

Article

Characteristics of Bark Stripping Damage by Deer and Nutrient Content in Black Cherry (*Prunus serotina* Ehrh.)

Michał Jessa ^{1,*}, Marlena Baranowska ¹ , Piotr Karolewski ², Robert Korzeniewicz ¹ , Szymon Łacki ³ and Adrian Łukowski ¹ 

¹ Faculty of Forestry and Wood Technology, Poznań University of Life Sciences, Wojska Polskiego 28, PL60-627 Poznań, Poland; marlena.baranowska@up.poznan.pl (M.B.); robert.korzeniewicz@up.poznan.pl (R.K.); adrian.lukowski@up.poznan.pl (A.Ł.)

² Institute of Dendrology, Polish Academy of Sciences, Parkowa 5, PL62-035 Kórnik, Poland; pkarolew@man.poznan.pl

³ Czulchów Forest District, Sobieskiego 3, PL77-300 Czulchów, Poland; szymon.lacki@szczecinek.lasy.gov.pl

* Correspondence: michal.jessa@up.poznan.pl

Abstract

Large ungulates significantly influence forest ecosystems through shoot biting and bark stripping, but their impact on the dynamics of invasive plant species still remains insufficiently investigated. The North American black cherry (*Prunus serotina* Ehrh.) is a widespread invasive species in European forests, known for its strong defensive capabilities against herbivores. Despite this, recent observations indicate that deer occasionally utilize its bark and phloem as a food source. This study aimed to determine the extent of deer bark stripping on *P. serotina* across different age/size classes and evaluate the associated nutrient content in plant tissues. Conducted in two Polish forest districts varying in *P. serotina* stand and deer pressure structure, we inventoried bark wounds on mature and mid-aged trees. Furthermore, we analyzed nitrogen, glucose, total non-structural carbohydrates (TNC), and the C:N ratio in both healthy and damaged trees. Our findings reveal that mature trees were damaged more often than mid-aged individuals, with wounds positioned higher on the trunks. Interestingly, the dimensions of individual wounds did not significantly differ between age classes. Chemical analysis showed that undamaged mid-aged trees naturally possess higher TNC and glucose contents than mature trees. Given the occurrence of bark stripping, one would expect higher browsing pressure; however, this is not the case. Following bark stripping, only mature trees exhibited a significant chemical response: damaged trees showed increased relative nitrogen content (decreased C:N ratio) and a marked reduction in glucose and TNC. These results suggest the rapid reaction in mature individuals, leading to reduction in local palatability, which likely explains the observed lack of repeated feeding on previously stripped trees. Ultimately, while deer herbivory alone may not directly limit the expansion of *P. serotina*, the resulting physical wounds provide critical entry points for pathogenic microorganisms, highlighting a novel trophic interaction with significant implications for the biological control of this invasive species.

Keywords: bark wounds; carbohydrates; Cervidae; nitrogen; nutrient content; primary metabolites; invasive species management; plant-herbivore interactions



Academic Editor: Ning Du

Received: 30 July 2026

Revised: 7 September 2026

Accepted: 8 September 2026

Published: 9 September 2026

Copyright: © 2026 by the authors.

Licensee MDPI, Basel, Switzerland.

This article is an open access article distributed under the terms and conditions of the [Creative Commons Attribution \(CC BY\)](https://creativecommons.org/licenses/by/4.0/) license.

1. Introduction

Deer species are characterized by a wide range of occurrence and inhabit most of Europe, utilizing both open landscapes and diverse forest habitats [1]. The red deer (*Cervus*

elaphus L.), roe deer (*Capreolus capreolus* L.), and fallow deer (*Dama dama* L.) are widespread ungulates in Europe [2–4]. However, their historical habitat preferences differ significantly. The red deer is traditionally considered an inhabitant of the ecotone between forests and open habitats, such as the woodland–grassland interface [4–6]. In contrast, the roe deer was originally strictly associated with the early successional stages of woods and has only recently colonized open habitats and croplands [3]. The fallow deer, an introduced species in Central Europe, is originally native to Anatolian pinewoods and oakwoods; it is a highly flexible species that readily inhabits grasslands, woodlands, and scrublands [4]. Following their distinct evolutionary adaptations, the feeding styles of these species also fundamentally differ [7,8]. The roe deer is classified as a concentrate selector, preferentially browsing on easily digestible, nutrient-rich plant parts. Conversely, both red and fallow deer are mixed feeders, possessing a highly adaptable diet that seamlessly shifts between browsing trees or shrubs and grazing grasses. Given these dietary strategies and their regular presence in forested environments, woody plants may constitute a large part of their winter diet. During this period, they consume leaves, twigs and bark of trees and shrubs. Consequently, their impact on forest ecosystems varies [9]. Red deer pose a major threat to forestry, primarily due to their large body size and high daily food intake, which frequently leads to extensive bark stripping. In contrast, roe deer represent a minor threat in terms of bark damage; due to their smaller size and concentrate-selector feeding style, they predominantly browse on tender apical shoots and buds rather than stripping bark from trunks. The damage probability of host plants by deer is a complex process influenced by many factors and is mainly dependent on chemical traits rather than on physical characteristics of plants [10–12]. Some researchers argue that the primary factor regulating feeding behavior is the chemical defense of plant tissues [12]. This is often explained by the assumption that primary tissue metabolism is nearly identical across plant species; therefore, the baseline presence of nutrients such as carbohydrates, polysaccharides, lipids, amino acids, and proteins is similar [13], making secondary metabolites the main differentiator. Chemical defense mechanisms involve the production of compounds harmful to herbivores, i.e., secondary metabolites such as alkaloids, simple phenolic compounds, tannins, and flavonoids [14–17]. However, contrasting studies suggest that herbivores are primarily guided by nutrient contents, avoiding plants poor in nitrogen compounds and carbohydrates but also those rich in indigestible compounds like lignin [10,18,19]. Moreover, they emphasize that carbohydrates are the main factor determining palatability, as they constitute a basic component of herbivore diets [13]. In summary, deer tend to optimize their foraging strategy by selecting more digestible and palatable food while avoiding resources that do not provide sufficient energy and nutrients or contain high levels of deterrents [20].

Black cherry (*Prunus serotina* Ehrh.) originates from North America [21]. The first introduction of this species to Europe took place in the 17th century. At the turn of the 19th and 20th centuries it was widely introduced into forests as an admixture species [22]. In Poland, black cherry is recognized as an invasive species and occurs quite frequently throughout most of the country, occupying approximately 1.4% of the forest area managed by the State Forests [23–26]. In its native range, black cherry can exceed 35 m in height, whereas in invaded areas it generally takes the form of a shrub or a tree up to 20 m in height [27]. The species exhibits broad ecological plasticity, characterized by low light requirements, tolerance to deep shade, extreme temperatures, drought, and spring frosts [25,28]. It is well adapted to local climatic and soil conditions and poses a significant threat to European flora due to its strong expansion potential [21,29–31]. In addition to low habitat requirements, black cherry possesses other traits that facilitate its rapid spread. One of these is a high potential for generative reproduction. Trees are pollinated by non-

specialist insects [32], and fruiting may begin as early as 10 years of age [33]. Furthermore, the fruits are consumed by several dozen animal species [22], which disperse them over long distances [34,35]. Another important adaptive trait is the ability to produce numerous epicormic shoots, which occurs in approximately 50% of the population under European conditions [36]. This strong resprouting response are typically stimulated by damage or cutting of shoots [37]. Black cherry also exhibits allelopathic effects by releasing chemical compounds such as R-prunasin and amygdalin into the soil [38,39]. This increases its chances of survival by eliminating seedlings of native species [31,40,41] and discouraging herbivores from feeding [42].

