Regulatory Mechanisms in Biosystems

ISSN 2519-8521 (Print)
ISSN 2520-2588 (Online)
Regul. Mech. Biosyst.

Developmental features of small spruce bud scale (*Physokermes hemicryphus*) (Hemiptera, Coccidae) on spruce trees in arboretums and urban plantings

V. Melenti*, I. Lezhenina*, S. Stankevych*, I. Zabrodina*, L. Cherednik**

** State Biotechnological University, Kharkiv, Ukraine*
*** National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine*

Article info

Received 15.08.2025
Received in revised form 19.09.2025
Accepted 13.10.2025

State Biotechnological University, Alchevskikh st., 44, Kharkiv, 61000, Ukraine. Tel.: +38-068-660-32-81. E-mail: viktoriamelenti0607@gmail.com

Pedagogical Sciences National University of Life and Environmental Sciences of Ukraine, Heroiv Oborony st., 15, Kyiv, 03041, Ukraine. Tel.: +38-044-527-82-42. E-mail: pedagogic@ukr.net

Melenti, V., Lezhenina, I., Stankevych, S., Zabrodina, I., & Cherednik, L. (2025). Developmental features of small spruce bud scale (Physokermes hemicryphus) (Hemiptera, Coccidae) on spruce trees in arboretums and urban plantings. Regulatory Mechanisms in Biosystems, 16(4), e25171. doi:10.15421/0225171

Small spruce bud scale (*Physokermes hemicryphus* Dalman, 1826) is one of the most widespread and harmful phytophagous insects in spruce stands. A feature of its development is the clear synchronization of phenological stages with the seasonal growth dynamics of Norway spruce (*Picea abies* (L.) H. Karst, 1881) and blue spruce (*Picea pungens* Engelmann, 1875), which ensures a high level of pest adaptability and complicates control measures. Studies have shown that the pest overwinters as the first-instar larvae, which resume feeding in early spring, immediately after the start of host tree vegetation. The further development of the pest coincides with spruce growth: the formation of second-instar larvae and young females is observed precisely during the active elongation of shoots and the growth of needles. This leads to competition for assimilates and significant depletion of trees, which is manifested in a decrease in branch growth, loss of decorative properties and general weakening of the stands. An important factor is weather conditions. Increased spring temperatures accelerate development and generation change, while cool periods prolong individual stages, but increase the duration of larval feeding, increasing harmfulness. Outbreaks of *P. hemicryphus* not only limit tree growth but also create conditions for its secondary infection by fungal pathogens, in particular sooty molds that develop on honeydew. Thus, *P. hemicryphus* is a pest and worsens the health of spruce forests. Phenological observations are of key importance for timely forecasting of the abundance of *P. hemicryphus*. Recognizing the periods of active feeding of larvae and generation formation allows one to optimize the forest protection system, in particular, the use of biological agents and the rational use of insecticides. The obtained results confirm the need for comprehensive monitoring of the pest phenology, considering regional climatic features, which is the basis for the development of effective protection methods.

Keywords: *Physokermes hemicryphus*; *Picea abies*; *Picea pungens*; phenology; small spruce bud scale; harmfulness.

Introduction

Conifers in urbanized ecosystems provide important ecosystem services, particularly in reducing air and water pollution, air purification, and providing saturating phytoncides. Droughts and increases in average temperatures have significantly worsened the growing conditions of conifers in recent years, especially in urban areas, which has increased the negative impact of phytophagous insects on plants. Scale insects (Coccidae) are important sucking pests of conifers. In Europe, three native species of scale insects from the genus *Physokermes* Targioni-Tozzetti, 1868, live on conifers. In 2014, a North American species of scale insects *Toumeyella parvicornis* Cockerell, 1902, was discovered in Italy (Yataco et al., 2024).

In recent years, there has been a noticeable increase in the number of small spruce bud scale (*Physokermes hemicryphus* (Dalman, 1826)) in ornamental and forest plantations, especially in urbanized areas. A complex of factors, in particular, the intensification of urban greening with coniferous species, climate change, and increased anthropogenic load, created favorable conditions for the development and spread of this phytophagous insect. An increase in the number of *P. hemicryphus* leads to a significant deterioration in the health of plantings, a decrease in the decorative value of Norway spruce (*Picea abies* L.) and blue spruce (*Picea pungens* Engelm.), and can cause the death of trees. Symptoms of damage include deformation and premature fall of needles, inhibition of growth, drying, and general weakening of plants. Therefore, scientifically based approaches to monitoring and control are necessary.

