AGRICULTURAL ACADEMY –SOFIA
FRUIT GROWING INSTITUTE – PLOVDIV

PLAMEN IVANOV IVANOV

MONITORING AND RISK ASSESSMENT FROM PESTS IN THE PROPAGATION OF STANDARD AND CERTIFIED FRUIT PLANTING MATERIAL GROWN IN CONTAINERS

EXTENDED ABSTRACT

of a dissertation of educational and scientific "Ph.D. degree"
Professional field 6.2. "Plant Protection"
(Entomology)

Ph.D. SUPERVISORS: Prof. Stefan Gandev, DSc
Ass. Prof. Vinelina Yankova, PhD

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The dissertation is 188 pages long and contains 53 tables, 46 figures, and five annexes. The list of cited literature includes 338 sources, 13 of which are in Cyrillic. The experimental work was carried out from 2019 to 2021.

The dissertation was discussed and adopted at a meeting of the Expanded Scientific Council of the Section "Agrotechnics and Plant Protection" at the Institute of Fruit Growing - Plovdiv held on 05.12.2023.

The public defense of the dissertation will be held on 17.04.2024, at 11:00 in the conference hall of Fruit Growing Institute at a meeting of the Specialized Scientific Jury appointed by Order № РД-05-15/02.02.2024.

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The materials of the dissertation will be available on the website of the Institute of Fruit Growing: https://fruitgrowinginstitute.com/

I. Introduction

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.

We understand that producers of planting material may find the transition to certified fruit planting material challenging due to the associated costs and practical difficulties. However, we believe in the long-term benefits of this transition, and we are committed to supporting our producers through further studies to mitigate the risks of pest attacks and optimize forecasting and signaling models.

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. According to *Directive 2014/98/EU*, three types of aphids are not eligible for inclusion, as they are considered pests: woolly apple aphid (*Eriosoma lanigerum* Hausm.), San José scale (*Quadraspidiotus perniciosus* Comst.), and white peach scale (*Pseudaulacaspis pentagona* Targ.). 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 GABI, Bulgaria is one of the six countries with a wide distribution of this pest. More and more producers of planting material are reporting an attack by both species, likely caused by the ban on using proven, registered plant protection products and changes in climatic conditions. This material requires optimizing forecasting models, implementing new ones, and developing systems for risk analysis under a changing climate.

Container cultivation is a modern way of producing fruit planting material that involves growing fruit plants in containers. Although it is a relatively new method, it provides numerous benefits, such as the ability to select the appropriate container, soil, and optimal requirements for light, water, and nutrients for individual plants. This production method enables the customization of the water and nutrition regime for each plant to maximize its growth potential. However, many unexplored factors associated with container cultivation still need to be further investigated.

II. Aim and objectives of the study

This thesis aims to investigate and establish effective methods and practices for tracing the correlation between three primary factors: environmental conditions, host plants, and pests. The data collected will be used to monitor the growth and spread of the woolly apple aphids (*Eriosoma lanigerum* Hausm.) and the San José scale (*Diaspidiotus* (*Quadraspidiotus*) *perniciosus* Comstock) under changing climatic conditions and the use of protective nets. It will also be used to evaluate the risk of pest infestation in fruit propagation.

The main objectives and areas of study in this dissertation are as follows:

1. Monitoring the variations and trends of major climatic factors that affect the production of fruit planting material in insect-proof net houses and shaded and non-shaded fields.
2. Monitoring the vegetation performance in producing fruit planting material in growing conditions in insect-proof net houses and shaded and non-shaded fields.
3. Monitoring the development of major economically significant pests in cultivating fruit planting material in insect-proof net houses and shaded and non-shaded fields.
4. Assessing the risk of infestation by woolly apple aphid (*Eriosoma lanigerum* Hausm.) and San José scale (*Diaspidiotus* (*Quadraspidiotus*) *perniciosus* Comstock) in the production of fruit planting material in containers.

III. Materials and methods

III.1. Site, scheme, and object of the study

The surveys were conducted at the Fruit Growing Institute in Plovdiv from 2019 to 2021. To achieve the aim and objectives of the thesis, the following fields were established:

- A 15x30 meter field is covered by a green, 45g/m^2, UV-stabilized polyethylene tape shading net with a shading factor of 50% and resistance to weather conditions.
- A 7x50 m field covered with a UV-resistant polyethylene entomological net with holes of 0.28x0.78 mm weighs 105 g/m^2 and has a low shading percentage of 10%.

III.2. Monitoring the variations and trends of main climatic factors in the production of fruit planting material in growing conditions in insect-proof net houses, shaded and non-shaded fields

In the monitored fields, data logger devices (specifically BSIDE BTH81) were placed to record variations in temperature and relative humidity automatically every hour. Rain gauges were also installed to determine the amount of precipitation.

The following temperature indicators were reported and calculated: *average daily temperature* (TM), *average temperature for each month* (TM_m), *average daily minimum temperature for each month* (TN_m), *average daily maximum temperature for each month* (TX_m), and extremums for each month: *the highest daily average maximum temperature* (TX_x), *the highest daily average minimum temperature* (TN_x), *the lowest daily average maximum temperature* (TX_n), and *the lowest daily average minimum temperature* (TN_n).

The NIMH network provided information on deviations analyzed against the climate rate from 1969 to 2018.

The thesis used CLIMPACT software to calculate seasonal and annual values of extreme temperature indices.

Data correction and filling in of missing values were conducted, followed by statistical analysis to ensure data quality. Each dataset was subjected to quality control to detect and correct any errors and missing values. The parameters for persistent deviations were determined using linear regression based on the least squares method. Climatic ranks were adjusted for short-term fluctuations using the moving average method.

A significance level of $\alpha \leq 0.05$ was assumed to determine the risk of first-order errors, which means the results will have statistical significance at this value. The software product RHtestsV4 (Wang and Feng, 2013), based on F-test (Wang, 2008 a,b) and t-test (Wang et al., 2007), was used to check the number ranks for mean temperature homogeneity.

The trends of the sequences studied were estimated using the nonparametric test of Mann - Kendall (Gilbert, 1987) and their statistical significance with the Sen test (Sen, 1968; Gilbert, 1987).

III.3. Monitoring the vegetation performance in producing fruit planting material in growing conditions in insect-proof net houses and shaded and non-shaded fields.

The fruit species observed were apple (*Malus domestica* Borkh.), plum (*Prunus domestica* L.), and sweet cherry (*Prunus avium* L.).

The experiment involved using two different grafting techniques - budding (in late summer and spring) and winter grafting (using the "hot callus" and "stratification" methods). The task was to graft 50 pieces using each technique. The progress of the grafted pieces was measured at three different intervals - ten days after planting, before each fertilizer application, and at the end of the growing season.

Based on the reported climatic data and visual observations (BBCH scale), the following biometric indicators were observed: average *Compound Annual Growth Rate* (CAGR) of vegetative growth, average *Annual Average Growth Rate* (AAGR) of vegetative growth, the *growth rate of shoots* (AGR) and the *length of vegetation period* (GSL) as a phenological indicator

The obtained results were subjected to variance analysis and multiple comparisons using the Duncan method (Steele and Torrie, 1960) via the "R Studio" software (R Core Team, 2020).

III.4. Monitoring of pests in the production of standard and certified fruit propagating material with the category "free of regulated non-quarantine pests (RNQF)" and an eligibility factor of 0% (EPPO standard)

The pests monitored for risk of occurrence and spread were the woolly apple aphid (*Eriosoma lanigerum* Hausm.) and San José scale (*Diaspidiotus* (*Quadraspidiotus*) *perniciosus* Comstock).

The plants were visually examined once a week from February to early March and again after the average daily temperature rose above 10°C to determine if any pests were present. These observations were conducted twice a week on ten plants.

To report the density of the pests, we utilized the following methods:

The research involved observing *individual plants* in their natural habitat. The study used a five-point rating scale developed by Bower in 1987. The scale is as follows:

- 0 – No colonies were observed on the plants.
- 1 – Traces of colonies present on the plants.
- 2 – Colonies covering a negligible part of the leaves or branches of plants (up to 10%).
- 3 – Colonies covering a significant part of the leaves or branches of plants (from 11% to 25%).
- 4 – Dense colonies covering a substantial part of the leaves or branches of plants (from 26% to 50%).
- 5 – Many colonies of lice cover a significant part (over 51%) of the surface of plants.

During the observation, *individual shoots* and *leaves* were examined. Readings were taken on the shoots to determine the number of pests on a 1-meter-long twig. The length of some parts of the shoots was found to be 10 cm. The metropolitan method was used to count the pests on the leaves, and the average number per leaf was recorded. One hundred leaves were observed, and 50 average samples were taken from them in the laboratory. The density of the pests was then calculated based on the recorded data.

During the monitoring process of pest species composition, we use the identification methods provided by Remaudière and Remaudière (1997), Leclant (2000), and Blackman and Eastop (2004). We determine the *onset of flying* (*emergence*) through visual observation and double-sided tape, while pheromones and white sticky catches are used to detect *mass flying*. We also determine *population density* through visual observation and reading on shoots and leaves. To assess the *influence on vegetative indicators*, we use *biometric analysis*. We use a five-point scale to calculate the *damage rate* and a simple triple rule to determine the percentage of damaged plants. Finally, we calculate the *harmfulness coefficient* through a specific equation.

We propagate plants using infected cuttings and rootstocks to achieve the set aims of artificial infestation and multiplication.

III.5. Law of effective temperatures – methods of calculation

The thesis paper used *the Average method* (DDAM), *the Modified average method* (DDMAM), *the Sine wave method* (DDSWM), and *the Triangle method*.

The software product DegDay was used to calculate degrees/day.

IV. Results and discussion

IV.1. Monitoring and risk assessment of the "environmental condition" factor in the production of fruit propagating material under growing conditions in an insect-proof net house, a shaded, and a non-shaded field

IV.1.1. Climatic variations of temperature and precipitation

IV.1.1.1. Variations of average temperature

The data reveals a tendency towards an increase in the average annual temperature from 1969 to 2018. Since 2013, the annual average temperature for the Plovdiv region has remained constant at a minimum of 13°C. The average annual temperature for the Plovdiv region between 1969 and 2018 was 12.7°C, as illustrated in Figure 1.

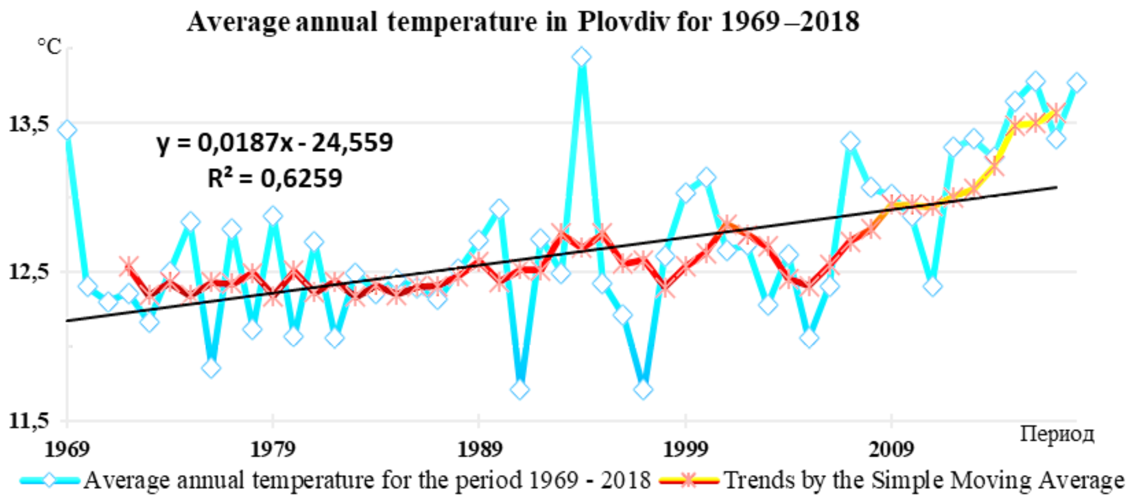

Figure 1. *The average annual temperature (ºC) for the Plovdiv region from 1969 to 2018*

Between April and September, the average daily temperature in a shaded field was 0.1ºC higher than in a non-shaded field, whereas it was 0.7ºC higher in an insect-proof net house. The temperature range recorded in the non-shaded field was between 1ºC and 33ºC, while in the shaded field, it was between 1ºC and 32ºC, and in the insect-proof net house, it was between 2ºC and 30ºC. (Please refer to Figure 2 for further details.)

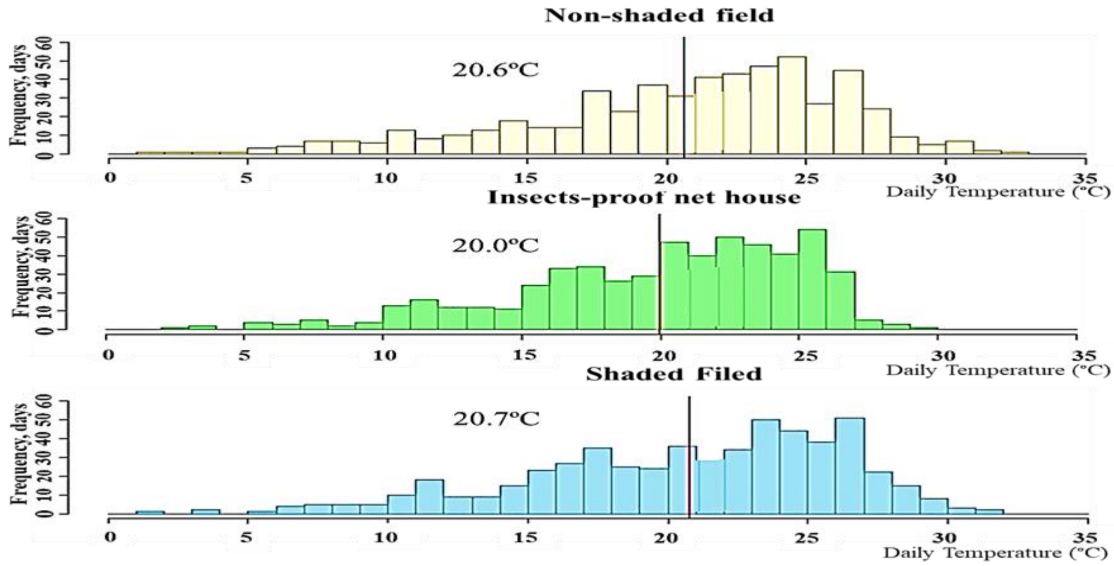

Figure 2. *Histogram of daily average temperature (ºC) for 2019 – 2021 at April – September in an insects-proof net house, a shaded, and a non-shaded field*

The average temperatures for April-September in an insect-proof net house show significantly lower values. In 2020, a shading net led to a temperature increase of 0.6ºC; in 2021, the temperature was 0.1ºC lower (Table 1).

Table 1. *Average temperature (ºC) for the period April-September in an insect-proof net house, a shaded, and a non-shaded field*

Year of Observation	Non-shaded Field	Insects-Proof Net House	Shaded Field
2019	20.9	20.5	20.9
2020	20.2	20.0	20.7
2021	20.6	19.4	20.5
Average	*20.6*	*20.0*	*20.8*

The temperature inside an insect-proof net house was 0.2ºC lower on average compared to a non-shaded field. The temperature range inside the net house was recorded between -5º to 30ºC, whereas in the non-shaded area, this range was between -7º to 33ºC (Figure 3).

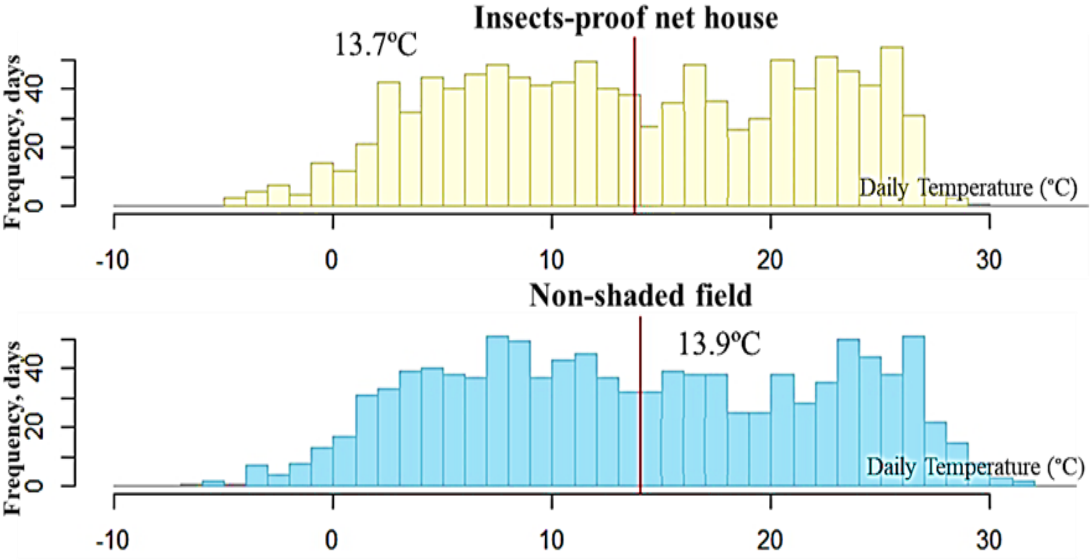

Figure 3. *Histogram of the average daily temperature (ºC) for 2019 – 2021 in an insects-proof net house and a non-shaded field*

Between 2019 and 2021, the average annual temperature was 0.2°C lower inside an insect-proof net house than in a non-shaded field. However, in 2020, the temperature inside the insect-proof net house was 0.1°C higher than in the non-shaded field. Additionally, there were temperature fluctuations within the insect-proof net house during 2019 and 2021 (Table 2).

Table 2. *Annual temperature (ºC) in an insect-proof net house and a non-shaded field*

Year of Observation	Non-Shaded Field ºC	Insect-Proof Net House ºC
2019	14.5	14.3
2020	13.7	**13.8**
2021	13.5	13.0
Average	*13.9*	*13.7*

The average monthly temperatures for 2019 to 2021 were higher in April, with an average of 0.9ºC, compared to temperatures recorded in non-shaded fields. A similar trend was observed in June and July, with average temperatures of 0.4ºC and 0.5ºC, respectively. On the other hand, in the shaded field, lower temperatures were recorded in May throughout the three-year observation period. The average deviation from the measured temperature in May for a non-shaded field was -0.5ºC (Figure 4).

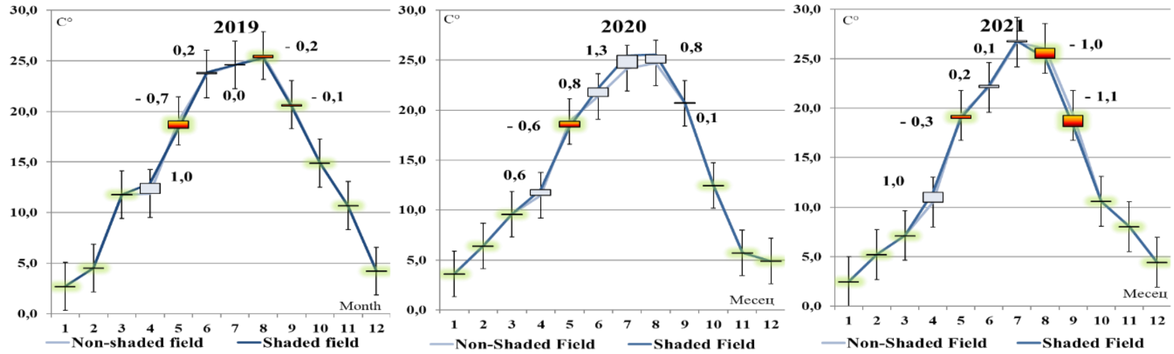

Figure 4. *Trend of the average temperature (ºC) for 2019-2021 in a shaded and a non-shaded field*

In the observation period from May to September over three years, the most significant deviation was observed in August, with an average temperature of 1.4°C lower than the non-shaded field (Figure 5).

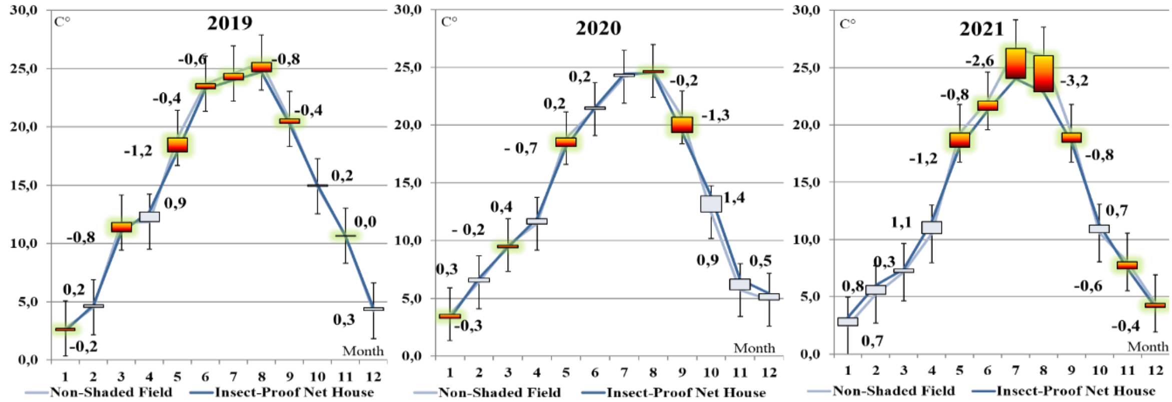

Figure 5. *The trend of the average temperature (ºC) for 2019 – 2021 in an insect-proof net house and a shaded field*

It has been observed that during the growing season, the temperature is significantly different between the insect-proof net house and the shaded field. The temperature in the insect-proof net house is considerably lower. From 2019 to 2021, the average deviation for July was -1.5°C; for August, it was -1.2°C (Figure 6).

