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Studies on Potential Pests of Japanese Quince (*Chaenomeles japonica* (Thunb.) Lindl. ex Spach) in Latvia

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Abstract. The objective of this research was to study potential pests of Japanese quince (*Chaenomeles japonica*) plantations in Latvia. Studies were carried out in eight plantations during 2017–2019. Major pests that would regularly cause significant yield losses for this plant were not observed. Black-veined white (*Aporia crataegi*) was considered a local pest, mass outbreaks of which can occur in individual plantations and cause significant losses of plant foliage. Four species were considered minor pests: garden chafer (*Phyllopertha horticola*), yellow-banded weevil (*Chlorophanus viridis*), silver-green weevil (*Phyllobius argentatus*) and copse snail (*Arianta arbustorum*); they are also pests of plant foliage. The European red spider mite (*Panonychus ulmi*) was not considered as a pest of Japanese quince. A small population was observed in summers only in one plantation, which was located next to a heavily infested orchard. Overwintering eggs were not found on the plants in any year, and we concluded that the species was an accidental immigrant in this plantation. No aphid (Aphididae) colonies were observed on the quince plants. Monitoring and evaluation of potential harmfulness of four tortrix moths – large fruit-tree tortrix (*Archips podana*), rose tortrix (*Archips rosana*), codling moth (*Cydia pomonella*) and holly tortrix (*Rhopobota naevana*) – was done. It was concluded that rose tortrix is a minor fruit pest, but the other three species were not yet considered pests of Japanese quince. Significant pests of quince flowers and fruits were not detected in our study.
Key words: minor pests, polyphagous pests, *Aporia crataegi*, foliage damage, *Panonychus ulmi*.

Introduction

Japanese quince (*Chaenomeles japonica*) (further: CHAE) is a comparably small bush (0.5–1.5 m in height) being native to the eastern part of China and to Japan and belonging to the rose family (Rosaceae). In the Baltic region, CHAE was introduced a comparably long time ago, and until the middle of twentieth century, it was cultivated mainly as an ornamental plant; at this time, cultivation of CHAE as a fruit crop began (Mauriņš & Zvirgzds, 2009). During the seventies and eighties of the last century, the total area of plantations reached 300 ha in Latvia (Rumpunen, 2011). In spite of the significant food value of CHAE fruits (Hellín et al., 2003; Ros et al., 2004), cultivation of this crop almost stopped during the nineties. It was caused by several reasons, e.g., the fruits are firm and cannot be consumed fresh (1), the comparably low diversity of processed products (2), fully manual harvesting of yield (3), etc. (Rumpunen, 2011). During the last two decades, new processed food products of CHAE were introduced into the market and also the potential to use them as a source of cosmetic ingredients was studied (Kikowska et al., 2018), therefore cultivation of this plant slowly restarted. For instance, in the beginning of 2016, in Latvia, the total area of CHAE plantations was 275 ha and it also has the tendency to increase in recent years reaching 673 ha in 2021 (Central Statistical Bureau Republic of Latvia).

Recently, as the popularity of CHAE growing increases, farmers have started to show increasing interest in pests and pathogens potentially harmful to the quantity and quality of yield. There is a lack of sufficient information on potential pests of CHAE in Europe. During the second half of the twentieth century, when growing of CHAE was on its first peak in Latvia, significant pests of this plant were not registered. In Lithuania, a yellow-banded leaf weevil (*Chlorophanus viridis*) was observed causing

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damage to leaves of CHAE plants in the Pomological collections of the Vilnius University Botanical Garden (Grigaliūnaitė, Žilinskaitė & Radaitienė, 2012). In Poland, six species of aphids – green apple aphid (*Aphis pomi*), black bean aphid (*Aphis fabae*), leaf-curling plum aphid (*Brachycaudus helichrysi*), common dogwood-grass aphid (*Anoecia corni*), *Aphis spiraephaga* and *Acyrthosiphon ignotum* – were found on CHAE plants in parks of the city of Lublin (Jaśkiewicz, 1995; Jaśkiewicz, Kmieć & Gantner, 2004). All of these studies were done in conditions where CHAE was cultivated for ornamental or scientific purposes. However, in fruit plantations, potential CHAE pests have not been studied yet.

From 2017 to 2019, the project 'Environment-friendly cultivation of emerging commercial fruit crop Japanese quince – *Chaenomeles japonica* and waste-free methods of its processing' (No. 1.1.1.1/16/A/094) supported by the European Regional Development Fund (ERDF) was implemented in Latvia. One of the objectives of this project was to study potential pests

Table 1

Data on studied Japanese quince plantations

Farm's name	Plantation's coordinates	Area, ha	Farming system	Description of the plantation and its surroundings
Institute of Horticulture (LatHort)	56°36'28.7"N 23°17'57.7"E	0.35	Integrated	There was geotextile on the soil, the old branches of the bushes were pruned in the spring, and the inter-rows were mowed regularly. Next to the plantation was an orchard (apple trees, plums, cherries) heavily infested with European red spider mite.
Farm A	57°25'16.5"N 22°38'50.5"E	2.19	Organic	There was geotextile on the soil, the old branches of the bushes were pruned in the spring and the inter-rows were mowed regularly. The plantation mostly was surrounded by strawberries. On the southern edge, it was bordered by mixed forest. There was also a farmstead nearby with a small backyard orchard.
Farm B	57°25'44.8"N 25°16'31.4"E	4.59	Organic	There was geotextile on the soil, the inter-rows were regularly mowed. The plantation was bordered by grasslands, arable lands and mixed forests.
Farm C	56°49'57.8"N 21°38'15.3"E	30.0	Organic	The plantation was surrounded by arable land. The soil was uncovered; the inter-rows were not mowed. CHAE plants were overgrown by thick grass, and in many places, clumps of small wild deciduous trees and shrubs grow.
Farm D	57°28'00.1"N 25°50'02.7"E	15.0	Organic	Inter-rows were harrowed. The soil was uncovered, the CHAE plants were overgrown with weeds, but they, along with all the weeds, were trimmed once during the growing season (the tops and sides of the bushes were trimmed). The plantation was bordered mainly by forests.
Farm E	57°01'45.2"N 24°58'03.1"E	10.0	Organic	The inter-rows were mowed, but the CHAE plants were overgrown with weeds (soil not covered). The plantation was surrounded on three sides by forests and thickets; on the fourth edge, berry plantations were located.
Farm F	57°08'37.7"N 24°35'44.9"E	20.0	Organic	The inter-rows were mowed, but the CHAE plants were overgrown with weeds and small trees (soil not covered). Various forest biotopes were located near the plantation. On 15 May 2019, the biological insecticide 'NeemAzal-TS' (active substance – azadirachtin) was applied.
Farm G	57°24'04.6"N 25°22'52.3"E	13.5	Organic	The plantation was surrounded by coniferous and mixed forest on all sides. Inter-rows were mowed once a year. CHAE plants were overgrown by weeds and small trees (soil not covered).

Figure 1. Geographical location of the studied Japanese quince plantations.

of CHAE plantations. To achieve the objective, we performed the following tasks:

1) Monitoring of the presence of European red spider mite (*Panonychus ulmi*), large fruit-tree tortrix (*Archips podana*), rose tortrix (*Archips rosana*), codling moth (*Cydia pomonella*), holly tortrix (*Rhopobota naevana*) and black-veined white (*Aporia crataegi*) in CHAE plantations and assessment of potential harmfulness of these invertebrates.

2) Monitoring of damage intensity of CHAE flower buds / flowers, leaves and fruits; identification and assessment of potential harmfulness of pests damaging these parts of CHAE plants.

The European red spider mite and tortrix moths were chosen because they are more or less important pests in various orchards and/or berry plantations both in Latvia and in the neighbouring countries. Therefore, we hypothesised that these species could be present and potentially harmful in CHAE plantations in Latvia. Black-veined white was not originally included in the list of species to be monitored. However, in the second year of the study (vegetation season of 2018), larval nests of this butterfly were observed in large quantities in one CHAE plantation. Therefore, in the second and third year of the study, we also monitored this species in CHAE plantations.

