

OBSERVATION ON THE INFLUENCE OF APPLE WOOLLY
APHID (*ERIOSOMA LANIGERUM* HAUSM.)
ON VEGETATIVE PARAMETERS OF GRAFTED
PLANTS IN CONTAINER PRODUCTION

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Abstract

The use of fruit-propagated planting material has played a vital role in the growth of the fruit market from both economic and social perspectives. When creating new orchards using a material with unclear phytosanitary conditions, the trees may dry out gradually or rapidly during the early stage. This material leads to significant losses and failure to recoup the investment in establishing and cultivating the orchards. As responsible producers, Bulgaria and other EU member countries adhere to Commission Implementing Directive 2014/98/EU, which enforces Directive 2008/90/EC on marketing fruit trees for propagation purposes. This compliance ensures that we uphold the highest standards in our operations, contributing to the overall health and sustainability of the fruit market. Pests play a crucial role in producing planting material as they can, directly and indirectly, influence the process. Pests can directly damage the quality and quantity of the produced material, while indirectly, they can act as carriers of infection. Observations on woolly apple aphids in Bulgaria's scientific community date back to the end of the last century. According to a 2021 report by CABI, Bulgaria is one of the six countries with a wide distribution of the woolly aphid (*Eriosoma lanigerum* Hausm.).

Key words: apple woolly aphids, *Eriosoma lanigerum*, apple, fruit planting material, container cultivation

Introduction. The woolly aphid (*Eriosoma lanigerum* Hausm.) is a widely distributed pest that causes significant economic damage to apple crops. According to studies [1,2], pests are one of the most important factors affecting apple production. It is found in 88 countries worldwide, with 13 in Africa, 27 in Asia, 31 in Europe, 6 in North America, 2 in Oceania, and 9 in South America, as reported by [3]. Bulgaria is one of the six countries in the world where the woolly aphid is present and causing damage to apple crops. In 2019, according to Annex IV, the European and Mediterranean Plant Protection Organization (EPPO) categorized the pest as RNQP with a 0% threshold for admissibility in producing fruit planting material for pome fruit crops.

In Bulgaria, it was first established by V. Striburni in 1896 in the region of Kyustendil [4].

The woolly aphid (*Eriosoma lanigerum* Hausm.) is a pest species originating from eastern North America but has now spread worldwide. It has been studied for 234 years since its first discovery in England in 1787. The pest commonly spreads through apple rootstocks and poses a phytosanitary risk to imported apple rootstocks due to their root habitat. In Norway, *E. lanigerum* is considered a quarantine as the aphid has not yet been established there [5].

The woolly aphid (*Eriosoma lanigerum* Hausm.) can cause significant damage to apples (*Malus* spp.) and some other woody host plants in the Rosaceae family. In some areas where it has been introduced, such as parts of Australia, it is restricted to apples only [6]. The pest can also occur in *Crataegus*, *Sorbus*, and *Cotoneaster* species and, on rare occasions, in pears and *Cydonia* [7].

Changes in pesticide application programmes and disruption of biological control may contribute to the increase in woolly apple aphid outbreaks [8].

Based on the literature, it has been found that current research on certified and standard fruit planting materials is innovative in the field of fruit growing. However, to improve the situation in the country, it is necessary to overhaul the pest monitoring methods and establish a national network for sharing information by region. Despite the need for such measures, studies have yet to be conducted on monitoring and preparing models to limit the spread of pests in fruit tree container production in individual regions of Bulgaria.

New information has been obtained on the development of apple woolly aphid (*Eriosoma lanigerum* Hausm.) in protected facilities like an insect-proof net house and shaded fields. This information will be helpful in preparing risk analyses and implementing solutions to prevent plant damage in the production of planting material both locally and internationally.

Material and methods. The research was carried out at the Fruit Growing Institute in Plovdiv between 2019 and 2021.

To achieve the aim of the study, in 2018, two experimental fields were constructed:

- The shade field measures 15×30 m and is covered with a shading net made of polyethylene tape, type Raffia, which is UV-stabilized and resistant to atmospheric conditions. The net has a shading factor of 50%, and it is coloured green with a weight of 45 g/m².
- The insect-proof net field measures 7×50 m and is covered with an entomological net made of UV-resistant polyethylene. The net has a hole size of 0.28×0.78 mm and a weight of 105 g/m². It is coloured white and offers a low shading percentage of 9–10%.

The following grafting techniques were used: vegetative grafting by budding, and fifty grafted plants were observed in the fields. The grafting of a late summer budding was performed at the beginning of September (01–10.09), while a spring budding was grafted during the period of 20–30.03. The budding was carried out in the fields being observed.