Of particular importance is the study of *P. hemicryphus* phenology, because the synchronization of its life stages with the growth of the host affects its harmfulness. The study of critical development stages, the dependence of the cycle duration on weather conditions, and interaction with other components of the biocenosis allows us to refine predictions regarding the risk of mass propagation of the pest. The results obtained have practical significance for optimizing protection systems for both urban green spaces and forest stands in the context of climate change. Thus, *P. hemicryphus* should be considered not only as a dangerous local pest but also as a potential bioindicator of transformations in coniferous ecosystems (Zak-Ogaza et al., 1964; Foroutan et al., 2021).

Studies by Kozár et al. (2005) indicate that the population of *Physokermes* sp. increases significantly in urbanized ecosystems. Scientists attribute this to a decrease in the activity of natural entomophages because of the simplification of trophic relationships in the urban environment. However, the use of entomopathogens against forest phytophages is a component of integrated pest management (Skrzecz et al., 2024). According to Basnet et al. (2024) and Yataco et al. (2024), *P. abies* and *P. pungens* are the main hosts of *P. hemicryphus*. Damage by these pests can lead to tree mortality.

Studies by Pellizzari et al. (2014) analyzed the distribution of scale insects in southern European countries. Scientists found that *P. hemicryphus* is an invasive species and can expand its range due to global warming and urbanization. According to their observations, in regions with mild winters, larval survival increases, as does population size and tree damage in the spring (Petrík et al., 2024).

In Poland (Malec et al., 2015), the ecological features of *P. hemicryphus* were studied, and it was noted that the influence of anthropogenic factors may increase the harmfulness of this species. In the Czech Republic, the spectrum of hosts was described in detail, with *Picea* sp. predominant (Bednář et al., 2022).

The biology, harmfulness, and trophic relationships of *P. hemicryphus* were studied in Serbia (Simonović et al., 2018; Derviševic et al., 2019). The authors indicate that in urban plantings in Serbia, *P. hemicryphus* can cause severe damage to spruce, leading to the drying of shoots, falling needles, and, in some cases, the death of trees. The scientists have paid special attention to the natural enemies of the pest, both parasites and predators (Graora et al., 2012).

In Germany, the morphology, biology, and pest activity of *P. hemicryphus* were studied (Schmutterer, 1956). The adverse effects of the scale on spruce stands were described, including tree depletion due to sap sucking, as well as the development of sooty mold, which limits photosynthesis and contributes to further tree growth suppression. By investigating the phylogenetic relationships of *Physokermes* sp. in Sweden, scientists have confirmed the importance of a molecular genetic approach to studying this genus. They emphasize that understanding the taxonomy is critical for developing methods to monitor and predict population dynamics of *P. hemicryphus* (Jonsson et al., 2023).

According to generalized data, the original range of *P. hemicryphus* covers the Palearctic. Later, the species spread to the Holarctic. In North America, it was long mistakenly identified as *P. piceae* Schrank, although tested specimens indicate *P. hemicryphus*. The species was introduced with planting material (Schmutterer et al., 1956; Tang et al., 1991).

According to the Fauna Europaea Database, *P. hemicryphus* is found in 28 countries in Europe, Asia, and North America. In Europe, the species is widespread in countries such as Austria, Bulgaria, France, Germany, Hungary, Italy, Poland, Serbia, Sweden, Ukraine, etc. In Asia, it is recorded in Turkey and Mongolia. In North America, *P. hemicryphus* is found in the USA (California, Virginia, New York, etc.) and Canada (British Columbia). In Ukraine, *P. hemicryphus* occurs in artificial and natural coniferous stands, in particular, in Polissia, Carpathians, Crimea, as well as in urban stands of the forest-steppe zone (Skrzecz et al., 2024; Melenti et al., 2025).

The study aims to clarify the biology of *P. hemicryphus*, its phenology, and identify its most harmful stage on spruce trees in arboretums and urban plantings.