Materials and Methods

Field study sites and conditions

Our studies were performed in Latvia during 2017–2019 in eight plantations of Japanese quince. Seven of them belonged to various organic farms (in this paper, these are named by letters: A, B, C, D, E, F and G) where CHAE was managed for economic purposes to obtain a yield of fruits. Only CHAE seedlings of unidentifiable varieties were grown in these plantations. One plantation was managed by a scientific institution – Institute of Horticulture of Latvia University of Life Sciences and Technologies (further in the text: LatHort) – and was managed and used mainly for scientific purposes since it was established. Three CHAE varieties – 'Rondo', 'Darius' and 'Rasa' – as well as various hybrids were grown in this plantation. The creation of the plantations of farms C and G started in the early nineties of the twentieth century. On the other hand, the rest of the plantations were eight years old or younger at the time of the start of the research. The plantation management regimes were very different. In several farms, geotextile was applied to the soil under the CHAE plants, the rows were mowed regularly, and the old branches were cut at the beginning of each growing season. However, in some plantations, the management regime was minimal – the only economic activities were harvesting and periodically increasing the area by planting new CHAE plants. As a result, these plantations visually resembled grasslands overgrown with wild bushes and trees. The manner in which the studied plantations were managed describes the significant differences in the understanding and opinions of various farmers regarding the cultivation of CHAE plants in Latvia well. A more detailed

Table 2

Average air temperature (°C) and total precipitation (mm) observed in the ten-day periods of the spring and summer months of 2017–2019 in Latvia (State Limited Liability Company 'Latvian Environment, Geology and Meteorology Centre' public data)

	April			May			June			July			August		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
Air temperature in 2017	6.4	1.6	4.2	7.0	11.2	13.4	12.5	15.4	14.4	14.7	15.5	17.5	17.8	18.2	14.8
Air temperature in 2018	5.5	9.1	8.8	12.6	15.8	17.2	15.0	17.1	15.3	15.3	21.2	22.6	22.1	18.0	16.2
Air temperature in 2019	5.1	5.4	12.9	7.2	13.5	14.1	18.7	19.4	17.7	14.3	15.4	18.8	15.1	17.7	18.0
Precipitation in 2017	6.0	12.6	32.2	3.0	4.1	15.1	21.2	25.4	24.7	19.8	39.9	12.6	23.4	21.9	45.5
Precipitation in 2018	24.2	7.9	10.9	12.5	9.1	2.3	2.7	6.5	34.8	16.6	22.5	12.9	19.4	30.4	19.4
Precipitation in 2019	1.9	0.1	0.9	13.6	9.2	28.6	6.1	27.0	14.7	52.4	17.8	19.0	26.4	9.8	12.7

description of the plantations and their surroundings is given in Table 1. The geographical location of the research sites can be seen in Figure 1.

In the research season of 2017, there were drastically different meteorological conditions compared to the other two years. This year was relatively cool and rainy, especially May, June and July, when temperatures were atypically low for the last decade. On the other hand, in 2018 and 2019, in the spring and summer months, the average air temperature significantly exceeded the long-term average, but the amount of precipitation was significantly lower with some exceptions (Table 2).

Data acquisition and processing methods

At the beginning of each growing season, in all plantations, observation points – CHAE plants marked with poles – were set up, in which various observations of potential pests and their activity were made during the season. At each commercial plantation, 20 observation points were arranged along a transect, which was made from the edge of the plantation towards its middle; the distance between observation points was 10 m. If the plantation was too small and all the observation points could not be arranged on one transect, then two diagonal transects with 10 observation points on each were arranged in such a plantation. Thirty observation points were set up in the LatHort plantation in 2017 and 2018 – 10 each in sectors of the varieties 'Rasa', 'Rondo' and 'Darius'. However, in 2019, 40 observation points were set up in this plantation – an additional 10 points in the sector of the plantation where hybrids were located. The design and area of the LatHort plantation were not suitable for transects because it consisted of six sectors – two for each variety and one for hybrids. Therefore, five observation points were set up in each variety's sector and ten – in the sector of hybrids. In every sector, the distance between the observation points was three meters.

European red spider mite monitoring was conducted in three CHAE plantations – farms A and B, as well as LatHort. These plantations were located in the western, central and eastern parts of Latvia, respectively. The number of monitoring sites was determined according to the project budget. To count the overwintered eggs, one 20 cm long, randomly selected twig was cut from each observation point plant. The collected twigs on the same day were examined with a stereo microscope (magnification 7.5–80 times) to count the overwintered eggs of the European red spider mite. These activities were carried out during the second ten-day period of April each year. In the summers of 2017 and 2018, seasonal European red spider mite motile stage monitoring was carried out in the same plantations. From the time the plants had developed leaves until the end of September, 10 randomly selected leaves were collected from each marked CHAE plant every two weeks. During the same day, on these leaves, European red spider mite eggs and motile stages were counted. Monitoring was not continued in 2019 as it was recognised as useless.

Black-veined white monitoring was not planned at the start of these studies, but the decision to conduct it was made during the 2018 vegetation season when nests of caterpillars of this butterfly were found on CHAE plants in some of the studied plantations, and black-veined white caterpillars caused 30–50% foliage loss of the infested plants. Consequently, black-veined white monitoring took place in all plantations in the 2018 and 2019 seasons. In 2018, it was done once, in mid-August, but in 2019 – throughout the research season. Each time the plantations were visited, nests of black-veined white caterpillars were counted on CHAE plants. In commercial plantations, nest counts were made on 10 CHAE plants at each observation point, so 200 plants in total. In the LatHort plantation, larval nests were counted on 6–7 CHAE plants at each observation point in 2018 and on five plants in 2019, for a total of 200 CHAE plants.

Monitoring of tortrix moths was carried out in three plantations – farms A and B and LatHort. These sites were chosen for the same reasons as for European red spider mite monitoring. Two sticky delta traps with large fruit-tree tortrix, rose tortrix, codling moth and holly tortrix's sex pheromone dispensers were placed in each plantation. The traps were attached to small poles in the planted rows in the foliage level of CHAE close to observation points so that there was a distance of at least 30 m between two traps equipped with pheromones of the same species. In the first two years of the study, we used only traps and pheromone dispensers produced by Pherobank, but in the last year, only holly tortrix pheromone dispensers from Pherobank were used, while the traps and pheromones of the other species were produced by Csalomon®. Trapped moths were counted and removed from the traps every two weeks. Fresh sticky sheets and pheromone dispensers were replaced in the traps every four weeks. The time of trap installation was different in each year – in 2017, it was 31 May, in 2018 – 19 June, and in 2019 – 14 May. In the first two years, the traps in the plantations were kept until the end of September, as they continued to capture some individuals of the studied moths. In the last year, the traps were taken away from the plantations on 20 August, because the studied insects were no longer caught in them. Our aim was not to precisely study the phenology of the tortrix moths in different years, but to determine whether these species might be present in CHAE plantations and to judge their potential harmfulness to CHAE plants by analysing data from pheromone traps and observation on pest-damaged CHAE flowers, leaves and fruits. Therefore, pheromone traps were installed at different times in each year, but in all years, their presence in CHAE plantations occurred during the peak activity period of the studied tortrix moths.

The assessment of damaged flower buds / flowers of CHAE plants was done as follows. When most of the flowers of the CHAE plants had bloomed, one twig at least 20 cm long was randomly selected from each observation point plant in the plantations. Initially, damage-causing invertebrates were listed on it (if taxon identification was not possible in the field, then it was done in the laboratory). Then the twig was cut and examined in more detail in the laboratory using the stereo microscope. Traces of pest activity (punctures, bites, etc.) were searched for on flower buds and flowers. Pest-damaged and intact buds/flowers were counted separately. In 2017, this study was conducted in three plantations – farms B and D and LatHort. In the following years, buds/flowers were studied in all eight CHAE plantations.