The negative consequences of black cherry expansion have sparked interest in the potential utilization of this alien species by native herbivores [43]. This perspective is the main reason for ongoing research on its use by insect herbivores [44–47]. Direct observations and recent reports based on camera traps suggest that the tissues of this plant may also constitute a potential food source for large herbivores [48–50]. Despite numerous defense mechanisms against herbivores, it appears that certain stimulants (such as nitrogen compounds and carbohydrates), combined with the high availability of this species, may encourage deer to feed on it. While wounds resulting from bark stripping constitute a serious problem in traditional silviculture [19,51–56], they may paradoxically also become an ally for foresters in combating this invasive species. To date, few effective and environmentally friendly methods of controlling black cherry have been developed [57–59], and the greatest hopes are placed in pathogenic fungi, whose reservoir may be the soil [57,60–62]. Crucially, physical damage such as bark stripping not only creates entry wounds for these pathogens but also forces the tree to drastically reallocate its resources, permanently altering its chemical profile. Understanding how the contents of primary metabolites, specifically nitrogen and non-structural carbohydrates, shift post-wounding is vital, as these induced physiological responses reflect the tree's weakened state and may dictate its future survival or alternatively help explain why previously bark-stripped individuals are not subjected to repeated damage. Considering these facts, a detailed examination of the damage to the phloem and bark of the black cherry seems highly justified and necessary, while taking into account the age of the trees.

Building on this premise, the main aim of this study was to assess whether and to what extent deer are interested in utilizing the bark and phloem of black cherry of different ages as a food source, and how this foraging behavior permanently impacts on the chemical composition of the remaining tissues. To achieve this, several specific objectives were formulated:

- (a) To determine the effect of black cherry age on the frequency of damaged trees;
- (b) To characterize the size and location of wounds in mid-aged and mature individuals;
- (c) To determine the baseline content of nitrogen and non-structural carbohydrates in undamaged black cherry trees across different age classes and subsequently compare these metabolic profiles with those of bark-stripped individuals.

Based on these objectives, we tested the following hypotheses:

- I. Mature individuals (i.e., fruiting trees) are bark-stripped more frequently than mid-aged individuals (i.e., younger, non-fruiting trees) (rationale: age-related changes in bark structure and physical properties make the trunks of mature trees more attractive or accessible for foraging deer).
- II. The physical characteristics and vertical distribution of bark wounds are dependent on the developmental stage of the tree (rationale: because morphological traits such as stem diameter and overall tree height naturally constrain the feeding behavior and physical reach of herbivores, we predict that bark stripping on mature trees will result in larger wounds located higher on the trunk compared to mid-aged individuals).

- III. The baseline content of nitrogen and non-structural carbohydrates in undamaged individuals is stage-dependent (rationale: as trees transition between developmental stages, their changing physiological demands and storage capacities fundamentally alter the baseline accumulation of these nutrients).
- IV. Damaged trees exhibit a distinct shift in chemical composition compared to undamaged ones, specifically an increase in nitrogen content and a decrease in the content of non-structural carbohydrates (rationale: bark stripping and the subsequent systemic reallocation of resources alter the concentration of essential nutrients and energy reserves across the tree stem).

2. Materials and Methods

2.1. Study Sites and Plant Material

The field research began in mid-autumn 2018 in Poland, in the Człuchów Forest District (53°45' N, 17°29' E) and the Łopuchówko Forest District (52°51' N, 17°12' E). Both study sites belong to the Wielkopolska-Pomeranian nature region, one of the eight regions distinguished for forestry management in Poland. This selection ensured that the investigated areas are shared, in order to select an area with similar physiographic conditions, where the studied type of forest develops best. The study site in the Człuchów Forest District is inhabited mainly by red deer and roe deer, and mid-aged black cherry occurs as individuals that have not yet reached the fruiting stage. On the other hand, the study site in the Łopuchówko Forest District is characterized by the regular present of red deer and fallow deer, and black cherry populations are characterized by a predominance of mature specimens (fruiting individuals) in the understory layer. It should be noted that, in this study, the terms 'mid-aged' and 'mature' operate as designations for distinct developmental stages (differentiated objectively by reproductive capacity (fruiting status) and stem morphology) rather than exact chronological age, which is highly variable and difficult to determine non-destructively. While some variability in absolute age within the plots was acceptable, ensuring a consistent morpho-developmental structure across a given plot was the primary criterion. They grew in mature fresh mixed forest stands, under the canopy of pine, with admixture of oak and birch. Based on the information obtained and observations carried out in both Forest Districts, it was concluded that deer population densities were at a constant level, although the precise game abundance was measured directly at the entire Forest Districts rather than individual study sites.

Field research and sample collection were conducted with the explicit permission and cooperation with the administration of the Człuchów and Łopuchówko Forest Districts.

A total of 30 circular sample plots with a radius of 5 m (78.54 m²) were established. This plot size was chosen a priori because it provides an optimal area for accurately inventorying dense understory layers and mid-aged stands. The central points of the plots were randomly designated on a digital map using Geotracer software (Android 8.1 Oreo) to ensure representative distribution within the selected forest stands. These designated coordinates were subsequently located in the field using a GPS receiver. Fifteen plots were located in the Człuchów Forest District, and the remaining 15 in the Łopuchówko Forest District. The sample plots were randomly designated, maintaining a minimum distance of 50 m between plot centers to ensure spatial independence. At the end of October 2018, on each sample plot, a central tree, stripped trees, and healthy ones were permanently marked by giving them a number written on a colored tape, following the methodology described by Kurek et al. [19]. On each plot, the number of black cherry individuals was recorded (to estimate density), and the diameter at breast height (DBH) of the two trees located closest to the plot center was measured. All previous damage was permanently marked on the trees using small colored pins.

The subsequent phase of the research was conducted in late March 2019. All sample plots were surveyed for new damage sustained during the winter and early spring. Fresh bark stripping was identified primarily by the absence of colored pins (which marked all previous damage), supported by visual criteria such as exposed, unweathered xylem, its light coloration, and a complete lack of callus tissue. Attribution of the damage to cervids was based on characteristic bark-stripping signs and the known composition of the local fauna. For the purposes of this study, all observed bark stripping was treated collectively as cervid-induced damage; no attempt was made to differentiate the specific feeding signs among red, roe, or fallow deer on individual trees, as our primary focus was on the plant's physical and metabolic response. Whenever a new bark wound was observed, its maximum width was measured, along with the distance from the ground to its lower and upper edges to determine its maximum length. Assuming a generally rectangular shape, the approximate area of each wound was calculated by multiplying its maximum length by its maximum width. Trees within the sample plots were classified as “damaged” if they sustained fresh wounds during the study period, whereas “undamaged” trees were required to have no visible wounds of any kind. Consequently, trees previously marked with colored pins were excluded from the chemical analyses.

Subsequently, plant material (an approx. 4 cm² square piece of bark and phloem) was excised from the trunk on the side directly opposite the fresh wound at a height corresponding individually to the height of the wound on the damaged tree. This sampling location was intentionally chosen to investigate the systemic response of the tree to browsing damage, avoiding the localized metabolic changes that occur at the immediate boundary of the wound. The samples representing the damaged variant (N = 60; 19 mid-aged and 41 mature individuals) were collected using a heavy-duty utility knife with snap-off blades to ensure a clean cut and minimize tissue damage. To prevent cross-contamination, a new blade segment was used for each sampled tree. Additionally, three healthy individuals with no visible damage were selected within each sample plot to serve as an undamaged control group (undamaged variant) for the chemical analysis (N = 90; 2 study sites × 15 circular sample plots × 3 samples). On each control tree, plant material was collected at a height of approximately 90 cm on the side of the trunk, which corresponds to the typical average height of cervid bark-stripping activity in these stands, thereby providing a standardized and ecologically relevant baseline. To minimize the risk of sample degradation or the leaching of soluble compounds, all material was collected on rainless days. Upon collection in the field, the samples were packed into paper envelopes and transported to the laboratory.

2.2. Chemical Analysis

The chemical composition of the bark and phloem of *P. serotina* (non-structural carbohydrates, including glucose, and nitrogen) was tested on ground and dried material using gas chromatography and spectrophotometry. The collected plant material was air-dried by storing it for a period of 4 months at room temperature. The initial air-drying process rapidly reduced the moisture content of the tissues, effectively halting the enzymatic degradation of carbohydrates. Furthermore, because all samples were subjected to the identical storage conditions and duration before the final oven-drying and analysis, the relative differences between groups remain robust and unbiased by the storage protocol. Before analyses, plant material was additionally dried for 3 days at 65 °C using a laboratory dryer with forced air circulation (Pol-Eko, Wodzisław Śląski, Poland), and ground into powder with an impact mill (IKA®-Labortechnik Staufen, Janke & Kunkel GmbH & Co. KG, Staufen im Breisgau, Germany). Nitrogen and carbon contents (% d.m.) were determined using an ECS CHNS-O 4010 analyzer (Costech Instruments, Pioltello, Italy).

