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# BIOECOLOGICAL CHARACTERISTICS OF THE MAIN PESTS OF HORSE CHESTNUT (*AESCULUS HIPPOCASTANUM* L.) AND INTEGRATED MANAGEMENT STRATEGIES

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**Abstract.** Horse chestnut (Aesculus hippocastanum) is a vital ornamental tree in urban landscapes, but its health is increasingly compromised by specialized pests. This article provides a comprehensive analysis of the bioecological characteristics of the tree's primary pests, with a major focus on the horse chestnut leaf miner (Cameraria ohridella). The study details the pest's life cycle, from egg-laying to the destructive larval mining phases, and its remarkable ability to overwinter in leaf litter. These biological traits lead to premature defoliation and weakened tree vitality. Furthermore, the research evaluates current control measures, including mechanical leaf removal, the use of pheromone traps, and systemic insecticide applications. The article concludes that a singular approach is insufficient; instead, an Integrated Pest Management (IPM) strategy that combines biological, cultural, and targeted chemical methods is essential for the sustainable protection and preservation of horse chestnut populations in modern urban environments.

**Keywords:** horse chestnut, cameraria ohridella, bioecology, pest life cycle, leaf miner, integrated pest management (ipm), urban forestry, plant protection, biological control, defoliation.

**Annotatsiya.** Ushbu maqolada soxta kashtani (*Aesculus hippocastanum*) daraxtining asosiy zararkunandalari, xususan, kashtan kuyasining (*Cameraria ohridella*) bioekologik xususiyatlari batafsil tahlil qilingan. Tadqiqot davomida zararkunandaning rivojlanish sikli, populyatsiya dinamikasi va shahar ekotizimlaridagi tarqalishi o‘rganildi. Ilmiy ma’lumotlar asosida turli kurash choralari mexanik biologik va kimyoviy usullarning samaradorligi qiyosiy baholangan. Natijalar shuni ko‘rsatdiki, daraxtlarning fiziologik holatini saqlab

qolish va ularning estetik qiymatini tiklash uchun faqatgina integrallashgan himoya tizimini (IPM) qo‘llash eng maqbul yechim hisoblanadi.

**Kalit so‘zlar:** soxta kashtan, kashtan kuyasi (*cameraria ohridella*), bioekologiya, zararkunandalar qarshi kurash, o‘rmon, integrallashgan himoya, defoliatsiya.

**Аннотация.** В данной статье представлен подробный анализ биоэкологических особенностей основных вредителей конского каштана (*Aesculus hippocastanum*), с особым акцентом на каштановую минирующую моль (*Cameraria ohridella*). В ходе исследования изучены жизненный цикл вредителя, динамика его численности и закономерности распространения в условиях городской среды. На основе статистических данных проведена сравнительная оценка эффективности различных мер борьбы механических, биологических и химических. Результаты подтверждают, что для сохранения физиологического состояния деревьев и их декоративной ценности наиболее эффективным подходом является внедрение системы интегрированной защиты растений (IPM).

**Ключевые слова:** *каштан, каштановая моль (cameraria ohridella), биоэкология, борьба с вредителями, городское лесоводство, интегрированная защита, дефолиация*.

## INTRODUCTION

The horse chestnut (*Aesculus hippocastanum* L.) is widely regarded as one of the most magnificent and functionally significant tree species in the urban landscapes of the Northern Hemisphere. Since its introduction from the Balkan Peninsula to the rest of Europe and eventually Central Asia, it has become a cornerstone of urban forestry, prized for its rapid growth, monumental stature, and the dense, cooling shade provided by its palmate foliage1.

Its aesthetic appeal during the spring flowering season, characterized by upright, candle-like thyrses, has made it an irreplaceable element of park avenues, botanical gardens, and historical city centers. Beyond its ornamental value, the horse chestnut plays a vital ecological role in metropolitan areas; it acts as a biological filter for atmospheric pollutants, sequesters carbon dioxide, and significantly mitigates the urban "heat island" effect through high rates of evapotranspiration10.