Assessment of pest-damaged CHAE leaves was done in all plantations. In farms A and B and in LatHort, this activity was carried out every two weeks. But the other plantations were visited every four weeks for this purpose. The prevailing meteorological conditions determined that in 2017, the evaluation of CHAE leaves began in the middle of June, in 2018 – in the first days of June, and in 2019 – in the middle of May. Leaf assessment in each year was finished shortly before CHAE plants entered the maturity of the fruit and seed stage (mid-August). In each observation point plant, one branch was randomly selected, on which 10 leaves were selected (each third leaf starting from the freshest fully developed one). They were assessed and counted into two groups: damaged and intact. It was also determined what kind of damage was observed on the leaves (punctures, bites, etc.) and what invertebrates were causing these damages if the phytophage was present (if the taxon could not be identified in the field, it was done in the laboratory). These counts were not made on CHAE branches infested with black-veined white.

From the obtained data, the percentage of damaged leaves was calculated for each marked CHAE plant at each evaluation time. By summing the data obtained in each assessment, the total proportion of leaves damaged by CHAE plants was determined for each plantation in each year. Using ANOVA and the Bonferroni-Holm post hoc test, it was analysed whether there were significant differences in the proportion of pest-damaged leaves among different plantations within each year and whether there were significant differences between years within each plantation. Data obtained in LatHort were analysed to see if there were significant differences in the proportion of damaged leaves among CHAE plants of varieties and hybrids mentioned above. Calculations were performed with MS Excel 2016 and Daniel's XL Toolbox version 7.3.4 add-in (http://www.xltoolbox.net).

CHAE fruits were evaluated once each year, at the end of August, when they were ripe. In all plantations, 10 CHAE fruits were randomly collected at each observation point and analysed in laboratory. All fruits were investigated and divided into two groups: pest-damaged and intact. Thus, the proportion of damaged fruits was determined. For damaged fruits, the type of damage was determined (superficially gnawed peel, bored holes, etc.) and potential pests were identified.

Results

European red spider mite

Overwintered spider mite eggs on plants were not observed in any CHAE plantation in any growing season. During the vegetation period, individuals of this species were found in one plantation – LatHort.

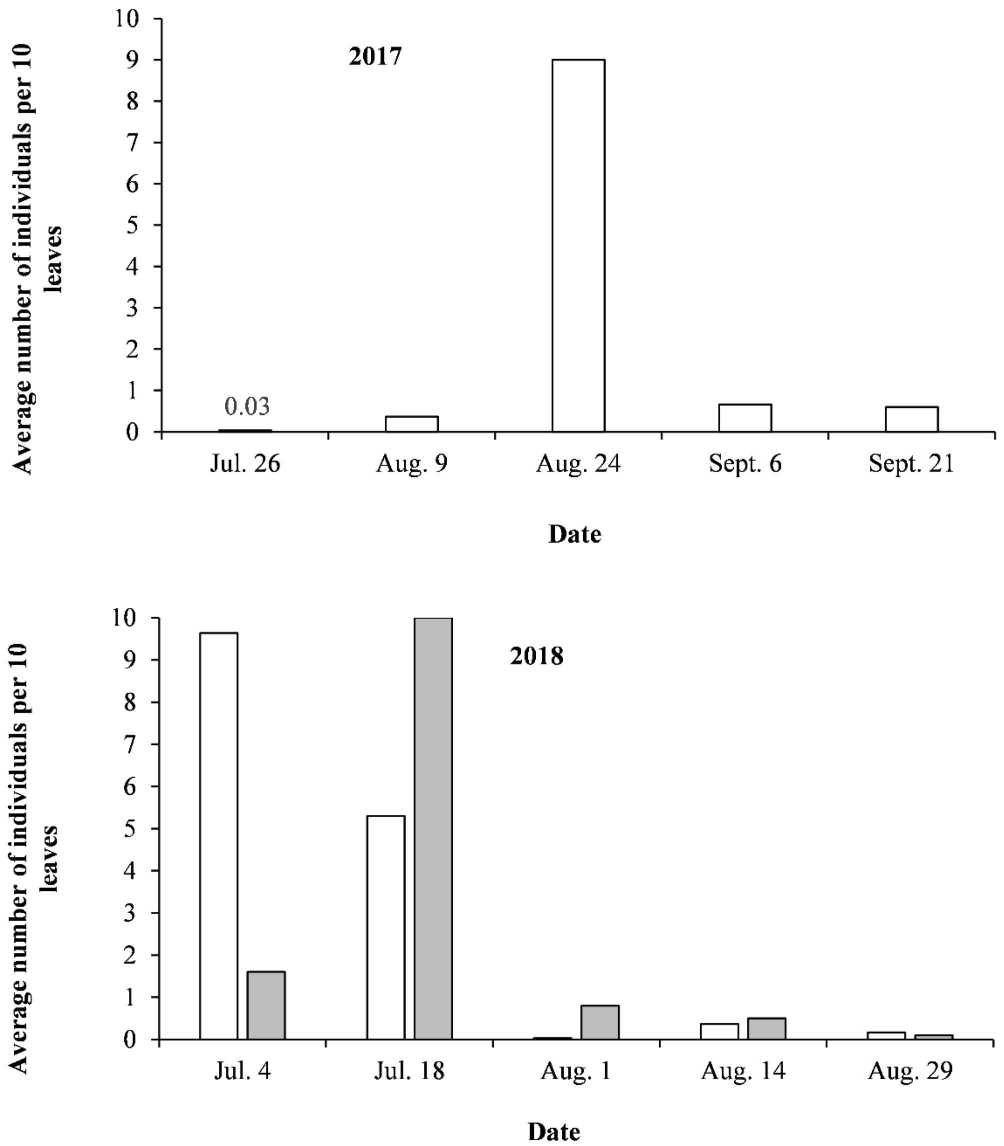

Figure 2. Phenology of the European red spider mite (*Panonychus ulmi*) in the Japanese quince plantation of the Institute of Horticulture (LatHort) in 2017 and 2018 (□ – motile stages; ■ – eggs).

In 2017, from the end of July to the end of September, imagines and immature stages were observed on CHAE leaves in this plantation; the peak of population density was observed in the end of August. In 2018, however, hatched individuals and eggs of this species appeared from the beginning of July to the end of August; the peak of population density was in the first half of July. In both years, the population density of the European red spider mite significantly decreased shortly after reaching its peak level (Fig. 2). Although egg-laying happened in the plantation of LatHort in the vegetation season of 2018, no overwintered eggs were found on quince branches in the spring of 2019. For this reason and because the European red spider mite was not present in any other plantation in the first two years of the study, it was decided not to continue the monitoring of this species in 2019.

Black-veined white

The monitoring of black-veined white was started in the second year of the research, when nests of caterpillars of this butterfly were observed for the first time in two plantations. A larger infestation of this species in 2018 was at farm F, where in the second ten-day period of August, 19 nests of black-veined white caterpillars were counted on 200 CHAE plants. Caterpillars caused moderate leaf damage to the infested CHAE plants – 30–50% of foliage of the plant was destroyed, and there were no fruits on the infested branches. At the same time, five caterpillar nests were also observed in farm A. Black-veined white was not detected in other plantations in 2018.