Materials and methods

The main studies were conducted from 2017 to 2021. Additional information on biology and the harmfulness of *P. hemicryphus* was obtained during 2023–2024. Stationary observations were carried out on permanent sample plots (Table 1). These plots had different planting areas and anthropogenic load. Observations were carried out in park plantings (Table 1, locations 1–3) which were subjected to recreational load, ornamental plant nurseries (Table 1, locations 4–7), and individual groups of spruce trees in a village, which grew in optimal conditions with minimal anthropogenic load (Table 1, location 8). Group plantings of spruce trees along a highway with heavy traffic were also surveyed; the spruce trees in this plot grew under significant air pollution and strong soil compaction (Table 1, location 9).

Table 1
Locations of stationary observations of *P. hemicryphus*

No.	Location	Latitude / Longitude
1	V. N. Karazin Botanical Garden	50°01′ N, 36°13′ E
2	Dendrological Park of the State Biotechnological University (SBTU)	49°90′ N, 36°45′ E
3	Feldman EcoPark	50°06′04.3″ N, 36°16′39.2″ E
4	Ornamental plant nursery	49°59′ N, 36°36′ E
5	Ornamental plant nursery	49°59′ N, 37°37′ E
6	Ornamental plant nursery	49°59′ N, 36°36′ E
7	Ornamental plant nursery	50°03′ N, 36°18′ E
8	Rohan village (minimum anthropogenic load)	49°54′14″ N, 36°29′11″ E
9	Spruce trees along a busy highway (significant anthropogenic load)	49°58′22″ N, 36°18′00.62″ E

Laboratory studies of *P. hemicryphus* were conducted at the Department of Entomology, Zoology, Phytopathology, Integrated Plant Protection and Quarantine of the B. M. Litvinov State Biotechnological University. Route surveys were performed in urban spruce (*Picea* spp.) plantings in Kharkiv and Kharkiv region. Trees were visually inspected, with special attention to specimens with poor health. The population level was assessed on a five-point scale (Kosztarab et al., 1988, 2005; Santas et al., 1988), which allows us to quantitatively evaluate the extent of damage and use the data for planning protection measures.

Phenological observations were conducted in natural conditions at intervals of three days. On the middle tier of at least four trees of each spruce species, four branches were examined from all points of the compass. The stages of pest development were recorded in field journals and documented by photography, if necessary.

To assess the impact of *P. hemicryphus* on the host tree, current-year shoot growth was measured on four infested and four non-infested spruce trees. Forty shoots (10 from each point of the compass) were examined on each tree, ensuring sufficient representativeness of the data.

The collected material was examined in the laboratory. Females of *P. hemicryphus* were preserved in 70 % ethanol; the location, date of collection, and type of host plant were indicated. Biological observations were conducted on cut spruce branches kept in water. Morphological structures were examined using a binocular microscope in permanent preparations in Canada balsam or Faure-Berleze gum arabic mixture and temporary preparations in glycerin-gelatin; fuchsin was used for staining (Kozár et al., 2005; Petrik et al., 2024). Female fecundity was evaluated by dissecting under a binocular microscope and counting the number of eggs in at least 25 individuals.

The effect of temperature on phenology was assessed by comparing it with data from the Weather Station of the State Biotechnological University.

Results

Morphology of P. hemicryphus. During the research, material was collected that allowed us to describe in detail the morphological features of *P. hemicryphus*.

The immature female is light brown, with a body length of 2–5 mm and a width of up to 4 mm (Fig. 1). The underside of the body has a white waxy coating. The body is covered with a soft false shield and dusted with a white powdery coating. The mature unfertilized female changes color to brown, and the body length remains within 2–5 mm, and the width is 4 mm. The surface is shiny, the shield remains soft, and the body is dusted with a white powdery coating. The fertilized female changes color to brown or dark brown; the body dimensions are similar (2–5 mm long, 4 mm wide, Fig. 2). The false shield hardens.

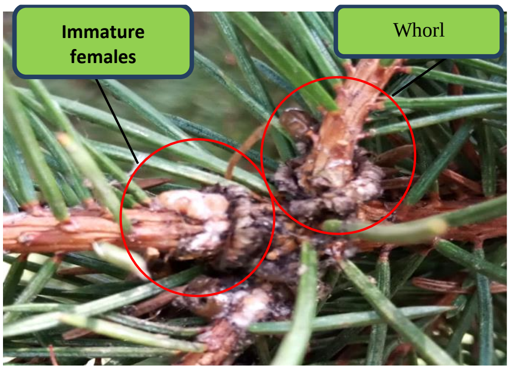

Fig. 1. Immature females of *P. hemicryphus* (V. N. Karazin Botanical Garden, 2018)

Fig. 2. Fertilized females of *P. hemicryphus* (Dendrological Park of the SBTU, 2017)

Males. The body is divided into the head, thorax, and abdomen. The legs and wings are well developed, but the mouthparts are absent. The body length is about 1.0 mm.