These results were subsequently used to calculate the C:N ratio. The methodology for determining the concentration of total non-structural carbohydrates (TNC) and nitrogen was performed without any modifications, exactly as previously described in detail by Karolewski et al. [63]. Total non-structural carbohydrates (with glucose evaluated as an integral component within the same analytical procedure, rather than via a separate assay) were assayed in methanol–chloroform–water extracts, and results were expressed as % d.m. The content of soluble carbohydrates was measured at $\lambda = 625$ nm following a color reaction with anthrone. Absorbances were determined using the UV-1700 Visible Spectrophotometer (PharmaSpec, Shimadzu, Kyoto, Japan).

2.3. Statistical Analysis

All statistical analyses were performed using JMP[®] software, version 19.0 (SAS Institute Inc., Cary, NC, USA). Before conducting hypothesis testing, the normality of data distributions was verified using the Shapiro–Wilk test, and the assumption of homogeneity of variances was tested via Bartlett’s test. Because the assumptions for parametric testing (e.g., Student’s t-test or one-way analysis of variance) were not met in any case (due to non-normal data distribution and heteroscedasticity), we used the non-parametric one-way Wilcoxon test with a χ^2 approximation (equivalent to the Mann–Whitney U test) for all pairwise comparisons.

To evaluate the effect of tree age on physical characteristics, this non-parametric approach was employed to compare tree diameter (DBH), wound dimensions (length, width, area), and wound placement (distance from the ground to the lower and upper edges) between mid-aged and mature individuals. Furthermore, to assess baseline ontogenetic differences in primary metabolites, the concentrations of nitrogen, total non-structural carbohydrates (TNC), glucose, and the C:N ratio were compared between undamaged mid-aged and undamaged mature trees. Finally, to quantify the physiological response to bark stripping, the chemical profiles of damaged trees were compared against undamaged controls. Because the baseline chemical content was found to be strictly dependent on the developmental stage, these physiological comparisons were conducted separately within the mid-aged cohort and the mature cohort. In the reported results, *p*-values presented in bold indicate significant differences at $p < 0.05$. All figures present mean values with their corresponding standard errors.

3. Results

In total, 1456 mid-aged and 622 mature *P. serotina* individuals were recorded across all sample plots. Winter mortality was zero, ensuring the complete cohort was available for the spring assessment. After converting the obtained counts into density (per hectare), the density of mid-aged trees was more than twice as high as that of mature ones (Figure 1A). In addition to abundance, tree diameter at breast height (DBH) differed significantly between the two developmental stages, with mature individuals exhibiting substantially larger diameters (8.13 ± 0.70 cm) than mid-aged ones (3.67 ± 0.24 cm; $N = 60$; $F_{1,28} = 17.09$; $p < 0.0001$). The density of trees damaged both before winter (Figure 1B) and after winter (Figure 1C) was significantly higher in plots dominated by mature trees. It was also found that the increase in the density of damaged trees per hectare during winter was significantly higher in the mature-dominated site (Figure 1D). The high standard error observed in this parameter is driven by high spatial variance in the emergence of new wounds among the sampling plots. To account for the differences in total stand density and to standardize our measure of bark-stripping, we calculated the per-tree damage probability. Damaged individuals accounted for only 1.36% (± 0.29) of the total available mid-aged

trees, compared to a significantly higher proportion of 13.24% (± 3.44) among the available mature trees ($N = 30$; $F_{1,28} = 11.86$; $p = 0.0018$).

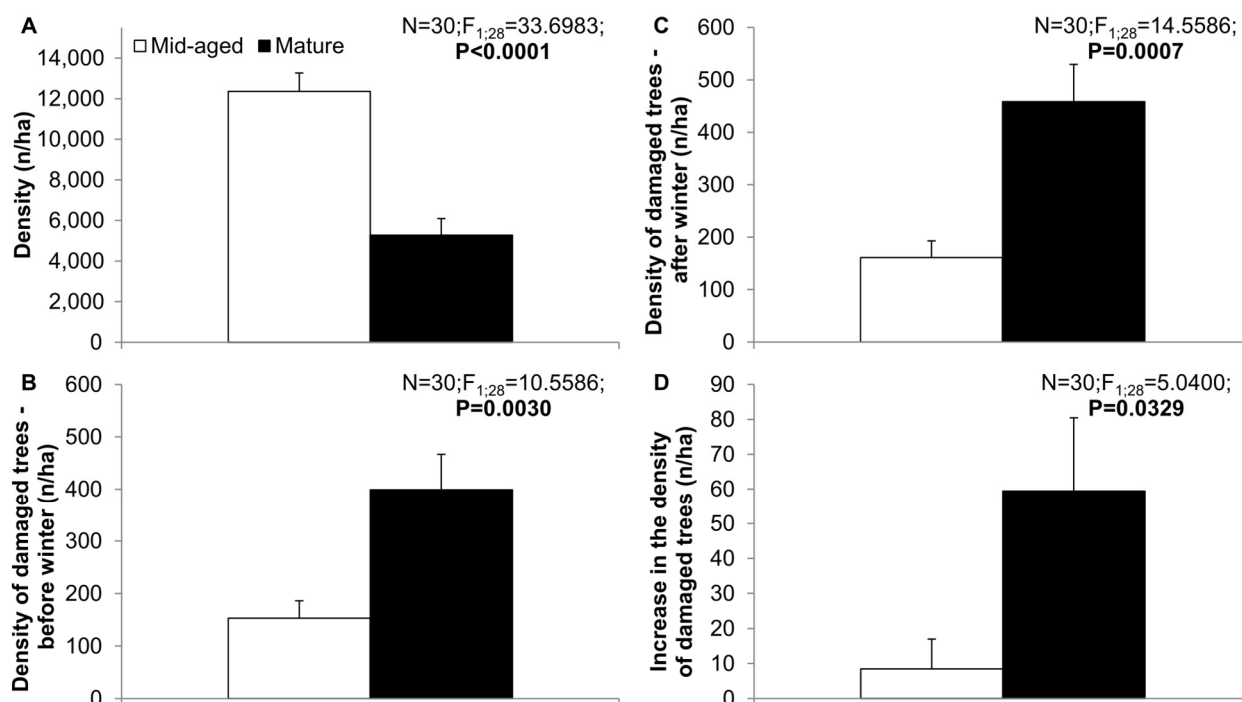


Figure 1. Comparison of *Prunus serotina* Ehrh. stand density and bark stripping incidence between plots dominated by mid-aged (white bars) and mature (black bars) trees. (A) Mean ($\pm$ SE) density of all trees per hectare; (B) mean ($\pm$ SE) density of previously damaged trees before the 2018/2019 winter; (C) mean ($\pm$ SE) density of damaged trees after the winter; and (D) mean ($\pm$ SE) winter increment in the density of damaged trees. The p -values derived from Generalized Linear Mixed Models (GLMMs) are presented above the bars, with bold font indicating statistically significant differences ($p < 0.05$).

During the field study, 73 instances of bark and phloem stripping (wounds) were measured on trees across the two developmental stages. Among them, 19 were located on sample plots dominated by mid-aged trees, and the remaining 54 were inventoried on plots dominated by mature ones. Both the distance from the ground to the lower edge of the damage, as well as to the upper edge, were significantly greater in mature trees (Figure 2A,B). Conversely, GLMM-based comparisons of wound dimensions revealed no significant differences in length, width, or total area between the two age classes (Figure 2C–E).

The baseline concentrations of primary metabolites in the phloem and bark of undamaged trees were determined to assess ontogenic nutritional differences (Figure 3). Nitrogen content (% dry mass) did not differ significantly between undamaged mid-aged and mature individuals ($N = 90$; $F_{1,28} = 0.1915$; $p = 0.6650$). Similarly, the mean C:N ratio in undamaged individuals showed no significant difference between the two developmental stages ($N = 90$; $F_{1,28} = 0.7714$; $p = 0.3873$). However, mean glucose content ($N = 60$; $F_{1,28} = 55.7372$; $p < 0.0001$) and total non-structural carbohydrates (TNC) content ($N = 60$; $F_{1,28} = 55.6309$; $p < 0.0001$) were both significantly higher in mid-aged individuals than in mature individuals.