In the spring of the third year of the study (30 April 2019), in the plantations of four farms – B, E, F and G – some overwintered caterpillars and remains of their nests were observed on CHAE plants. As the nests of overwintered caterpillars were almost completely disintegrated during this time, their exact count was not possible. Later in the vegetation season, on 14 May, three fresh nests of black-veined white caterpillars, created in the current year, were observed in farms A and B. However, in farm F, the number of nests had significantly increased compared to the previous year – they were a total of 37 nests on 200 plants. Caterpillar nests were also visible on other plants of this plantation, so the next day the CHAE plants were sprayed with insecticide, while the nests were eliminated manually in the other farms. Two weeks later, on 28 May, one nest of caterpillars was found in the LatHort plantation (also eliminated manually), but several flying imagines were observed in farms D and G. On the other hand, in farms A, B and F, no nests of black-veined white caterpillars were detected after the controlling measures were applied. During the following months of the research season, this species was no longer observed in any plantation, neither caterpillar nests nor imagines.

Tortrix moths monitoring

In 2017 and 2018, tortrix moths were actively flying, but in the third year of the study, relatively fewer individuals were caught in the pheromone traps. In all plantations where these moths were monitored, the most common species was the large fruit-tree tortrix. Rose tortrix was represented by a similar number of individuals, but in farm B, it was relatively infrequent. A significant codling moth population was observed in the plantation of LatHort, but in other places, it was either not found (farm B), or few individuals were occasionally observed (farm A). Holly tortrix was present in approximately equal abundance at all studied sites. However, the population density of this species in CHAE plantations was low (Figure 3).

Pest-damaged CHAE flower buds / flowers

CHAE buds/flowers were damaged in relatively small amounts. In the first two research seasons, more than 98% of them were intact. In 2019, however, there were slightly more damaged flowers/buds. The average level of damage did not exceed 12%, but in farms C and E, one-quarter and fifth respectively of the buds/flowers were damaged. The results of the assessment of pest-damaged and intact CHAE buds/ flowers are presented in Table 3.

Buds/flowers were damaged mostly by invertebrates with piercing and sucking mouthparts.

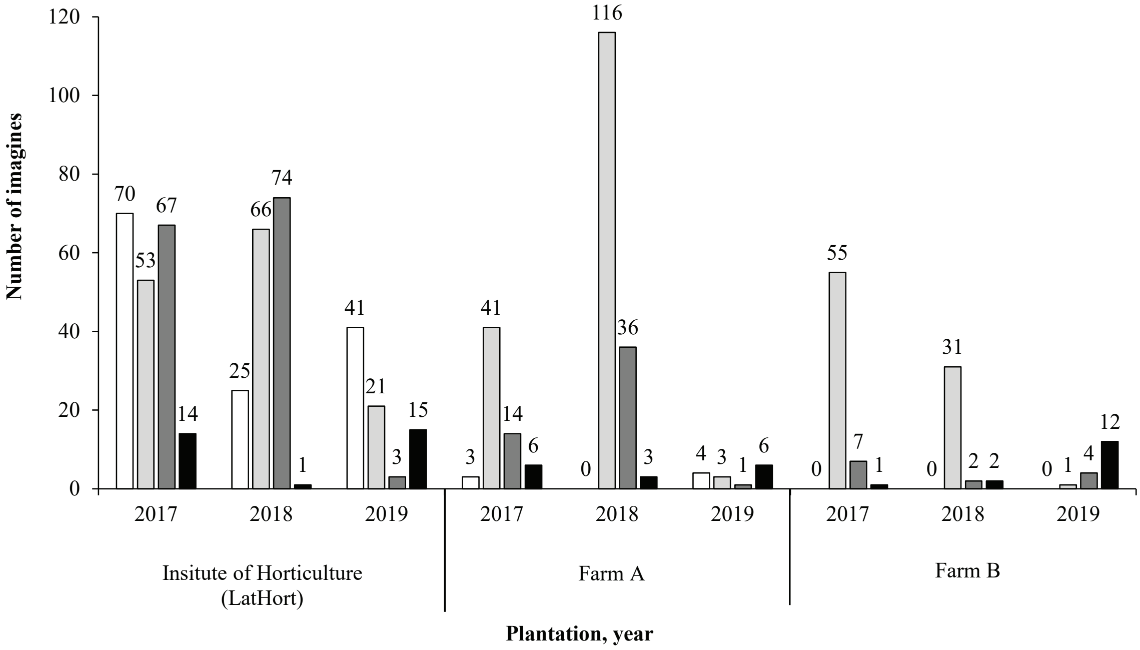

Figure 3. The number of tortrix moths caught in pheromone traps in Japanese quince plantations during 2017–2019 (□ – codling moth (*Cydia pomonella*), ■ – large fruit-tree tortrix (*Archips podana*), ■ – rose tortrix (*Archips rosana*), ■ – holly tortrix (*Rhopobota naevana*)).

Table 3

Percentage of pest-damaged buds/flowers in studied Japanese quince plantations by year

Plantation	2017	2018	2019
Farm A	n/a	0.55	13.90
Farm B	1.15	0.00	2.92
Farm C	n/a	0.00	24.74
Farm D	2.95	0.00	6.43
Farm E	n/a	6.47	20.44
Farm F	n/a	4.94	1.12
Farm G	n/a	0.00	3.62
Institute of Horticulture (LatHort)	0.97	0.16	18.47
Average	1.69	1.52	11.46

In several plantations, a few individual thrips (Thysanoptera) and two-spotted spider mite (*Tetranychus urticae*) were observed on buds/flowers. Insects with chewing mouthparts caused comparably less damage. Several apple fruit weevil (*Tatianaerhynchites aequatus*) imagines and tortrix moth (*Archips* spp.) caterpillars should be added to this group. These insects were observed on CHAE flowers with partially gnawed petals. In addition, some copse snail (*Arianta arbustorum*) individuals were observed damaging buds/flowers in 2017 when the weather was cool and wet. In other years, when it was significantly warmer and drier, snails were not observed in CHAE plantations.

Pest-damaged CHAE leaves

The average proportion of damaged leaves in 2017 and 2018 was slightly above 13%, and in 2019 – slightly above 21%. However, the amount of CHAE leaf damage observed each year was highly variable among different plantations. The lowest average proportion of damaged leaves was observed in 2017 in the LatHort plantation (5.6%) and the highest in 2019 in farm D (35.3%). In three plantations – farms D, F and G – the proportions of damaged leaves were among the highest every year, while in the other three plantations – farms A, C and LatHort – the amounts of leaf damage every year were among the lowest compared to that observed in the other plantations.

Table 4

The average proportion of leaves damaged by various pests in Japanese quince plantations in 2017–2019

Plantation	Proportion of damaged leaves, %		
	2017	2018	2019
Farm A	6.5^{c}_{P}	8.9^{m}_{P}	13.4^{z}_{Q}
Farm B	10.2^{b}_{P}	$11.5^{l,m}_{P}$	22.9^{y}_{Q}
Farm C	13.2^{b}_{P}	9.9^{m}_{P}	12.5^{z}_{P}
Farm D	10.2^{b}_{P}	20.9^{k}_{Q}	35.3^{x}_{R}
Farm E	$13.2^{b}_{P,Q}$	$10.4^{l,m}_{P}$	$19.5^{y,z}_{Q}$
Farm F	23.7^{a}_{P}	$14.7^{k,l}_{P}$	$21.0^{y,z}_{P}$
Farm G	27.2^{a}_{P}	$15.7^{k,l}_{Q}$	25.8^{y}_{P}
Institute of Horticulture (LatHort)	5.6^{c}_{P}	14.6^{l}_{Q}	18.6^{z}_{Q}
Average	13.7_{P}	13.3_{P}	21.1_{Q}

Indexes a,b,c; k,l,m and x,y,z show statistically significant differences ($p \leq 0.05$) in the leaf damage amount among plantations within one year.

Indices P,Q,R show statistically significant differences in the amount of leaf damage differences within each plantation among years.