First-instar larva. It measures 0.60–0.65 mm in length and 0.25–0.30 mm in width. The body is oval and light pink in color. The antennae and eyes are clearly visible on the head. The larva is very mobile and has developed walking legs.

Second-instar larva. The length varies from 0.6 to 0.8 mm. The body acquires an orange color and becomes very flattened. The eyes are clearly visible. The larva has developed legs and antennae.

Eggs. Oval shape, crimson color. The surface is covered with a thin layer of white powdery wax. Length – 0.5 mm, width – 0.3 mm. The morphology of these stages does not differ from similar stages in other regions of the range. The age features of the stages are given in Table 2. Studies conducted in the Kharkiv region have shown characteristic age-related features of the development of this species.

Life cycle of P. hemicryphus. The life cycle of *P. hemicryphus* is closely related to the biology of conifers, particularly spruce. It includes several main stages of development. The species is monovoltine, with one generation per year. The second-instar larvae overwinter: males on needles, females in whorls of annual and biennial shoots. In Kharkiv region, diapause reactivation occurs in late April – early May at stable temperatures above +10 °C.

Table 2
The age features of *P. hemicryphus* stages in V. N. Karazin Botanical Garden

Stage	Dimensions	Age features
Immature females	body length 2–5 mm, width 4 mm	Light brown, with a white waxy coating on the underside of the body, has a soft false shield
Mature unfertilized females	body length 2–5 mm, width 4 mm	Brown in color, shiny, with a soft false shield, dusted with a white powdery coating.
Fertilized females	body length 2–5 mm, width 4 mm	Brown or dark brown in color, with a hard false shield
Males	body length 1.0 mm	The body consists of a head, thorax, and abdomen; it has well-developed legs and wings, but no mouthparts.
First-instar larvae	length 0.60–0.65 mm, width 0.25–0.30 mm	The body is oval and light pink in color. The antennae and eyes are clearly visible on the head. The larvae are very mobile and have well-developed walking legs.
Second-instar larvae, males and females	length 0.6–0.8 mm	Orange in color, flat in shape, with simple eyes. They have well-developed legs and antennae.
Eggs	length 0.5 mm, width 0.3 mm	Oval, crimson in color, covered with a thin layer of white powdery wax

Immature females appear in the first decade of May, mature ones in the third decade of May. Fertilization is recorded in late May – early June. Egg laying occurs in the second half of June – early July; fecundity varies from 30 to 347 eggs per female. Oviposition lasts 12–15 days, and its start depends on the year within the range of June 10–15.

First-instar larvae emerge in July, feed actively for a week, and then enter summer diapause. From the second decade of September, after molting into the second instar, they resume feeding, which lasts until November. Then the larvae enter winter diapause. The phenological calendar of females of *P. hemicryphus* is given in Table 3.

Table 3
Life cycle and harmfulness of *P. hemicryphus* in the Botanical Garden of V. N. Karazin University

Phenological phenomena	Stages of development	Dates of phenological phenomena	Causing harm
Hibernation	second-instar larvae	the end of November – the 2nd decade of March	–
Emergence from hibernation	second-instar larvae	the 2nd decade of March – the beginning of May	+
Emergence of females	immature females	the beginning of May – the end of May	+
	mature males	the end of May – the 2nd decade of June	+
Oviposition	fertilized females	the 2nd decade of June – the beginning of July	–
Emergence of larvae	first-instar larvae	the 1st decade of July – the 2nd decade of July	+
Summer diapauses	first-instar larvae	the end of July – the 1st decade of September	–
Emergence from summer diapause and feeding of the second-instar larvae	second-instar larvae	the 2nd decade of September – the 2nd decade of November	–
Starting hibernation	second-instar larvae	the end of November	+