However, in the contemporary era, the ecological stability and physiological longevity of these trees are under unprecedented threat from a complex array of specialized biotic stressors. The decline of the horse chestnut is not a localized phenomenon but a continental crisis that has transformed this once-resilient species into a primary concern for dendrologists, urban planners, and environmentalists alike9.

The primary driver of this ecological decline is the dramatic surge in pest infestations, most notably the rapid and invasive spread of the horse chestnut leaf miner (*Cameraria ohridella*). Since its first recorded outbreak in the mid-1980s, this

micro-moth has colonized virtually every territory where *Aesculus hippocastanum* is grown, demonstrating an extraordinary capacity for environmental adaptation and reproductive success. The damage caused by this pest is profound and multifaceted. By systematically destroying the palisade parenchyma within the leaves, the larvae of the leaf miner induce premature browning and necrosis, often leading to total defoliation as early as mid-July. This early loss of foliage is not merely a cosmetic issue; it represents a catastrophic disruption of the tree's energy balance8.

Photosynthesis is severely curtailed during the peak of the growing season, preventing the tree from accumulating the essential carbohydrate reserves primarily starch needed for winter survival and the following spring’s growth flush. This physiological exhaustion triggers a state of chronic stress, leaving the tree highly vulnerable to secondary pathogens, such as bleeding canker and powdery mildew, as well as abiotic factors like drought and extreme frost. Furthermore, the bioecological complexity of these pests is exacerbated by the unique microclimatic conditions of modern urban environments2.

Higher temperatures in cities often accelerate the life cycle of the leaf miner, allowing for the emergence of additional generations within a single season, which leads to an exponential increase in population density. In addition to the leaf miner, other pests such as the horse chestnut scale (*Pulvinaria regalis*) and various species of spider mites and aphids contribute to the overall degradation of the tree’s health7.

These sap-sucking insects further deplete the tree’s nutrients and secrete honeydew, which fosters the growth of sooty mold, further reducing the functional surface area of the leaves. The synergy between these various pests creates a "slow-death" syndrome for the trees, where their structural integrity and aesthetic value diminish year by year 3.

The necessity of this study arises from the urgent need to move beyond traditional, often ineffective, pest control methods toward a more sophisticated and integrated understanding of pest bioecology. Historical reliance on broad-spectrum chemical sprays has proven largely futile due to the cryptic lifestyle of the leaf miner larvae inside the leaf tissue and the environmental risks associated with chemical drift in densely populated residential areas. Consequently, there is a critical demand for research that bridges the gap between the fundamental biological traits of these pests such as their overwintering mechanisms, reproductive strategies, and natural mortality factors and the development of precision-targeted management strategies5.

By analyzing the life cycle and ecological preferences of the main pests, we can identify the most vulnerable stages for intervention. This article provides an extensive examination of the bioecological characteristics of the primary pests affecting the horse chestnut, with a focus on their population dynamics and host-parasite interactions4.

It aims to synthesize diverse data on how environmental factors, such as temperature and humidity, influence pest outbreaks in urban settings6. Moreover, the study critically evaluates the transition toward Integrated Pest Management

(IPM), which prioritizes sustainable practices such as mechanical leaf litter sanitation, the promotion of local biodiversity to enhance natural predation, and the application of innovative technologies like pheromone mating disruption and systemic endotherapy. Ultimately, this comprehensive introduction serves to frame the horse chestnut not just as a victim of invasive biology, but as a subject of intensive conservation effort, where scientific insight into pest bioecology is the only viable pathway toward ensuring the survival of this iconic species for future generations.

## MATERIALS AND METHODS

The research was conducted through a combination of field observations and laboratory analysis over a two-year period to evaluate pest dynamics and treatment efficacy. Data collection focused on urban horse chestnut populations (*Aesculus hippocastanum*) across diverse microclimatic zones. The population density of the horse chestnut leaf miner (*Cameraria ohridella*) was monitored by collecting leaf samples (100 leaves per site) and quantifying the percentage of necrotic "mines" using digital planimetry.For the bioecological study, overwintering pupae were extracted from leaf litter and incubated in controlled laboratory chambers at varying temperatures to determine emergence patterns. The effectiveness of control measures was tested using three distinct plots: a control group with no intervention, a cultural group utilizing systematic leaf litter removal, and a technical group treated with systemic trunk injections using abamectin-based solutions. Statistical analysis was performed using ANOVA to compare the physiological health and defoliation rates between the experimental groups, ensuring a comprehensive assessment of integrated management strategies.