The plants' condition was assessed through visual inspections to check for the presence of pests. The inspections were carried out weekly from February to early March and twice a week on 10 randomly selected plants once the average daily temperature rose above 10 °C. These observations helped determine the appearance and spread of pests in the designated observation fields.

The density of pests inhabiting the aerial parts of plants was measured using the following method:

Direct reporting on individual plants in situ. Each plant was carefully observed, and the number of individuals, along with their stage of development, were recorded. Insects of very small sizes were counted by scale due to the difficulty of enumeration. Bower's five-scale system was used in the study:

- 0 – no colonies on plants;
- 1 – traces of colonies on plants;
- 2 – colonies covering an insignificant part of the leaves or branches of the plants (up to 10%);
- 3 – colonies covering a significant part of the leaves or branches of the plants (from 11% to 25%);
- 4 – dense colonies covering a significant part of the leaves or branches of the plants (from 26% to 50%);
- 5 – aphid colonies are numerous and cover a greater part (over 51%) of the plant surface.

During the monitoring, the following were observed: Average length of vegetative growth (AAGR), Degree of damage (5-point scale), and the percentage P of damaged (infested) plants (simple rule of thumb):

$$(1) \quad P = \frac{A * 100}{B},$$

where A is the number of damaged plants and B is the number of all plants examined.

Coefficient K of harmfulness is calculated by the equation

$$(2) \quad K = \frac{a - b}{a} * 100,$$

where a is the number of undamaged plants and b is the number of damaged plants.

The obtained results were processed by analysis of variance and multiple comparisons according to Duncan's method [9] through the program **R studio** [10], using the packages **agricolae** [11].

Results and discussion. Upon visual inspection, it was observed that the infected plants have a significantly deteriorated commercial appearance. A greater percentage of the observed plants have been partially or completely covered by the woolly apple aphid (*Eriosoma lanigerum* Hausm.) in all three observation fields (Fig. 1). Premature leaf drop and breakage were observed in areas with higher pest density. Due to the high density of the aphid infestation, the plants did not develop their potential and became suitable for commercial activity.

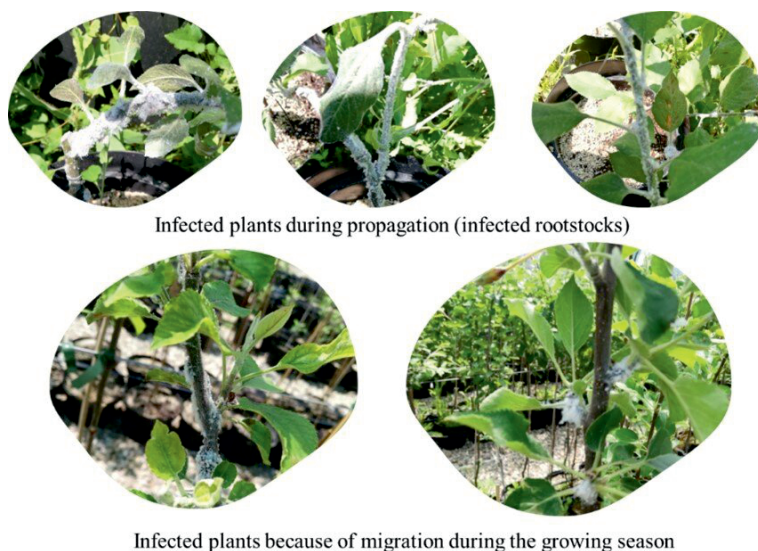


Fig. 1. Infected plants during propagation (infected rootstocks)

When a species migrates during its life cycle and infects plants, there is a noticeable decrease in overall vegetative growth, although this is only in small percentages. The pest is mainly found in the branches of fruit species (Fig. 1). Even though the plants reach a marketable size after the end of the growing season, there are no visible signs of woolly apple aphid infestation. Due to the way container production works, the wintering forms (root colonies) are hidden in the soil, which increases the risk of the pest spreading.

The results of visual observation confirm that the emergence density of pests on aboveground parts is linked to the movement of first-instar larvae up the roots, and the root colonies are a persistent source of infection [12].