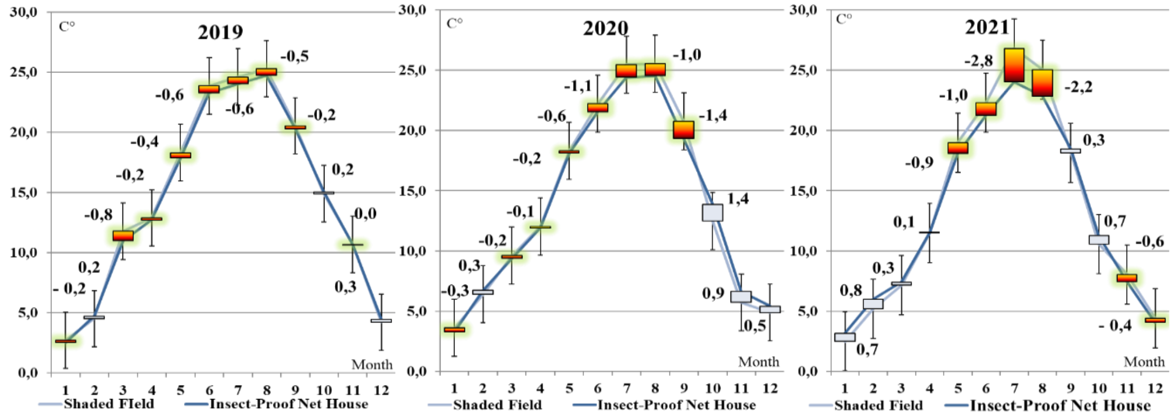

Figure 6. *Trend of the average temperature (ºC) for 2019 – 2021 in an insect-proof net house and a shaded field*

Figure 7 displays the monthly temperature range. In January, readings were within the 7.00 to 13.00 range, like those in a non-shaded area.

In the insect-proof net house, April was the only month with higher temperatures between 05:00 and 23:00. Throughout the year, April, May, and June recorded distinctly lower temperatures between 0:00 and 07:00, while the highest temperatures were observed in September and October. The months with the most significant temperature variation during daylight were July, August, and September.

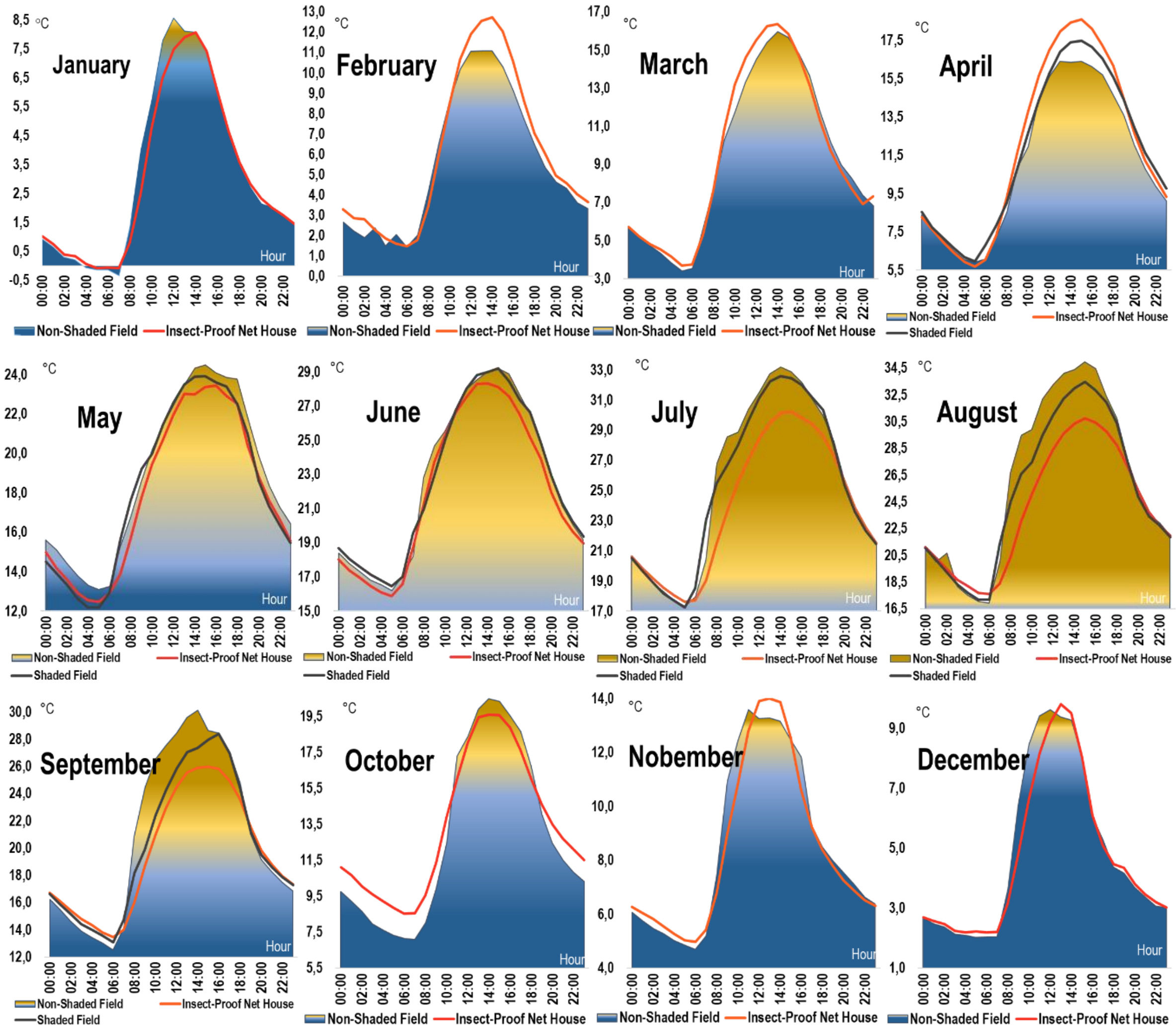

Figure 7. *Average hourly temperature (ºC) by month for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

The hourly temperature distribution for non-shaded field and insect-proof net house varied across seasons. In the winter and fall seasons, higher temperatures were observed during the dark part of the day. At the same time, during spring and summer, they were lower or close to those recorded at the non-shaded field, while the summer and fall seasons witnessed lower values during the visible part of the day. In the afternoons of winter, they have higher temperatures, while during the spring season, the interval between 09.00 and 17.00 hours experienced higher temperature values (as shown in Figure 8).

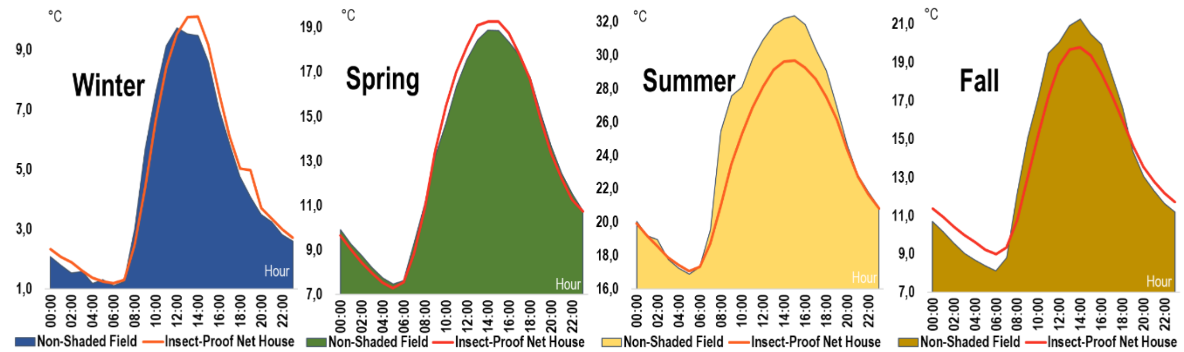

Figure 8. *Average hourly temperature (ºC) by season for 2019 – 2021 in an insect-proof net house and a non-shaded field*

IV.1.1.2. Maximum temperature variations

From 2019 to 2021, the highest average temperature recorded annually (TX_a) was 20.0°C, which deviated 1.5°C from the 1969 – 2018 norm.

At maximum winter temperatures, values above the 75th percentile were prominent in all three observed fields for the numerical series (Figure 9).

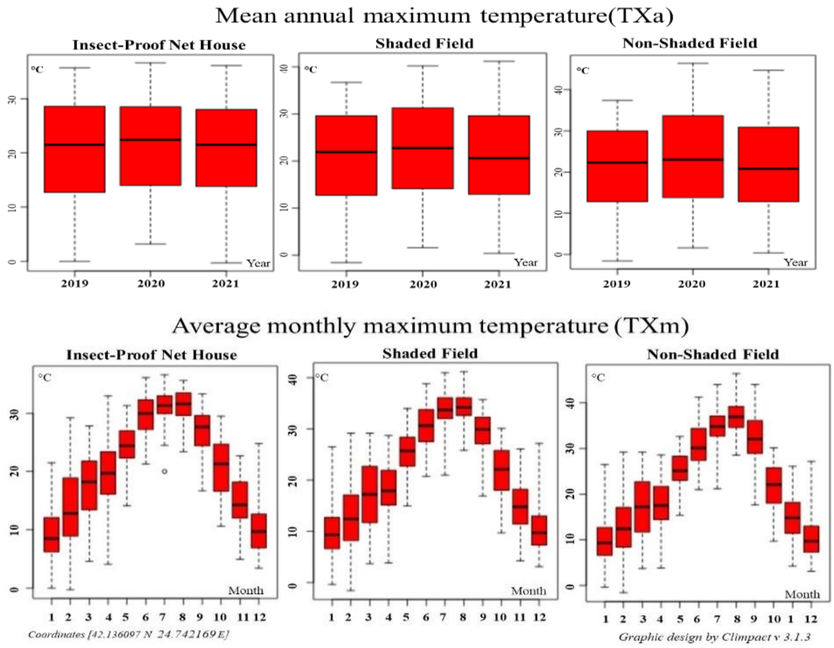

Figure 9. *Statistical deviations of the average maximum annual and monthly temperature (ºC) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

The average maximum temperature from 2019 to 2021 in a field without shade was 22.0°C. In an insect-proof net house, the average annual maximum temperature was lower, with a deviation of -1.1°C and an average temperature of 20.9°C. In a shaded field, the deviation was lower at -0.2°C with an average yearly temperature of 21.8°C (as shown in Table 3).

Table 3. *Deviation of maximum temperature values (ºC) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Indicator	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation
TX_a	22.0	20.9	**-1.1**	21.8	**-0.2**
TX_m (January)	9.9	9.1	**-0.8**	9.9	**0**
TX_m (February)	12.4	14.9	**2.5**	12.4	**0**
TX_m (March)	16.7	17.3	**0.6**	16.7	**0**
TX_m (April)	17.7	19.5	**1.8**	18.2	**0.5**
TX_m (May)	25.4	24.7	**-0.7**	25.4	**0**
TX_m (June)	30.5	29.7	**-0.8**	30.3	**-0.2**
TX_m (July)	34.6	31.0	**-3.6**	33.6	**-1.0**
TX_m (August)	37.0	31.4	**-5.6**	34.2	**-2.8**
TX_m (September)	31.8	26.9	**-4.9**	29.2	**-2.6**
TX_m (October)	21.5	20.7	**-0.8**	21.5	**0**
TX_m (November)	15.0	14.8	**-0.2**	15.0	**0**
TX_m (December)	10.9	10.5	**-0.4**	10.9	**0**

In the insect-proof net house, the temperature was significantly lower in August and September by 5.6°C and 4.9°C, respectively. However, with a shaded field, the temperature was only lower by 2.8°C in August and 2.6°C in September.

In contrast, the average maximum temperature values were higher in the insect-proof net house in February, March, and April compared to the non-shaded field values. The values were

2.5°C for February, 0.6°C for March, and 1.8°C for April. In April, the temperature in the shaded field was only lower by 0.5°C.

IV.1.1.3. Minimum temperature variations

The average minimum temperature in Plovdiv from 1969 to 2018 was 7.6°C. The average minimum temperature for 2019 to 2021 was 8.4°C, 0.8°C higher than the reference period (Figure 10).

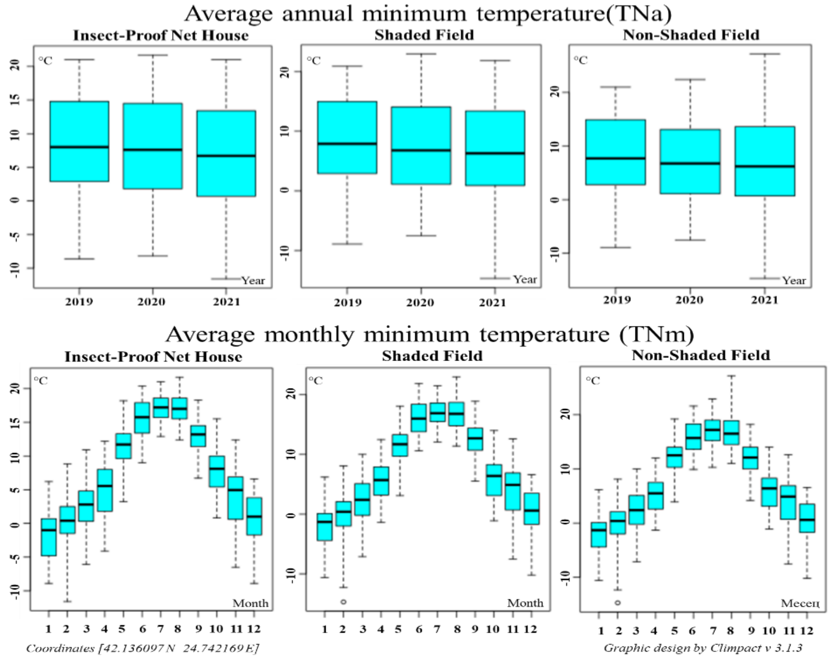

Figure 10. *Statistical deviations of the average minimum annual and monthly temperature (ºC) for 1969 – 2018 in an insect-proof net house, a shaded, and a non-shaded field.*

The minimum annual temperature for a non-shaded field was 7.4°C on average from 2019 to 2021. The insect-proof net house had an average minimum annual temperature of 7.8°C, with a deviation of 0.4°C. The most significant difference in the average monthly minimum temperature was observed in October, with a deviation of 1.6°C for the insect-proof net house. When a shading net was used, the deviation was 0.7°C in September, compared to a non-shaded field. The slightest deviation was observed in May, with a decrease of 0.7°C in both observation fields (Table 4).

Table 4. *Deviations of minimum temperature values (ºC) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field.*

Indicator	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation
TN_a	7.4	7.8	**0.4**	7.8	**0.4**
TN_m (January)	-1.8	-1.6	**0.2**	-1.8	**0**
TN_m (February)	-0.2	0.2	**0.4**	-0.2	**0**
TN_m (March)	2.4	2.6	**0.2**	2.4	**0**
TN_m (April)	5.1	5.1	**0**	5.4	**0.3**
TN_m (May)	12.2	11.5	**-0.7**	11.5	**-0.7**
TN_m (June)	15.8	15.5	**-0.3**	16.0	**0.2**
TN_m (July)	16.9	17.2	**0.3**	17.0	**0.1**
TN_m (August)	16.5	17.1	**0.6**	16.7	**0.2**
TN_m (September)	11.8	12.9	**1.1**	12.5	**0.7**
TN_m (October)	6.1	7.7	**1.6**	6.1	**0**
TN_m (November)	3.8	4.0	**0.2**	3.8	**0**
TN_m (December)	0.6	0.9	**0.3**	0.6	**0**

IV.1.1.4. Variations in precipitation

The amount of precipitation between 2019 and 2021 was not evenly distributed. In 2019, the annual precipitation was 490.8 mm; in 2021, it was 608.9 mm (73.9 mm above the norm). The annual rainfall was 547.5 mm, 12.5 mm above the average for the area. The most significant deviation above the standard data was recorded in October and December, with a deviation of 15.7 mm. Table 5 shows the average changes in precipitation from 2019-2021 at the observed sites - insect-proof net house, shaded field, and non-shaded field. An entomological net revealed a deviation of 316.2 mm below the values for the mean annual amount of precipitation in a non-shaded field. Based on monthly values, the deviation is between -45.1 and -5.2 mm. Using a shading net, the annual total precipitation is -61.7 mm. During the period of use (April-September), the monthly deviation is between -20.2 and -1.5 mm.

Table 5. *Deviations of the mean precipitation values (mm) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Indicator	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation
PR_a	498.0	181.8	**-316.2**	436.3	**-61.7**
PR_m (January)	42.6	16.8	**-25.8**	42.6	**0**
PR_m (February)	25.5	7.1	**-18.4**	25.5	**0**
PR_m (March)	35.1	8.6	**-26.5**	35.1	**0**
PR_m (April)	68.0	23.6	**-44.4**	47.8	**-20.2**
PR_m (May)	37.0	14.2	**-22.8**	25.8	**-11.2**
PR_m (June)	73.8	28.7	**-45.1**	58.1	**-15.7**
PR_m (July)	25.1	9.5	**-15.6**	18.7	**-6.4**
PR_m (August)	27.2	10.6	**-16.6**	20.7	**-6.5**
PR_m (September)	6.9	1.7	**-5.2**	5.4	**-1.5**
PR_m (October)	70.1	33.0	**-37.1**	70.1	**0**
PR_m (November)	34.9	14.1	**-20.8**	34.9	**0**
PR_m (December)	51.6	14.0	**-37.6**	51.6	**0**

IV.1.1.5. Climatic variations of air humidity

The region of Plovdiv had an average annual relative humidity of 70.9% from 1969 to 2018. The highest rates were observed in January, November, and December, at 81.9%, 80.0%, and 83.1%, respectively. The lowest values were recorded in the summer months of July and August at 59.6% and 60.4%. For 2019 – 2021, the average annual relative humidity was 2.1% lower (68.8%). Larger values relative to the norm were found in April, June, August, and November, with deviations of 3.3%, 5.3%, 4.1%, and 9.6%, respectively (Figure 11).

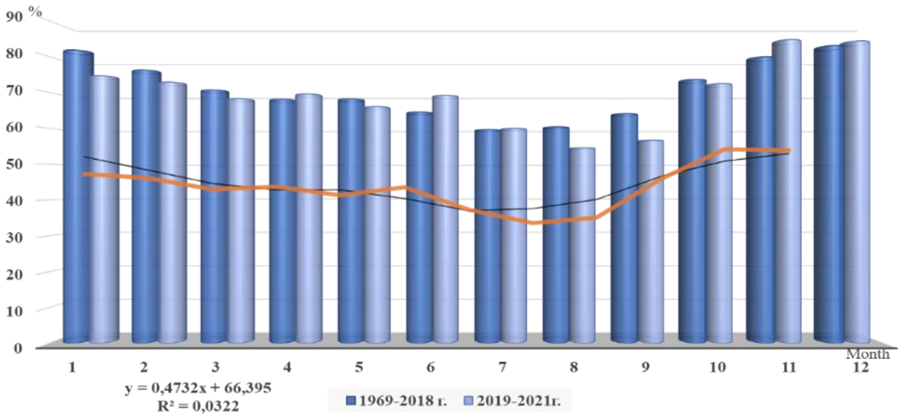

Figure 11. *Average monthly relative humidity for the region of Plovdiv for 2019 – 2021 compared to 1969 – 2018*

The average monthly relative humidity in the shaded field was 68.4%, and in the non-shaded field, it was 4.4% higher. The most significant deviations were reported in May, August, and September, 5.7%, 5.4%, and 5.1%, respectively (Figure 12).