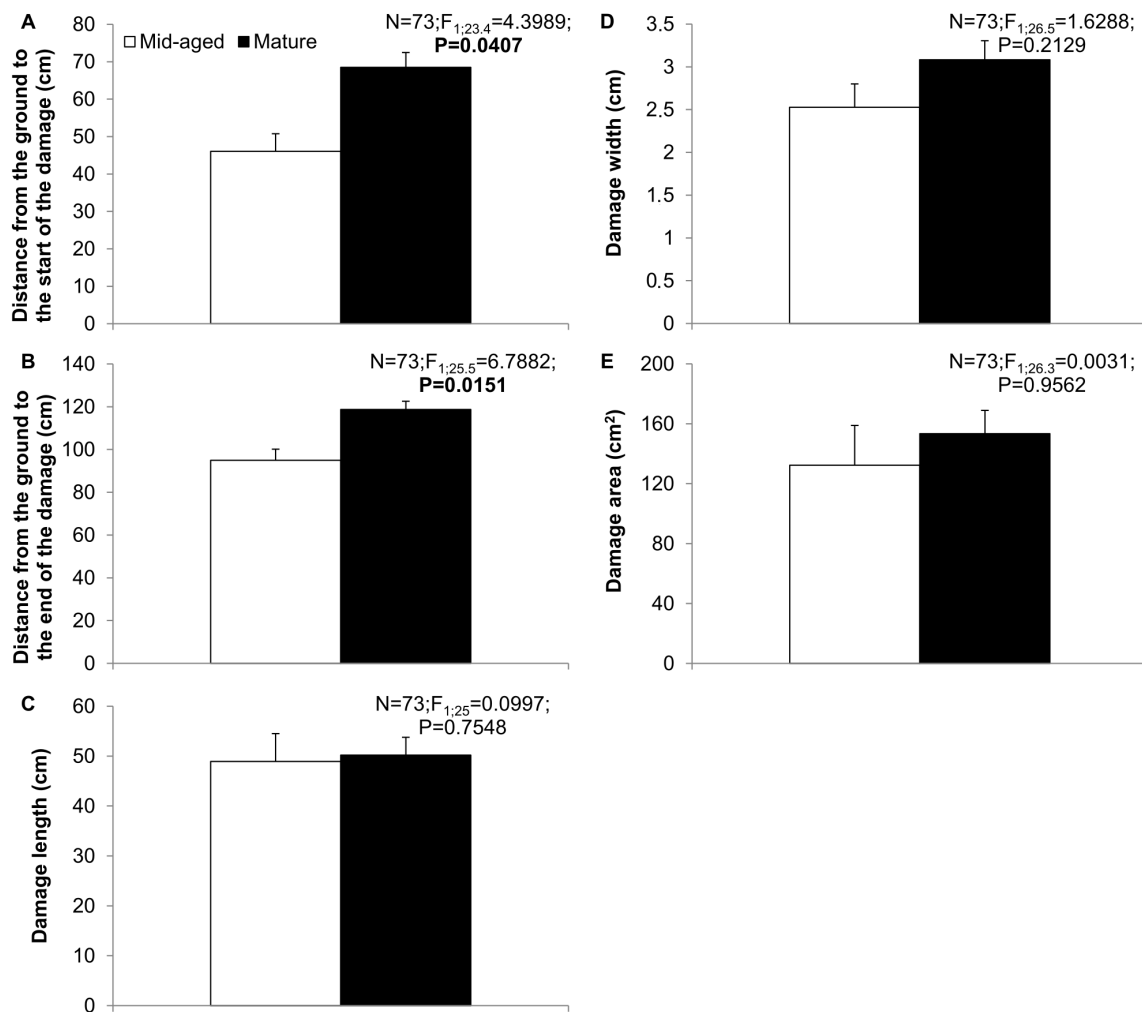


Figure 2. Characteristics of wounds caused by deer bark stripping on mid-aged and mature *Prunus serotina* Ehrh. trees. (A) Mean ($\pm$ SE) distance from the ground to the lower edge (start) of the wound; (B) mean ($\pm$ SE) distance from the ground to the upper edge (end) of the wound; (C) mean ($\pm$ SE) wound length; (D) mean ($\pm$ SE) wound width; and (E) mean ($\pm$ SE) wound area. The p -values derived from Generalized Linear Mixed Models (GLMMs) are presented above the bars, indicating the significance of differences between the two developmental stages. Bold font indicates statistically significant differences ($p < 0.05$).

To evaluate the differences in chemical composition associated with bark stripping, we compared the mean percentage of nitrogen between damaged and undamaged individuals of black cherry within each developmental stage.

Interestingly, mid-aged trees showed no significant chemical response to the damage; there were no significant differences in the mean percentage of nitrogen, C:N ratio, glucose, or TNC content between damaged and undamaged mid-aged trees (Figure 3A–D). In contrast, mature trees exhibited significant chemical alterations following bark stripping. Damaged mature individuals had a significantly higher mean nitrogen content (Figure 3A) and a correspondingly lower C:N ratio (Figure 3B) compared to their undamaged counterparts. Furthermore, the concentrations of both glucose (Figure 3C) and TNC (Figure 3D) were significantly lower in damaged mature trees than in undamaged mature controls.

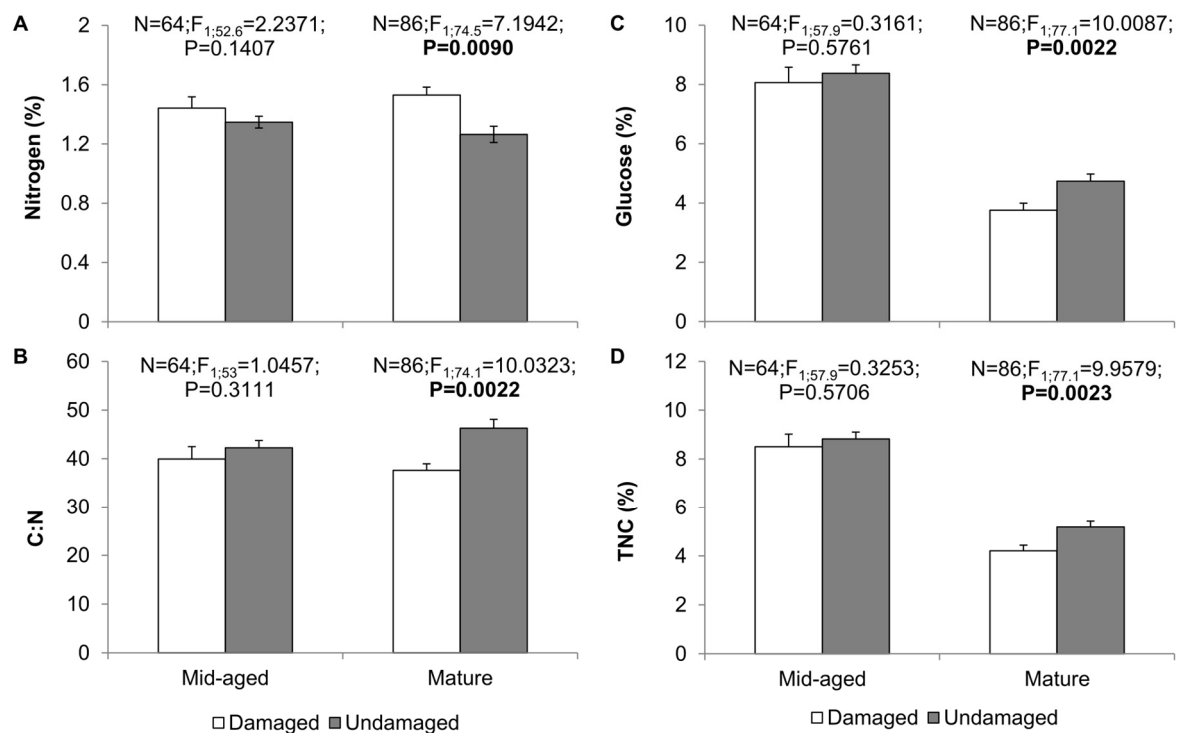


Figure 3. Chemical profiles of the bark and phloem of mid-aged and mature *Prunus serotina* Ehrh. trees in undamaged and bark-stripped (damaged) variants. (A) Mean ($\pm$ SE) percentage of nitrogen; (B) mean ($\pm$ SE) Carbon:Nitrogen ratio; (C) mean ($\pm$ SE) percentage of glucose; and (D) mean ($\pm$ SE) percentage of total non-structural carbohydrates (TNC) based on dry mass. Within each developmental stage, white bars represent damaged trees and gray bars represent undamaged trees. The p -values derived from Generalized Linear Mixed Models (GLMMs) represent pairwise comparisons between damaged and undamaged treatments within the respective developmental stage. Bold font indicates statistically significant differences ($p < 0.05$).