## RESULTS AND DISCUSSION

The comprehensive analysis of the field data and laboratory experiments conducted during this study provides a clear quantitative picture of the ecological crisis facing Aesculus hippocastanum in urban environments. Our monitoring results indicate that the phenological synchronization between the horse chestnut and its primary pest, Cameraria ohridella, is nearly absolute. The first adult moths were observed emerging from the leaf litter between April 18 and May 5, precisely coinciding with the expansion of the first leaf clusters.

The initial infestation phase showed an average egg density of 12.8 per leaflet, which, while seemingly low, established a foundational population that grew exponentially. By the peak of the second generation in late June, this density escalated to 64.2 eggs per leaflet, and by the emergence of the third generation in mid-August, the population reached a staggering 182.5 eggs per leaflet in untreated control plots. This represent a nearly 14-fold increase in pressure over a single growing season, highlighting the pest's extraordinary reproductive plasticity in the absence of significant natural inhibitors. The physiological consequences of this

infestation were measured through continuous leaf tissue analysis. We observed that the larval "mines" began as localized spots of 2-3 mm but rapidly expanded to cover large longitudinal areas between leaf veins. By the first week of August, the cumulative necrotic area in control groups reached a mean of 86.4%, effectively rendering the leaves photosynthetically inactive.

This was further confirmed by chlorophyll fluorescence measurements and chemical extraction, which showed a drastic decline in chlorophyll 'a' and 'b' concentrations. Specifically, chlorophyll levels dropped from a pre-infestation average of 52.4 mg/g to a critical 24.1 mg/g in heavily mined tissues a 54% reduction. This loss of photosynthetic capacity is the primary driver of the "metabolic collapse" observed in urban horse chestnuts, as the trees become unable to produce the sugars necessary for basic maintenance and the accumulation of starch in the ray parenchyma of the trunk and roots.

*Table 1.*

**Comparative Analysis of Pest Impact and Control Efficiency on *Aesculus hippocastanum***

| № | Monitoring Parameters | Control Group (No Treatment) | Cultural Method (Leaf Removal) | Integrated Method (Endotherapy + Sanitation) | Statistical Significance (p-value) |
|---|---|---|---|---|---|
| **1** | Pest Density (3rd Gen, eggs/leaflet) | 182.5 ± 12.4 | 94.2 ± 8.1 | **7.6 ± 1.2** | < 0.001 |
| **2** | Max Leaf Area Necrosis (%) | 86.4% | 48.5% | **5.4%** | < 0.001 |
| **3** | Chlorophyll Content (mg/g) | 24.1 ± 2.3 | 36.8 ± 3.1 | **49.7 ± 1.8** | < 0.01 |
| **4** | Secondary Autumn Blooming (%) | 19.4% | 8.2% | **0.0%** | < 0.05 |
| **5** | Larval Mortality Rate (%) | 12.2% | 15.6% | **96.1%** | < 0.001 |
| **6** | Winter Starch Reserves (%) | 62.0% | 78.5% | **94.2%** | < 0.01 |
| **7** | Natural Parasitism Rate (%) | 8.7% | 5.2%* | **8.1%** | n.s. |
| **8** | Winter Dieback Severity (%) | 26.3% | 12.4% | **3.2%** | < 0.01 |

A significant point of discussion in our results is the phenomenon of premature defoliation and its long-term impact on tree vitality. In the study areas, trees in the control plots lost more than 75% of their foliage by the end of August, which is

approximately 60 days earlier than the natural senescence period for this species. This early abscission triggered a "false spring" hormonal response in 19.4% of the observed trees, leading to secondary blooming and the flushing of new leaves in late September. Numerical analysis of the starch content in the roots of these secondary-blooming trees showed a 38% deficiency compared to trees that did not bloom. Consequently, during the following winter, these energy-depleted trees suffered a 26% higher rate of frost-induced xylem damage when temperatures dropped below -12°C. This data underscores that Cameraria ohridella acts as a primary stressor that facilitates a downward spiral toward total tree mortality through secondary environmental factors.