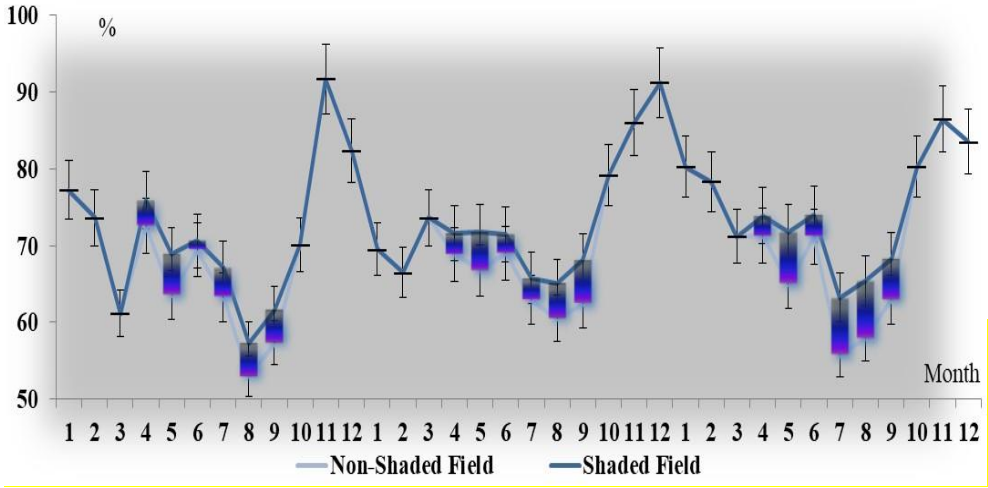

Figure 12. *Average monthly relative humidity in a shaded and a non-shaded field for 2019 – 2021*

The annual relative humidity at an insect-proof net house was 74.3%, 3.3% above that in a non-shaded field (71.0%). The most significant deviations were calculated in the summer months of June, July, August, and early fall – September, with 5.2%, 6.2%, 5.6%, and 6.2%, respectively (Figure 13).

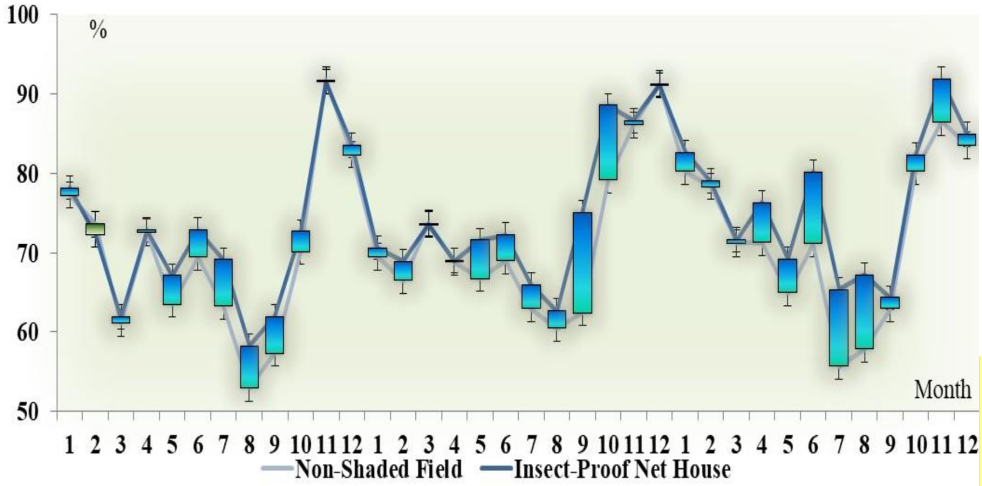

Figure 13. *Average monthly relative humidity in an insect-proof net house and a non-shaded field during 2019 – 2021*

The average monthly relative humidity for April-September in an insect-proof net house was 68.9%, and in a shaded field, it was 68.4%. Except for April and May, the monthly average relative humidity at an insect-proof net house had a higher positive deviation, with the most significant value found in June at 3.1% (Figure 14).

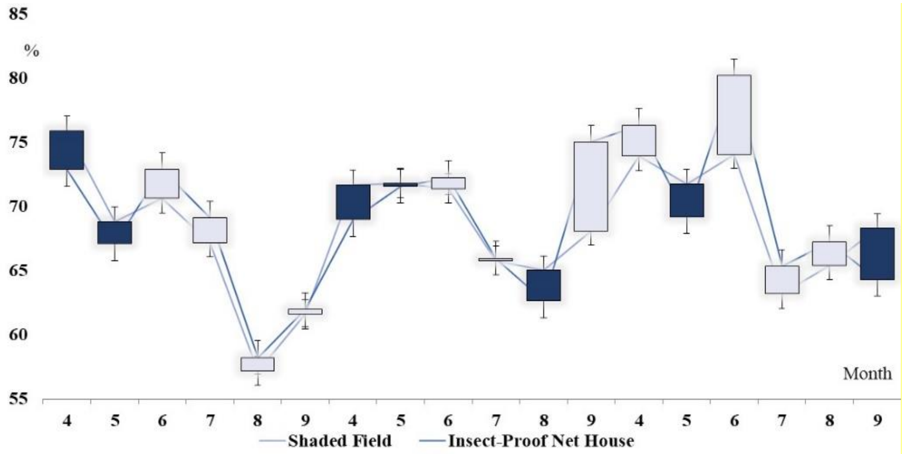

Figure 14. *Average monthly relative air humidity in an insect-proof net house and a non-shaded field for 2019 – 2021.*

Based on the obtained results, using a shading net increases the average relative air humidity by 6.8% during the period of use. The most significant increase was observed in August, with 9.5%. When combining entomological and shading nets, the increase was 4.6% higher than an open field and 0.8% higher than using only a shading net. The most significant increase was observed in July and September, with an increase of 10.2%. These results support the findings of other authors, such as Xu et al. (2017), who found that using an entomological net led to a 1.96% increase in relative humidity compared to an open field. Tafoya et al. (2015) observed an increase of 9.8% in pepper production when using a black net and 21.0% when using a beige net in a protected facility. Ahmed et al. (2016) reported an increase in relative humidity of 15-20% when using a shading net during summer.

IV.1.2. Climatic indices. Fluctuations and trends

IV.1.2.1. Indices related to the frequency of extreme temperatures

In the Plovdiv region, the highest temperatures are usually seen in July and August. From 1969 to 2018, an average of 5.15 days with a recurrence frequency of 0.80 was recorded for July, while August had 5.0 days with a frequency of 0.74.

Between 2019 and 2021, there were 50 days when the maximum temperature reached or exceeded 35°C. Of these, 12 days were recorded in an insect-proof net house, while 83 days were recorded in a shaded field.

The Mann-Kendall test has statistically proven a positive trend for the frequency of occurrence of extreme maximum temperatures (≥35.0°C) at a 10% significance level (ρ = 0.069), with a trend slope of 0.136.

IV.2.1.2. Indices related to the degree of extreme temperatures

From 2019 to 2021, temperatures above the normal range have been observed, with deviations of 0.6°C for TX_x and 3.2°C for TX_n. The highest values of TX_x were recorded in July and August, with peak temperatures of 36.8°C and 36.0°C, respectively. In contrast, the lowest value of TX_x was observed in January, with a temperature of 14.6°C. When comparing temperatures in an insect-proof net house and a shaded field, lower values of annual temperature extremes were recorded, as shown in Table 6.

Table 6. *Deviation of the absolute maximum and minimum values of the maximum temperature (°C) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Indicator	Absolute Max. Value of Maximum Temperature (TX_x, °C)					Absolute Min. Value of Maximum Temperature (TX_n, °C)				
	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation
TX_a	30.5	28.2	**-2.3**	29.8	**-0.7**	12.9	12.5	**-0.4**	13.1	**0.2**
TX_m (January)	18.8	17.1	**-1.7**	18.8	**0.0**	1.9	2.0	**0.1**	1.9	**0.0**
TX_m (February)	23.2	24.1	**0.9**	23.2	**0.0**	0.2	1.0	**0.8**	0.2	**0.0**
TX_m (March)	27.5	26.1	**-1.4**	27.5	**0.0**	5.1	7.0	**1.9**	5.1	**0.0**
TX_m (April)	26.1	28.9	**2.8**	27.5	**1.4**	8.3	9.8	**1.5**	8.6	**0.3**
TX_m (May)	32.4	35.0	**2.6**	32.4	**0.0**	16.4	15.2	**-1.2**	17.1	**0.7**
TX_m (June)	38.8	34.7	**-4.1**	37.4	**-1.4**	22.1	22.7	**0.6**	21.7	**-0.4**
TX_m (July)	40.9	35.6	**-5.3**	39.3	**-1.6**	27.7	24.7	**-3.0**	27.3	**-0.4**
TX_m (August)	42.8	35.3	**-7.5**	39.0	**-3.8**	29.5	25.2	**-4.3**	26.9	**-2.6**
TX_m (September)	40.4	32.1	**-8.3**	34.9	**-5.5**	21.3	20.1	**-1.2**	20.5	**-0.8**
TX_m (October)	29.6	26.5	**-3.1**	29.6	**0.0**	12.5	12.5	**0.0**	12.5	**0.0**
TX_m (November)	23.2	22.4	**-0.8**	23.2	**0.0**	6.1	6.6	**0.5**	6.1	**0.0**
TX_m (December)	22.8	20.4	**-2.4**	22.8	**0.0**	3.4	3.5	**0.1**	3.4	**0.0**

According to Table 7, the insect-proof net house and shaded field exhibit some variations. The annual TNx values have decreased by 0.1°C, whereas the annual TNn values have increased by 0.5°C in the insect-proof net house.

Table 7. *Deviation of the absolute maximum and minimum values of the minimum temperature (°C) for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Indicator	Absolute Max. Value of Minimum Temperature (TN_x, °C)					Absolute Min. Value of Minimum Temperature (TN_n, °C)				
	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation	Non-Shaded Field	Insect-Proof Net House	Deviation	Shaded Field	Deviation
TN_a	13.6	13.5	**-0.1**	13.7	**0.1**	1.1	1.6	**0.5**	1.4	**-0.2**
TN_m (January)	5.3	5.2	**-0.1**	5.3	**0**	-8.9	-8.5	**0.4**	-8.9	**0**
TN_m (February)	7.3	7.6	**0.3**	7.3	**0**	-9.8	-8.8	**1.0**	-9.8	**0**
TN_m (March)	8.8	9.4	**0.6**	8.8	**0**	-4.0	-3.7	**0.3**	-4.0	**0**
TN_m (April)	11.0	11.4	**0.4**	11.6	**0.6**	-1.0	-1.4	**-0.4**	-0.6	**0.4**
TN_m (May)	18.5	17.7	**-0.8**	17.4	**-1.1**	5.3	4.2	**-1.1**	4.6	**-0.7**
TN_m (June)	20.1	19.4	**-0.7**	20.1	**0**	10.7	9.8	**-0.9**	11.2	**0.5**
TN_m (July)	21.0	21.0	**0**	21.2	**0.2**	13.0	13.2	**0.2**	12.8	**-0.2**
TN_m (August)	23.5	21.2	**-2.3**	21.5	**-2.0**	12.2	13.7	**1.5**	12.9	**0.7**
TN_m (September)	16.9	17.4	**0.5**	17.9	**1.0**	5.4	7.0	**1.6**	6.6	**1.2**
TN_m (October)	12.2	13.8	**1.6**	12.2	**0**	0.3	1.7	**1.4**	0.3	**0**
TN_m (November)	11.9	11.8	**-0.1**	11.9	**0**	-1.9	-1.7	**0.2**	-1.9	**0**
TN_m (December)	6.1	6.3	**0.2**	6.1	**0**	-7.7	-6.8	**0.9**	-7.7	**0**

IV.2. Monitoring and risk assessment of the "plant-host" factor in the production of fruit planting material under shaded fields and proof insect net house conditions

IV.2.1. Vegetative indicators of grafted fruit species

IV.2.1.1. Growing season – duration and trends

From 1969 to 2018, the average length of the growing season in Plovdiv was 285.1 days.

The average number of days with daily temperatures TM < 5˚C and TM < 10˚C is 81.4 and 141.5 days, respectively. A decreasing linear trend with a slope of -0.083 was observed at both temperature values. Linear equation at daytime temperatures TM < 5˚C is y = -0.0847x + 83.52 (R2 = 0.0068), and at TM < 10˚C is: y = -0.0897x + 143.83 (R2 = 0.011).

The average number of days with daily maximum temperatures TX > 30˚C and TX > 35˚C is 58.7 and 9.7 days, respectively. At both temperature values, an increasing linear trend with a slope of 0.444 (TX > 30˚C) and 0.136 (TX > 35˚C) was observed.

The duration of the growing season in the insect-proof net house and non-shaded field keeps a tendency to increase the number of days with temperature TM ≥ 5˚C (Table 8).

Table 8. *Duration of the growing season for the region of Plovdiv for 2019 – 2021 in an insect-proof net house and a shaded field*

Field of Observation	*Growing Season*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	28.02	30.11	275	11.02	15.11	282	01.02	03.12	306
Insect-Proof Net House	17.02	30.11	286	26.01	20.11	298	01.02	13.12	316

Table 9 presents various indicators such as the total effective temperatures at TM ≥ 10, the number of days when TM was less than 5˚C and 10˚C, the number of days when the maximum daily temperature TX was greater than 30˚C and 35˚C at three different locations - insect-proof net house, shaded field, and non-shaded field. The most significant reduction of 88.4% was observed at temperatures greater than 35˚C compared to the non-shaded field, averaged over three years of observation. This reduction was 38.8% in the shaded field.

Table 9. *Deviations of the sums of effective temperatures at TM ≥ 10, number of days at TM < 5˚C and TM < 10˚C, number of days at maximum daily temperatures TX > 30˚C and TX > 35˚C in an insect-proof net house, a shaded, and a non-shaded field.*

Indicators	Year	Insect-Proof Net House	Shaded Field	Non-Shaded Field	
				1.2 m	2.0 m
GDD (TM≥10)	2019	2196.0	2285.6	2321.6	2259.5
	2020	2163.9	2284.2	2414.5	2200.9
	2021	1979.6	2117.8	2214.8	2057.5
TM<5˚C	2019	55	58	58	54
	2020	43	49	49	53
	2021	39	48	48	65
TM<10˚C	2019	111	108	109	114
	2020	129	129	130	136
	2021	126	141	143	152
TX>30˚C	2019	72	83	93	86
	2020	69	102	109	74
	2021	62	90	96	71
TX>35˚C	2019	4	12	19	13
	2020	3	36	81	10
	2021	5	38	50	27

IV.2.1.2. Vegetative indicators of grafted plants of the apple fruit species (Malus domestica **Borkh.***)*

According to Table 10, the average duration of vegetative growth for plants grown in the shaded field was 241 days, while for those in the insect-proof net house, it was 244 days. In the spring budding plants in 2019, development was observed 23 days later in the shaded field and 21 days later in the insect-proof net house compared to late summer budding. Similarly, in the late summer budding plants of 2020 and 2021, development was observed 29 days later.

Table 10. *Beginning, end, and duration of vegetative growth at grafted plants by budding of the fruit species apple (Malus domestica* Borkh.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Field of Observation	*Late Summer Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	01.04	03.12	247	06.04	20.11	228	08.04	12.12	248
Insect-Proof Net House	05.04	10.12	249	10.04	28.11	232	12.04	18.12	250
Field of Observation	*Spring Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	24.04	03.12	223	05.05	20.11	199	07.05	12.12	219
Insect-Proof Net House	26.04	10.12	228	07.05	28.11	205	09.05	18.12	223

In Table 11, the average length of vegetative growth (AAGR) was highest for propagated plants during winter dormancy using the "stratification" and "hot callus" methods. On average, the "stratification" method resulted in higher values, with plants growing up to 173.0 cm in an insect-proof net house and 172.9 cm in a shaded field. For plants grafted on late summer budding grown in a shaded field, the average vegetative growth length was 152.9 cm, while in an insect-proof net house, it was 157.0 cm. No statistically significant differences were found at $\rho < 0.05$.

During the first reporting period (01-10.05), the speed of growth rate (AGR, $cmday^{-1}$) was monitored. Compared to other grafting methods, budding plants showed the highest increase in height during spring. The plants grown in an insect-proof net house showed a higher value of 1.53 cm day^{-1}.

Late summer budding plants in the two observation fields showed differences in growth peaks. In an insect-proof net house, a peak growth rate of 1.16 cm day^{-1} was observed from 01-10.05. However, the peak growth rate of 1.08 cm day^{-1} in a shaded field was observed during 01-10.08.

No significant differences have been reported in plants propagated during the dormant period. The highest growth rate was observed in May, and both methods showed faster development in a shaded field. In the "stratification" method, the development rate per day is 1.15 cm; in the "hot callus" method, it is 1.28 cm. The values of the plants grown in an insect-proof net house are 1.14 cm per day for the "stratification" method and 1.17 cm per day for the "hot callus" method.

Table 11. *The average length of annual vegetative growth (AAGR) and growth rate of annual vegetative growth (AGR) of grafted plants at the fruit species apple (Malus domestica* Borkh.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Grafting Method **	Field of Observation	Year	Reporting Period						Reporting Period					
			01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm	01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm
			The Average Length of Annual Vegetative Growth (AAGR)						*Growth Rate of Annual Vegetative Growth (AGR)*					
Late Summer Budding	Shaded Field	2019	32.0 ab*	84.0 a	108.3 a	123.2 a	147.5 ab	160.9 a	1.067 c*	1.677 a	0.808 b	0.482 a	0.783 a	0.447 a
		2020	31.4 b	78.6 a	101.1 a	123.7 a	144.5 ab	150.4 a	1.258 c	1.520 a	0.751 b	0.727 a	0.672 a	0.196 cd
		2021	36.9 a	85.2 a	106.0 a	119.6 a	140.4 b	147.4 a	1.604 b	1.558 a	0.694 b	0.572 a	0.669 a	0.234 bc
		Average	**33.5**	**82.6**	**105.1**	**122.2**	**144.1**	**152.9**	***1.310***	***1.585***	***0.751***	***0.549***	***0.708***	***0.292***
	Insect-Proof Net House	2019	31.7 b	74.0 a	102.5 a	123.2 a	145.8 ab	157.6 a	1.220 c	1.365 a	0.947 ab	0.669 a	0.729 a	0.412 a
		2020	31.2 b	78.6 a	113.0 a	136.4 a	157.9 a	164.0 a	1.486 b	1.527 a	1.149 a	0.754 a	0.693 a	0.304 b
		2021	35.9 ab	82.9 a	101.9 a	119.6 a	139.2 b	151.3 a	1.889 a	1.516 a	0.633 b	0.572 a	0.632 a	0.111 d
		Average	**32.9**	**78.5**	**105.8**	**126.4**	**147.6**	**157.0**	***1.532***	***1.469***	***0.910***	***0.665***	***0.685***	***0.276***
Spring Budding	Shaded Field	2019	-	21.9 cd	42.3 b	77.9 a	102.1 a	114.2 abc	-	0.593 d	0.679 b	1.319 a	0.782 a	0.401 c
		2020	-	14.2 e	28.0 c	58.1 c	88.0 b	110.4 bc	-	0.568 d	0.460 bc	0.970 b	0.965 a	0.746 ab
		2021	-	20.9 d	31.9 c	60.9 bc	88.9 b	105.1 c	-	0.907 c	0.368 c	0.936 b	0.902 a	0.541 bc
		Average	**-**	**19.0**	**34.1**	**65.6**	**93.0**	**109.9**	***-***	***0.689***	***0.502***	***1.075***	***0.883***	***0.563***
	Insect-Proof Net House	2019	-	25.9 bc	56.4 a	77.9 a	102.2 a	122.0 a	-	0.739 cd	1.017 a	0.695 c	0.782 a	0.662 ab
		2020	-	28.0 ab	48.1 b	64.8 bc	91.1 b	116.5 ab	-	1.218 b	0.670 b	0.604 c	0.849 a	0.847 a
		2021	-	31.9 a	48.9 b	67.7 b	93.3 b	109.7 bc	-	1.519 a	0.568 bc	0.538 c	0.828 a	0.545 bc
		Average	**-**	**28.6**	**51.1**	**70.1**	**95.5**	**116.1**	***-***	***1.159***	***0.752***	***0.612***	***0.820***	***0.685***
Dormant Grafting “Hot Callus” Method	Shaded Field	2019	55.9 a	97.2 a	131.4 a	150.6 a	171.4 a	182.0 a	0.917 a	1.330 a	1.142 a	0.618 a	0.671 a	0.408 b
		2020	57.7 a	96.1 a	117.5 b	138.0 bc	159.1 bc	174.2 a	0.946 a	1.238 ab	0.715 b	0.660 a	0.680 a	0.582 a
		2021	59.3 a	98.6 a	114.0 b	131.5 c	152.3 c	160.9 b	0.942 a	1.270 ab	0.511 b	0.566 a	0.670 a	0.330 bc
		Average	**57.6**	**97.3**	**121.0**	**140.0**	**160.9**	**172.4**	***0.945***	***1.279***	***0.789***	***0.615***	***0.674***	***0.440***
	Insect-Proof Net House	2019	52.7 a	94.6 a	131.4 a	147.7 ab	172.5 a	179.2 a	0.864 a	1.350 a	1.228 a	0.523 a	0.802 a	0.222 c
		2020	58.5 a	88.8 a	113.0 b	135.6 c	165.5 ab	178.8 a	0.960 a	0.977 b	0.805 b	0.730 a	0.964 a	0.442 ab
		2021	56.5 a	93.6 a	110.3 b	129.3 c	152.3 c	157.8 b	0.926 a	1.195 ab	0.557 b	0.615 a	0.741 a	0.184 c
		Average	**55.9**	**92.3**	**118.2**	**137.5**	**163.4**	**171.9**	***0.917***	***1.174***	***0.863***	***0.623***	***0.835***	***0.283***
Dormant Grafting “Stratification” Method	Shaded Field	2019	55.9 a	97.8 a	129.7 a	150.4 a	167.4 a	175.1 a	0.917 a	1.350 a	1.065 a	0.667 a	0.547 a	0.296 b
		2020	58.8 a	90.3 a	121.8 ab	143.8 a	169.2 a	180.6 a	0.964 a	1.017 b	1.055 a	0.705 a	0.817 a	0.439 a
		2021	59.3 a	93.1 a	110.0 c	129.3 b	155.6 b	163.1 b	0.971 a	1.091 b	0.564 b	0.622 a	0.847 a	0.288 b
		Average	**58.0**	**93.7**	**120.6**	**141.2**	**164.0**	**172.9**	***0.951***	***1.153***	***0.895***	***0.665***	***0.737***	***0.341***
	Insect-Proof Net House	2019	53.2 a	95.4 a	123.7 a	144.8 a	167.4 a	173.9 a	0.872 a	1.362 a	0.943 a	0.679 a	0.730 a	0.216 b
		2020	61.6 a	91.7 a	124.4 a	148.0 a	173.3 a	183.3 a	1.009 a	0.973 b	1.088 a	0.761 a	0.818 a	0.333 ab
		2021	62.3 a	95.5 a	112.0 bc	130.9 b	155.6 b	161.8 b	1.021 a	1.072 b	0.550 b	0.611 a	0.795 a	0.208 b
		Average	**59.0**	**94.2**	**120.0**	**141.2**	**165.4**	**173.0**	***0.967***	***1.135***	***0.861***	***0.684***	***0.781***	***0.253***

**According to Duncan's test, means marked with the same letter are not significantly different (ρ < 0.05) *Mean values were compared between observation fields for each grafting method

IV.2.1.3. Vegetative indicators of grafted plants of the plum fruit species (Prunus domestica* L.*)

In the plum (*P. domestica* L.) plant species, the development process was observed to occur earlier by 23 days in 2019, 19 days in 2020, and 18 days in 2021 in a shaded field. In plants propagated on late summer budding, the development occurred 25 days earlier in 2019, 24 days earlier in 2020, and 17 days earlier in 2021, compared to those propagated on spring budding in an insect-proof net house.