4. Discussion

To our knowledge, this research reports for the first time the phenomenon of bark stripping on black cherry (*P. serotina*) by deer in the area of its invasive range. The most important observation is that deer actively utilize black cherry as a food source, resulting in bark and phloem damage. However, it is likely not a highly desirable food item, as indicated by the small percentage of damaged trees on the sample plots. The recently observed mild winters in Central Europe, characterized by a lack of severe frosts, reduced snowfall, and relatively high temperature [64,65] may not encourage deer to intensively strip the bark of this geographically alien species. This is clearly shown by the very little increase in the number of wounds during the winter period of 2018/19. However, as local weather conditions and deer foraging activity were not monitored over multiple years, the potential influence of winter severity should be considered as a hypothesis rather than a demonstrated explanation for the observed pattern. It can be speculated that during harsh winters season with severe frosts, easily available food in the form of phloem and bark of black cherry may become a quite important in the dietary component for deer. Under such conditions, the energetic cost of foraging for higher-quality food might outweigh the benefits, prompting deer to utilize black cherry more frequently. Thus, most of the observed wounds were likely the result of foraging activity during earlier, harsher seasons.

The results of the field studies clearly show that there is no correlation between the number of damaged specimens and the total number of available trees per area unit. The areas covered with mid-aged black cherries are characterized by a very high stem density, which probably makes it difficult for deer to enter and navigate the stand, thus limiting

the use of this food resource. In addition, the smaller size of mid-aged trees (i.e., smaller trunk circumference, lower height) and high elasticity of the trunks make bark stripping mechanically more difficult in contrast to mature black cherry trees that have a much larger DBH. Both the distances from the ground to the lowest and the highest point of the damage were clearly higher in mature trees, which is a natural consequence of their greater height. It might seem that deer would be much more likely to strip mature trees due to better availability of food and the possibility of taking more bark from a single individual. However, it turned out that there are no significant differences between the length, width and area of wounds between trees of both studied tree age classes, which may indicate that deer, during a single act of consumption, consistently take a slice of plant material with a similar size (biomass). These observations differ from patterns recorded for bark stripping in other tree species, where wounds tend to be larger on trees with a larger girth. For example, in lodgepole pine *Pinus contorta* Dougl. ex Loud., the width of the damage is over three times greater, and the length is half as much compared to the black cherry [60]. The size of the damage to the black cherry was mostly similar to that observed for Sitka spruce *Picea sitchensis* (Bong.) Carr. [66], although in this species single wounds many times larger than those for black cherry were also observed [54]. The species-specific susceptibility to separating the bark and phloem from the xylem should also be taken into account, as well as the fact that in winter it is generally more difficult to separate these tissues [67]. In general, we did not observe more than one damage on the same individual made at different times. This indicates that after consuming a section of bark and phloem, deer do not continue feeding on it, nor do they return to the previously wounded individual. This observation is inconsistent with what has been reported for common beech *Fagus sylvatica* L. [19] or lodgepole pine [60], where deer returned to previously damaged and weakened individuals. Taking all the above into account, we can conclude that our hypothesis I was fully supported, whereas hypothesis II was only partially confirmed: while wounds occurred at different heights depending on tree age, their size did not differ significantly between mid-aged and mature individuals. Mid-aged black cherries were stripped to a lesser extent than mature ones.

Carbon and nitrogen are the most important macronutrients in the plant, serving as integral parts of the most important compounds for the organism's life [68–70]. An optimal ratio of carbon to nitrogen must be maintained for a plant to function efficiently. This is regulated by mechanisms sensing the C:N ratio, which activate nitrogen assimilation in the case of excess carbon skeletons and nitrogen deficiency, and stop nitrogen assimilation in the case of carbon deficiency and high nitrogen contents [68]. Here, it can be concluded that despite the age differences in black cherry, there are no differences in the baseline content of these key elements within undamaged tissues. The nitrogen content often turns out not to be stage-dependent but strongly correlated with photosynthesis and carbon metabolism [71]. The same is true for the carbon content of plant tissues, as it is adjusted to the nitrogen level [69]. Moreover, in damaged tissues of mature trees, there was a significantly lower C:N ratio (indicating a higher relative concentration of nitrogen) than in healthy tissues; however, this statistically significant response to bark stripping stress was noted only in mature trees. This may be due to the plant's induced defensive reaction, resulting in nitrogen translocation and the production of alkaloids, i.e., compounds containing large amounts of nitrogen [12,13,72,73]. These compounds are synthesized and accumulated in damaged tissues to protect against herbivores due to their harmful and toxic properties [12,74–76].

Analyses indicate a significantly higher content of glucose (which is the main component of TNC) in mid-aged black cherry specimens. The reason for this may be the fact that glucose indirectly influences the synthesis of auxins, which are responsible for stimulating

plant growth and are present in greater amounts in immature individuals that record greater growth rates than older individuals [77,78]. Another reason for such a difference may be the potentially different access of leaves to light, due to the varied structure of the crown, between mid-aged and mature individuals. The quantity and quality of solar radiation reaching the lower parts of the crown of older trees could be much weaker, which could reduce photosynthesis intensity and decrease glucose production during the growing season. A different mechanism of glucose allocation to different tissues may be just as likely. The greater glucose content in mid-aged trees is directly proportional to the greater content of TNC in them. Furthermore, the glucose content in undamaged black cherry tissues was significantly higher than in damaged tissues, but this significant difference occurred only in mature specimens. In this case, as with nitrogen, only mature trees reacted to bark stripping stress. It can be concluded that this difference is driven by the systemic defense response of these trees against herbivores, during which systemic reserves are mobilized or translocated away from potential attack sites, thereby reducing the nutritional value of tissues across the stem [14,79]. In general, herbivores avoid plants characterized by low nutritional value, manifested by a low content of nutritive nitrogen compounds and carbohydrates, alongside high concentrations of indigestible compounds such as lignin [18]. Studies examining tissue directly adjacent to wounds often report a localized accumulation of carbohydrates. For instance, in common beech (*F. sylvatica*), studied by Kurek et al. [19] in June, the carbohydrate concentration in the phloem right next to fresh stripping was up to three times higher due to a girdling-like interruption of transport, as bark stripping physically interrupts the phloem pathway and the movement of assimilates. In contrast, our systemic samples, taken from the opposite side of the trunk in early spring, revealed a decrease in glucose content in damaged mature trees. This highlights the fundamental difference between localized accumulation at wound sites during the peak growing season and systemic resource mobilization throughout the tree. Taking all the above into account, we can conclude that hypotheses III and IV have been partially positively verified. Mid-aged black cherries did not respond to damage in the form of changes in N content, C:N ratio, or carbohydrate content. On the other hand, mature individuals activated their induced systemic defense mechanisms, simultaneously increasing the relative amount of N and decreasing the content of non-structural carbohydrates.

An important factor determining the choice of food by deer is the development of various forms of defense by plants. One of them is the production of secondary metabolites such as terpenoids, alkaloids, and phenols [12,80]. These types of compounds most effectively protect the plant against generalist species, which also include deer [1,81,82]. One of the most important subgroups of terpenoids that influence the damage incidence of plants by deer are monoterpenes. The property of monoterpenes to deter deer is not taste but smell [83]. However, smell alone would not be an effective defense in the long term. It has been proven that monoterpenes in higher concentrations inhibit the growth of ruminal microorganisms. As a consequence, digestion is inhibited in ruminants such as deer [83,84]. It is highly possible that some of the glucose in trees damaged as a result of a defense reaction has been invested directly in the production of protective carbon-based metabolites, e.g., simple phenols or monoterpenes, although we have not studied this directly.