Fecundity of P. hemicryphus. According to our research, the fecundity of *P. hemicryphus* females depends on the environmental conditions and the health of the host plant. The minimum fecundity (10–40 eggs/female) was recorded in areas with anthropogenic load (spruce trees along a highway with heavy traffic and compacted soil), the maximum (up to 347 eggs/female) in the village of Rohan, where spruce trees grow in optimal conditions. The egg-laying period of *P. hemicryphus* lasts 12–15 days. In 2017, egg laying began on June 10, in 2018 on June 12. In 2019, the spring was long, March was cooler than the average long-term data, but the later development of *P. hemicryphus* than *P. piceae* Schrank,1801 did not greatly affect the timing of egg laying: compared to the two previous years, it differed by only 3–5 days, and it began on June 15 (Table 3). In 2023, *P. hemicryphus* oviposition was registered on June 11, and in 2024, on June 12. However, it is known that the dates of insect development depend on weather conditions.

P. hemicryphus fecundity is largely dependent on the density of individuals in the whorl (the fewer females in the whorl, the better the feeding conditions) and on the host plant (healthy trees contribute to better development of females). Thus, *P. hemicryphus* fecundity depends on the density of individuals in the whorl and the quality of the host plant. Less competition for resources contributes to an increase in the scale population. Data on fecundity are given in Table 4.

Thus, favorable conditions for spruce growth (optimal soil characteristics, sufficient moisture, good light) contribute to higher fecundity of *P. hemicryphus*. Unfavorable environmental factors (pollution, soil compaction, insufficient light) lead to plant suppression, which, in turn, reduces the reproductive capacity of the pest.

Table 4
Fecundity of *P. hemicryphus* females on Norway spruce in the plots with different anthropogenic loads (2017–2024)

Fecundity, eggs/female by years	Plot with insignificant anthropogenic load			Plot with high anthropogenic load		
	mean, eggs	maximal, eggs	minimal, eggs	mean, eggs	maximal, eggs	minimal, eggs
2017	154.5 ± 8.3	290	68	88.4 ± 7.8	191	0
2018	161.4 ± 9.0	290	60	127.2 ± 8.1	253	0
2019	204.9 ± 10.1	347	75	88.0 ± 6.7	178	10
2023	146.2 ± 8.1	217	78	90.1 ± 8.1	103	51
2024	111.7 ± 7.7	188	59	61.7 ± 5.7	58	2

P. hemicryphus damages the needles and young shoots of Norway spruce (*Picea abies*) and blue spruce (*P. pungens*). Feeding is accompanied by yellowing and premature falling of needles, drying of shoots, growth inhibition, and death of trees in the case of mass infestation. The secretion of honeydew promotes the development of saprophytic sooty fungi (*Apiosporium pinophilum*), which additionally increases the damaging effect (Fig. 3). Two periods are the most dangerous for spruces: May (active feeding of immature females) and September–November (feeding of second-instar larvae).

Discussion

The obtained data confirm the stability of morphological features of *P. hemicryphus* in different parts of the range. At the same time, the phenology reveals significant regional variability, which is determined by climatic conditions. In the Kharkiv region, the termination of winter diapause occurs 1–2 months later than in Serbia (Simonović et al., 2018), but 1–2 weeks earlier than in northern Europe (Schmutterer, 1956; Pechhacker, 1988). This indicates a latitudinal dependence of insect development on the temperature regime (Table 5).

Fig. 3. Premature falling of needles due to small spruce bud scale feeding on Norway spruce

Table 5
Timing of *P. hemicryphus* phenological stages in different regions

Stage of development	Kharkiv region (Ukraine)	Serbia (Graora et al., 2012)	Czech Republic (Bednář et al., 2022)	Germany (Schmutterer et al., 1956)
Termination of winter diapause	end of April – beginning of May	end of February – March	April – the beginning of May	the 2nd decade of May
Appearance of immature females	the 1st decade of May	beginning of April	the 2nd decade of May – July	May
Appearance of males (adults)	the 2nd – 3rd decade of May	the 1st decade of April	end of May – June	May
Start of egg laying	middle – end of June	middle of May	beginning – middle of June	beginning of June
Completion of egg laying	end of June	end of July	July	the 1st decade of July

Analysis of fecundity showed significant differences between regions. The maximum fecundity was recorded in Serbia (360–650 eggs/female), the average values in Germany (38–335), while in the Kharkiv region, the fecundity did not exceed 347 eggs. It is obvious that environmental factors – in particular, the health of host plants, pest population density, and urbanization impact – are of key importance for the reproductive capacity of females.