The average growing season duration from 2019 to 2021 in dormant bud-grafted plants was 236 days in a shaded field and 246 days in an insect-proof net house, 10 days longer. This information is presented in Table 12.

In the case of plants grafted on spring budding, their development was observed in the second half of April. An earlier development of plants was found in an insect-proof net house.

Table 12. *Beginning, end, and duration of vegetative growth of grafted plants by budding at the fruit species plum (Prunus domestica* L.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Field of Observation	*Late Summer Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	28.03	25.11	243	03.04	15.11	226	12.04	08.12	240
Insect-Proof Net House	25.03	01.12	250	28.03	22.11	239	07.04	15.12	250
Field of Observation	*Spring Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	20.04	25.11	219	22.04	15.11	207	30.04	08.12	222
Insect-Proof Net House	19.04	01.12	226	21.04	22.11	215	24.04	15.12	235

The highest values for the length index of one-year vegetative growth (AAGR, cm) for 2019-2021 were recorded for plants propagated during the dormant period (winter grafting) using grafting. In both propagation methods - "stratification" and "hot callus" higher results were reported in an insect-proof net house (Table 13). Statistically proven differences between observation fields and individual years were not demonstrated at $\rho \leq 0.05$.

In the annual vegetative growth rate (AGR, cmday^{-1}) dynamics, higher values were observed in the first half of the summer season. In plants propagated by budding, the most intense growth rate was recorded one month after vegetative growth was established. Plants budding in the late summer in a shaded field had higher growth rate values at the beginning of the growing season than those grown in an insect-proof net house.

Differences in the propagated plants using the "hot callus" and "stratification" methods were reported in the periods 01 ÷ 10.06 and 01 ÷ 10.07, with higher development rates observed in the shaded field. For the hot callus method, these values were 1.07 cm day^{-1} and 0.91 cm day^{-1} in a shaded field and 0.93 cm day^{-1} and 0.87 cm day^{-1} in an insect-proof net house. In the stratification method, they are 1.14 cm day^{-1} and 1.04 cm day^{-1} in the shaded field, 1.00 cm day^{-1}, and 0.84 cm day^{-1} in the insect-proof net house.

Table 13. *The average length of one-year vegetative growth (AAGR) and growth rate of one-year vegetative growth (AGR) of grafted plants at the fruit species plum (Prunus domestica* L.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Propagation Method **	Field of Observation	Year	Reporting Period						Reporting Period					
			01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm	01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm
			The Average Length of Annual Vegetative Growth (AAGR)						*Growth Rate of Annual Vegetative Growth (AGR)*					
Late Summer Budding	Shaded Field	2019	22.4 a*	58.1 a	94.3 a	115.0 a	136.4 a	146.4 ab	0.680 ab	1.149 a	1.207 a	0.668 a	0.630 a	0.333 a
		2020	16.8 bc	51.2 ab	74.4 b	99.8 ab	126.5 a	136.5 ab	0.600 b	1.109 a	0.776 b	0..55 a	0.864 a	0.331 a
		2021	15.6 c	48.9 b	72.8 b	95.4 b	120.6 a	129.5 b	0.823 a	1.073 a	0,797 b	0.730 a	0.813 a	0.296 a
		Average	***18.3***	***52.7***	***80.5***	***103.4***	***127.9***	***137.5***	***0.701***	***1.110***	***0.926***	***0.738***	***0.761***	***0.320***
	Insect-Proof Net House	2019	20.6 ab	55.5 ab	92.8 a	113.1 a	141.0 a	151.6 a	0.557 b	1.126 a	1.242 a	0.657 a	0.898 a	0.353 a
		2020	19.7 abc	51.3 ab	76.2 b	102.7 ab	130.4 a	139.3 ab	0.579 b	1.020 a	0.831 b	0.855 a	0.891 a	0.299 a
		2021	17.4 bc	48.9 b	73.8 b	97.0 b	120.0 a	128.4 b	0.727 ab	1.020 a	0.825 b	0.749 a	0.738 a	0.284 a
		Average	***19.2***	***52.0***	***80.9***	***104.3***	***130.4***	***139.8***	***0.621***	***1.055***	***0.966***	***0.753***	***0.842***	***0.312***
Spring Budding	Shaded field	2019	-	23.6 a	57.0 ab	80.1 a	104.8 a	122.4 a	-	0.562 a	1.112 a	0.746 a	0.796 a	0.586 a
		2020	-	23.1 ab	55.2 abc	79.4 a	107.2 a	118.6 a	-	0.593 a	1.068 a	0.783 a	0.897 a	0.380 b
		2021	-	21.3 ab	47.1 d	74.6 a	104.7 a	115.6 a	-	0.593 a	0.859 b	0.888 a	0.968 a	0.363 b
		Average	***-***	***22.7***	***53.1***	***78.1***	***105.6***	***118.9***	***-***	***0.582***	***1.013***	***0.806***	***0.887***	***0,443***
	Insect-Proof Net House	2019	-	23.7 a	58.5 a	82.5 a	106.5 a	119.6 a	-	0.564 a	1.159 a	0.777 a	0.774 a	0.436 b
		2020	-	22.8 ab	52.1 bcd	78.9 a	105.5 a	116.5 a	-	0.586 a	0.975 ab	0.865 a	0.859 a	0.367 b
		2021	-	20.6 b	50.9 cd	78.4 a	105.5 a	117.6 a	-	0.571 a	1.012 ab	0.886 a	0.875 a	0.401 b
		Average	***-***	***22.4***	***53.8***	***79.9***	***105.9***	***117.9***	***-***	***0.573***	***1.049***	***0.843***	***0.836***	***0.401***
Dormant Grafting "Hot Callus" Method	Shaded field	2019	63.0 ab	97.9 a	127.9 a	146.5 a	170.6 a	178.6 a	1.068 ab	1.126 a	0.999 a	0.601 b	0.779 a	0.265 b
		2020	61.8 ab	94.2 a	125.9 a	145.9 a	166.8 a	175.0 a	1.047 ab	1.068 ab	1.034 a	0.643 ab	0.676 a	0.272 ab
		2021	55.6 ab	86.9 ab	108.2 b	133.8 a	155.8 a	164.5 a	0.942 ab	1.009 ab	0.710 b	0.826 ab	0.709 a	0.293 ab
		Average	***60.1***	***93.2***	***120.7***	***142.0***	***164.4***	***172.7***	***1.019***	***1.068***	***0.914***	***0.690***	***0.721***	***0.277***
	Insect-Proof Net House	2019	62.3 ab	91.8 ab	116.7 ab	139.1 a	167.3 a	179.9 a	1.055 ab	0.952 b	0.829 ab	0.725 ab	0.913 a	0.414 a
		2020	66.2 a	94.9 a	121.5 ab	143.8 a	169.3 a	178.9 a	1.122 a	0.926 b	0.887 ab	0.719 ab	0.821 a	0.322 ab
		2021	52.3 b	80.9 b	107.8 b	136.8 a	161.5 a	169.5 a	0.887 b	0.921 b	0.899 ab	0.924 a	0.807 a	0.266 b
		Average	***60.3***	***89.2***	***115.3***	***139.8***	***166.1***	***176.1***	***1.022***	***0.933***	***0.871***	***0.789***	***0.847***	***0.334***
Dormant Grafting "Stratification" Method	Shaded field	2019	65.8 a	102.1 a	136.4 ab	158.1 a	175.0 a	183.1 a	1.116 a	1.171 a	1.141 ab	0.702 a	0.544 ab	0.271 ab
		2020	63.9 a	99.8 a	137.3 a	157.6 a	173.3 ab	180.6 a	1.084 a	1.157 a	1.250 a	0.654 a	0.508 b	0.244 b
		2021	56.8 a	90.7 a	112.6 c	141.1 b	163.9 ab	172.3 a	0.963 a	1.093 a	0.730 c	0.919 a	0.737 ab	0.279 ab
		Average	***61.2***	***97.5***	***128.7***	***152.2***	***170.7***	***178.7***	***1.054***	***1.140***	***1.040***	***0.758***	***0.596***	***0.265***
	Insect-Proof Net House	2019	66.7 a	98.9 a	123.9 bc	148.3 ab	171.1 ab	182.0 a	1.131 a	1.037 a	0.833 c	0.789 a	0.735 ab	0.364 a
		2020	63.5 a	97.0 a	125.3 abc	147.5 ab	173.7 ab	183.9 a	1.077 a	1.079 a	0.944 bc	0.717 a	0.843 a	0.341 ab
		2021	62.2 a	89.5 a	112.1 c	137.8 b	160.6 b	171.9 a	1.053 a	0.882 b	0.755 c	0.828 a	0.736 ab	0.377 a
		Average	***64.1***	***95.1***	***120.4***	***144.5***	***168.5***	***179.3***	***1.087***	***0.999***	***0.844***	***0.788***	***0.771***	***0.361***

**According to Duncan's test, means marked with the same letter are not significantly different (ρ < 0.05). *Mean values were compared between observation fields for each grafting method.

IV.2.1.4. Vegetative indicators of grafted plants of the fruit sweet cherry species (Prunus avium **L.***)*

Between 2019 and 2021, sweet cherry species (*Prunus avium* L.) developed later than plum plants (*Prunus domestica* L.). In late summer budding plants, the development was, on average, 11 days later in a shaded field and 8.7 days later in an insect-proof net house. During the spring, budding plants developed 5.5 days later in shaded fields and three days later in an insect-proof net house for 2020 and 2021.

The average duration of vegetative growth of propagated plants by late summer budding in shaded fields was 222 days, while it was 234 days in insect-proof net houses (Table 14).

Table 14. *Beginning, end, and duration of vegetative growth of grafted plants by budding at the fruit sweet cherry species (Prunus avium* L.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Field of Observation	*Late Summer Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	10.04	20.11	224	15.04	14.11	213	20.04	06.12	230
Insect-Proof Net House	03.04	22.11	233	08.04	20.11	226	12.04	10.12	242
Field of Observation	*Spring Budding*								
	2019			2020			2021		
	Begin	End	Days (no.)	Begin	End	Days (no.)	Begin	End	Days (no.)
Shaded Field	23.04	20.11	211	29.04	14.11	199	01.05	06.12	220
Insect-Proof Net House	18.04	22.11	218	25.04	20.11	209	26.04	10.12	228

Our research has shown that the growth rate of sweet cherry plants (*Prunus avium* L.) was highest when propagated through late summer budding, as shown in Table 15. However, the vegetative growth rate was significantly lower when propagated through spring budding. The growth rate was higher in insect-proof net houses (106.7 cm) compared to shaded fields (103.4 cm), but the difference was not statistically significant at $\rho \leq 0.05$. We observed statistical differences between 2019 and 2021 and between insect-proof net houses and shaded fields.

In both cultivation fields, the lowest average height was recorded for plants propagated through the dormant method. Our study suggests that budding plants have the highest growth rate (AGR, cm day^{-1}), which holds significant implications for future propagation methods. During the dormant season, a higher growth rate was observed in the shaded field at the start of the vegetative season.

The 'hot callus' propagation method showed a growth rate of 0.33 cm day-1 in the shaded field and 0.32 cm day-1 in the insect-proof net house. The growth rates for plants propagated through the 'stratification' method were 0.37 cm day-1 and 0.33 cm day-1 in the shaded field and the insect-proof net house, respectively. In 2019, we observed a higher growth rate in both fields of observation. These differences were statistically significant at $\rho \leq 0.05$, highlighting the importance of considering the propagation method and environment in future cultivation strategies.

Our research indicates that the sweet cherry species grown in an insect-proof net house exhibited a significant increase in development rate towards the end of the growing season. This rate was 1.9 times higher when late summer budding was implemented than when grown in a shaded field. These findings could guide future cultivation practices for the sweet cherry species.

Table 15. *The average length of annual vegetative growth (AAGR) and growth rate of annual vegetative growth (AGR) of grafted plants at the fruit sweet cherry species (Prunus avium* L.*) for 2019 – 2021 in an insect-proof net house and a shaded field*

Propagation Methods**	Field of Observation	Year	Reporting Period						Reporting Period					
			01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm	01-10.05 / dd-dd.mm	01-10.06 / dd-dd.mm	01-10.07 / dd-dd.mm	01-10.08 / dd-dd.mm	01-10.09 / dd-dd.mm	01-10.12 / dd-dd.mm
			Average Length of Annual Vegetative Growth (AAGR)						*Growth Rate of Annual Vegetative Growth (AGR)*					
Late Summer Budding	Shaded Field	2019	8.0 b*	45.9 ab	86.7 a	100.3 a	116.6 ab	118.0 ab	0.127 b	1.225 a	1.360 a	0.436 b	0.527 ab	0.047 b
		2020	7.5 b	44.4 abc	78.7 b	94.3 ab	112.8 ab	115.6 ab	0.095 cd	1.191 a	1.144 b	0.502 b	0.597 ab	0.094 ab
		2021	7.3 b	44.4 abc	71.7 bc	89.1 b	108.1 b	111.5 b	0.082 d	1.197 a	0.909 c	0.562 ab	0.613 ab	0.111 ab
		Average	***7.6***	***44.9***	***79.1***	***94.6***	***112.5***	***115.0***	***0.101***	***1.204***	***1.137***	***0.500***	***0.579***	***0.084***
	Proof Insect Net House	2019	9.6 a	47.8 a	88.6 a	102.7 a	118.4 a	122.9 a	0.153 a	1.233 a	1.359 a	0.455 b	0.505 b	0.151 a
		2020	8.6 ab	41.7 c	79.2 b	95.7 ab	114.2 ab	119.2 ab	0.108 c	1.070 b	1.250 ab	0.531 b	0.596 ab	0.168 a
		2021	8.0 b	43.7 bc	69.3 c	90.4 b	109.9 b	115.0 ab	0.090 d	1.152 ab	0.853 c	0.681 a	0.626 a	0.173 a
		Average	***8.7***	***44.4***	***79.1***	***96.3***	***114.1***	***119.1***	***0.117***	***1.152***	***1.154***	***0.556***	***0.576***	***0.164***
Spring Budding	Shaded Field	2019	-	42.2 ab	77.4 a	92.4 ab	103.8 ab	106.4 ab	-	1.360 ab	1.173 a	0.485 b	0.366 ab	0.087 b
		2020	-	40.0 bc	70.3 bc	90.4 ab	100.6 bc	103.7 bc	-	1.289 bc	1.012 ab	0.648 a	0.328 b	0.105 b
		2021	-	37.4 c	67.5 c	88.1 b	97.1 c	100.1 c	-	1.217 c	0.993 b	0.664 a	0.291 b	0.099 b
		Average	***-***	***40.0***	***71.7***	***90.3***	***100.5***	***103.4***	***-***	***1.289***	***1.059***	***0.599***	***0.328***	***0.097***
	Proof Insect Net House	2019	-	43.7 a	77.4 a	92.6.a	106.3 a	110.1 a	-	1.411 a	1.121 ab	0.503 b	0.430 a	0.129 ab
		2020	-	40.0 bc	74.4 ab	93.6 a	102.4 ab	107.4 ab	-	1.288 bc	1.148 ab	0.619 a	0.284 b	0.167 a
		2021	-	38.5 c	69.9 bc	90.2 ab	99.2 bc	102.7 bc	-	1.242 c	1.045 ab	0.655 a	0.291 b	0.116 b
		Average	***-***	***40.7***	***73.9***	***92.2***	***102.6***	***106.7***	***-***	***1.314***	***1.105***	***0.592***	***0.335***	***0.137***
Dormant Grafting “Hot Callus” Method	Shaded Field	2019	24.0 a	50.5 ab	75.6 ab	89.7 ab	105.3 a	107.8 a	0.381 a	0.853 a	0.838 ab	0.456 a	0.501 ab	0.080 a
		2020	24.3 a	49.3 ab	72.1 bc	87.9 ab	101.6 ab	104.7 ab	0.308 b	0.804 a	0.762 bc	0.510 a	0.441 bc	0.104 a
		2021	26.8 a	54.0 a	68.6 c	85.3 b	96.1 b	99.4 b	0.301 b	0.875 a	0.488 d	0.538 a	0.349 c	0.109 a
		Average	***25.1***	***51.2***	***72.1***	***87.6***	***101.0***	***104.0***	***0.330***	***0.844***	***0.696***	***0.501***	***0.431***	***0.098***
	Proof Insect Net House	2019	24.2 a	49.0 b	78.3 a	92.5 a	106.0 a	109.4 a	0.384 a	0.800 a	0.978 a	0.456 a	0.436 bc	0.111 ab
		2020	24.9 a	48.9 b	68.9 c	88.1 ab	106.3 a	109.9 a	0.315 b	0.775 a	0.667 bc	0.619 a	0.586 a	0.121 a
		2021	23.8 a	47.5 b	66.8 c	83.8 b	97.6 b	100.8 b	0.267 b	0.764 a	0.645 cd	0.550 a	0.445 bc	0.104 a
		Average	***24.3***	***48.5***	***71.3***	***88.1***	***103.3***	***106.7***	***0.322***	***0.780***	***0.763***	***0.542***	***0.489***	***0.112***
Dormant Grafting “Stratification” Method	Shaded Field	2019	24.0 a	51.7 a	72.8 a	86.3 a	101.3 ab	104.9 a	0.394 a	0.893 a	0.755 a	0.434 b	0.485 ab	0.120 a
		2020	22.9 a	48,3 a	70.8 a	84.0 ab	97.6 bc	100.3 bc	0.322 bc	0.821 ab	0.750 a	0.425 b	0.438 b	0.090 a
		2021	26.1 a	49.9 a	65.7 b	79.8 c	94.4 c	97.8 c	0.293 bc	0.768 ab	0.527 b	0.453 b	0.472 ab	0.116 a
		Average	***24.3***	***50.0***	***69.8***	***83.3***	***97.8***	***101.0***	***0.366***	***0.827***	***0.677***	***0.437***	***0.465***	***0.109***
	Proof Insect Net House	2019	23.9 a	47.5 a	66.6 b	85.7 a	102.9 a	106.3 a	0.391 a	0.760 ab	0.685 a	0.614 a	0.555 a	0.113 a
		2020	24.2 a	47.1 a	70.7 a	86.0 a	101.2 ab	104.0 ab	0.341 ab	0.740 b	0.786 a	0.493 b	0.491 ab	0.093 a
		2021	23.4 a	49.9 a	71.4 a	80.6 bc	95.3 c	97.9 c	0.263 c	0.857 ab	0.714 a	0.297 c	0.475 ab	0.087 a
		Average	***23.8***	***48.2***	***69.6***	***84.1***	***99.8***	***102.7***	***0.332***	***0.786***	***0.728***	***0.468***	***0.507***	***0.098***

** According to Duncan's test, means marked with the same letter are not significantly different (ρ < 0.05). * Mean values were compared between observation fields for each grafting method.

In 2019, the warmest year on record, effective temperatures were measured in an insect-proof net house and a non-shaded field. The temperature in the insect net house was 3,385.35 degrees/day, 8.9% lower than in the non-shaded field, which was 3,716.54 degrees/day (as shown in Table 16). The most significant differences were observed in May and October, with 393.2 degrees/day and 323.7 degrees/day, respectively, in the insect-proof net house and the non-shaded field. These values were 421.6 degrees/day and 467.6 degrees/day. The decrease in degree/day in a shaded field was only 0.2%. In 2020, the temperature was measured at 3,284.2 degrees/day in the insect-proof net house, while in the non-shaded field, it was 3,227.4 degrees/day.