Analysing the changes in the proportion of leaves damaged by pests in different years of the study, it should be concluded that no common trend can be observed among all plantations. In different farms, damage has changed differently over the years. For example, in two plantations (farms A and B), the highest percentage of damaged leaves was observed in 2019, and it was statistically significantly higher ($p \leq 0.05$) than that observed in the previous two years. On the other hand, in farm G, the largest amounts of leaf damage were observed in 2017 and 2019 (they did not differ significantly from each other), but in 2018 it was significantly lower. In the farm D plantation, the amount of leaf damage increased significantly every year, but in two plantations (farms C and F), a similar, not significantly different proportion of damaged leaves, was observed in all years (Table 4).

In the LatHort plantation, the proportion of leaves damaged by pests was compared between CHAE varieties 'Rasa', 'Rondo', 'Darius' and hybrids. In all years, the leaves of the variety 'Darius' were the least damaged, but the amount of damage was not always significantly different from that of the damage to the leaves of other varieties. In 2017, the leaves of 'Darius' were significantly ($F=3.67$; $p=0.03$) less damaged than the leaves of the variety 'Rasa', but the proportion of damaged leaves of 'Rondo' did not differ significantly from the two other varieties. In 2018, the amount of leaf damage did not differ significantly between varieties. In 2019, judging by the proportion of damaged leaves, two groups of varieties could be distinguished – the amount of leaf damage of 'Darius' and 'Rasa' was significantly less ($F=8.17$; $p<0.001$) than that of 'Rondo' and hybrid leaves. Therefore, it was not established that leaf-damaging pests damage the leaves of plants of certain varieties significantly more or significantly less.

Invertebrates with chewing mouthparts mostly damaged CHAE leaves. The damage was manifested as larger or smaller notches or holes in the edges and surface of blades, but in rare cases, the leaves were skeletonised. It was observed that this type of damage was most often caused by copse snail, yellow-banded weevil (*Chlorophanus viridis*), silver-green weevil (*Phyllobius argentatus*) and garden chafer (*Phyllopertha horticola*). Caterpillars of tortrix and geometrid (Geometridae) moths were rarely observed. The copse snail was noticeably common in CHAE plantations in 2017. However, in the other two years, this species was almost absent in the plantations. The other leaf pests mentioned above were observed in similar numbers every year. Weevils and garden chafer damaged the leaves at the beginning of the vegetation period – in May and June. Moths' caterpillars were observed on the leaves in the second half of summer – July and August. The copse snails, if present, damaged CHAE leaves throughout the vegetation season.

Invertebrates with piercing and sucking mouthparts comparably rarely damaged CHAE leaves. In some cases, two-spotted spider mite (small colonies) and a few individual thrips were observed on the plants. In the plantation of LatHort, the previously mentioned European red spider mite was also observed every year in the second half of summer. Colonies of aphids (Aphididae) and scale insects (Coccomorpha) were not detected in the studied CHAE plantations.

Pest-damaged CHAE fruits

The proportion of pest-damaged fruits was relatively small each year. In 2017, evaluating all plantations together, the proportion of damaged fruits was 1.0%. In the following years, it slightly increased – 4.6% in 2018 and 6.4% in 2019. Significant differences between plantations were observed only in 2018, when pests damaged 12.0% of fruits in farm B, while this proportion was slightly below the average in the other plantations.

About half (41.2%) of the damaged fruits had unrecognisable peel surface damages caused by invertebrates with chewing mouthparts. These were minor damages – small bites. Looking at them, one got the impression that some specimen had tried to gnaw the peel, but after a short period of time had stopped doing so for some reason. One-third (33.3%) of the damaged fruits had round holes with a diameter of about 1.5 mm on the surface. The holes were followed by tunnels in the deeper tissues of the fruit. It is likely that these damages were caused by tortrix moths or sawfly (Tenthredinidae) larvae. Some of these larvae – one sawfly larva and five tortrix caterpillars – were found in a few fruits, but we were unable to identify them. In most of the fruit, the bored tunnels were empty. Several fruits were damaged by social wasps (Vespidae) – bites characteristic of them were found on 14.3% of all damaged fruits. Several fruits (5.6% of all damaged fruits) were most likely damaged by rose tortrix caterpillars. These fruits looked similar to other pome fruits such as pears and apples that have been damaged by this moth. On a similar amount (4.8%) of damaged fruits, wounds typical of those caused by apple fruit moth (*Argyresthia conjugella*) caterpillars were observed. These CHAE fruits looked similar to rowan (*Sorbus aucuparia*) berries or apples damaged by the apple fruit moth. Some fruits were damaged by small rodents.

Discussion

European red spider mite

The European red spider mite is a cosmopolitan polyphagous species, which has become an economically important pest of various cultivated plants in many places. Among its host plants are apple trees, plums, cherries, vines, mulberries and others (Bostanian et al., 2007; Dar, Rao & Ramegowda, 2016; Gottwald, 2016; Gravite & Kaufmane, 2013; Kasap & Atlihan, 2021; Mendonça et al., 2011). However, for now, there is reason to believe that Japanese quince may not be a suitable host plant for this mite. This is evidenced by the fact that in seven of the eight studied plantations, the red spider mite was not observed. On the other hand, the only plantation where this species was observed was right next to a heavily infested orchard, where a large population of European red spider mites has existed for many years. It is likely that the mites observed on quince leaves in mid-summer are accidental migrants, which may even reproduce and lay eggs, as our observations showed. However, due to unknown reasons, they are not able to create a stable population on CHAE plants. This is evidenced by the relatively rapid decrease of the observed population until the end of the vegetation season in both years when the spider mite was monitored, as well as the fact that overwintering eggs were not found on the CHAE plants.

Black-veined white

So far, black-veined white has not been observed anywhere in the world infesting Japanese quince. This has been observed for the first time in our study. In Russia, in the Ural region, black-veined white was found to be a polyphagous species, whose larvae feed mainly on the buds and leaves of woody plants of the rose (Rosaceae) and heath (Ericaceae) families. The main food plant for this species is bird cherry (*Prunus padus*), as caterpillar nests are almost exclusively observed on these trees in years when the black-veined white population is low. However, as the population density increases, caterpillar nests are also observed on rowans (*Sorbus* spp.), apple trees (*Malus* spp.) and hawthorns (*Crataegus* spp.) (Zakharova et al., 2020). In Slovenia, it was concluded that black-veined white is most often found on blackthorn (*Prunus spinosa*) and common hawthorn (*Crataegus monogyna*), but relatively less often on rosehip (*Rosa* sp.) and rock cherry (*Prunus mahaleb*) (Jugovic, Grando & Genov, 2017). The results of both studies show that the main host plants can be significantly different in various regions of the distribution area of this species. In Latvia, studies on the preferences of black-veined white host plants have not been conducted so far.

From an economic point of view, black-veined white is mentioned as a moderately important pest of almond plantations in Eastern Mediterranean countries (Schlalo & Kassis, 2016; Talhouk, 1977). In addition, this butterfly belongs to the complex of species mentioned as pests of young apple orchards in Bulgaria (Velcheva et al., 2012). In Latvia, black-veined white had been considered an important pest of orchards until the middle of the 20th century (Ozols, 1963). However, later its economic importance decreased, and at the end of the last century it was no longer among the important pests of fruit trees (Priedītis, 1996). In the 21st century, black-veined white infestations were not observed in Latvian orchards. However, our study shows that this species should be considered a potential pest at least in CHAE plantations. CHAE plants due to their morphology could be suitable host plants for the butterfly. It has been established that black-veined white is a thermophilic species. Females prefer to lay their eggs on the smallest possible bushes that are sheltered from the wind, where it is warmer, and under which leaf litter covers >50% of the soil. Eggs are laid and larvae prefer to inhabit the outer branches of bushes (Jugovic, Grando & Genov, 2017; Jugovic & Kržič, 2019). This explains why in our study, the greatest infestation of black-veined white was observed exactly in farm F. This plantation was tightly surrounded by forest on all sides creating constant sheltered conditions and ensuring a relatively warmer microclimate. Currently, there is no reason to believe that black-veined white is a major pest that could massively infest any CHAE plantation. Rather, it should be considered a local pest, which should be monitored by managers of the plantations. Special attention should be paid to those plantations whose location and surrounding biotopes contribute to a warmer microclimate.