It has been found that in urbanized ecosystems of the Kharkiv region, the fecundity of *P. hemicryphus* may be higher than in natural stands, which is consistent with the data of European authors (Pellizzari et al., 2014; Dervišević et al., 2019). This is explained by the decrease in the number of natural enemies and the weakening of biotic regulators in the urban environment.

Conclusions

Small spruce bud scale *P. hemicryphus* is a serious pest that negatively affects the growth and development of spruce trees. Timely detection, monitoring and integrated protection can significantly reduce its impact on coniferous plantations. The detailed morphology, biology, phenology and harmfulness of *P. hemicryphus* have been studied in the Kharkiv region. Studies have shown that the phytophage exhibits the greatest harmfulness at certain stages of development.

The most dangerous periods are: the stage of immature females – from the second decade of April to the first decade of May, when they intensively suck the sap from the plant, as well as the second-instar larvae – from the third decade of August to the third decade of November, when active feeding occurs, which significantly weakens the tree and increases the risk of its infection by secondary pathogens. One generation develops during the year.

The second-instar larvae overwinter – males on needles, females in whorls of one-year and two-year growths. Reactivation of diapause after overwintering begins after the stable transition of temperatures to over +10 °C, namely in the third decade of April – first decade of May. The fecundity of the small spruce bud scale ranges from 10–347 eggs and depends on the population density and food quality. Less competition for resources contributes to an increase in the number of eggs.

Small spruce bud scale damages Norway spruce (*Picea abies*) and blue spruce (*Picea pungens*). Larvae and females suck sap from needles and shoots, which leads to weakening of trees, reduced growth and intensive needle shedding. Infested trees show slowed growth, dieback and immunity decrease, which can lead to death.

To optimize the system of protecting spruce from spruce scale insects, which pose an increased danger to urbanized planting due to the decrease in the number of entomophages and climate change, it is necessary to focus further research on studying the species composition of predators and parasitoids of these phytophages, creating optimal conditions for enriching the diversity of zoophages and increasing their populations.

The authors are grateful to Candidate of Biological Sciences, Associate Professor M. O. Filatov, for assistance in taking photos.

References

Basnet, S., Burger, A., Homolová, Z., Märker, F., Trouillier, M., & Wilmking, M. (2024). Effect of bedrock, tree size and time on growth and climate sensitivity of Norway spruce in the High Tatras. European Journal of Forest Research, 143, 1835–1851.

Bednář, P., Souček, J., Krejza, J., & Černý, J. (2022). Growth and morphological patterns of Norway spruce (*Picea abies*) juveniles in response to light intensities. Forests, 13(11), 1804.

D'Andrea, G., Šimůnek, V., Pericolo, O., Vacek, Z., Vacek, S., Corleto, R., Olejár, L., & Ripullone, F. (2023). Growth response of Norway spruce (*Picea abies* [L.] Karst.) in Central Bohemia (Czech Republic) to climate change. Forests, 14(6), 1215.

Dervisevic, M., Stojanovic, A., Simonovic, M., & Graora, D. (2019). First report of tritrophic relationships among soft scale *Physokermes hemicryphus* Acta Zoologica Bulgarica, 71(2), 305–307.

Fetykó, K., Kozár, F., & Daróczi, K. (2010). Species list of the scale insects (Hemiptera, Coccoidea) of Romania, with new data. Acta Phytopathologica Hungarica, 45, 291–302.

Gertsson, C.-A., & Isacsson, G. (2012). Gransköldlöss (Hemiptera, Coccoidea, släktet Physokermes) i Sydsverige. Entomologisk Tidskrift, 133(4), 121–128.

Graora, D., Spasić, R., & Mihajlović, L. (2012). Bionomy of spruce bud scale, *Physokermes piceae* (Schrank) (Hemiptera: Coccidae) in the Belgrade Area, Serbia. Archives of Biological Sciences, 64, 337–343.

Jetsonen, J., Laurén, A., Muhonen, O., Ikonen, V.-P., Nevalainen, J., Pikkarainen, L., Kilpeläinen, A., Launiainen, S., & Palviainen, M. (2025). Spatial evenness of fertilization and short-term volume growth responses of Scots pine and Norway spruce to fertilization intensity. Silva Fennica, 59(1), 24026.