Table 16. *Temperature sums in the range TM 5°C ÷ 25°C during the months of the active growing season for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Year	Month	Non-Shaded Field		Insect-Proof Net House		Shaded Field	
		DD*	CDD**	DD	CDD	DD	CDD
2019	March	215.34	215.34	198.95	198.95	215.34	215.34
	April	211.73	427.07	229.0	427.98	228.03	443.38
	May	421.61	848.68	393.22	821.1	400.24	843.62
	June	525.98	1374.66	519.28	1340.48	525.4	1369.08
	July	546.66	1921.31	539.07	1879.55	546.90	1915.9
	August	565.15	2486.46	556.57	2436.12	560.79	2476.78
	September	451.88	2938.33	443.98	2880.10	453.51	2930.29
	October	467.55	3405.89	323.67	3203.77	467.55	3397.84
	November	310.66	**3716.54**	181.57	**3385.35**	310.66	**3708.50**
2020	March	93.1	93.11	160.60	160.60	93.11	93.11
	April	209.22	302.32	215.57	376.18	215.94	309.05
	May	420.71	723.03	412.94	789.12	403.75	712.80
	June	484.53	1207.56	486.00	1275.12	493.55	1206.35
	July	546.19	1753.76	545.23	1820.34	552.32	1758.68
	August	554.87	2308.63	558.77	2379.11	559.67	2318.35
	September	477.66	2786.29	448.34	2827.45	467.36	2785.71
	October	294.98	3081.27	328.03	3155.48	294.98	3080.69
	November	146.12	**3227.39**	128.72	**3284.20**	146.12	**3226.81**
2021	March	112.65	112.65	148.33	148.33	112.65	112.65
	April	173.05	285.70	228.94	377.26	185.58	298.23
	May	415.85	701.55	387.69	764.95	418.91	717.14
	June	490.76	1192.31	484.04	1248.99	491.06	1208.20
	July	580.25	1772.56	553.75	1802.74	565.45	1773.65
	August	565.05	2337.60	528.54	2331.29	547.09	2320.74
	September	443.16	2780.77	408.62	2739.90	429.34	2750.08
	October	202.06	2982.82	205.72	2945.63	202.06	2952.13
	November	118.37	**3101.20**	127.23	**3072.85**	118.37	**3070.51**

*DD – degrees/day

**GDD – growing degrees/day

At a temperature of 25°C or higher, there was a stronger connection between temperature sums and areas protected by insect-proof net houses or shaded fields, as shown in Table 17. In these environments, the temperature sums decrease significantly. For example, in 2019, the temperature sum was 237.41 degrees per day in a non-shaded field, whereas it was only 155.19 degrees per day (a 51.5% reduction) in an insect-proof net house and 214.04 degrees per day (a 9.85% reduction) in a shaded field. In 2020 and 2021, the temperature reduction in an insect-proof net house was 62.2% and 56.5%, respectively, while in a shaded field, it was 33.0% and 20.1% for the respective years.

Overall, from 2019 to 2021, the temperature reduction was 56.7% in an insect-proof net house and 21.0% in a shaded field.

Table 17. *Temperature sums at TM ≥ 25°C during the months of the active growing season for 2019 – 2021 in an insect-proof net house, a shaded, and a non-shaded field*

Year	Month	Non-Shaded Field		Insect-Proof Net House		Shaded Field	
		DD*	CDD**	DD	CDD	DD	CDD
2019	March	0.18	0.18	0.04	0.04	0.18	0.18
	April	0.00	0.18	0.02	0.06	0.01	0.19
	May	10.66	10.84	5.39	5.45	6.76	6.94
	June	48.06	58.90	35.32	40.77	44.95	51.89
	July	52.88	111.78	39.27	80.04	48.86	100.75
	August	80.56	192.34	59.40	139.45	68.81	169.56
	September	21.56	213.90	14.42	153.86	20.98	190.54
	October	22.31	236.21	1.32	155.19	22.31	212.85
	November	1.19	**237.41**	0.00	**155.19**	1.19	**214.04**
2020	March	0.00	0.00	0.00	0.00	0.00	0.00
	April	0.65	0.65	0.40	0.40	0.49	0.49
	May	8.47	9.12	4.71	5.11	7.45	7.94
	June	46.87	55.99	23.79	28.90	45.09	53.03
	July	110.67	166.66	42.83	71.73	80.43	133.46
	August	131.32	297.97	50.84	122.57	84.08	217.53
	September	75.24	373.21	18.26	140.83	31.94	249.47
	October	1.65	374.86	0.81	141.64	1.65	251.12
	November	0.04	**374.90**	0.00	**141.64**	0.04	**251.16**
2021	March	0.33	0.33	0.24	0.24	0.33	0.33
	April	0.06	0.39	1.87	2.10	0.37	0.70
	May	7.12	7.51	3.22	5.33	9.48	10.18
	June	38.91	46.42	33.97	39.29	36.86	47.04
	July	94.14	140.56	54.05	93.35	92.01	139.04
	August	125.76	266.32	36.10	129.44	81.51	220.56
	September	41.95	308.27	5.04	134.48	25.76	246.31
	October	0.68	308.95	0.00	134.48	0.68	246.99
	November	0.00	**308.95**	0.00	**134.48**	0.00	**246.99**

*DD – degrees/day

**GDD – growing degrees/day

IV.3. Monitoring of pests of fruit propagating material in conditions of shaded field and proof insect net house with category "free of regulated non-quarantine pests (RNQV)" and eligibility factor – 0% (EPPO standard)

IV.3.1. The Woolly apple aphid (*Eriosoma lanigerum* Hausm.)

IV.3.1.1. Observation on the development of the woolly apple aphid (Eriosoma lanigerum Hausm.*) on the apple propagated fruit tree at a constant temperature*

A study was conducted on the activity of the woolly apple aphids (*Eriosoma lanigerum* Hausm.) at two different temperatures, 15°C and 20°C. The activity of the aphids was observed to start on the sixth day at 15°C and on the fourth day at 20°C. The peak of the observed activation of wintering forms was found on the tenth day at 15°C and on the sixth day at 20°C. The data was statistically analyzed using the Shapiro-Wilk normality test, and the ρ-values obtained (at 15°C – ρ = 3.717e-06 and 20°C – ρ = 3.5e-04) were significantly lower than ρ = 0.05. This means that the difference was not normally distributed. Further analysis using a nonparametric Wilcoxon test showed no proven differences between the individual replicates, with a ρ-value of 0.67 at 15°C and 0.77 at 20°C.

Table 18. *Beginning and peak of activity of a wooly apple aphid (Eriosoma lanigerum* Hausm.*) on apple propagated fruit trees at constant temperatures*

Temperature, °C	Repetition	Days of Observation														
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th
15°C	Ist	0.0*	0.0	0.0	0.0	0.0	0.0	1.4	5.2	5.4	10.6	8.0	5.2	3.6	1.6	2.0
	IInd	0.0	0.0	0.0	0.0	0.0	0.2	1.6	6.6	15.6	4.8	6.2	3.8	2.0	0.8	2.4
	IIItd	0.0	0.0	0.0	0.0	0.0	0.0	1.6	5.4	6.6	14.0	7.4	6.0	3.2	0.8	1.2
	Average	***0.0***	***0.0***	***0.0***	***0.0***	***0.0***	***0.1***	***1.5***	***5.7***	***9.2***	***9.8***	***7.2***	***5.0***	***2.9***	***1.4***	***1.9***
20°C	Ist	0.0	0.0	0.2	1.0	3.4	8.6	6.2	6.4	4.4	2.4	2.6	1.4	1.4	0.6	1.2
	IInd	0.0	0.0	0.0	0.8	4.4	8.0	9.8	5.6	4.0	2.2	3.0	2.4	2.2	0.8	1.2
	IIItd	0.0	0.0	0.4	1.4	4.0	7.8	7.2	5.4	5.0	3.0	2.2	1.4	2.6	1.2	0.8
	Average	***0.0***	***0.0***	***0.2***	***1.1***	***3.9***	***8.1***	***7.7***	***5.8***	***4.5***	***2.5***	***2.6***	***1.7***	***2.1***	***0.9***	***1.1***

* Number of larvae caught on one pc. plant

From the observations, we developed predictive polynomial equations at two different temperatures. At 15°C, the equation was $y = -0.103x^2 + 2.2281x - 6.8075$, while at 20°C, it was $y = -0.1186x^2 + 2.1564x - 4.7767$.

During the development of the woolly apple aphids (*Eriosoma lanigerum* Hausm.), the migration of the pests from the aboveground parts to the soil surface is a crucial stage. At a constant temperature of 15°C, this stage was observed to occur on the 18th day from the beginning of their placement. However, there was no reported peak (Table 19).

On the other hand, after 16 days of observation at 20°C, pest migration was observed, and more individuals were caught.

Table 19.*Beginning and peak of migration of a woolly apple aphid (Eriosoma lanigerum* Hausm.*) on apple propagated fruit tree at constant temperatures*

Temperature, °C	Repetition	Days of Observation														
		16th	17th	18th	19th	20th	21st	22nd	23rd	24th	25th	26th	27th	28th	29th	30th
15°C	Ist	0.0*	0.0	1.0	4.0	4.4	6.8	7.6	7.6	7.4	10.0	11.6	12.0	11.4	13.0	12.0
	IInd	0.0	0.0	1.6	3.6	4.6	7.4	8.4	8.2	8.0	9.8	12.0	11.4	11.0	13.4	11.6
	IIItd	0.0	0.0	0.4	3.6	3.8	6.8	7.2	6.8	7.0	9.0	10.2	10.8	10.8	11.0	11.6
	Average	***0.0***	***0.0***	***1.0***	***3.7***	***4.3***	***7.0***	***7.7***	***7.5***	***7.5***	***9.6***	***11.3***	***11.4***	***11.1***	***12.5***	***11.7***
20°C	Ist	1.4	2.6	2.0	3.2	4.4	7.0	8.0	7.8	7.8	10.0	11.6	14.2	14.4	14.6	14.8
	IInd	2.0	3.6	2.6	4.2	6.4	8.0	8.6	8.6	7.6	9.4	10.4	13.0	13.6	13.8	13.4
	IIItd	1.2	3.2	4.4	5.2	4.2	5.8	6.4	7.8	7.2	6.8	7.6	11.8	10.4	12.8	12.0
	Average	***1.5***	***3.1***	***3.0***	***4.2***	***5.0***	***6.9***	***7.7***	***8.1***	***7.5***	***8.7***	***9.9***	***13.0***	***12.8***	***13.7***	***13.4***

* Number of larvae caught on one pc. plant

According to the Shapiro-Wilk test, higher probabilities of no differences exist at 15°C ($\rho = 0.113$) and 20°C ($\rho = 0.31$). Fisher's parametric method then analyzed the statistical data, which showed $\rho = 1.46e{-}04$ (strong evidence) and $\rho = 0.02$ (moderate evidence) at 20°C for statistical evidence between replicates.

Finally, the following predictive polynomial equations were derived. At a temperature of 15°C – $y = -0.0472x^2 + 1.792x - 4.339$ and at 20°C $y = 0.0017x^2 + 0.8588x + 0.01$.

IV.3.1.2. Observation on the development of a woolly apple aphid (Eriosoma lanigerum Hausm.*) on the apple in grafted plants during the dormant period on rootstocks Malling 9 (M.9) and Malling-Merton 106 (MM.106)*

The woolly apple aphids (*Eriosoma lanigerum* Hausm.) were studied in a stratification room with a temperature of 20°C and air humidity of 75%. The results in Table 20 indicate that the highest number of first-age larvae for both Malling 9 (M.9) and Malling-Merton 106 (MM.106) rootstocks was observed on the sixth day after placing the grafted plants in the stratification room with 16 larvae for Malling 9 (M.9) and 12.2 larvae for Malling-Merton 106 (MM.106) rootstock.

Table 20. *Average number of first-age larvae per day (ANOVA one-factor analysis)*

Rootstock	Days									
	1st	2nd	3td	4th	5th	6th	7th	8th	9th	10th
Malling 9 (M.9)	0	0	0	0.4	7.6	16.0	1.6	0	0	0
Malling-Merton 106	0	0	0	0.4	1.6	12.2	1.6	0	0	0
	Total number	*Average*			*Dispersion*			*Error trial*		
Malling 9 (M.9)	128	25.6			33.3			23.39		
Malling-Merton 106	81	16.2			25.2			1.73		
				ANOVA						
Source of Variation	*SS*	*df*	*MS*		*F*		*P-value*		*F crit*	
Between Groups	1288.9	2	644.47		31.695		1.63e-05		3.885	
Within Groups	244	12	20.33							
Total	1532.9	14								

Our study observed the number of woolly apple aphid larvae found in two different rootstocks: Malling 9 (M.9) and Malling-Merton 106 (MM.106). The total number of larvae found in M.9 was 128, with an average of 25.6 larvae per plant. In contrast, we found 81 larvae in MM.106, with an average of 16.2 larvae per plant.

We also observed that the woolly apple aphid develops 1.7 generations in 25 days in the stratification room. During the first generation, 12.3% of M.9 plants were infested, while only 4.9% of MM.106 plants were infested. In the second generation, the infestation rate increased, with 35.8% of M.9 plants and 7.4% of MM.106 plants being infested.

We found that the woolly apple aphid's first-age larvae tended to concentrate at the grafting sites and at the base of the buds to form new colonies after their activity.

According to our study, MM.106 rootstock appears to be more tolerant to the woolly apple aphid than M.9 rootstock, with a three times lower infection rate in the first generation and four times lower in the second generation. This finding is consistent with the research of Lepaja et al. (2014), who also found that MM.106 rootstock is more tolerant to the woolly apple aphid than M.9 rootstock.

We also observed that the first generation of the woolly apple aphid was less mobile and tended to colonize adjoining plants during overwintering. This finding suggests that plant protection measures can be applied during winter rest to control the spread of the pest.

IV.3.1.3. Observation on the time of recovery of the activity of a woolly apple aphid (Eriosoma lanigerum **Hausm.***) on the apple propagated fruit tree in a container*

As per Beliën et al. (2011), three critical time functions must be considered while determining the timing of chemical control treatments against *E. lanigerum*: activity recovery, migration, and colonization.

Table 21 shows that the activity of the woolly apple aphids in an insect-proof net house was observed two days later (29.03) than in containers in a non-shaded field (27.03) in 2019. However, in 2020, activity was observed seven days earlier than the previous year and 17 days earlier than in a non-shaded field. The earliest development was noted in 2021, with development in an insect-proof insect net house reported on 08.03, 14 days earlier than a non-shaded field (25.03).

In 2019, pest migration in the insect-proof net house was detected ten days after activity recovery (08.04). However, it was reported at 31.03 (9 days earlier) in 2020 and 13.03 (5 days earlier) in 2021. Plants grown in containers outdoors were recorded five days earlier than plants in the insect-proof net house in 2019, 14 days later in 2020, and 10 days earlier in 2021.

Table 21*. The activity of a woolly apple aphid in an insect-proof net house and a non-shaded field*

Year	Recovery of Activity	Migration	Colonization
	Insect-Proof Net House		
2019	29.03	08.04	20.04
2020	22.03	31.03	16.04
2021	08.03	13.03	04.04
	Non-Shaded Field (container)		
2019	27.03	03.04	17.04
2020	08.04	15.04	24.04
2021	25.03	3.04	12.04

IV.3.1.4. Sums of effective temperatures of a woolly apple aphid (Eriosoma lanigerum Hausm.*) on the apple fruit propagated tree in container production*

Effective temperatures in the woolly apple aphid *E. lanigerum* were calculated starting January 1st (biofix). In the insect-proof net house, the sums of effective temperatures were calculated for the years 2019 to 2021 using four different methods: *the Average method* (210.38 degrees/day), *the Modified average method* (320.05 degrees/day), *the Triangle method* (250.61 degrees/day), and *the Sine wave method* (269.96 degrees/day) (Table 22). The sine wave method produced the lowest standard deviation (SDDD) and mean standard error (SEDD) with values of 1.94 and 1.12, respectively. The average method had a standard deviation of 10.68 and an error of 6.17 degrees/day, which was lower than the modified mean method but higher than the sine wave method.

The following amounts were calculated by each method: *the Sine wave method* - 251.57 degrees/day (SDDD = 33.36 and SEDD = 19.26); *the Triangle method* - 229.52 degrees/day (SDDD = 35.37 and SEDD = 20.42); *the Modified average method* - 310.49 degrees/day (SDDD = 36.45 and SE DD = 21.05); and *the Average method* - 182.03 (SDDD = 44.97 and SE DD = 25.96).

Table 22*. Sums of effective temperatures of a woolly apple aphid (Eriosoma lanigerum* Hausm.*) at the apple fruit tree in a container production in an insect-proof net house and a non-shaded field*

Year	Average Method	Modified Average Method	Triangle Method	Sine Wave Method
		Insect-Proof Net House		
2019	222.67	309.91	254.94	270.77
2020	205.18	312.59	248.31	267.74
2021	203.30	337.65	248.57	271.36
DD_{ave}	**210.38**	**320.05**	**250.61**	**269.96**
SD_{DD}	**10.68**	**15.30**	**3.76**	**1.94**
SE_{DD}	**6.17**	**8.83**	**2.17**	**1.12**
S_{DDave} %	**2.93**	**2.76**	**0.87**	**0.41**
		Non-Shaded Field (container)		
2019	227.00	307.85	257.61	272.64
2020	137.06	275.43	189.80	213.10
2021	182.02	348.19	241.14	268.96
DD_{ave}	**182.03**	**310.49**	**229.52**	**251.57**
SD_{DD}	**44.97**	**36.45**	**35.37**	**33.36**
SE_{DD}	**25.96**	**21.05**	**20.42**	**19.26**
S_{DDave} %	**14.26**	**6.78**	**8.90**	**7.66**

The results obtained show that to determine the onset of activity of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) in the insect-proof net house can be used the *method of Sine wave* with biofix January 1st with a sum of effective temperatures of 269.96 degrees/day (±1.94). No working models have been established in the non-shaded field for sums of effective temperatures.

IV.3.1.5. Observation on the influence of a woolly apple aphid (Eriosoma lanigerum **Hausm.***) on apple fruit tree on vegetative indices of grafted plants in container production*

Based on visual assessment, the infected plants had a significantly deteriorated commercial appearance. In all three fields of observation, a higher percentage of the woolly apple aphid (Eriosoma lanigerum Hausm) partially or entirely covered the plants' surface. Premature leaf loss and areas with higher densities of the pest were also observed.

For plants infected by the aphid migration, the pest concentration was mainly concentrated in the branches of the fruit tree species. The plants reached sizes suitable for sale, and after the growing season, there were no pronounced visible signs of the woolly apple aphid infestation. However, due to the specifics of container production, wintering forms (root colonies) remain hidden in the soil, increasing the risk of spreading the pest.

In plants that were infected during their propagation (using infected rootstocks), the percentage of reduction in the values of the total vegetative growth was between 78.8% and 81.0% (as shown in Table 23). In plants growing in the non-shaded field, a higher reduction percentage was found - 80.4%, compared to the insect-proof net house and shaded field - 79.7%.

Table 23*. Influence of a woolly apple aphid (Eriosoma lanigerum* Hausm.*) on the total vegetative growth of the fruit apple species (Malus domestica* Borkh.*) in an insect-proof net house, a shaded and a non-shaded field*

Fruit Species	Field of Observation	Year	Total Vegetative Growth				
			Non-Infected Plants	Infected Plants in Propagation (Infected Rootstocks)	Deviation %	Infected Plants as a Result of Migration	Deviation %
Apple (*Malus domestica* Borkh.)	Insect-Proof Net House**	2019	303.2 a*	61.9 a	-79.6	277.4 a	-8.6
		2020	289.8 b	58.2 b	-80.0	260.5 b	-10.7
		2021	281.2 bc	56.6 b	-79.5	255.1 bc	-7.9
	Average		***290.8***	***58.9***	***-79.7***	***264.3***	***-9.1***
	Shaded Field	2019	287.3 b	58.0 b	-79.9	262.4 b	-9.1
		2020	277.2 bcd	54.4 b	-80.5	248.6 bcd	-10.7
		2021	267.6 cd	55.6 b	-78.8	239.8 d	-9.0
	Average		***276.9***	***56.0***	***-79.7***	***250.3***	***-9.6***
	Non-Shaded Field	2019	263.9 d	50.5 c	-81.0	243.1 cd	-8.6
		2020	245.9 e	47.6 c	-80.9	234.3 d	-6.0
		2021	235.8 e	48.1 c	-79.3	215.5 e	-7.8
	Average		***249.6***	***48.7***	***-80.4***	***230.9***	***-7.5***

*Mean values marked with the same letter are not significantly different according to Duncan's test (ρ < 0.05)
**Mean values were compared between observation fields

IV.3.1.6. Degree of damage by a woolly apple aphid (Eriosoma lanigerum **Hausm.***) on the apple in containerized cultivation of plants in an insect-proof net house, shaded field, and open field*

According to Bower's (1987) five-rate scale for assessing plant damage, the most significant damage was found in plants grown in the insect-proof net house (Table 24). On average, from 2019 to 2021, the damage rate was 4.2, with the highest value observed in 2019 (4.4). A decreasing trend was observed in the shaded field, with an average damage rate of 3.3.