It is important to acknowledge certain limitations of our study. Firstly, a critical limitation of our study design is the complete nesting of tree developmental stages within the two study sites (i.e., mid-aged individuals located in Człuchów and mature individuals in Łopuchówko). These specific locations were purposively selected because they are well-known areas of active, confirmed cervid bark-stripping, which was an essential prerequisite for our field sampling. Consequently, the developmental class of the trees is inherently confounded with site-specific environmental conditions, local forest stand structure, and

the exact composition of the cervid community. Therefore, while our findings strongly align with ontogenetic theories of plant defense, any differences tentatively attributed to tree development must be interpreted cautiously, as they represent comparisons between two distinct, age-dominated site types. Future studies incorporating multi-site replication are required to definitively decouple the effects of ontogeny from local environmental drivers. Second, our inferences regarding deer behavior are based on ex post observations of tree damage rather than direct monitoring of feeding activity. Consequently, the exact timing of the older bark stripping events remains an estimate. Third, because our chemical analyses were strictly limited to primary metabolites (nitrogen and non-structural carbohydrates), our inferences regarding the subsequent production of secondary defense compounds (e.g., alkaloids or phenolics) and their actual effect on deer palatability and feeding behavior remain hypothetical and warrant future targeted research. It should be noted that, in our sampling design, damaged tissues were collected directly opposite the wound at varying heights, whereas undamaged controls were sampled at a fixed height of approximately 90 cm. While this standardization of controls was necessary to establish a consistent baseline, we acknowledge it as a minor limitation of the study, as metabolite concentrations can theoretically exhibit some vertical variation along the tree stem.

5. Conclusions

This study provides the first documented evidence that deer actively utilize the bark and phloem of invasive *P. serotina* in European forests, with both foraging patterns and the systemic chemical composition of the trees being highly dependent on plant age. Based on our findings, several key conclusions can be drawn:

- While wounds on both mid-aged and mature trees share similar dimensions, only mature individuals exhibit a distinct, systemic chemical defense response to bark stripping. Mature trees react by significantly reducing total non-structural carbohydrates (TNC) and lowering the C:N ratio (increasing the relative nitrogen pool) in tissues opposite the wound, indicating a systemic defense mechanism not observed in mid-aged trees.
- The induced chemical shifts in mature trees likely degrade the nutritional value and palatability of the local tissue. This systemic response explains the observed behavioral pattern: deer rarely return to feed on previously wounded individuals, actively avoiding tissues that have become energetically deficient or chemically deterrent. From an applied perspective, the most promising potential of these findings lies in invasive species management. Bark stripping creates vital entry points for pathogenic microorganisms and wood-decaying fungi, which are currently considered among the most viable biocontrol agents against *P. serotina*. However, while the physical damage from bark stripping could facilitate this pathogen ingress, our study did not measure secondary infections, subsequent tree decline, or broader demographic effects on the population. Therefore, the practical relevance of cervid bark stripping as an effective biocontrol strategy currently remains untested and requires long-term field validation. To advance this concept, future studies should prioritize the comprehensive chemical profiling of black cherry tissues to identify the specific secondary metabolites—both stimulants and deterrents—that drive damage probability by deer foraging behavior. Ultimately, if these mechanisms are fully understood, developing methods to safely attract deer to selectively strip *P. serotina* could naturally facilitate targeted pathogenic infections. While currently hypothetical, this approach could eventually offer a novel, environmentally friendly tool for foresters combatting this persistent invasive species.

Author Contributions: Conceptualization, M.J. and A.Ł.; Data curation, M.J. and A.Ł.; Formal analysis, M.J.; Methodology, M.J. and S.Ł.; Visualization, M.J.; Writing—original draft preparation, M.J.; Writing—review and editing, M.B., P.K., R.K., S.Ł. and A.Ł.; Validation, P.K. and A.Ł.; Funding acquisition, R.K.; Project administration, R.K.; Investigation, S.Ł.; Resources, A.Ł.; Supervision, A.Ł. All authors have read and agreed to the published version of the manuscript.

Funding: This study was co-financed by the State Forests National Forest Holding, General Directorate of the State Forests in Warsaw (Poland), programmed as “Development of methods for combating black cherry in pine stands” (Project number OR.271.3.13.2017), and also financially supported by the statutory activities of PULS and ID PAS.

Data Availability Statement: The data presented in this study are included in this published article.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Gebert, C.; Verheyden-Tixier, H. Variations of diet composition of red deer (*Cervus elaphus* L.) in Europe. *Mammal. Rev.* **2001**, *31*, 189–201. [\[CrossRef\]](#)
2. Apollonio, M.; Andersen, R.; Putman, R. (Eds.) *European Ungulates and Their Management in the 21st Century*; Cambridge University Press: Cambridge, UK, 2010.
3. Corlatti, L.; Zachos, F.E. (Eds.) *Terrestrial Cetartiodactyla*. In *Handbook of the Mammals of Europe*; Springer: Cham, Switzerland, 2022.
4. Melletti, M.; Focardi, S. (Eds.) *Deer of the World*; Princeton University Press: Princeton, NJ, USA, 2025.
5. Cuervo, M.; del Olmo, D.G.; Horcajada, D.; López-Sánchez, A.; Azcárate, F.M.; Perea, R.; Serrano, E.; Brolly, M.; Burnside, N.; San Miguel, A.; et al. Short-term effects of red deer overabundance on herbaceous communities in Mediterranean woody ecosystems. *Biol. Conserv.* **2025**, *311*, 111412. [\[CrossRef\]](#)
6. Dzieciółowski, R. Winter food of the red deer (*Cervus elaphus* L.) as determined by tracking routes. *Ekol. Pol. Ser. A* **1969**, *17*, 127–145.
7. Hofmann, R.R. Digestive physiology of the deer: Their morphophysiological specialisation and adaptation. In *Biology of Deer Production*; Fennessy, P.F., Drew, K.R., Eds.; The Royal Society of New Zealand: Wellington, New Zealand, 1985; pp. 393–407.
8. Putman, R. *The Natural History of Deer*; Cornell University Press: Ithaca, NY, USA, 1988.
9. Isla, J.; Serrano, E.; Calleja, J.A.; Hernández-Castellano, C.; Alcalá-Herrera, R.; Albanell, E.; Alonso, C.; Baraza, E.; Brolly, M.; Burnside, N.; et al. High Densities of Large Herbivores Rapidly Disrupt Ecosystem Integrity. *Glob. Change Biol.* **2026**, *32*, e70964. [\[CrossRef\]](#) [\[PubMed\]](#)
10. Torres-Blas, I.; Serra-Sarró, L.; Salgo-Periago, J.; Bartolomé, J.; Albanell, E.; Calleja, J.A.; Cardells, J.; Lavín, S.; Rello, C.; Perea, R.; et al. Role of plant nutritional value and physical traits on feeding preferences of red deer (*Cervus elaphus*) in a Mediterranean environment: A multiple-choice test. *Mamm. Biol.* **2026**, *106*, 719–730. [\[CrossRef\]](#)
11. Latham, J.; Staines, B.W.; Gorman, M.L. Comparative feeding ecology of red (*Cervus elaphus*) and roe deer (*Capreolus capreolus*) in Scottish plantation forests. *J. Zool.* **1999**, *247*, 409–418. [\[CrossRef\]](#)
12. Iason, G. The role of plant secondary metabolites in mammalian herbivory: Ecological perspectives. *Proc. Nutr. Soc.* **2005**, *64*, 123–131. [\[CrossRef\]](#) [\[PubMed\]](#)
13. Harborne, J.B. *Introduction to Ecological Biochemistry*; Elsevier Academic Press: London, UK, 1993.
14. Karban, R.; Myers, J.H. Induced plant responses to herbivory. *Annu. Rev. Ecol. Syst.* **1989**, *20*, 331–348. [\[CrossRef\]](#)
15. Wittstock, U.; Gershenzon, J. Constitutive plant toxins and their role in defense against herbivores and pathogens. *Curr. Opin. Plant Biol.* **2002**, *5*, 300–307. [\[CrossRef\]](#) [\[PubMed\]](#)
16. Kant, M.R.; Jonckheere, W.; Knecht, B.; Lemos, F.; Liu, J.; Schimmel, B.C.J.; Villarroel, C.A.; Ataíde, L.M.S.; Dermauw, W.; Glas, J.J.; et al. Mechanisms and ecological consequences of plant defence induction and suppression in herbivore communities. *Ann. Bot.* **2015**, *115*, 1015–1051. [\[CrossRef\]](#) [\[PubMed\]](#)
17. Poelman, E.H. From induced resistance to defence in plant-insect interactions. *Entomol. Exp. Appl.* **2015**, *157*, 11–17. [\[CrossRef\]](#)
18. Koricheva, J.; Nykänen, H.; Gianoli, E. Meta-analysis of trade-offs among plant antiherbivore defenses: Are plants jacks-of-all-trades, masters of all? *Am. Nat.* **2004**, *163*, E64–E75. [\[CrossRef\]](#) [\[PubMed\]](#)
19. Kurek, T.; Todys, J.; Pazdrowski, W.; Szymański, M.; Łukowski, A. Intensity of stripping and sugar content in the bark and the bast of European beech (*Fagus sylvatica*). *Open Life Sci.* **2019**, *14*, 19–28. [\[CrossRef\]](#) [\[PubMed\]](#)
20. Verheyden-Tixier, H.; Renaud, P.C.; Morellet, N.; Jamot, J.; Besle, J.M.; Dumont, B. Selection for nutrients by red deer hinds feeding on a mixed forest edge. *Oecologia* **2008**, *156*, 715–726. [\[CrossRef\]](#) [\[PubMed\]](#)