Tortrix moth monitoring

Large fruit-tree tortrix and rose tortrix have been mentioned as pests of orchards and greeneries in many parts of Europe, but these species also often infest other woody plants in other biotopes (Cuthbertson & Murchie, 2006; Momunova et al., 2019; Özbek & Çalmaşur, 2005; Safonkin & Triseleva, 2005; Selikhovkin et al., 2018; Velcheva, 2009). In Latvia, of these two species, only rose tortrix, which is mainly associated with apple orchards, is considered a relatively significant pest (Priedītis, 1996). Despite the relatively large number of imagines of these moths caught in the traps, they did not cause significant damage to CHAE plants. Caterpillars of these species were not observed feeding on CHAE leaves. Some caterpillars were observed feeding on CHAE flower buds or flowers. Few rose tortrix caterpillars did fruit damage, but the proportion of damaged fruit by this species was one damaged for every 200 intact.

The codling moth is a well-known, economically important pest of apple trees worldwide, but no caterpillar-made damage of this species was observed in CHAE plantations. Individuals caught in pheromone traps were likely to have immigrated from neighbouring areas. The plantation of LatHort was located right next to the apple orchard, while near the plantation of farm A, there was a homestead with several apple trees in the backyard garden. The fact that codling moth caterpillars and their damage were not observed in CHAE suggests that the males of this species (and of other monitored tortrix moths) were more likely attracted to the plantations by the pheromones placed in the traps and not by the CHAE plants as a potential food resource for their offspring.

Holly tortrix was included in this study because it is a polyphagous species and therefore potentially harmful to CHAE plants. However, the results of our study show that relatively few of these moths were found in such an environment. In North America, holly tortrix is a major pest of cranberries and blueberries (*Vaccinium* spp.) (Drolet et al., 2019; McMahan, Steffan & Guédot, 2017), but in Japan, it infests Japanese bird cherry (*Prunus grayana*) (Konno, 2005). There is minimal information about the harmfulness of this species in other crops. Apparently, CHAE also does not contribute to the mass reproduction of this species, therefore, it cannot yet be considered a pest of this crop.

Pest-damaged CHAE flower buds / flowers

The amount of damage to buds/flowers in CHAE is estimated to be negligible, as fruits develop from only a small proportion of the original flowers. Research conducted in Latvia has concluded that only under controlled conditions, when a number of favourable factors coincide, fruits develop from 80–90% of the flowers (Kaufmane & Rumpunen, 2002). Under natural conditions, fruits develop on average from 10.4% of the flowers (Andersone & Kaufmane, 2003). CHAE bud/flower pests identified at the species level are not narrowly specialised on certain host plants, including quinces. Hence, there is no reason to think that these species could multiply massively in CHAE plantations only because of the high density of CHAE plants. The two-spotted spider mite and copse snail are well-known polyphagous species that infest most cultivated plants and many wild plant species. On the other hand, the apple fruit weevil is an oligophagous species feeding on plants of the rose family (Rosaceae). Its imagines feed on the buds, flowers and young leaves of these plants, while the larvae feed on the young fruits (Rheinheimer & Hassler, 2010). This species is not considered a crop pest in Latvia. Tortrix moth caterpillars most likely belonged to the studied species – large fruit-tree tortrix and rose tortrix – because their imagines were caught in pheromone traps in greater or lesser numbers in all vegetation periods. We did not make a more precise identification of these caterpillars and thrips, as their effect on CHAE flower buds/flowers was obviously economically insignificant.

Pest-damaged CHAE leaves

The effect of the leaf damage on CHAE yield was not evaluated and cannot be evaluated in studies of this type. For now, we and the farmers have the opinion that leaf-damaging invertebrates do not cause significant yield losses (except for the black-veined white). According to our observations, in the damaged leaves, most parts of the blades remained intact and green, so they were able to continue photosynthesis. As a fruit crop, Japanese quince is relatively minimally cultivated in the world so far, so there are no comparative studies available that examine the impact of leaf-damaging pests on yield. However, such research would be worthwhile in the future.

Initially, it was expected that the highest proportion of damaged leaves in plantations would be observed in 2019. This was justified by the fact that the climate was warm and dry that year, and the vegetation period of 2018 was also warm and dry, while the summer of 2017 was cool and wet. This prediction came true in four of the eight plantations. In other plantations, the proportion of leaf damage found in 2019 did not differ significantly from the proportion observed in 2017. Meteorological conditions are the only factor that could be used to characterise the differences among vegetation periods in our study. However, it is obvious that, based on them, it may not be possible to predict the amount of damage to CHAE leaves, which in Latvian conditions most likely depends on other environmental factors about which there is currently a lack of knowledge.

In our study, the most commonly observed leaf-damaging invertebrates are polyphagous phytophages. The garden chafer is ecologically associated with grasslands, where its larvae develop by gnawing on plant roots. In parts of Europe, this species is recognised as a pest of cultivated grasslands (Hann et al., 2015; Laznik, Vidrih & Trdan, 2012). Adults feed on the leaves of various plants, including trees and shrubs. A suitable environment for the development of a population of this species could be formed in such CHAE plantations that are minimally managed since the best larval survival success is in the soil that is not tilled and that is covered by herbaceous vegetation. Both observed weevils – silver-green weevil and yellow-banded weevil – are polyphagous species. The silver-green weevil feeds on the leaves of various deciduous trees and shrubs, so finding it in CHAE is not surprising. The yellow-banded weevil feeds not only on tree leaves, but also on herbaceous plants (Rheinheimer & Hassler, 2010). This species has also been observed

Table 5

The list of the invertebrate species and assessment of their potential harmfulness for Japanese quince plantations in Latvia and required management activities if applicable

No.	Species (taxon)	Systematic affiliation	Potential harmfulness and required management activities
1	Black-veined white (*Aporia crataegi*)	Lepidoptera, Pieridae	Local pest. May be significantly harmful in case of a mass outbreak. Should be monitored and controlled if necessary in all Japanese quince plantations.
2	Garden chafer (*Phyllopertha horticola*)	Coleoptera, Scarabaeidae	Minor pest. Should be monitored together with other leaf-feeding invertebrates during May and June. If necessary, control measures on leaf-damaging pests should be applied.
3	Yellow-banded weevil (*Chlorophanus viridis*)	Coleoptera, Curculionidae	Minor pest. Should be monitored together with other leaf-feeding invertebrates during May and June. If necessary, control measures on leaf-damaging pests should be applied.
4	Silver-green weevil (*Phyllobius argentatus*)	Coleoptera, Curculionidae	Minor pest. Should be monitored together with other leaf-feeding invertebrates during May and June. If necessary, control measures on leaf-damaging pests should be applied.
5	Copse snail (*Arianta arbustorum*)	Gastropoda, Helicidae	Minor pest. Should be monitored together with other leaf-feeding invertebrates during the whole vegetation period. The activity of this species is increasing if the weather is cool and humid. Should be controlled if necessary.
6	Rose tortrix (*Archips rosana*)	Lepidoptera, Tortricidae	Minor pest. Can cause insignificant damage to quince pods, flowers, leaves and fruits, however, does not need attention yet.
7	European red spider mite (*Panonychus ulmi*)	Trombidiformes, Tetranychidae	Not harmful. Can be present in low numbers in quince plantations located close to heavily infested orchards of other pome or stone fruits. Does not cause significant damage to Japanese quince plants.
8	Two-spotted spider mite (*Tetranychus urticae*)	Trombidiformes, Tetranychidae	Not harmful. During vegetation season, it is present in low numbers in Japanese quince plantations causing insignificant damage to plants.
9	Aphids	Hemiptera, Aphididae	Not harmful yet. Colonies of aphids were not observed on Japanese quince plants. Perhaps they should be monitored because some species can potentially feed on Japanese quince plants.
10	Thrips	Thysanoptera	Not harmful. During vegetation season, some individuals are present on Japanese quince plants, but they do not cause significant damage.
11	Large fruit-tree tortrix (*Archips podana*)	Lepidoptera, Tortricidae	Not harmful. Does not cause significant damage to Japanese quince plants.
12	Codling moth (*Cydia pomonella*)	Lepidoptera, Tortricidae	Not harmful. Does not cause significant damage to Japanese quince plants.
13	Holly tortrix (*Rhopobota naevana*)	Lepidoptera, Tortricidae	Not harmful. Does not cause significant damage to Japanese quince plants.
14	Apple fruit weevil (*Tatianaerhynchites aequatus*)	Coleoptera, Rhynchitidae	Not harmful. Some individuals appear on Japanese quince plants during springtime.