The highest damage rate was recorded in 2019 (3.6), followed by 2020 (3.2) and 2021 (3.0). The non-shaded field had a lower damage rate, with an average of 2.3 for the period. The highest damage rate was observed in 2020 (2.6), followed by 2021 (2.3) and 2019 (2.0).

***Table 24**. Damage rate of a woolly apple aphid (Eriosoma lanigerum* Hausm.*) on the 5th-rating scale at the fruit species apple (Malus domestica* Borkh.*) in an insect-proof net house, a shaded, and a non-shaded field*

Year	Insect-Proof Net House	Shaded Field	Non-Shaded Field
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***

In the study of the frequency of plant damage, it was observed that plants in the insect-proof net house had the highest percentage of damage (strong to very strong) at over 25% (as shown in Figure 15). The highest damage frequency (10% – 25% failure) was observed in a shaded field at rate 2. Plants grown in non-shaded fields had the highest frequency of medium damage to traces of damage.

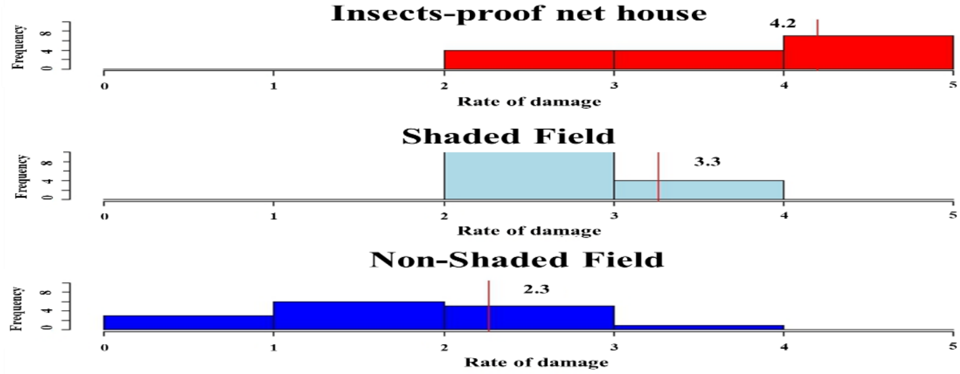

***Figure 15.** Frequency of rate of damage in an insect-proof net house, a shaded, and a non-shaded field in container growing*

The highest percentage in the experimental sample was found in plants in the non-shaded field (Table 25). The average rate for 2019 – 2021 was 41.7%, with the highest in 2019 – 50%, followed by 2020 – 40% and 2021 with 35% of plants infected. A higher percentage was found in shaded fields using nets. On average, for the period, the percentage in a shaded field was 31.7%, and in an insect-proof net house, it was 28.3%. By year, the highest percentage was observed in 2019 in both fields of cultivation; in 2019, in a shaded field, it was 40%, and in an insect-proof net house, it was 35%. In 2020, both fields of shaded and insect-proof net house reported the same percentage – 30%, while in 2021 the trend towards a higher percentage in the shaded field was maintained – 25% and 20% respectively in the insect-proof net house.

***Table 25**. Percentage of attacked plants per woolly apple aphid (Eriosoma lanigerum* Hausm.*) at the fruit species apple (Malus domestica* Borkh.*) in an insect-proof net house, a shaded, and a non-shaded field*

Year	Insect-Proof Net House %	Shaded Field %	Non-Shaded Field %
2019	35	40	50
2020	30	30	40
2021	20	25	35
Average	***28.3***	***31.7***	***41.7***

Through visual assessment during the growing season, a more pronounced migration of the larvae of the first age of the pest into a non-shaded field was established, probably due to abiotic environmental factors. In the insect-proof net house, colonies with a higher density of the pest were found compared to the other observation fields due to the creation of more favorable conditions for developing a woolly apple aphid (*Eriosoma lanigerum* Hausm.).

In the calculation of the pest's harmfulness factor in the production of propagating material in containers, depending on the direction (standard and certified), the highest percentage was found in the insect-proof net house – 71.7% using an entomological net, followed by the 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 (Table 26).

Table 26. *Coefficient of the harmfulness of a woolly apple aphid (Eriosoma lanigerum* Hausm.*) at the fruit species apple (Malus domestica* Borkh.*) in an insect-proof net house, a shaded and a non-shaded field*

Year	Insect-Proof Net House %	Shaded Field %	Non-Shaded Field %
2019	65	60	50
2020	70	70	60
2021	80	75	65
Average	***71.7***	***68.3***	***58.3***

IV.3.2. San José scale (Quadraspidiotus perniciosus Comst.*)*

Critical phases in the species' development are males' flying and when wintering larvae and females begin to leave the wintering sites and move along the branches (Kyparissoudas, 1990; Petrova, 2017).

IV.3.2.1. Observation on the behavior of a San José Scale (Quadraspidiotus perniciosus Comst.*) at constant temperature*

Following the development of the pest at a constant temperature of 15°C, it was found that the flight of the males began on the 10th day (±1 day) of placing the infected plants in the stratification room (Table 27). The apple (Malus domestica Borkh) was observed one day earlier than the stone fruit species. The most significant average number of males caught was found in apple plants – 8 pcs. (24 pcs. – total number), in plum plants – 5.67 pcs. (16 pcs.) and for sweet cherry plants – 6.33 pcs. with a total number of 19 pcs. males caught. In all three fruit species, after reaching the peak of massive flight, a constant value of the number of males was found for 2 – 3 days.

Table 27. *Male flight of San José scale (Quadraspidiotus perniciosus* Comst.*) at 15°C*

Fruit Tree Species	Repetition	Days				
		8th	9th	10th	11th	12th
Apple (*Malus domestica* Borkh.)	Ist	0.0	5.0	7.0	7.2	6.8
	IInd	0.0	5.0	5.8	6.0	5.4
	IIIrd	0.4	10.6	11.2	11.4	11.0
	Average	***0.1***	***6.9***	***8.0***	***8.2***	***7.7***
Plum (*Prunus domestica* L.)	Ist	0.0	0.4	4.8	6.2	6.2
	IInd	0.0	0.0	6.2	6.4	6.0
	IIIrd	0.0	0.0	4.8	5.2	4.6
	Average	***0.0***	***0.1***	***5.3***	***5.9***	***5.6***
Sweet Cherry (*Prunus avium* L.)	Ist	0.0	0.0	3.2	6.2	6.4
	IInd	0.0	0.0	2.0	5.8	6.2
	IIIrd	0.0	0.0	3.8	6.8	7.4
	Average	***0.0***	***0.0***	***3.0***	***6.3***	***6.7***

After statistical data processing, at a temperature of 15°C were calculated, ρ = 4.91e-03 (very strong evidence) and effect size between replicates $\hat{w}p^2$ = 0.12 (moderately expressed influence) for acceptance of statistically proven differences between individual replicates.

At 20°C constant temperature, the flight of males was observed on day 8th (±1 day), two days earlier than at the constant temperature of 15°C (Table 28).

In stone fruit species plum and sweet cherry, males began their flight one day later than in apples. The peak in male development was recorded on the 10th day.

The results showed an earlier male appearance in the pome fruit species by one day. In the case of apples, the period until the peak was one day longer than that of stone fruit species – plum and sweet cherry. A higher number of males caught was observed in the apple species.

***Table 28**. Male flight of San José scale (Quadraspidiotus perniciosus* Comst.*) at 20°C*

Fruit Tree Species	Repetition	Days				
		6th	7th	8th	9th	10th
Apple (*Malus domestica* Borkh.)	Ist	0.0	4.8	7.6	8.2	8.8
	IInd	0.0	5.2	8.8	9.2	9.4
	IIItd	0.0	2.6	7.6	8.0	8.4
	Average	***0.0***	***4.2***	***8.0***	***8.5***	***8.9***
Plum (*Prunus domestica* L.)	Ist	0.0	0.0	0.8	4.0	4.6
	IInd	0.0	0.0	2.8	4.4	5.2
	IIItd	0.0	0.0	2.2	3.2	3.4
	Average	***0.0***	***0.0***	***1.9***	***3.9***	***4.4***
Sweet Cherry (*Prunus avium* L.)	Ist	0.0	0.0	1.8	4.2	4.6
	IInd	0.0	0.0	2.6	5.6	6.2
	IIItd	0.0	0.0	3.8	5.0	5.6
	Average	***0.0***	***0.0***	***2.7***	***4.9***	***5.5***

The predictive polynomial equations are presented in Table 29.

***Table 29.** Predictive polynomial equations for monitoring males flight of San José scale (Quadraspidiotus perniciosus* Comst.*) on apple, plum, and sweet cherry fruit tree species at constant temperatures of 15°C and 20°C*

Fruit Tree Species	Polynomial Equation	R^2
	15°C	
Apple (*Malus domestica* Borkh.)	$y = -0.028x^2 + 0.977x – 2.6813$	0.4503
Plum (*Prunus domestica* L.)	$y = -0.0005x^2 + 0.3486x – 1.1414$	0.3689
Sweet Cherry (*Prunus avium* L.)	$y = 0.0024x^2 + 0.2778x – 0.9707$	0.31
	20°C	
Apple (*Malus domestica* Borkh.)	$y = -0.1049x^2 + 1.9109x – 4.0773$	0.3836
Plum (*Prunus domestica* L.)	$y = -0.0069x^2 + 0.3698x – 0.9727$	0.4033
Sweet Cherry (*Prunus avium* L.)	$y = -0.0208x^2 + 0.5862x – 1.4273$	0.3319

At both observed temperatures, the earlier development and the higher average number of males were in the apple fruit species (*Malus domestica* Borkh.). Statistically proven differences were found between the observed cultivars at a constant temperature of 15°C at ρ = 0,02 and a constant temperature of 20°C at ρ = 0,03.

The second critical stage in the development of the San José scale (*Quadraspidiotus pernicious* Comst.) *to bring out adequate plant protection* is the departure of females and their migration to the vegetative parts of the plants. The observation was carried out at a constant temperature of 15°C; it was observed after the 33rd day (Table 30). In the observed fruit species, apple (*Malus domestica* Borkh.), *plum* (Prunus domestica L.), and sweet cherry (*Prunus avium* L.), earlier development of females was found in the pome fruit species apple (*Malus* domestica Borkh.) with a peak in development after five days (37th day).

In the stone fruit species, the onset of female development was recorded one day after that of the apple fruit species. A peak in development was observed after four days.

Table 30. *Female larvae movement of San José scale (Quadraspidiotus perniciosus* Comst.*) at 15°C*

Fruit Tree Species	Repetition	Days					
		32^{nd}	33^{td}	34^{th}	35^{th}	36^{th}	37^{th}
Apple (*Malus domestica* Borkh.)	I^{st}	0.0	1.0	5.2	5.8	10.4	11.8
	II^{nd}	0.0	1.6	6.0	7.4	10.8	10.4
	III^{td}	0.0	0.8	7.4	8.4	11.0	11.4
	Average	***0.0***	***1.1***	***6.2***	***7.2***	***10.7***	***11.2***
Plum (*Prunus domestica* L.)	I^{st}	0.0	0.0	2.4	6.6	13.6	14.2
	II^{nd}	0.0	0.0	0.0	7.6	11.8	15.4
	III^{td}	0.0	0.0	0.0	6.8	14.8	15.2
	Average	***0.0***	***0.0***	***0.8***	***7.0***	***13.4***	***14.9***
Sweet Cherry (*Prunus avium* L.)	I^{st}	0.0	0.0	0.4	5.4	9.2	12.2
	II^{nd}	0.0	0.0	0.0	6.2	11.0	12.2
	III^{td}	0.0	0.0	0.0	5.2	12.6	13.0
	Average	***0.0***	***0.0***	***0.1***	***5.6***	***10.9***	***12.5***

Statistical analysis found that the data obtained were evenly distributed between replicates and at a coefficient for effect size $\hat{w}_p^2$ = 3.01e-03 – inferior evidence of acceptance of differences.

At 20°C, female development was observed on day 24 (Table 31). Earlier development was again found in the apple species, with one day compared to the fruit species plum and sweet cherry.

The results showed an impressive number of females in the plum fruit species.

Table 31. *Female larvae movement of the San José scale (Quadraspidiotus perniciosus* Comst.*) at 20°C*

Fruit Tree Species	Repetition	Days				
		23^{td}	24^{th}	25^{th}	26^{th}	27^{th}
Apple (*Malus domestica* Borkh.)	I^{st}	0.0	0.4	10.6	11.0	9.0
	II^{nd}	0.0	0.0	11.8	11.8	9.6
	III^{td}	0.0	0.0	10.2	11.4	8.6
	Average	***0.0***	***0.1***	***10.9***	***11.4***	***9.1***
Plum (*Prunus domestica* L.)	I^{st}	0.0	0.0	0.2	6.2	15.0
	II^{nd}	0.0	0.0	0.0	7.2	17.0
	III^{td}	0.0	0.0	0,0	7.2	16.9
	Average	***0.0***	***0.0***	***0.1***	***6.9***	***16.0***
Sweet Cherry (*Prunus avium* L.)	I^{st}	0.0	0.0	0.4	4.6	13.6
	II^{nd}	0.0	0.0	0.0	5.8	11.6
	III^{td}	0.0	0.0	0.2	5.6	13.2
	Average	***0.0***	***0.0***	***0.2***	***5.3***	***12.8***

And at 20°C, no statistically proven differences between cultivars were found in the development of females (ρ = 0.79; $\hat{w}_p^2$ = 0.00).

The predictive polynomial equations are presented in Table 32.

Table 32. *Predictive polynomial equations for monitoring female larvae movement of the San José scale (Quadraspidiotus perniciosus* Comst.*) on apple, plum, and sweet cherry fruit tree species at constant temperatures of 15°C and 20°C*

Fruit Tree Species	Polynomial Equation	R^2
	15˚C	
Apple (*Malus domestica* Borkh.)	$y = 0.0153x^2 – 0.4395x + 2.06$	0.6519
Plum (*Prunus domestica* L.)	$y = 0.0166x^2 – 0.4871x + 2.3263$	0.5265
Sweet Cherry (*Prunus avium* L.)	$y = 0.0134x^2 – 0.3949x + 1.8887$	0.5085

	20˚C	
Apple (*Malus domestica* Borkh.)	$y = 0.0205x^2 – 0.4009x + 1.2808$	0.4603
Plum (*Prunus domestica* L.)	$y = 0.0224x^2 – 0.4788x + 1.6855$	0.4182
Sweet Cherry (*Prunus avium* L.)	$y = 0.0164x^2 – 0.3485x + 1.2171$	0.3792

IV.3.2.2. Observation on the time of appearance of a San José Scale (Quadraspidiotus perniciosus **Comst.***)*

In 2019, the male's flight of the San José scale (*Quadraspidiotus pernicious* Comst.) in the insect-proof net house was detected on 11.04., three days later than that found in the non-shaded field (Table 33). In 2020, it was detected 12 days earlier than grown plants in the non-shaded field and 11 days earlier in a shaded field. For 2020, it was observed at the earliest in plants grown in shaded fields – 3 days earlier than an insect-proof net house and six days earlier than a non-shaded field.

The development of females in 2019 in the insect-proof net house was found 19 days after the males' flight. This period was longer by six days in the non-shaded field and shorter by four days in the shaded field. In 2020 and 2021, there was an extension of the period of sexual maturation of females in the insect-proof net house by five days for 2020 and two days for 2021.

Table 33. *The time of emergence of the San José scale (Quadraspidiotus perniciosus* Comst.*)*

Year	Non-Shaded Field		Insect-Proof Net House		Shaded Field	
	Males Flight	Female (overwintering larvae)	Males Flight	Female (overwintering larvae)	Males Flight	Female (overwintering larvae)
2019	08.04	03.05	11.04	01.05	11.04	05.05
2020	12.04	01.05	30.03	22.04	11.04	29.04
2021	11.05	25.05	08.05	24.05	05.05	23.05

The observations for 2019 – 2021 show pronounced differences in the development of the pest, which confirms the need for monitoring to properly determine the pest's control. In years with temperatures higher than the established average for the area, the development of the San José scale (*Quadraspidiotus perniciosus* Comst.) was observed one month earlier.

IV.3.2.3. ***Sums of effective temperatures of the San José scale*** **(*Quadraspidiotus perniciosus* Comst.*) in container production in an insect-proof net house, a shaded and a non-shaded field*)**

In this dissertation, a comparative analysis was made between six known lower temperature thresholds of the pest development.

The lowest deviation from the established starting dates for the activation of males was found by the *Average method* (Table 34). In the non-shaded field deviation in the range of -1.1 – 2.1 degrees/day for the observation period 2019 – 2021, a lower temperature threshold of 10.6°C was found with a temperature sum of 155 degrees/day. The lowest deviations were reported when using a net – in a shaded field with an interval of -5.0 – 5.0 degrees/day at a lower temperature threshold of 9.2°C with a temperature sum of 211 degrees/day and in an insect-proof net house with an interval of -7.7 – 14.8 degrees/day with a temperature sum of 160 degrees/day.

Table 34. *Comparative analysis of different lower temperature thresholds of male development at the San José scale* (*Quadraspidiotus perniciosus* Comst.*)*

Lower threshold	Year	Insect-Proof Net House				Shaded Field				Non-Shaded Field			
		Average Method	Modified Average Method	Triangle Method	Sine Wave Method	Average Method	Modified Average Method	Triangle Method	Sine Wave Method	Average Method	Modified Average Method	Triangle Method	Sine Wave Method
7˚C	2019	**333.8**	**313.1**	**240.4**	**261.1**	**322,2**	**319.4**	**252.5**	**271.2**	**316.9**	**303.7**	**231.9**	**250.6**
		13.3	105.0	81.3	89.1	13.9	41.6	14.8	23.1	19.6	69.6	46.8	55.2
	2020	**370.5**	**267.2**	**190.3**	**211.0**	**341,7**	**223.6**	**132.8**	**156.2**	**360.2**	**232.1**	**141.6**	**164.9**
		-23.4	150.8	131.5	139.2	-5.6	137.4	134.5	138.0	-23.7	141.1	137.1	140.9
	2021	**336.9**	**673.8**	**534.5**	**578.6**	**344,4**	**540.0**	**416.7**	**455.3**	**332.4**	**583.9**	**462.5**	**502.0**
		10.2	-255.8	-212.8	-228.3	-8.3	-179.0	-149.3	-161.1	4.1	-210.7	-183.8	-196.2
7.3˚C	2019	**316.4**	**301.5**	**226.9**	**247.8**	**305,4**	**307.8**	**239.0**	**257.9**	**301.0**	**292.4**	**219.3**	**238.2**
		12.1	103.2	79.1	87.0	-85.2	39.9	13.8	21.8	16.3	67.2	44.6	52.9
	2020	**352.2**	**256.1**	**178.5**	**199.2**	**321,3**	**211.3**	**122.3**	**145.0**	**339.2**	**219.6**	**130.7**	**153.5**
		-23.7	148.5	127.6	135.6	-101.1	136.3	130.6	134.7	-21.9	140.0	133.2	137.6
	2021	**317.0**	**656.4**	**512.7**	**557.4**	**324**	**523.8**	**397.2**	**436.3**	**311.7**	**566.8**	**441.7**	**481.6**
		11.5	-251.7	-206.7	-222.6	-103.8	-176.2	-144.4	-156.5	5.6	-207.2	-177.7	-190.5
9.2˚C	2019	**217.8**	**233.8**	**153.2**	**174.5**	**211.7**	**241.9**	**165.1**	**185.3**	**211.4**	**228.8**	**151.5**	**171.4**
		8.0	92.4	66.0	74.0	-0.1	28.3	10.1	15.8	1.3	51.9	33.4	39.7
	2020	**244.8**	**192.7**	**115.7**	**135.7**	**206.6**	**143.6**	**71.5**	**89.9**	**219.9**	**150.7**	**78.1**	**96.6**
		-19.0	133.5	103.5	112.8	5.0	126.6	103.7	111.2	-7.2	130.0	106.8	114.5
	2021	**214.8**	**552.1**	**388.6**	**435.3**	**216.6**	**425.1**	**289.0**	**328.2**	**206.8**	**462.7**	**325.1**	**365.5**
		11.0	-225.9	-169.4	-186.8	-5.0	-154.9	-113.8	-127.1	5.9	-182.0	-140.2	-154.3
10˚C	2019	**181.0**	**208.2**	**127.8**	**148.9**	**175.6**	**217.5**	**139.3**	**159.7**	**176.6**	**205.6**	**128.3**	**148.3**
		7.2	87.5	60.8	68.6	-1.0	24.4	9.5	14.2	0.2	46.4	29.7	35.2
	2020	**204.7**	**169.0**	**94.9**	**114.2**	**168.7**	**121.8**	**56.3**	**73.0**	**180.3**	**128.5**	**62.3**	**79.2**
		-16.5	126.6	93.6	103.4	5.9	120.2	92.5	100.9	-3.5	123.5	95.7	104.4
	2021	**179.0**	**509.8**	**343.0**	**389.5**	**179.6**	**386.6**	**250.7**	**289.0**	**173.5**	**421.9**	**283.5**	**323.1**
		9.2	-214.1	-154.4	-171.9	-5.0	-144.6	-102.0	-115.1	3.3	-169.9	-125.5	-139.6
10.5˚C	2019	**159.0**	**193.3**	**113.4**	**134.4**	**154.8**	**203.4**	**124.6**	**145.1**	**156.0**	**192.3**	**115.2**	**135.1**
		7.5	84.4	57.7	65.2	-0.6	22.2	9.2	13.3	1.0	43.1	27.6	32.6
	2020	**181.6**	**155.7**	**83.4**	**102.0**	**148.5**	**109.8**	**48.1**	**63.7**	**159.1**	**116.2**	**53.7**	**69.5**
		-15.1	122.0	87.7	97.6	5.7	115.8	85.7	94.6	-2.1	119.1	89.1	98.2
	2021	**158.8**	**484.1**	**316.4**	**362.5**	**159.2**	**363.5**	**228.8**	**266.3**	**155.9**	**397.5**	**259.5**	**298.5**
		7.7	-206.4	-145.3	-162.8	-5.0	-138.0	-94.9	-107.9	1.1	-162.2	-116.7	-130.8
10.6˚C	2019	**154.6**	**190.4**	**110.7**	**131.6**	**150.9**	**200.6**	**121.8**	**142.3**	**152.0**	**189.6**	**112.7**	**132.6**
		7.7	83.8	57.0	64.6	-0.5	21.7	9.2	13.1	1.3	42.5	27.2	32.1
	2020	**177.1**	**153.1**	**81.2**	**99.7**	**144.9**	**107.4**	**46.6**	**62.0**	**155.2**	**113.8**	**52.1**	**67.7**
		-14.8	121.1	86.5	96.5	5.5	114.9	84.4	93.4	-1.9	118.2	87.8	97.0
	2021	**155.2**	**479.0**	**311.3**	**357.2**	**155.4**	**359.0**	**224.6**	**261.9**	**152.8**	**392.8**	**254.9**	**293.7**
		7.1	-204.8	-143.6	-161.0	-5.0	-136.6	-93.6	-106.5	0.5	-160.7	-115.0	-129.0

From the comparative analysis of nine forecast models, with the lowest deviation from the established dates in the study, the model proposed by Huba (1963), which predicts the appearance of a larva at a lower temperature threshold of 7.3°C and the appearance of the first generation at a temperature sum of 500°C calculated by *the Average method*. The deviation in the non-shaded field during the three years of study was – two days for 2021 and 2020 and three days for 2019 (Table 35).