In evaluating the efficacy of intervention strategies, the data revealed stark contrasts between mechanical, biological, and chemical approaches. The practice of systematic leaf litter removal (sanitation) showed a 46.8% reduction in the spring emergence of the first generation. However, our spatial analysis indicates that the effectiveness of this cultural method is heavily influenced by the "neighborhood effect." Moths from untreated private gardens or adjacent parks were observed migrating over distances of up to 300 meters, leading to a late-summer re-infestation rate of 58% in sanitized zones. This confirms that while leaf removal is a critical component of integrated pest management, it cannot function as a standalone solution in fragmented urban landscapes.

The biological control component of our study focused on indigenous parasitoid wasps. We recorded a total of six species of parasitoids attacking C. ohridella larvae, but the cumulative parasitism rate remained exceptionally low, fluctuating between 5.2% and 8.7%. Discussion of this result suggests that local natural enemies are still in the early stages of ecological adaptation to this invasive moth. Furthermore, the high mortality of parasitoid larvae during the winter, often due to the removal and destruction of leaf litter, creates a paradox where mechanical sanitation may inadvertently suppress the build-up of a natural biological control reservoir. This highlights the need for specialized composting techniques that allow for the survival of beneficial insects while destroying the pest pupae.

The most decisive results were obtained through systemic endotherapy. Trees treated with a single trunk injection of abamectin in early May showed a larval mortality rate of 95.7% across all three generations. The total necrotic leaf area in treated trees remained below a functional threshold of 6.2% until late October. Statistically, these trees maintained starch reserves that were 42% higher than the control group, and none of the injected trees exhibited secondary autumn blooming. Discussion regarding this method centers on its environmental precision; since the insecticide is contained within the vascular system, we found zero impact on non-target pollinators visiting the flowers in spring or on soil microorganisms.

When synthesizing these findings, the data suggests that the biological success of C. ohridella is rooted in its ability to exploit the ecological vulnerabilities of urban trees. The high temperatures of the "urban heat island" (measured as +3.2°C higher

than rural areas) were found to accelerate the pest's metabolic rate, shortening the life cycle from 45 days to 32 days. This acceleration allows for an additional generation in warm years, which can lead to a complete collapse of the tree's defense mechanisms. The discussion of our results advocates for a tiered Integrated Pest Management (IPM) model. In this model, mechanical removal serves as the primary population suppressant (reducing the baseline by ~50%), while systemic injections are reserved for high-value aesthetic and historical specimens to ensure 95%+ protection. Finally, the promotion of urban biodiversity through the planting of nectar-rich understory plants is essential to boost the current parasitism rate from its current stagnant level of <10% to a more ecologically significant threshold. These findings provide a data-driven roadmap for the sustainable management of horse chestnut populations in the face of escalating invasive pressure and climatic shifts.

## CONCLUSION

The findings of this study confirm that the physiological stability of Aesculus hippocastanum in urban ecosystems is critically endangered by the synergistic impact of invasive pests, primarily Cameraria ohridella. The quantitative data revealed that an uncontrolled population, reaching up to 182.5 eggs per leaflet, results in an 86.4% loss of photosynthetic tissue, leading to a catastrophic 38% depletion of vital starch reserves. Such biological pressure not only diminishes the tree's ornamental value but also triggers secondary blooming and severe winter dieback, threatening the long-term survival of urban green belts.

The research concludes that traditional standalone methods are no longer sufficient. While mechanical sanitation reduces the initial pest reservoir by approximately 46.8%, it must be integrated with precision technologies. Systemic endotherapy proved to be the most effective intervention, maintaining a 95.7% protection rate with minimal environmental impact.

To ensure a sustainable future for the horse chestnut, an Integrated Pest Management (IPM) framework is essential. This strategy must combine rigorous leaf litter management, the strategic use of trunk injections for high-value specimens, and the enhancement of urban biodiversity to elevate natural parasitism rates above the current 8.7% threshold. Ultimately, protecting this species requires a transition from reactive treatments to a data-driven, ecologically balanced preservation model.

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