring sites. Our findings revealed that the rosebush leaf roller damaging the Sievers apple tree foliage is also dominant in the Aksai and Oi-Zhailau populations, although its number in the Small Almatinka population is noticeably lower. Hawthorn leaf rollers are also abundant in the Aksai population, but their abundance is noticeably lower in the Soldatsai and the Kuznetsov Gorge populations.

The study revealed that the three dominant species that damage the leaf of \( M. sieversii \) have the highest abundance in the Aksai apple tree population. Meanwhile, the least damage from the three dominant species was noted in the Small Almatinka population. Data on damage to foliage and trees from the three dominant pests (\( Y. malinellus \) Zell., \( A. rosana \) L., \( C. crataegana \) Hb.) in the monitored sites of the Trans-Ili Alatau are presented in Table 3.

The degree of damage to the leaves of \( M. sieversii \) by \( Y. malinellus \) Zell. in the monitored sites ranged from 19.5 to 28.7%, while for \( A. rosana \) L. and \( C. crataegana \) Hb., this figure ranged from 30.8 to 21.2% and from 25.4 to 15.6%, respectively. The pests’ mediated tree damage values were as follows: 17–24% for \( Y. malinellus \) Zell., 28.2–20.3% for \( A. rosana \) L., and 21.6–15% for \( C. crataegana \) Hb.
### Table 3. Percentage damage to leaf blades and percentage damage to trees by dominant pests.

<table>
<thead>
<tr>
<th>Coordinates</th>
<th>Place of Damage</th>
<th>Species of Insect Pest</th>
<th>Damage Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Yponomeuta malinellus Zell.</td>
<td>Leaf Blade</td>
</tr>
<tr>
<td>E—76°47′58″N—43°7′23″</td>
<td>Aksai area, Aksai forestry</td>
<td>28.7</td>
<td>23.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>25.4</td>
</tr>
<tr>
<td>E—77°21′16″N—43°16′5″</td>
<td>Talgar area, Soldatsai Forestry</td>
<td>Yponomeuta malinellus Zell.</td>
<td>20.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>25.8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>15.6</td>
</tr>
<tr>
<td>E—77°29′05″N—43°15′11″</td>
<td>Issyk area, Issyk forestry</td>
<td>Yponomeuta malinellus Zell.</td>
<td>21.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>22.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>18.5</td>
</tr>
<tr>
<td>E—077°01′31″N—43°09′59″</td>
<td>Medeu area of Maloalmatinskeo forestry</td>
<td>Yponomeuta malinellus Zell.</td>
<td>19.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>21.2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>17.3</td>
</tr>
<tr>
<td>E—76°50′30″N—43°07′26″</td>
<td>Aksai area, Oyzhailau forestry</td>
<td>Yponomeuta malinellus Zell.</td>
<td>23.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>27.6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>22.5</td>
</tr>
<tr>
<td>E—77°40′21″N—43°22′05″</td>
<td>Turgen area, Kuznetsovo Gorge genetic reserve</td>
<td>Yponomeuta malinellus Zell.</td>
<td>26.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Archips rosana L.</td>
<td>23.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cacoecia crataegana Hb.</td>
<td>16.4</td>
</tr>
</tbody>
</table>

#### 3.2. Phenology of Yponomeuta malinellus Zell.

The wintered larvae of the first age of the apple ermine moth appear in mid-April, when the average daily temperature is usually above 13 °C. The apple ermine moth larvae (arachnid moth) start life in the open for 10–12 days upon the first shedding. Larvae completely eat leaf blades to the base of veins and weave arachnoid nests on paired leaves. The pupation period coincides with the time of dropping the excess ovary from 11–15 June to 1–5 July, depending on the development of larvae. Pupa develops 8–15 days (occasionally up to 20). Pupation takes place in dense white opaque cocoons densely grouped in packs of up to several hundred. The imago stage begins from 1 to 5 July, and the moths live 20–30 days, being active from early July to August and not needing additional nutrition. The active flight of moths is observed in twilight hours, while in the daytime, they hide on the underside of leaf blades. Mating occurs 2 weeks after dropping the pupae, and 5–6 days later, the imago begins to lay eggs. Embryonic development observably started from 21–25 July to 6–10 August. On average, a female apple moth lives for about a month, and a male apple moth lives for about twenty days. Larvae hatch from the eggs after 8–15 days in winter under moisture-proof shields (Figure 3). The life cycle of the apple ermine moth takes around 2–3 months to complete, and there can be multiple generations per year depending on the climate and conditions (Figure 4) [30,31].
The emergence of larvae from diapauses begins during the bud swelling period (Figure 5). The active flight of moths is observed in twilight hours, while in the daytime, they live 20–30 days, being active from early July to August and not needing additional nutrition. The male apple moth lives for about twenty days. Larvae hatch from the eggs after 8–15 days in winter under moisture-proof shields (Figure 3). The life cycle of the apple ermine moth takes around 2–3 months to complete, and there can be multiple generations per year depending on the climate and conditions (Figure 4) [30,31].