In net-using fields, the deviation in the shaded field was – -1 day (2020), 1 day (2021), and in the insect-proof net house – -2 days (2021) and 1 day (2019, 2020).

Good results were also found in the University of California Model (Rice, 1982) with a lower temperature threshold of 10.6°C and the occurrence of first-generation larvae at 225°C in all three observed cultivation fields. For the fields under the net, significantly low deviations were found in the Comel Model (Leedham and Grigg-McGuffin, 2013) calculated by *the Average method* at a lower temperature threshold of 10°C and appearance of larvae of 1st generation at 278°C.

***Table 35**. Comparative analysis of predictive models for developing the San José scale (Quadraspidiotus perniciosus* Comst.*)*

Models	Year	Insect-Proof Net House				Shaded Field				Non-Shaded Field			
		Average Method	Modified Average Method	Triangle Method	Sine Wave Method	Average Method	Modified Average Method	Triangle Method	Sine Wave Method	Average Method	Modified Average Method	Triangle Method	Sine Wave Method
Baker Model	2019	22.05	12.06	9.06	8.06	30.05	10.06	8.06	7.06	22.05	9.06	7.06	6.06
		-21 days	**-43 days**	**-38 days**	**-37 days**	**-25 days**	**-35 days**	**-33 days**	**-32 days**	**-19 days**	**-37 days**	**-35 days**	**-34 days**
	2020	15.05	9.06	9.06	7.06	23.05	17.06	15.06	13.06	21.05	19.06	15.06	13.06
		-23 days	**-48 days**	**-48 days**	**-46 days**	**-24 days**	**-49 days**	**-45 days**	**-43 days**	**-20 days**	**-50 days**	**-46 days**	**-39 days**
	2021	19.06	25.05	4.06	31.05	10.06	3.06	9.06	5.06	19.06	6.06	10.06	7.06
		-26 days	**-1 days**	**-11 days**	**-6 days**	**-18 days**	**-11 days**	**-17 days**	**-13 days**	**-25 days**	**-12 days**	**-16 days**	**-13 days**
MacLeod Model	2019	27.05	12.06	14.06	12.06	5.06	10.06	12.06	10.06	26.05	9.06	11.06	8.06
		-26 days	**-43 days**	**-45 days**	**-43 days**	**-31 days**	**-35 days**	**-37 days**	**-35 days**	**-22 days**	**-37 days**	**-39 days**	**-36 days**
	2020	21.05	9.06	14.06	10.06	31.05	18.06	18.06	17.06	30.05	20.06	19.06	17.06
		-29 days	**-48 days**	**-53 days**	**-49 days**	**-31 days**	**-50 days**	**-50 days**	**-49 days**	**-29 days**	**-51 days**	**-50 days**	**-43 days**
	2021	24.06	25.05	10.06	6.06	14.06	3.06	13.06	10.06	23.06	6.06	15.06	11.06
		-31 days	**- 1 days**	**-17 days**	**-13 days**	**-22 days**	**-11 days**	**-21 days**	**-18 days**	**-29 days**	**-12 days**	**-21 days**	**-17 days**
Kozár Model	2019	11.05	18.05	28.05	26.05	19.05	17.05	27.05	24.05	10.05	17.05	26.05	23.05
		-10 days	**-17 days**	**-27 days**	**-25 days**	**-14 days**	**-12 days**	**-22 days**	**-19 days**	**- 7 days**	**-14 days**	**-22 days**	**-19 days**
	2020	3.05	15.05	24.05	21.05	13.05	23.05	1.06	29.05	12.05	23.05	31.05	27.05
		-11 days	**-23 days**	**-32 days**	**-29 days**	**-14 days**	**-24 days**	**-32 days**	**-29 days**	**-11 days**	**-22 days**	**-30 days**	**-26 days**
	2021	7.06	25.04	19.05	11.05	30.05	7.05	25.05	20.05	6.06	9.05	25.05	22.05
		-14 days	**+30 days**	**+ 5 days**	**+13 days**	**-7 days**	**+16 days**	**-2 days**	**+3 days**	**-12 days**	**+16 days**	**0 days**	**+3 days**
Gentile and Summers Model	2019	29.05	11.06	15.06	14.06	8.06	9.06	14.06	12.06	29.05	8.06	13.06	11.06
		-28 days	**-42 days**	**-46 days**	**-45 days**	**-33 days**	**-34 days**	**-39 days**	**-37 days**	**-25 days**	**-36 days**	**-41 days**	**-39 days**
	2020	25.05	9.06	16.06	13.06	5.06	17.06	20.06	18.06	4.06	19.06	20.06	18.06
		-33 days	**-48 days**	**-55 days**	**-52 days**	**-36 days**	**-49 days**	**-52 days**	**-50 days**	**-35 days**	**-50 days**	**-51 days**	**-44 days**
	2021	26.06	25.06	12.06	8.06	15.06	2.06	16.06	12.06	24.06	6.06	17.06	13.06
		-33 days	**-32 days**	**-19 days**	**-15 days**	**-23 days**	**-10 days**	**-24 days**	**-20 days**	**-30 days**	**-12 days**	**-23 days**	**-15 days**
Kentaku Model	2019	-	8.05	22.05	19.05	-	5.05	20.05	18.05	-	6.05	20.05	18.05
		-	**-7 days**	**-21 days**	**-18 days**	**-**	**0 days**	**-15 days**	**-13 days**	**-**	**-3 days**	**-17 days**	**-15 days**
	2020	-	6.05	18.05	16.05	-	15.05	22.05	20.05	-	15.05	21.05	19.05
		-	**-16 days**	**-26 days**	**-15 days**	**-**	**-16 days**	**-22 days**	**-20 days**	**-**	**-14 days**	**-20 days**	**-18 days**
	2021	-	12.04	9.05	2.05	-	30.04	18.05	13.05	-	1.05	19.05	14.05
		-	**+42 days**	**+15 days**	**+23 days**	**-**	**+23 days**	**+5 days**	**+10 days**	**-**	**+24 days**	**+6 days**	**+11 days**
Cornel Model	2019	26.04	28.04	15.05	10.05	2.05	26.04	12.05	6.05	26.04	28.04	12.05	9.05
		+5 days	**+3 days**	**-14 days**	**-7 days**	**+3 days**	**+9 days**	**-7 days**	**-1 day**	**+7 days**	**+5 days**	**-9 days**	**- 6 days**
	2020	18.04	26.04	12.05	9.05	28.04	9.05	17.05	15.05	27.04	9.05	16.05	14.05
		+4 days	**-4 days**	**-20 days**	**-8 days**	**+1 day**	**-9 days**	**-18 days**	**-16 days**	**+23 days**	**-8 days**	**-15 days**	**-13 days**
	2021	23.05	30.03	1.05	25.04	19.05	15.04	9.05	4.05	23.05	15.04	11.05	5.05
		+1 day	**+54 days**	**+23 days**	**+30 days**	**+4 days**	**+38 days**	**+13 days**	**+18 days**	**+2 days**	**+40 days**	**+13 days**	**+19 days**
Huba Model	2019	30.04	12.05	19.05	16.05	5.05	11.05	17.05	15.05	30.04	12.05	18.05	15.05
		+1 day	**-11 days**	**-18 days**	**-14 days**	**0 days**	**-6 days**	**-12 days**	**-10 days**	**+3 days**	**-11 days**	**-17 days**	**-13 days**
	2020	21.04	10.05	16.05	14.05	30.04	18.05	22.05	20.05	29.04	18.05	21.05	19.05
		+1 day	**-18 days**	**-24 days**	**-22 days**	**-1 day**	**-19 days**	**-23 days**	**-31 days**	**+2 days**	**-17 days**	**-20 days**	**-19 days**
	2021	26.05	21.04	7.05	3.05	22.05	3.05	16.05	13.05	27.05	4.05	18.05	13.05
		-2 days	**+33 days**	**+17 days**	**+21 days**	**+1 day**	**+20 days**	**+7 days**	**+10 days**	**-2 days**	**+21 days**	**+5 days**	**+10 days**
Washington Model	2019	-	20.04	9.05	3.05	-	17.04	6.05	20.05	-	19.04	7.05	3.05
		-	**+10 days**	**-8 days**	**-2 days**	**-**	**+18 days**	**-1 day**	**-15 days**	**-**	**+14 days**	**-4 days**	**0 days**
	2020	-	19.04	9.05	3.05	-	30.04	13.05	11.05	-	2.05	13.05	12.05
		-	**+3 days**	**-19 days**	**-12days**	**-**	**-1 day**	**-14 days**	**-12 days**	**-**	**-1 day**	**-12 days**	**-11 days**
	2021	-	18.03	27.04	17.04	-	1.04	5.05	1.05	-	1.04	5.05	2.05
		-	**+67 days**	**+28 days**	**+37 days**	**-**	**+53 days**	**+22 days**	**+23 days**	**-**	**+54 days**	**+20 days**	**+23 days**
California Model	2019	24.04	22.04	11.05	4.05	29.04	19.04	7.05	2.05	24.04	21.04	9.05	4.05
		+6 days	**+8 days**	**-10 days**	**-3 days**	**+6 days**	**+16 days**	**-2 days**	**+3 days**	**+9 days**	**+12 days**	**-6 days**	**-1 day**
	2020	15.04	20.04	10.05	4.05	26.04	3.05	14.05	13.05	24.04	3.05	14.05	12.05
		+7 days	**+2 days**	**-18 days**	**-13 days**	**+3 days**	**-4 days**	**-15 days**	**-14 days**	**+6 days**	**-2 days**	**-13 days**	**-11 days**
	2021	21.05	20.03	28.04	19.04	17.05	2.04	6.05	2.05	21.05	1.04	6.05	2.05
		+3 days	**+65 days**	**+27 days**	**+35 days**	**+6 days**	**+52 days**	**+21 days**	**+22 days**	**+ 4 days**	**+30 days**	**+21 days**	**+23 days**

IV.3.2.4. Population density dynamics of the San José scale (Quadraspidiotus perniciosus **Comst.***) in grafted plants of the fruit species apple (Malus domestica* **Borkh.***), plum (Prunus domestica* **L.***) and sweet cherry (Prunus avium* **L.***) in containers*

In the stone fruit species plum (*Prunus domestica* L.) and sweet cherry (*Prunus avium* L.), a higher density of the pest was reported relative to the pome fruit apple species (*Malus domestica* Borkh.) (Table 36). A higher density in both stone fruit species was observed in an insect-proof net house. Statistically proven differences were reported between the years of cultivation. In apples, a higher average density was found in the shaded field – 82.6 pcs. in the non-shaded field, the average number was 79.5 pcs. and 78.4 pcs in the insect-proof net house.

Statistically proven differences were also found in the three observed fruit species between the years of observation, which in turn confirms the claim of Beşleagă et al. (2009) that temperature is the main factor influencing the development of the San José scale (*Quadraspidiotus perniciosus* Comst.).

Table 36. *Population density of the San José scale (Quadraspidiotus perniciosus* Comst.*) at grafted plants of the fruit species apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*) and sweet cherry (Prunus avium* L.*) in a containers*

Fruit tree species	Field of Observation**	Year	Average Density Number of Individuals (1 m/vegetative growth)
Apple (*Malus domestica* Borkh.)	Insect-Proof Net House	2019	59.4 d*
		2020	100.4 a
		2021	75.5 bcd
	Average		***78.4***
	Shaded Field	2019	69.5 cd
		2020	96.6 ab
		2021	81.6 abcd
	Average		***82.6***
	Non-Shaded Field	2019	70.1 cd
		2020	93.5 abc
		2021	75.0 bcd
	Average		***79.5***
Plum (*Prunus domestica* L.)	Insect-Proof Net House	2019	79.5 b
		2020	123.8 a
		2021	91.0 b
	Average		***98.1***
	Shaded Field	2019	75.5 b
		2020	127.3 a
		2021	75.4 b
	Average		***92.7***
	Non-Shaded Field	2019	74.1 b
		2020	121.8 a
		2021	82.5 b
	Average		***92.8***
Sweet cherry (*Prunus avium* L.)	Insect-Proof Net House	2019	78.2 b
		2020	118.7 a
		2021	74.1 b
	Average		***90.3***
	Shaded Field	2019	73.2 b
		2020	109.5 a
		2021	75.3 b
	Average		***86.0***
	Non-Shaded Field	2019	73.9 b
		2020	115.0 a
		2021	76.7 b
	Average		***88.6***

*Mean values marked with the same letter are not significantly different according to Duncan's test ($\rho < 0.05$)
**Mean values were compared between observation fields

IV.3.2.5. Observation on the influence of the San José scale (Quadraspidiotus perniciosus* Comst.*) on vegetative indicators of grafted plants of the fruit species apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*) and sweet cherry (Prunus avium* L.*) in container

The San José scale (*Quadraspidiotus perniciosus* Comst.) had a negative influence in its development on the total vegetative growth of the fruit species apple (*Malus domestica* Borkh.), plum (*Prunus domestica* L.) and sweet cherry (*Prunus avium* L.).

By crop, the highest value of the total vegetative growth of uninfected plants was found in apple—246.7 cm, followed by plum—214.7 cm and 103.8 cm in sweet cherry. Statistically proven differences between 2019 and 2021 have not been identified.

In the fruit apple species (*Malus domestica* Borkh.), statistically proven differences were found between fields using net and non-shaded field. The highest total vegetative growth was in the insect-proof net house, 286.3 cm, followed by 263.5 cm in the shaded field and 190.2 cm in the non-shaded field. A positive correlation was found between uninfected plants and plants with the presence of the pest. In the infected plants (with infected cuttings), the highest percentage was found in plants grown in the non-shaded field – 12.7%, compared to 8.9% in the shaded field and 5.0% in the insect-proof net house. The percentage was significantly lower in plants infected due to natural migration of the species – 4.4% in the non-shaded fields, 2.0% in the shaded fields, and 1.4% in the insect-proof net houses.

There were no statistically proven differences between the observation fields in stone fruit species. In plum, the mean vegetative growth in non-infected plants in the different fields was 225.1 cm in the insect-proof net house, followed by 218.1 cm in the shaded field and 200.8 cm in the non-shaded field. Significantly lower results were reported in the sweet cherry – 109.6 cm in the insect-proof net house, 105.5 cm in the shaded field, and 96.4 cm in the non-shaded field. The results showed a persistent trend for higher scores in the insect-proof net house.

Because of the development of the pest, a more significant percentage of harmfulness was again reported in the plants infected in reproduction compared to those infected by the migration of the species (Table 37). Due to infected cuttings, the highest percentage was observed in a non-shaded field – 13.0%, followed by 11.1% in a shaded field and 9.4% in an insect-proof net house. Significant differences were found in sweet cherry. The highest percentage was found in an insect-proof net house – 19.5% and 18.9% in a non-shaded field and 18.8% in a shaded field. The percentages were significantly lower in plants infected due to the natural migration of the pest. Higher was found in sweet cherry, respectively, 7.6% in a shaded field, 6.9% in a non-shaded field, and 6.0% in an insect-proof net house, relative to plum – 5.0% in a shaded field; 3.8% in a non-shaded field and 2.7% in an insect-proof net house.

The results show that the host on which the pest develops also influences temperature, in addition to the climatic factor.

Table 37. *Influence of development of the San José scale (Quadraspidiotus perniciosus* Comst.*) on the total vegetative growth at the fruit species apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*) and sweet cherry (Prunus avium* L.*), in an insect-proof net house, a shaded, and a non-shaded field*

Fruit tree species	Field of Observation **	Year	Total Vegetative Growth: Non-Infected Plants	Infected Plants in Propagation (infected cuttings)	Deviation %	Infected Plants Due to Migration	Deviation %
Apple (*Malus domestica* Borkh.)	Insect-Proof Net House	2019	308.8 a*	287.0 a	6.3	305.4 a	1.1
		2020	300.4 a	291.5 a	3.0	294.7 ab	1.9
		2021	249.8 abc	237.9 abc	5.7	246.6 abc	1.3
	Average		***286.3***	***272.1***	***5.0***	***282.3***	***1.4***
	Shaded Field	2019	283.5 ab	260.0 ab	8.2	279.3 ab	1.5
		2020	263.5 ab	240.0 abc	8.8	247.2 abc	1.6
		2021	243.5 abc	220.0 cde	9.6	235.8 abcd	3.2
	Average		***263.5***	***240.0***	***8.9***	***258.1***	***2.0***
	Non-Shaded Field	2019	215.2 bcd	191.2 cde	11.0	194.3 bcd	3.9
		2020	190.2 cd	166.2 de	12.5	169.3 cd	4.4
		2021	165.2 d	141.2 e	14.5	144.3 d	5.1
	Average		***190.2***	***166.2***	***12.7***	***181.7***	***4.4***
Plum (*Prunus domestica* L.)	Insect-Proof Net House	2019	274.8 a	250.2 a	9.0	269.2 a	2.0
		2020	197.4 bc	179.6 bc	8.2	192.0 bc	2.7
		2021	203.0 bc	180.1 bc	10.9	195.7 bc	3.6
	Average		***225.1***	***203.3***	***9.4***	***219.0***	***2.7***
	Shaded Field	2019	262.0 ab	240.4 ab	8.3	253.6 ab	3.2
		2020	197.6 bc	180.1 bc	9.1	186.9 bc	5.4
		2021	194.8 bc	165.2 c	15.8	180.9 c	7.1
	Average		***218.1***	***195.2***	***11.1***	***207.2***	***5.0***
	Non-Shaded Field	2019	232.2 abc	205.4 abc	11.6	226.3 abc	2.5
		2020	192.8 bc	167.2 c	13.7	185.5 bc	3.8
		2021	177.4 c	153.8 c	15.8	167.5 c	7.1
	Average		***200.8***	***175.5***	***13.0***	***193.1***	***3.8***
Sweet Cherry (*Prunus avium* L.)	Insect-Proof Net House	2019	124.9 a	112.2 a	10.8	118.6 a	5.0
		2020	101.4 ab	80.1 b	22.3	94.1 ab	7.2
		2021	102.5 ab	76.8 b	25.3	96.4 ab	6.0
	Average		***109.6***	***89.7***	***19.5***	***103.1***	***6.0***
	Shaded Field	2019	116.4 ab	94.1 ab	18.9	109.9 ab	5.6
		2020	98.9 ab	87.4 ab	11.3	91.2 ab	7.8
		2021	101.4 ab	74.4 b	26.2	91.5 ab	9.8
	Average		***105.5***	***85.3***	***18.8***	***97.5***	***7.6***
	Non-Shaded Field	2019	96.5 b	76.6 b	20.9	89.9 b	6.8
		2020	101.4 ab	87.4 ab	14.5	96.7 ab	4.7
		2021	91.4 b	71.6 b	21.2	82.7 b	9.5
	Average		***96.4***	***78.5***	***18.9***	***89.7***	***6.9***

*Mean values marked with the same letter are not significantly different according to Duncan's test ($\rho < 0.05$)
**Mean values were compared between observation fields

IV.3.2.6. Damage rate of the San José scale (Quadraspidiotus perniciosus Comst.*) on apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*) and sweet cherry (Prunus avium* L.*) propagating material in container growing in an insect-proof net house, shaded field and non-shaded field*

Calculating the damage rate on a five-rate scale, the most significant value was in an insect-proof net house in all three types of fruit crops (Table 38). On average, for 2019 – 2021, the value in the apple fruit tree was 2.7, followed by 2.2 in a shaded field and 2.1 in a non-shaded field. 2020 was distinguished as the study period with the highest values.