21. Pairon, M.; Petitpierre, B.; Campbell, M.; Guisan, A.; Broennimann, O.; Baret, P.V.; Jacquemart, A.L.; Besnard, G. Multiple introductions boosted genetic diversity in the invasive range of black cherry (*Prunus serotina*; Rosaceae). *Ann. Bot.* **2010**, *105*, 881–890. [[CrossRef](#)] [[PubMed](#)]
22. Starfinger, U. Introduction and naturalization of *Prunus serotina* in central Europe. In *Plant Invasions: Studies from North America and Europe*; Backhuys Publishers: Kerkwerve, The Netherlands, 1997; pp. 161–171.
23. Zajac, A.; Zajac, M. *Distribution Atlas of Vascular Plants in Poland*; Institute of Botany, Jagiellonian University: Kraków, Poland, 2001.
24. Chabrierie, O.; Loinard, J.; Perrin, S.; Saguez, R.; Decocq, G. Impact of *Prunus serotina* invasion on understory functional diversity in a European temperate forest. *Biol. Invasions* **2010**, *12*, 1891–1907. [[CrossRef](#)]
25. Halarewicz, A. The reasons underlying the invasion of forest communities by black cherry, *Prunus serotina* and its subsequent consequences. *For. Res. Pap.* **2011**, *72*, 267–272. [[CrossRef](#)]
26. Bijak, S.; Czajkowski, M.; Ludwisiak, Ł. Occurrence of black cherry (*Prunus serotina* Ehrh.) in the State Forests in Poland. *For. Res. Pap.* **2014**, *75*, 359–365. [[CrossRef](#)]
27. Seneta, W. *Dendrologia*; Państwowe Wydawnictwa Naukowe: Warszawa, Poland, 1973.
28. Namura-Ochalska, A. Walka z czeremchą amerykańską *Padus serotina* (Ehrh.) Borkh.—Ocena skuteczności wybranych metod w karpinoskim parku narodowym. *Stud. Mater. CEPL* **2012**, *33*, 190–200. (In Polish)
29. Starfinger, U. Population biology of an invading tree species—*Prunus serotina*. In *Species Conservation: A Population-Biological Approach*; Springer: Berlin/Heidelberg, Germany, 1991; pp. 171–184.
30. Deckers, B.; Verheyen, K.; Vanhellemont, M.; Maddens, E.; Muys, B.; Hermy, M. Impact of avian frugivores on dispersal and recruitment of the invasive *Prunus serotina* in an agricultural landscape. *Biol. Invasions* **2008**, *10*, 717–727. [[CrossRef](#)]
31. Dyderski, M.K.; Jagodziński, A.M. How do invasive trees impact shrub layer diversity and productivity in temperate forests? *Ann. For. Sci.* **2021**, *78*, 55. [[CrossRef](#)]
32. Jabłoński, B. The beekeeping value of the black cherry. *Pszczelarstwo* **1998**, *49*, 8–9. (In Polish)
33. Deckers, B.; Verheyen, K.; Hermy, M.; Muys, B. Effects of landscape structure on the invasive spread of black cherry *Prunus serotina* in an agricultural landscape in Flanders, Belgium. *Ecography* **2005**, *28*, 99–109. [[CrossRef](#)]
34. Higgins, S.I.; Richardson, D.M. Predicting plant migration rates in a changing world: The role of long-distance dispersal. *Am. Nat.* **1999**, *153*, 464–475. [[CrossRef](#)] [[PubMed](#)]
35. Cain, M.L.; Milligan, B.G.; Strand, A.E. Long-distance seed dispersal in plant populations. *Am. J. Bot.* **2000**, *87*, 1217–1227. [[CrossRef](#)] [[PubMed](#)]
36. Closset-Kopp, D.; Chabrierie, O.; Valentin, B.; Delachapelle, H.; Decocq, G. When Oskar meets Alice: Does a lack of trade-off in r/K-strategies make *Prunus serotina* a successful invader of European forests? *For. Ecol. Manag.* **2007**, *247*, 120–130. [[CrossRef](#)]
37. Bellon, S.; Tumiłowicz, J.; Król, S. *Obce Gatunki Drzew w Gospodarstwie Leśnym*; PWRiL: Warsaw, Poland, 1977. (In Polish)
38. Robakowski, P.; Bieliniś, E.; Stachowiak, J.; Bułaj, B. Wzrost, zawartość azotu w liściach i lotne związki allelochemiczne siewek dębu bezszypułkowego *Quercus petraea* i czeremchy amerykańskiej *Prunus serotina* w różnych warunkach ocienienia i konkurencji. *Stud. Mater. CEPL* **2012**, *33*, 208–216. (In Polish)
39. Bączek, P.; Halarewicz, A. Effect of black cherry (*Prunus serotina*) litter extracts on germination and growth of Scots pine (*Pinus sylvestris*) seedlings. *Pol. J. Ecol.* **2019**, *67*, 137–146. [[CrossRef](#)]
40. Hierro, J.L.; Callaway, R.M. Allelopathy and exotic plant invasion. *Plant Soil* **2003**, *256*, 29–39. [[CrossRef](#)]
41. Callaway, R.M.; Ridenour, W.M. Novel weapons: Invasive success and the evolution of increased competitive ability. *Front. Ecol. Environ.* **2004**, *2*, 436–443. [[CrossRef](#)]
42. Karolewski, P.; Łukowski, A.; Adamczyk, D.; Żmuda, M.; Giertych, M.J.; Mąderek, E. Species composition of arthropods on six understory plant species growing in high and low light conditions. *Dendrobiology* **2020**, *84*, 58–80. [[CrossRef](#)]
43. Vanhellemont, M.; Verheyen, K.; De Keersmaeker, L.; Vandekerckhove, K.; Hermy, M. Does *Prunus serotina* act as an aggressive invader in areas with a low propagule pressure? *Biol. Invasions* **2009**, *11*, 1451–1462. [[CrossRef](#)]
44. Halarewicz, A.; Jackowski, J. Leaf damage of the black cherry, *Prunus serotina* Ehrh., by the leaf beetle, *Gonioctena quinquepunctata* Fabr.: An accidental foraging on a neophytic host, or an established trophic link? *Pol. J. Ecol.* **2011**, *59*, 589–597.
45. Karolewski, P.; Łukowski, A.; Walczak, U.; Baraniak, E.; Mucha, J.; Giertych, M.J. Larval food affects oviposition preference, female fecundity and offspring survival in *Yponomeuta evonymellus*. *Ecol. Entomol.* **2017**, *42*, 657–667. [[CrossRef](#)]
46. Poyet, M.; Eslin, P.; Héraude, M.; Le Roux, V.; Prévost, G.; Gibert, P.; Chabrierie, O. Invasive host for invasive pest: When the Asiatic cherry fly (*Drosophila suzukii*) meets the American black cherry (*Prunus serotina*) in Europe. *Agric. For. Entomol.* **2014**, *16*, 251–259. [[CrossRef](#)]
47. Vanhellemont, M.; Baeten, L.; Smeets, A.; Mertens, J.; Verheyen, K. Spatio-temporal variation in seed predation by a native weevil in the invasive *Prunus serotina*. *Flora* **2014**, *209*, 495–502. [[CrossRef](#)]
48. Dzięciołowski, R. Food selectivity in the red deer towards twigs of trees, shrubs, and dwarf-shrubs. *Acta Theriol.* **1970**, *15*, 13–23. [[CrossRef](#)]