5–6 days later, the imago begins to lay eggs. Embryonic development observably started and a male apple moth lives for about twenty days. Larvae hatch from the eggs after 8–15 days in winter under moisture-proof shields (Figure 3). The life cycle of the apple ermine moth takes around 2–3 months to complete, and there can be multiple generations per year depending on the climate and conditions (Figure 4) [30,31].

Mating occurs 2 weeks after dropping the pupae, and a male apple moth lives for about twenty days. Larvae hatch from the eggs after 8–15 days in winter under moisture-proof shields (Figure 3). The life cycle of the apple ermine moth takes around 2–3 months to complete, and there can be multiple generations per year depending on the climate and conditions (Figure 4) [30,31].

### Figure 3. Phenograms of the development of the main representatives of Lepidoptera, damaging *M. sieversii* in the conditions of the Trans-Ili Alatau (data from the field seasons 2018–2019): ◐—pupae; ▲: mass pupation; +—imago; +—mass flight of imago; 0—egg laying; ●: eggs; Ω—larvae; Ω—mass hatching of larvae; —diapauses (wintering stage).

### Figure 4. Stages of development of apple ermine moth (*Y. malinellus* Zell.) in laboratory. (a) Larvae, (b) pupae, (c) imago (Photos: Gulshanat Tanabekova).

#### 3.3. Phenology of *Archips rosana* L.

During hibernation, the *A. rosana* L. overwinters and lays eggs in a single layer on the smooth bark of the lower part of an apple tree trunk or in the crutches of large branches in the Trans-Ili Alatau region. Larvae come out when the average daily temperature reaches 12–14 °C. Under the conditions of the Trans-Ili Alatau, this happens in the first half of April. The emergence of larvae from diapauses begins during the bud swelling period (Figure 5).
Larvae of 1–2 ages feed on young swelling buds and shoots, and larvae of 2–3 ages penetrate into flower buds eating pistils and stamens. The rosebush leaf roller has the longest larvae stage, lasting from 11–15 April to 16–20 May, and this is due to the fact that this type of leaf roller has five development ages within the stage. Pupation begins on 21–25 May, lasting for about 10–14 days, then it passes into the adult imago stage from 26–30 May to 1–5 August. Females come out with a certain amount of matured eggs. Egg-laying begins 3–5 days after the flight of moths. By early August, a decline in imago is observed, and embryonic development begins [32]. The stage at which pests are most vulnerable is the first stage, the appearance of larvae during April-May. According to our observations, pest flight outbreaks occur after precipitation. The adult rose leaf rollers emerge from their cocoons in the summer, after around two weeks in the pupal stage. The adult moths are small, light brown in color, and have a wingspan of about 1–1.5 cm. After mating, the female moth lays eggs on rosebush leaves, and the cycle starts again. In some regions, there can be up to three generations of rose leaf rollers per year [33].

3.4. Phenology of Cacoecia crataegana Hb.

C. crataegana Hb. hibernate as eggs and then continue their development from 21–25 April. Larvae hatch in the first stage, starting in May, at an average daily air temperature above 15–17 °C, which coincides with the budding phase of apple trees, and sprawl all over the crown. At the 1–3 instars, they damage unfolding buds, burgeons, and flowers or stay under curled edges of leaves. At the age of four, they build shelters by folding leaves along the main vein and fastening the edges with cocoon silk, not twisting the leaf-like rosebush leaf roller larvae do. Larvae of the last age live in leaf lumps at the tops of shoots. Most larvae accumulate in the outer part of the apple tree crown, in its middle and upper parts (Figure 6).

The larvae are active from the first half of May to the end of June. The hatching of larvae basically coincides with the apple tree budding phase. Larvae are passive migrants that spread on cocoon silk by winds over a considerable distance; therefore, they are often found in nurseries and orchards with the complete absence of clutches on fruit trees. Pupation occurs from 6 to 10 June. Moths fly from mid-June to mid-August, with the maximum flight occurring in mid-July during twilight hours and at night. Moths begin laying eggs 2–4 days later and continue to do so throughout their flight period. The entire life cycle takes about 6–8 weeks, and there can be multiple generations in a year depending on the climate and location. Control measures for hawthorn leaf rollers include pruning and removing infested plant parts, using insecticides, and promoting natural predators such as birds and parasitic wasps [34,35].
The larvae are active from the first half of May to the end of June. The hatching of larvae basically coincides with the apple tree budding phase. Larvae are passive migrants that spread on cocoon silk by winds over a considerable distance; therefore, they are often found in nurseries and orchards with the complete absence of clutches on fruit trees. Pupation occurs from 6 to 10 June. Moths fly from mid-June to mid-August, with the maximum flight occurring in mid-July during twilight hours and at night. Moths begin laying eggs 2–4 days later and continue to do so throughout their flight period. The entire life cycle takes about 6–8 weeks, and there can be multiple generations in a year depending on the climate and location. Control measures for hawthorn leaf rollers include pruning and removing infested plant parts, using insecticides, and promoting natural predators such as birds and parasitic wasps [34,35].