on quince plants in Lithuania in the Pomological collections of the Vilnius University Botanical Garden. The proportion of damaged leaves of this species in bushes fluctuated between 3–50% and was assessed as insignificant (Grigaliūnaitė, Žilinskaitė & Radaitienė, 2012). We explain the noticeable presence of copse snail in CHAE plantations only in 2017 with meteorological conditions. During that vegetation period, the weather was relatively cool and wet, while the next two summers were relatively hot and dry, less suitable for the development of copse snail individuals.

In our study, we did not find aphid colonies on CHAE plants. Several species of aphids have been observed on them in Poland (Jaśkiewicz, 1995; Jaśkiewicz, Kmieć & Gantner et al., 2004). Green apple aphid has also been used in studies on the effects of environmental stress factors on the ability of CHAE plants to defend against phytophages (Durak, Dampc & Dampc, 2020). All this indicates that aphids should also infest these plants in Latvia. However, the fact that aphid colonies were not observed on plants selected for pest studies in plantations, and that fact that there have been no reports of aphid damage from farmers, suggests that the level of aphid invasion in CHAE plantations is still low and unremarkable.

Pest-damaged CHAE fruits

Our study shows that, at least in Latvia, CHAE fruit pests are currently a minor problem. For example, in 2018 and 2019, many more fruits were damaged by hail. In addition, most pest-damaged fruits are suitable for further processing in the production of food products; consumption of fresh CHAE fruits usually does not occur. For now, we can conclude that there are potential pests in Latvia that could damage CHAE fruits, but they are not frequent. From a scientific point of view, research to find out the exact fruit-damaging species would be interesting and necessary. However, they have no practical significance yet.

Summary of pests of CHAE

In total, after three years of research, 12 invertebrate species and two higher-ranking taxa have been assessed for their potential harmfulness to CHAE plantations. Six species can be considered potentially harmful, five of which are recognised as minor pests. All the other species and taxa of the highest rank are not yet considered pests of CHAE plants under commercial plantation conditions. The assessment of species' harmfulness can be seen in Table 5.

Conclusions

Black-veined white (*Aporia crataegi*) is considered a local pest of Japanese quince in Latvia, which in case of a massive outbreak can cause significant damage to plants and affect their yield. In the future, it would be worth studying which factors contribute to the presence of this species in the quince plantations, so that successful prevention strategies can be developed.

Four species of invertebrates – garden chafer (*Phyllopertha horticola*), yellow-banded weevil (*Chlorophanus viridis*), silver-green weevil (*Phyllobius argentatus*) and copse snail (*Arianta arbustorum*) – are minor pests of Japanese quince by damaging foliage of the plants in Latvia. Currently, it is estimated that these species do not cause significant damage, but their presence in plantations should be monitored and, if necessary, control measures should be applied.

Of the four studied species of tortrix moths – large fruit-tree tortrix (*Archips podana*), rose tortrix (*Archips rosana*), codling moth (*Cydia pomonella*) and holly tortrix (*Rhopobota naevana*) – rose tortrix can be considered a minor pest, the caterpillars of which had damaged Japanese quince fruits to an insignificant extent. The other three species are not considered pests of the quince in Latvia.

Piercing and sucking invertebrates (mites, aphids and similar) are not significant pests of Japanese quince yet. However, in the future, studies on aphids in Latvian quince plantations would be useful because these insects are invading Japanese quince plants in some other countries, therefore, there is a possibility of something similar in our country.

The damage-rate of Japanese quince flowers and fruits were insignificant during the years of the study and we did not observe significant pests of them.

For now, Japanese quince is grown in a relatively small area in Latvia. This is a prerequisite for the cultivated plant to be free of significant pests. However, if the quince-occupied areas continue to increase, it would be worth repeating a similar study on the potential pests of this plant in the future.

References

Andersone, D., & Kaufmane E. (2003). Flowering and Fruit Set in Japanese Quince (*Chaenomeles japonica*). In K. Rumpunen (ed.), *Japanese Quince – Potential Fruit Crop for Northern Europe*. (pp. 29–36), Lomma Municipality, Sweden: Swedish University of Agricultural Sciences.

Bostanian, N.J., Hardman, J.M., Racette, G., & Franklin, J.L. (2007). The relationship between winter egg counts of the European red mite Panonychus ulmi (Acari: Tetranychidae) and its summer abundance in a reduced spray orchard. *Experimental and Applied Acarology*, 42(3), 85–195. DOI: 10.1007/s10493-007-9078-x

Cuthbertson, A.G.S., & Murchie, A.K. (2006). Environmental monitoring of economically important invertebrate pests in Bramley apple orchards in Northern Ireland. *International Journal of Environmental Science and Technology*, 3(1), 1–7. DOI: 10.1007/BF03325901

Dar, M.Y., Rao, R.J., & Ramegowda, G.K. (2016). Age-stage, two-sex life table of European red spider mite, Panonychus ulmi (Koch) (Prostigmata: Tetranychidae) on mulberry varieties. *Archives of Phytopathology and Plant Protection*, 49(7–8), 182–194. DOI: 10.1080/03235408.2016.1180049

Drolet, I., Guay, J.-F., Fournier, V., & Cloutier C. (2019). Biodiversity of lepidopteran pests and their parasitoids in organic and conventional cranberry crop. *Biological Control*, 129, 24–36. DOI: 10.1016/j.biocontrol.2018.11.003

Durak, R., Dampc, J., & Dampc, J. (2020). Role of temperature on the interaction between Japanese quince Chaenomeles japonica and herbivorous insect Aphis pomi (Hemiptera: Aphidoidea). *Environmental and Experimental Botany*, 176, 104100. DOI: 10.1016/j.envexpbot.2020.104100

Gottwald, R. (2016). Neue Erkenntnisse zur Ökologie und Überwachung wichtiger Schädlinge im Apfelanbau (New Knowledge About the Ecology and Control of Important Pests in Apple Cultivation). *Gesunde Pflanzen*, 68, 27–32. (In German). DOI: 10.1007/s10343-016-0360-x

Gravite, I., & Kaufmane, E. (2013). The evaluation of resistance to shothole, leaf rust and fruit tree red spider mite in elite domestic plum hybrids in Latvia. *Acta Horticulturae*, 985, 181–188. DOI: 10.17660/actahortic.2013.985.22

Grigaliūnaitė, B., Žilinskaitė, S., & Radaitienė, D. (2012). Japoninio svarainio (Chaenomeles japonica) fitosanitarinė būklė Vilniaus universiteto Botanikos sode (Phytosanitary condition of Chaenomeles japonica in Vilnius university Botanical Garden). In the 8th Annual National Scientific Conference „Optimization of Ornamental and Garden Plant Assortment, Technologies and Environment", 21 March 2012 (pp. 25–29). Mastaičiai, Lithuania: Kauno kolegija/University of Applied Sciences. (In Lithuanian).