The following data pertains to the vegetative growth of propagated apple plants (*Malus domestica* Borkh.) grown in containers across three different fields of observation (Table 1). The highest value of total vegetative growth (cm) was recorded in an insect-proof net house, with an average value of 2019–2021 – 290.8 cm. Statistically significant differences ($\rho \leq 0.05$) were found between 2019 (303.2 cm) and both 2020 and 2021. In the shaded field, a 4.8% lower value was reported, with proven differences between 2019 (287.3 cm) and 2021 (267.6 cm). For the plants grown in a non-shaded field, there was a decrease in the values

T a b l e 1

Influence of woolly apple aphid (*Eriosoma lanigerum* Hausm.) on the total vegetative growth of the fruit species apple (*Malus domestica* Borkh.) in insect-proof net house, shaded field, and non-shaded field

Fruit species	Field	Year	Total vegetative growth				
			Non-infected plants	Infected plants during propagation (Infected rootstocks)	Deviation %	Infected plants due to migration	Deviation %
Apple (<i>Malus domestica</i> Borkh.)	Insect-proof net house*	2019	303.2a*	61.9a	–79.6	277.4a	–8.6
		2020	289.8b	58.2b	–80.0	260.5b	–10.7
		2021	281.2bc	56.6b	–79.5	255.1bc	–7.9
		Average	290.8	58.9	–79.7	264.3	–9.1
	Shaded field	2019	287.3b	58.0b	–79.9	262.4b	–9.1
		2020	277.2bcd	54.4b	–80.5	248.6bcd	–10.7
		2021	267.6cd	55.6b	–78.8	239.8d	–9.0
		Average	276.9	56.0	–79.7	250.3	–9.6
	Non-shaded field	2019	263.9d	50.5c	–81.0	243.1cd	–8.6
		2020	245.9e	47.6c	–80.9	234.3d	–6.0
		2021	235.8e	48.1c	–79.3	215.5e	–7.8
		Average	249.6	48.7	–80.4	230.9	–7.5

*Means marked with the same letter are not significantly different according to Duncan's test ($\rho < 0.05$)

**Mean values were compared between observation fields

of total vegetative growth by 14.2% compared to the insect-proof net house and by 9.9% compared to the shaded field. The calculated average value for a non-shaded field was 249.6 cm, with proven differences between 2019 (263.9 cm) and both 2020 (245.9 cm) and 2021 (235.8 cm).

From the data presented in Table 1, the pest infestation led to a reduction in total vegetative growth in each field of cultivation and between individual years. Plants infected during their propagation (use of infected rootstocks) showed a reduction of total vegetative growth between 78.8% and 81.0%. Plants growing in a non-shaded field showed a higher percentage of reduction (80.4%) compared to those in an insect-proof net house (79.7%) and a shaded field (79.7%). The differences between the three fields of observation were statistically proven.

The average value of the total vegetative growth in the insect-proof net house was 58.9 cm between 2019 and 2021. Lower values of 56.0 cm and 48.7 cm were recorded in the shaded field. The percentage of reduction in plants infected by host migration and colonization was between 6.0% and 10%, with the highest percentage in a shaded field (9.6%), followed by an insect-proof net house (9.1%) and a non-shaded field (7.5%). Statistically significant differences were found between non-shaded fields and fields using nets.

According to Bower’s five-rate scale for measuring damage levels, plants grown in an insect-proof net house showed the highest degree of damage (Table 2). From 2019 to 2021, the average damage rate was 4.2, with the highest value being

T a b l e 2

Degree of woolly apple aphid (*Eriosoma lanigerum* Hausm.) damage on a five-rate scale in the fruit species apple (*Malus domestica* Borkh.) in insect-proof net house, shaded field and non-shaded field

Year	Insect-proof net	Shaded field	Non-shaded field
Degree of damage (Five-rate scale)			
2019	4.4	3.6	2.0
2020	4.2	3.2	2.6
2021	4.0	3.0	2.3
Average	4.2	3.3	2.3
Coefficient of harmfulness (%)			
2019	65	60	50
2020	70	70	60
2021	80	75	65
Average	71.7	68.3	58.3
Percentage of plants infected (%)			
2019	35	40	50
2020	30	30	40
2021	20	25	35
Average	28.3	31.7	41.7

recorded in 2019 (4.4). However, there was a gradual decrease in values for the following years, with 4.2 rates for 2020 and 4.0 rates for 2021. The shaded area showed a declining trend in the insect-proof net house, with an average score of 3.3 rates over the period. The highest value was recorded in 2019 (3.6 rate), followed by 2020 (3.2 rate) and 2021 (3.0 rate). On the other hand, for the non-shaded field, the average score was low for the period 2019–2021, with a value of 2.3 rates. The highest value was recorded in 2020 (2.6 rate), followed by 2021 (2.3 rate) and 2019 (2.0 rate).

In the experimental sample, the highest percentage was found in plants grown outdoors, as stated in Table 2. From 2019 to 2021, the average percentage of infested plants was 41.7%, with the highest percentage reported in 2019 – 50%, followed by 40% in 2020 and 35% in 2021. In fields using nets, a higher percentage of infested plants was observed in a shaded field. For the entire period, the percentage of infested plants in a shaded field was 31.7%, while in an insect-proof net house, it was 28.3%. In 2019, the highest percentage was observed in both cultivation fields, with 40% in a shaded field and 35% in an insect-proof net house. In 2020, the same percentage of 30% was reported for both fields – shaded and insect-proof net houses, while in 2021, the trend towards a higher percentage in shaded fields was maintained at 25%, and in insect-proof net houses, it was 20%.