Table 38. Damage rate of the San José scale (Quadraspidiotus perniciosus Comst.*) on apple tree (Malus domestica* Borkh.*), plum tree (Prunus domestica* L.*), and sweet cherry tree (Prunus avium* L.*) in a container growing of plants in an insect-proof net house, a shaded, and a non-shaded field*

Fruit Tree Species	Year	Insect-Proof Net House	Shaded Field	Non-Shaded Field
Apple (*Malus domestica* Borkh.)	2019	2.6	2.0	1.6
	2020	3.0	2.6	2.6
	2021	2.6	2.0	2.0
	Average	***2.7***	***2.2***	***2.1***
Plum (*Prunus domestica* L.)	2019	3.8	3.4	1.8
	2020	4.6	3.0	2.4
	2021	4.0	3.2	1.0
	Average	***4.1***	***3.2***	***1.7***
Sweet Cherry (*Prunus avium* L.)	2019	3.4	2.8	1.4
	2020	4.0	2.6	2.0
	2021	4.0	2.4	2.8
	Average	***3.8***	***2.6***	***2.1***

Considering the frequency of the degree of damage in the fruit species apple (*Malus domestica* Borkh.) in an insect-proof net house (Figure 16), it was noteworthy that a significant part of the reported plants was between rate 2 and rate 3, while in a shaded field, they were between rate 1 and rate 2.

Despite the higher score reported in an insect-proof net house, the significantly lower frequency at rate 4 was impressive.

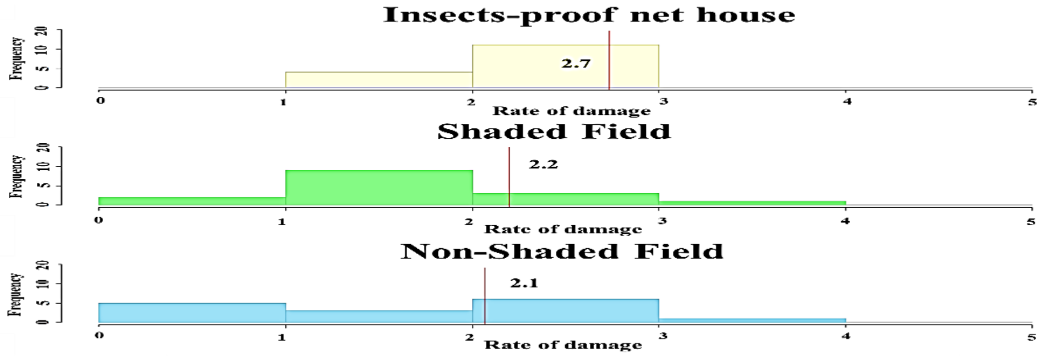

Figure 16. *Frequency of damage from the San José scale (Quadraspidiotus perniciosus* Comst.*) on an apple fruit tree (Malus domestica* Borkh.*) in an insect-proof net house, a shaded, and a non-shaded field in a container*

The highest rate in the fruit species plum (*Prunus domestica* L.) was in an insect-proof net house, with an increasing trend from rate 2 to rate 5 (Figure 17). In a shaded field, a pronounced peak in frequency at rate 2 and a uniform frequency distribution in a non-shaded field from rate 0 to rate 2 was found.

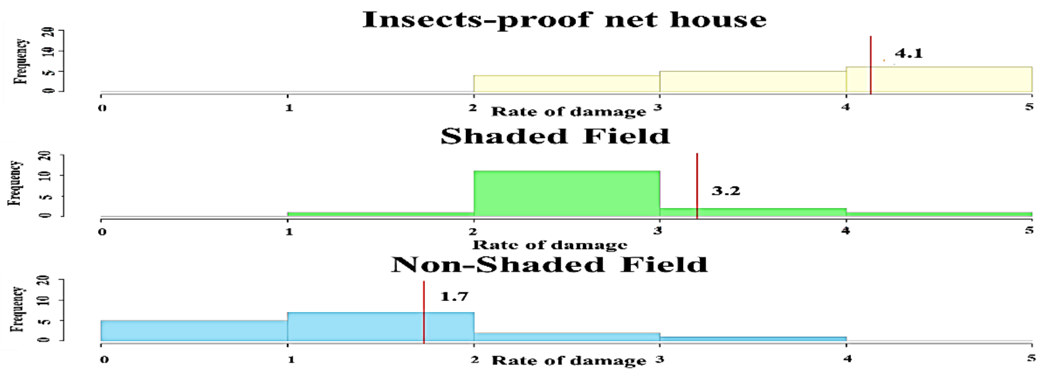

Figure 17. *Frequency of damage of the San José scale (Quadraspidiotus perniciosus* Comst.) *on plum fruit tree (Prunus domestica* L.*) in an insect-proof net house, a shaded, and a non-shaded field in a container*

In the sweet cherry fruit species (*Prunus avium* L.), trend persistence was observed in shaded and non-shaded fields, as in the stone plum species. In the insect-proof net house, the maximum failure frequency was found at rate 3 (Figure 18).

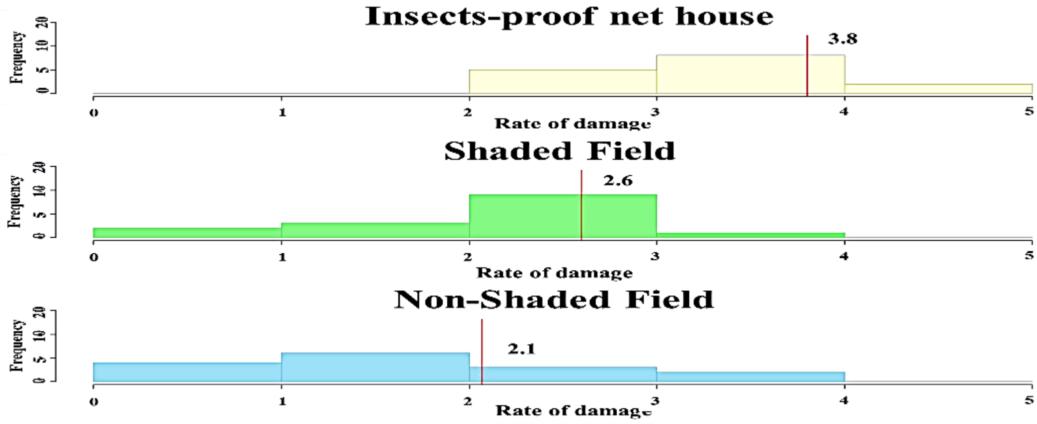

Figure 18. *Frequency of damage of the San José scale (Quadraspidiotus perniciosus* Comst.) *on a sweet cherry fruit tree (Prunus avium* L.*) in an insect-proof net house, a shaded, and a non-shaded field in a container*

Despite the higher failure score reported at apple trees in an insect-proof net house, a significantly higher percentage was found in a non-shaded field – 43.3% damaged plants, compared to 25.0% in an insect-proof net house and 28.3% in a shaded field (Table 39). In stone fruit species, a significantly higher percentage of damaged plants was reported in an insect-proof net house – 41.7% at plum trees and 31.7% at sweet cherry trees.

Table 39*. Percentage of plants attacked by San José scale (Quadraspidiotus perniciosus* Comst.*) on apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*), and sweet cherry (Prunus avium* L.*) fruit trees in a container growing in an insect-proof net house, a shaded, and a non-shaded field*

Fruit Tree Species	Year	Insect-Proof Net House %	Shaded Field %	Non-Shaded Field %
Apple (*Malus domestica* Borkh.)	2019	30.0	35.0	50.0
	2020	25.0	30.0	45.0
	2021	20.0	20.0	35.0
	Average	***25.0***	***28.3***	***43.3***
Plum (*Prunus domestica* L.)	2019	40.0	35.0	30.0
	2020	50.0	40.0	35.0
	2021	35.0	30.0	35.0
	Average	***41.7***	***35.0***	***33.3***
Sweet Cherry (*Prunus avium* L.)	2019	35.0	40.0	35.0
	2020	35.0	30.0	30.0
	2021	25.0	25.0	25.0
	Average	***31.7***	***31.7***	***30.0***

Calculating the complex harmfulness factor in the fruit apple species (*Malus domestica* Borkh), a significantly higher percentage — 75.0 % was calculated in an insect-proof net house (Table 40). It was 71.7% in the shaded and non-shaded fields and 56.7% in the shaded and non-shaded fields.

In stone fruit species, a higher percentage of harmfulness was reported in a non-shaded field, 66.7% in plum trees, and 70.0% in sweet cherry trees.

Table 40. *Coefficient of harmfulness from San José scale (Quadraspidiotus perniciosus* Comst.*) on apple (Malus domestica* Borkh.*), plum (Prunus domestica* L.*), and sweet cherry (Prunus avium* L.*) in a container growing in an insect-proof net house, a shaded, and a non-shaded field*

Fruit Tree Species	Year	Insect-Proof Net House %	Shaded Field %	Non-Shaded Field %
Apple (*Malus domestica* Borkh.)	2019	70.0	65.0	50.0
	2020	75.0	70.0	55.0
	2021	80.0	80.0	65.0
	Average	***75.0***	***71.7***	***56.7***
Plum (*Prunus domestica* L.)	2019	60.0	65.0	70.0
	2020	50.0	60.0	65.0
	2021	65.0	70.0	65.0
	Average	***58.3***	***65.0***	***66.7***
Sweet Cherry (*Prunus avium* L.)	2019	65.0	60.0	65.0
	2020	65.0	70.0	70.0
	2021	75.0	75.0	75.0
	Average	***68.3***	***68.3***	***70.0***

IV.4. *Electronic Computing Tables – Software Applied*

The applied software is the first calculation table presented entirely in Bulgarian. The table allows the user to perform calculations using four known methods for applying the *Law of Effective Temperatures*: the Average method, the Modified average method, the Triangle method*, and the Sine wave method*.

The table provides information on the calculated degrees/day DD for a desired period and the aggregate reading of the stored temperature CDD.

The study followed the development and influence of two economically essential pests on the production of fruit planting material, the woolly apple aphid (*Eriosoma lanigerum* Hausm.) and the San José scale (*Quadraspidiotus perniciosus* Comst.). The monitoring found that the pests are widespread in Bulgaria, Plovdiv, and the region.

The reported high coefficients of harmfulness in both pests indicate the extreme harmfulness and high risk of attack when nets are used to produce planting material.

Although they are considered absent in protected facilities, their introduction is possible when an infected host is introduced. The harmfulness of the pests can be reduced after strict observance of measures to limit the spread of the pest through visual monitoring of the rootstocks used to propagate the fruit species.

Appendix 1 and Appendix 2 present assessments of the risk of pest infestation when producing fruit-propagating material in containers.

V. CONCLUSIONS

Conclusions from the section: ***Monitoring and risk assessment of the factor "environmental condition" in the production of fruit planting material in growing conditions in an insect-proof net house, shaded field, and non-shaded field***

1. In the area of Plovdiv, a monotonically increasing trend has been established in the distribution of average annual temperature. The monthly temperatures for June and July tended to increase the values.
2. Positive monotonous trends have been found for Plovdiv at the maximum temperature for the summer months, with the most significant slope of the trend observed in August. A monotonous increasing linear trend was found at the minimum temperature for August.
3. Using sun-protective and entomological nets affects the abiotic factor—temperature. During the winter period, higher values were observed in the afternoon hours. The maximum temperature values decreased in the summer and fall seasons and increased in the winter and spring seasons. The minimum temperature increased in the winter, summer, and fall seasons, while these values decreased in spring.
4. In the seasonal distribution of hourly temperature in non-shaded field and insect-proof net house, higher temperature values were recorded during the dark part of the day for seasons winter and fall and lower or close to those in non-shaded field for seasons spring and summer.
5. The use of an entomological net reduces the amount of precipitation by up to 65% and 26% in a shading net. It increases the percentage of relative humidity for the entire period of use by 6.8% in a shaded field. When the entomological net is combined with a shading net, the increase is by 4.6% compared to a non-shaded field and by 0.8% using only a shading net.

Conclusions from the section: ***Monitoring and risk assessment of the factor "plant–host" in the production of fruit planting material under growing conditions in an insect-proof net house, shaded field, and non-shaded field***

1. For the Plovdiv region, the average duration of the annual number of days with an average daily temperature above 5°C was 285.1 days, and an increasing trend was found.
2. A decreasing linear trend was found in the average number of days with daily temperatures TM < 5°C and TM < 10°C and an increasing linear trend in the average number of days with daily temperatures TX > 30°C and TH > 35°C for the Plovdiv region.
3. The duration of the growing season in the insect-proof net house retains a tendency to increase the number of days with TM temperature ≥ 5°C. The use of nets decreased by 88.4% the number of days at TH > 35°C relative to a non-shaded field. In the shaded field, this decrease was by 38.8%.
4. In the annual vegetative growth length (AAGR) indicator for the fruit apple species (Malus domestica Borkh) and the fruit plum (*Prunus domestica* L.), the highest values were recorded in the propagated plants during the dormant period in the methods "stratification" and "hot callus."

5. In the fruit sweet cherry species (*Prunus avium* L.), the propagated plants recorded the highest values in terms of length per annual vegetative growth (AGR, cm) by late summer budding.

6. The calculated temperature sums at average daily temperature (TM) 5°C ÷ 25°C show no clear dependence on using nets in this range. A significant decrease in temperature sums was observed in an insect-proof net house, and a shaded field at temperature sums at temperatures T ≥ 25°C.

Conclusions from the section: ***Monitoring of pests in the propagation of fruit planting material in conditions of the insect-proof net house, shaded field, and non-shaded field with category "free from regulated non-quarantine pests (RNCB)" and eligibility factor – 0% (EPRO standard)***

1. At a constant temperature of 15°C, the onset of development activity of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) was recorded on the 6th day, four days after the observed at a constant temperature of 20°C. The migration of an aphid (*Eriosoma lanigerum* Hausm.) was established on the 18th day, and at 20°C, migration of the pest was observed after the 16th day of observation.

2. The percentage of infected plants of the first generation of a woolly apple aphid (*Eriosoma lanigerum* Hausm.) was 12.3% in Malling 9 rootstock (M.9) and 4.9% in Malling-Merton 106 rootstock (MM.106).

3. In an insect-proof net house, to determine the onset of activity of a woolly apple aphid (Eriosoma lanigerum Hausm), the Sine wave method with a biofix of January 1st and a sum of effective temperatures of 269,96 degrees/day (±1,94) at a lower development threshold of 5°C can be used.

4. In a non-shaded field, no workable models for sums of effective temperatures were established to determine the onset of activity of the woolly apple aphid (*Eriosoma lanigerum* Hausm.).

5. According to visual assessment, infected grafting fruit planting material has significantly deteriorated commercial appearance. In a more significant percentage of the observed plants in all three fields of observation, the density of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) covers the surface of the plants partially or entirely. Due to high density, the plants must develop their potential and be fit for commercial activity.

6. In plants infected in their propagation (use of infected rootstocks), the percentage of reduction in the values of total vegetative growth is between 78.8% and 81.0%. In plants growing in the non-shaded field, a higher percentage was found – 80.4% compared to in insect-proof net house and shaded field – 79.7%.

7. The conditions created by the development of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) when using nets increase the damage.

8. The male flight of the San José scale (*Quadraspidiotus perniciosus* Comst.) was found on the 10th day (±1 day) of the placement of the infected plants in the stratification room at a constant temperature of 15°C, while at 20°C constant temperature, the flight observed on the 8th day (±1 day). The departure of overwintering females of the San José scale (*Quadraspidiotus perniciosus* Comst.) and their migration to the vegetative parts of the plants

at a constant temperature of 15°C was established after the 33rd day of placement of the propagated plants and on the 24th day at 20°C constant temperature.

9. Overwintering Females of the San José scale (*Quadraspidiotus perniciosus* Comst.) developed earlier in the pome fruit species apple (*Malus domestica* Borkh.) than in stone fruit species, and a higher number of females was found in the fruit plum species (*Prunus domestica* L.).

10. Establish starting dates for activation of males of the San José scale (*Quadraspidiotus perniciosus* Comst.), with the lowest deviation found in the Average method. The lower temperature threshold is 10.6°C, with a temperature sum of 155 degrees/day in biofix on January 1st.

11. At a lower temperature threshold of 7.3°C, the appearance of a larva, the appearance of a first generation of San José scale (*Quadraspidiotus perniciosus* Comst.) was predicted at a temperature sum of 500°C calculated by *the Average method*.

12. Due to the development of the San José scale (*Quadraspidiotus perniciosus* Comst.), a higher percentage of harmfulness in plants was reported with the use of contaminated propagation material relative to plants from the species' migration.

13. Calculating the damage rate of the San José scale (*Quadraspidiotus perniciosus* Comst.) on a five-rate scale, the most significant value was recorded in an insect-proof net house in all three species of fruit crops.

VI. CONTRIBUTIONS

VI.1. Original Contributions

1. It has been found that growing fruit planting material in protected habitats through sustainable ecological practices is a promising alternative to meet the challenge of various biotic and abiotic factors.
2. A positive trend at the maximum temperature and an increasing linear trend at the minimum temperature for August for the Plovdiv region were found.
3. It has been observed that the maximum temperature values in the summer and fall seasons are lower, and the values during the winter and spring seasons are increased when using an insecticidal net and a shading net.
4. It has been proven that using a shading net (April-September) increases the percentage of relative humidity of the air for the entire period of use by 6.8%.
5. The average duration of the annual number of days with an average daily temperature above 5°C showed an increasing trend.
6. It was determined that using net reduced 88.4% of the number of days at TX > 35°C relative to a non-shaded field.
7. It was concluded that the conditions of development of the woolly apple aphid (*Eriosoma lanigerum* Hausm.) using nets increased the damage.
8. The risk of the woolly apple aphid (Eriosoma lanigerum Hausm.) and the San José scale (Quadraspidiotus perniciosus Comst.) pests was assessed in the production of fruit planting material.
9. An electronic calculation table has been developed to summate effective temperatures.

VI.2. Confirmatory contributions

1. The strong correlation between environmental factors, host plants, and pests has been confirmed.
2. The influence of using nets on the abiotic factors has been demonstrated.
3. A monotonous increasing trend of the mean annual temperature for the region of Plovdiv was confirmed.
4. It has been proved that using nets reduces the maximum extremum of the temperature factor during summer and increases the values in spring.
5. It was confirmed that because of the development of the San José scale (*Quadraspidiotus perniciosus* Comst.), a higher percentage of harmfulness is in plants with the use of contaminated propagation material relative to plants from the species' migration.
6. It was found that at a lower temperature threshold of 7.3°C, the appearance of a larva of a first generation of a San José scale (*Quadraspidiotus perniciosus* Comst.) at a temperature sum of 500°C calculated by the method of *the Average value* is predicted.

VI.3. Practical contribution

1. The possibility of producing fruit planting material grown in containers has been proven.

2. Earlier development of grafted plants by budding in late summer in all three fruit species in an insect-proof net house was found.

3. It was observed that the percentage of infected plants of the first generation of a woolly apple aphid (*Eriosoma lanigerum* Hausm.) was 12.3% in Malling 9 rootstock (M.9) and 4.9% in Malling-Merton 106 rootstock (MM.106).

4. It was found that the male flight of the San José scale (*Quadraspidiotus perniciosus* Comst.) was found on the 10th day (±1 day) of the placement of the infected plants in the stratification room at a constant temperature of 15°C. In contrast, at 20°C constant temperature, the flight was observed on the 8th day (±1 day). The departure of females of the San José scale (*Quadraspidiotus perniciosus* Comst.) and their migration to the vegetative parts of the plants at a constant temperature of 15°C was established after the 33rd day of the placement of the propagated plants and on the 24th day at 20°C constant temperature – preparation of predictive models.

5. It has been shown that the development of females of the San José scale (*Quadraspidiotus perniciosus* Comst.) in the pome fruit species apple (*Malus domestica* Borkh.) was earlier than stone fruit species, and a more significant number of females was found in the fruit species plum (*Prunus domestica* L.).

List of publications related to the dissertation

1. Ivanov, P., 2022. Climatic changes in the production of fruit planting material in containers using sunscreen and entomological network. *Journal of Mountain Agriculture on the Balkans (JMAB),* 25(4):213–227 (Bg).

2. Ivanov, P., Yankova, V., Gandev, St., 2023. Monitoring of the San Jose scale (*Quadraspidiotus perniciosus* Comst.) in container cultivation of plum plants (*Prunus domestica* L.). *Proceedings of the national scientific conference with international participation ecology and health ''Ecology and health –2023(spring),* 66–70 (Bg).