Hann, P., Trska, C., Wechselberger, K.F., Eitzinger, J., & Kromp, B. (2015). Phyllopertha horticola (Coleoptera: Scarabaeidae) larvae in eastern Austrian mountainous grasslands and the associated damage risk related to soil, topography and management. *SpringerPlus*, 4(1), 1–15. DOI: 10.1186/s40064-015-0918-6

Hellín, P., Jordána, M.J., Vila, R., Gustafsson, M., Göransson, E., Åkesson, B., Gröön, I., Laencina, J., & Ros, J.M. (2003). Processing and Products of Japanese Quince (Chaenomeles japonica) Fruits. In K. Rumpunen (ed.), *Japanese Quince – Potential Fruit Crop for Northern Europe* (pp. 169–175). Lomma Municipality, Sweden: Swedish University of Agricultural Sciences.

Jaśkiewicz, B. (1995). Sklad gatunkowy mszyc zerujacych na krzewach Chaenomeles japonica Lindl. w parku akademickim w Lublinie (The species composition of the aphids feeding on Chaenomeles japonica Lindl. in the Academy Park in Lublin). *Annales Universitatis Mariae Curie-Sklodowska. Sectio EEE, Horticultura*, 3, 145–158 (In Polish).

Jaśkiewicz, B., Kmieć, K., & Gantner, M. (2004). Mszyca burakowa a krzewy ozdobne (Beet aphid and ornamental shrubs). *Ochrona Roślin*, 49(6), 30–32. (In Polish).

Jugovic, J., Grando, M., & Genov, T. (2017). Microhabitat selection of Aporia crataegi (Lepidoptera: Pieridae) larvae in a traditionally managed landscape. *Journal of Insect Conservation*, 21, 307–318. DOI: 10.1007/s10841-017-9977-z

Jugovic, J., & Kržič, A. (2019). Behavior and oviposition preferences of a black-veined white, Aporia crataegi (Lepidoptera: Pieridae). *Journal of Entomological and Acarological Research*, 51(2), 50–59. DOI: 10.4081/jear.2019.8108).

Kasap, I., & Atlihan, R. (2021). Population growth performance of Panonychus ulmi Koch (Acarina: Tetranychidae) on different fruit trees. *Systematic and Applied Acarology*, 26(7), 1185–1197. DOI: 10.11158/saa.26.7.1

Kaufmane, E., & Rumpunen, K. (2002). Pollination, pollen tube growth and fertilization in Chaenomeles japonica (Japanese quince). *Scientia Horticulturae*, 94, 257–271. DOI: 10.1016/S0304-4238(01)00371-5

Kikowska, M.A., Chmielewska, M., Włodarczyk, A., Studzińska-Sroka, E., Żuchowski, J., Stochmal, A., Kotwicka, M., Thiem, B. (2018). Effect of Pentacyclic Triterpenoids-Rich Callus Extract of Chaenomeles japonica (Thunb.) Lindl. ex Spach on Viability, Morphology, and Proliferation of Normal Human Skin Fibroblasts. *Molecules*, 23(11), 3009. DOI:10.3390/molecules23113009

Konno, Y. (2005). Species composition of leaf-rolling caterpillars on three wild cherry strains. *Japanese Journal of Applied Entomology and Zoology*, 49(2), 57–61. DOI: 10.1303/jjaez.2005.57

Laznik, Ž., Vidrih, M., & Trdan, S. (2012). The effect of different entomopathogens on white grubs (Coleoptera: Scarabaeidae) in an organic hay-producing grassland. *Archives of Biological*

Sciences, 64(4), 1235–1246. DOI: 10.2298/ABS1204235L

Mauriņš, A., & Zvirgzds, A. (2009). *Dendroloģija* (*Dendrology*). Rīga, Latvia: UL Press. (In Latvian).

McMahan, E.E., Steffan, S.A., & Guédot, C. (2017). Population densities of lepidopteran pests in selected cranberry cultivars in Wisconsin. *Journal of Economic Entomology*, 110(3), 1113–1119. DOI: 10.1093/jee/tow274

Mendonça, R.S., Navia, D., Diniz, I.R., & Flechtmann, C.H.W. (2011). South American spider mites: New hosts and localities. *Journal of Insect Science*, 11(121), 1–18. DOI: 10.1673/031.011.12101

Momunova, G.A., Tukhtaev, T.M., Anara, M.K., Khalmurzaev, A.N., & Teshebaeva, Z.A. (2019). Developing an integrated plan of harvest protection as a tool of improving food supply security in Kyrgyzstan. *IOP Conference Series: Earth and Environmental Science*, 274(1), 1–11. DOI: 10.1088/1755-1315/274/1/012119

Özbek, H., & Çalmaşur, O. (2005). A review of insects and mites associated with roses in Turkey. *Acta Horticulturae*, 690, 167–174. DOI: 10.17660/ActaHortic.2005.690.25

Ozols, E. (1963). *Lauksaimniecības entomoloģija* (*Agricultural Entomology*). Rīga: Latvijas valsts izdevniecība. (In Latvian).

Priedītis, A. (1996). *Kultūraugu kaitēkļi* (*Crop Pests*). Rīga: Apgāds ‘Zvaigzne ABC’. (In Latvian).

Rheinheimer, J., & Hassler, M. (2010). *Die Rüsselkäfer Baden-Württembergs* (*The weevils of Baden-Württemberg*). Basel: Verlag Regionalkultur Heidelberg. (In German).

Ros, J.M., Laencina, J., Hellín, P., Jordan, M.J., Vila, R., & Rumpunen, K. (2004). Characterization of juice in fruits of different Chaenomeles species. *LWT – Food Science and Technology*, 37(3), 301–307. DOI: 10.1016/j.lwt.2003.09.005.

Rumpunen, K. (2011). Pros and cons of Japanese quince (Chaenomeles japonica) – an underutilized pome fruit. *Acta Horticulturae*, 918, 887–900.

Safonkin, A.F., & Triseleva, T.A. (2005). Fecundity of large fruit-tree tortrix Archips podana Scop. (Lepidoptera: Tortricidae) on different host plants. *Biology Bulletin*, 32(2), 207–210. DOI: 10.1007/s10525-005-0031-4

Selikhovkin, A.V., Baryshnikova, S.V., Denisova, N.V., & Timofeeva, Y.A. (2018). Species Composition and Population Dynamics of Dominant Dendrophagous Moths (Lepidoptera) in St. Petersburg and Its Environs. *Entomological Review*, 98(8), 963–978. DOI: 10.1134/S001387381808001X

Shlalo, A., & Kassis, W. (2016). Field studies on the black-veined white butterfly, Aporia crataegi (L.) infesting almonds in Syria. *Arab Journal of Plant Protection*, 34(2), 71–81.

Talhouk, A.S. (1977). Contributions to the knowledge of almond pests in East Mediterranean countries: VII. The defoliators. *Zeitschrift für Angewandte Entomologie*, 84(1–4), 242–250. DOI: 10.1111/j.1439-0418.1977.tb04284.x

Velcheva, N. (2009). Lepidopterian fauna in new planted apple orchard in west Bulgaria. *Biotechnology and Biotechnological Equipment*, 23(Sup. 1), 127–131. DOI: 10.1080/13102818.2009.10818382

Velcheva, N., Atanassov, A., Karadjova, O., & Hubenov, Z. (2012). Parasitoid assemblages isolated from externally feeding lepidopterans and codling moth (Cydia pomonella L., Tortricidae) in a young apple orchard in West Bulgaria. *Bulgarian Journal of Agricultural Sciences*, 18(5), 675–681.

Zakharova, E. Yu., Shkurikhin, A. O., Solonkin I. A., & Oslina, T. S. (2020). Effect of Host Plants on the Viability of Black-veined White Aporia crataegi L. at Low Natural Population Density. *Russian Journal of Ecology*, 51(6), 550–556. DOI: 10.1134/S1067413620060107

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