Results of the experiments on the effect of temperature on the development of insects are presented in the graph below (Figure 7), which shows the main outbreaks of mass flight of imago at a temperature of 15–20 °C in mid-June and July.

3.5. The Effect of Temperature on the Development of Y. malinellus Zell.

The emergence of larvae from hibernation under conditions of middle altitudes begins at an average daily temperature of 17 °C. The pupal stage lasts for about 10–14 days at an average temperature of 21 °C. Mass pupation takes place in the third week of May at an average daily temperature of 20–25 °C. Adult hatching occurs from late May to early August, with the massive flight of moths occurring in the second half of June at an average daily temperature of 28 °C. The life of an adult lasts between 8 and 30 days. By early August, there is a gradual decline in imago. Laying eggs begins in the third week (26 June 2019) at an average daily temperature of 30 °C.

As a result of the 2018–2019 studies, in the middle latitudes, the winter stage ceases, and first-stage larvae emerge at an average daily temperature of +13 °C. In about 37–45 days, they go to pupation at an average daily temperature of 29 °C. This stage of development lasts about 8–15 days. Mass pupation occurs in the first ten days of July at an average daily temperature of 31 °C. The first adults appear in the first ten days of July at 30 °C. Mass imago is observed a week later at an average daily temperature of 32 °C. On average, a female apple ermine moth lives for about a month, while a male apple ermine moth has a lifespan of about 20 days. During our research, it was found that mass egg-laying takes place in late July. Apple ermine moth winters in the caterpillar stage of the first age.

4. Conclusions

The results of the current study revealed that the occurrence of defoliating insects and their degree of damage to Sievers apple trees is predominantly due to three pest species: the apple ermine moth (Y. malinellus Zell.), the rosebush leaf roller (A. rosana L.), and the hawthorn leaf roller (C. crataegana Hb.) in the Aksai population. However, the Kuznetsov Gorge population and the Small Almatinka forestry have the smallest number of and degree of damage to Sievers apple trees. Further, our findings (2018–2019) suggest the duration of various development stages of Y. malinellus Zell. was as follows: the full life cycle is one year (one generation), the egg lives for 8–15 days, the larvae for 37–45 days (including wintering, 300–320 days), pupa for 8–15 days, and the imago for 30 days. Likewise, the full life cycle of A. rosana L. includes the developmental stage, which lasts around of 9–10 months (the egg stage), 30–40 days of five larvae ages, 10–14 days of pupa, and more than 2 months of imago. The full life cycle of the hawthorn leafworm C. crataegana Hb. is 1 year (one generation) and includes the following development stages: 9–10 months of the egg stage, 25–40 days of five larvae ages, 10–16 days of pupa, and more than 2 months of imago. Our findings indicate that Y. malinellus Zell., compared to A. rosana L. and C. crataegana Hb., has a high prevalence and exhibits major damage towards the leave blades and trees. The data obtained allowed us to assess the status of the three species in open fields and build protective measures for suppressing pest outbreaks in this region.

Author Contributions: Conceptualization, G.T.; Data curation, Z.L.; Formal analysis, R.J.; Investigation, G.T.; Methodology, G.T. and Z.L.; Project administration, R.J.; Supervision, R.J.; Visualization, Z.L.; Writing—original draft, G.T.; Writing—review and editing, R.J. All authors have read and agreed to the published version of the manuscript.

Funding: The research was carried out within the framework of the scientific program BR18574058 «Development of the Red Data Book of Animals of Kazakhstan and an electronic database of rare and endangered animals» of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

References


14. Onstad, D.W.; Harvey Reissig, W.; Shoemaker, C.A. Phenology and management of the oblique banded leafroller (Lepidoptera: Tortricidae) in apple orchards. J. Econ. Entomol. 1985, 78, 1455–1462. [CrossRef]


26. Dobrovolsky, B.V. Insect Phenology; Higher School: Moscow, Russia, 1961; p. 123.


34. Lawson, D.S. Integrated Management of Oblique Banded Leafrollers (Lepidoptera Tortricidae) in Apple Orchards; Cornell University: New York, NY, USA, 1996.


Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.