Jonsson, A. M., Marques, J. F., Winde, I., & Anderbrant, O. (2023). Taxonomic relationship among four European *Physokermes* species (Hemiptera:

Coccomorpha) based on nuclear and mitochondrial DNA. Frontiers in Forests and Global Change, 6, 1167541.
Kaydan, B., Ulgenturk, S., & Erkilic, L. (2007). Checklist of Turkish Coccoidea species (Hemiptera). Turkish Journal of Entomology, 17(2), 89–106.
Kozár, J., & Kosztarab, M. (1988). Scale insects of Central Europe. Springer, Dordrecht.
Malec, M., & Golan, K. (2015). Występowanie czerwców z rodzaju *Physokermes* (Hemiptera, Coccoidea) w Polsce i w Europie. Annales Universitatis Mariae Curie-Skłodowska. Sectio EEE: Horticultura, 25(2), 11–20.
Malumphy, C. P., Ostrauskas, H., & Pye, D. (2010). New data on the scale insects (Hemiptera, Coccoidea) of Southern Lithuania, including ten species new for the country. Acta Zoologica Lituanica, 20(3), 253–263.
Marques, J. F., Winde, I., Jonsson, A. M., & Anderbrant, O. (2023). Taxonomic relationship among four European *Physokermes* species (Hemiptera: Coccomorpha) based on nuclear and mitochondrial DNA. Frontiers in Forests and Global Change, 6, 1167541.
Melenti, V. O., Lezhenina, I. P., Stankevych, S. V., & Zabrodina, I. V. (2025). Unexpected spruce scale insect (*Physokermes inopinatus* Danzig & Kozár, 1973) on spruce trees and its harmfulness in the Kharkiv Region. Taurian Scientific Herald, 142, 3–12.
Papanastasiou, I., Kavallieratos, N. G., Papadoulis, G. T., Emmanouil, C., & Emmanouel, N. G. (2021). Geographical distribution and long-term monitoring of *Physokermes hellenicus* (Hemiptera: Coccomorpha: Coccidae) on *Abies* spp. (Pinales: Pinaceae) in Greece. Insects, 12(11), 1001.
Petrik, P., Scapucci, L., Petek Petrik, A., Bosela, M., Huang, W., Kurjak, D., & Ræbild, A. (2024). Winter warming response of gas exchange and growth of *Abies alba* and *Picea abies* seedlings. Trees, 38, 151–167.
Santas, L. A. (1988). *Physokermes hemicryphus* (Dalman), a fir scale insect useful to apiculture in Greece. Entomologia Hellenica, 6, 11–21.
Schmutterer, H. (1956). Zur Morphologie, Systematik und Bionomie der Physokermes-Arten an Fichte (Homopt. Cocc.). Zeitschrift für Angewandte Entomologie, 39, 445–466.
Simonović, M., Dervišević, M., & Graora, D. (2018). Bionomy of small spruce bud scale, *Physokermes hemicryphus* (Dalman) (Hemiptera: Coccidae) in Serbia. Pesticidi i Fitomedicina, 33(2), 89–96.
Skrzecz, I., Sierpińska, A., & Tumialis, D. (2024). Entomopathogens in the integrated management of forest insects: From science to practice. Pest Management Science, 80(6), 2503–2514.
Stathas, G., Eliopoulos, P., Salmas, I., & Kozár, F. (2011). Data on ecology of some Hemiptera species recorded in the forest of Taygetus Mountain, Peloponnesus, Greece. Phytoparasitica, 39, 377–383.
Szita, É., Fetykó, K., Konczné Benedicty, Z., Kozár, F., Partsinevelos, G. K., Milonas, P. G., & Kaydan, M. B. (2017). Data on the scale insect (Hemiptera: Coccomorpha) fauna of Greece, with description of two new species. Zootaxa, 4329(5), 463–476.
Ulgenturk, S., & Canakcioğlu, H. (2004). Scale insect pests on ornamental plants in urban habitats in Turkey. Journal of Pest Science, 77, 79–84.
Winde, I., Anderbrant, O., & Jönsson, A. M. (2018). Recovery of trees following an outbreak of *Physokermes inopinatus* in Southern Sweden. Scandinavian Journal of Forest Research, 33, 313–319.
Yataco, A. P., Noor, S., Girona, M. M., Work, T., & Despland, E. (2024). Limited differences in insect herbivory on young white spruce growing in small open plantations and under natural canopies in boreal mixed forests. Insects, 15(3), 196.