Based on the results obtained, it was observed that the plants grown under the used nets suffered greater damage compared to those in the non-shaded field. A high correlation of 0.96 was found between the degree of damage and the mean annual temperature. The use of nets increases the extent of damage caused by the woolly apple aphid (*Eriosoma lanigerum* Hausm.).

With regard to the frequency by degree of damage, plants with more than 25% damage (small to very small damage) were found in the insect-proof net house with the highest value (as shown in Fig. 2). In the shaded field, the highest frequency was reported at rate 2 (10–25% damage). Traces of damage to moderate rate damage were found with the highest frequency in plants grown outdoors.

The harmfulness coefficient of the pest in the production of planting material in containers was calculated, and the highest percentage was found in the insect-proof net house at 71.7% using an entomological net. The percentages were 68.3% and 58.3% for growing in a shaded field with a shading net and in a non-shaded field without a net, respectively. An inverse relationship was established between the recorded annual temperatures from 2019 to 2021 and the harmfulness coefficient.

The study found that environmental conditions influenced the development of the pest, as indicated by the observed inverse relationship between the degree of damage and the percentage of plants affected. The insect-proof net house was found to have a higher density of the pest than the other observation fields due to the more favourable conditions created for the development of woolly apple aphids.

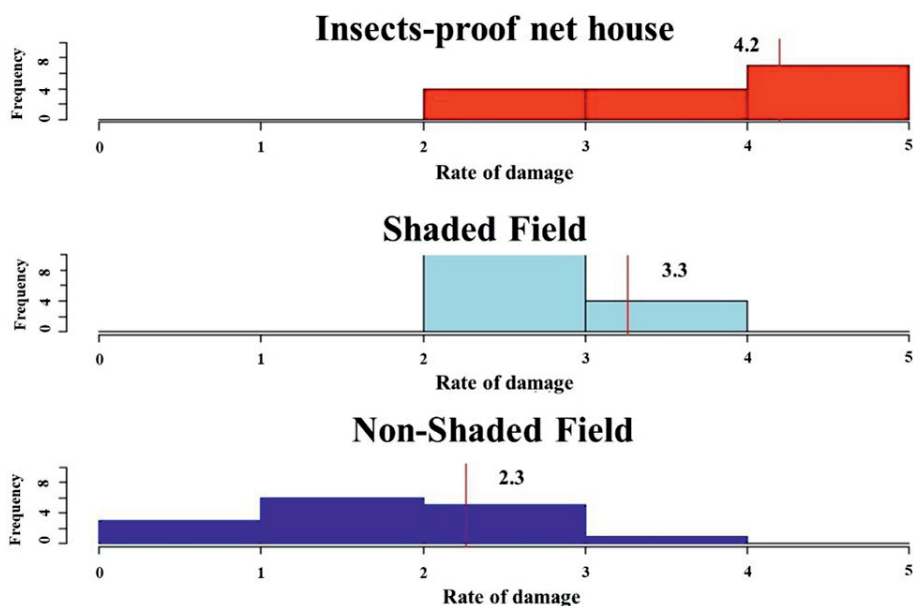


Fig. 2. Incidence of damage in insect-proof net house, shaded field, and non-shaded field under container cultivation

Additionally, the study found that a higher percentage was recorded with an entomological net than with other types of nets.

Conclusion. It was observed that the growth of plants was significantly reduced when infected planting elements (such as rootstocks) were introduced into areas at risk of pest development. Due to the high density, the plants did not reach their full potential and were therefore not suitable for commercial purposes. When using infected rootstocks during propagation, plants infected by woolly apple aphids showed a reduction in the values of total vegetative growth between 78.8% and 81.0%. The highest percentage of reduction was found in plants grown in non-shaded fields – 80.4%, compared to insect-proof net houses and shaded fields – 79.7%. On a five-rated scale for determining the degree of damage, the highest value was reported for plants grown in insect-proof net houses.

Calculating the coefficient of harmful from the pest, the highest percentage was found in the insect-proof net house – 71.7% using an entomological net, followed by a shaded field – 68.3% with the use of a shading net and 58.3% when growing in the non-shaded field without the use of a net.

The study confirms the need for monitoring to deduce the pest control measures accurately. The pests' high damage coefficients indicate an extreme risk of infestation when nets are used to produce planting material.

Although the pests are considered absent in protected facilities, their introduction was possible when an infected host was introduced. The harmfulness of the pests can be reduced after strict compliance with the measures to limit their

spread, such as visual monitoring of the materials used for the propagation of fruit species.

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