49. Gill, R.M.A. A review of damage by mammals in north temperate forests: 3. Impact on trees and forests. *Forestry* **1992**, *65*, 363–388. [\[CrossRef\]](#)
50. Hasstedt, S.L.; Annighöfer, P. Initial Survival and Development of Planted European Beech (*Fagus sylvatica* L.) and Small-Leaved Lime (*Tilia cordata* Mill.) Seedlings Competing with Black Cherry (*Prunus serotina* Ehrh.). *Plants* **2020**, *9*, 677. [\[CrossRef\]](#) [\[PubMed\]](#)
51. Candaele, R.; Lejeune, P.; Licoppe, A.; Malengreaux, C.; Brostaux, Y.; Morelle, K.; Latte, N. Mitigation of bark stripping on spruce: The need for red deer population control. *Eur. J. For. Res.* **2021**, *140*, 227–240. [\[CrossRef\]](#)
52. Welch, D.; Scott, D. Bark-stripping damage by red deer in a Sitka spruce forest in western Scotland: IV. Survival and performance of wounded trees. *Forestry* **1998**, *71*, 225–235. [\[CrossRef\]](#)
53. Vasiliauskas, R.; Stenlid, J. Discoloration following bark stripping wounds on *Fraxinus excelsior*. *Eur. J. For. Pathol.* **1998**, *28*, 383–390. [\[CrossRef\]](#)
54. Di Bitetti, M.S. Primates bark-stripping trees in forest plantations—A review. *For. Ecol. Manag.* **2019**, *449*, 117482. [\[CrossRef\]](#)
55. Vacek, Z.; Cukor, J.; Linda, R.; Vacek, S.; Šimůnek, V.; Brichta, J.; Gallo, J.; Prokúpková, A. Bark stripping, the crucial factor affecting stem rot development and timber production of Norway spruce forests in Central Europe. *For. Ecol. Manag.* **2020**, *474*, 118360. [\[CrossRef\]](#)
56. Krisans, O.; Saleniece, R.; Rust, S.; Elferts, D.; Kapostins, R.; Jansons, A.; Matisons, R. Effect of bark-stripping on mechanical stability of Norway Spruce. *Forests* **2020**, *11*, 357. [\[CrossRef\]](#)
57. Korzeniewicz, R.; Baranowska, M.; Behnke-Borowczyk, J. The effect of size of black cherry stumps on the composition of fungal communities colonising stumps. *Open Life Sci.* **2019**, *14*, 482–493. [\[CrossRef\]](#) [\[PubMed\]](#)
58. Łukowski, A.; Korzeniewicz, R.; Kowalkowski, W.; Jakubowski, M.; Krupiński, D.; Baranowska, M. Assessment of sodium chloride application for controlling invasive black cherry *Prunus serotina* Ehrh. *Sylvan* **2024**, *168*, 656–673.
59. Łukowski, A.; Jessa, M.; Duk, K.; Korzeniewicz, R.; Kowalkowski, W.; Szewczyk, W.; Baturo-Cieśniewska, A.; Baranowska, M. Directing wild boar behaviour through food-based baiting to increase suppression of *Prunus serotina* Ehrh. regeneration. *Sylvan* **2026**, *170*, 357–374. [\[CrossRef\]](#)
60. Archipova, N.; Jansons, A.; Zaluma, A.; Gaitnieks, T.; Vasaitis, R. Bark stripping of *Pinus contorta* caused by moose and deer: Wounding patterns, discoloration of wood, and associated fungi. *Can. J. For. Res.* **2015**, *45*, 1434–1438. [\[CrossRef\]](#)
61. Burneviča, N.; Jansons, Ā.; Zaluma, A.; Kļaviņa, D.; Jansons, J.; Gaitnieks, T. Fungi inhabiting bark stripping wounds made by large game on stems of *Picea abies* (L.) Karst. in Latvia. *Balt. For.* **2016**, *22*, 2–7.
62. Marciszewska, K.; Szczepkowski, A.; Otręba, A.; Oktaba, L.; Kondras, M.; Zaniewski, P.; Ciurzycki, W.; Wojtan, R. The dynamics of sprouts generation and colonization by macrofungi of black cherry *Prunus serotina* Ehrh. eliminated mechanically in the Kampinos National Park. *Folia For. Pol. Ser. A* **2018**, *60*, 34–51. [\[CrossRef\]](#)
63. Karolewski, P.; Giertych, M.J.; Żmuda, M.; Jagodziński, A.M.; Oleksyn, J. Season and light affect constitutive defenses of understory shrub species against folivorous insects. *Acta Acol.* **2013**, *53*, 19–32. [\[CrossRef\]](#)
64. Kundzewicz, Z.W.; Matczak, P. Climate change regional review: Poland. *Wiley Interdiscip. Rev. Clim. Change* **2012**, *3*, 297–311. [\[CrossRef\]](#)
65. Szwed, M. Variability of precipitation in Poland under climate change. *Theor. Appl. Climatol.* **2019**, *135*, 1003–1015. [\[CrossRef\]](#)
66. Welch, D.; Scott, D.; Staines, B.W. Bark stripping damage by red deer in a sitka spruce forest in Western Scotland III. Trends in wound condition. *Forestry* **1997**, *70*, 113–120.
67. Klich, D. Selective bark stripping of various tree species by Polish horses in relation to bark detachability. *For. Ecol. Manag.* **2017**, *384*, 65–71. [\[CrossRef\]](#)
68. Hamilton, J.; Zangerl, A.; DeLucia, E.; Berenbaum, M. The carbon-nutrient balance hypothesis: Its rise and fall. *Ecol. Lett.* **2001**, *4*, 86–95. [\[CrossRef\]](#)
69. Starck, Z. Multiple functions of carbon and nitrogen in plants. *Kosmos* **2006**, *55*, 243–257.
70. Imaji, A.; Seiwa, K. Carbon allocation to defense, storage, and growth in seedlings of two temperate broad-leaved tree species. *Oecologia* **2010**, *162*, 273–281. [\[CrossRef\]](#) [\[PubMed\]](#)
71. Starck, Z. Integration of biomass partitioning in the whole organism includes total export from photosynthate donors and partitioning of assimilates between various sinks. *Zesz. Probl. Postępów Nauk. Rol.* **2002**, *481*, 113–123.
72. Ando, M.; Yokota, H.O.; Shibata, E. Bark stripping preference of sika deer, *Cervus nippon*, in terms of bark chemical contents. *For. Ecol. Manag.* **2003**, *177*, 323–331. [\[CrossRef\]](#)
73. Pagare, S.; Bhatia, M.; Tripathi, N.; Pagare, S.; Bansal, Y.K. Secondary metabolites of plants and their role: Overview. *Curr. Trends Biotechnol. Pharm.* **2015**, *9*, 293–304.
74. Wink, M. The role of quinolizidine alkaloids in plant-insect interaction. In *Focus on Insect Plant Interactions*; CRC Press: Boca Raton, FL, USA, 1992; Volume 4, pp. 131–166.
75. Bennett, R.; Wallsgrove, R. Secondary metabolites in plant defence mechanisms. *New Phytol.* **1994**, *127*, 617–633. [\[CrossRef\]](#) [\[PubMed\]](#)

76. Macel, M. Attract and deter: A dual role for pyrrolizidine alkaloids in plant-insect interactions. *Phytochem. Rev.* **2011**, *10*, 75–82. [[CrossRef](#)] [[PubMed](#)]
77. Wang, L.; Ruan, Y.L. Regulation of cell division and expansion by sugar and auxin signaling. *Front. Plant Sci.* **2013**, *4*, 163. [[CrossRef](#)] [[PubMed](#)]
78. Ljung, K.; Nemhauser, J.L.; Perata, P. New mechanistic links between sugar and hormone signalling networks. *Curr. Opin. Plant Biol.* **2015**, *25*, 130–137. [[CrossRef](#)] [[PubMed](#)]
79. Herms, D.A.; Mattson, W.J. The dilemma of plants: To grow or defend. *Q. Rev. Biol.* **1992**, *67*, 283–335. [[CrossRef](#)]
80. Cunningham, J.P.; West, S.A.; Zalucki, M.P. Host selection in phytophagous insects: A new explanation for learning in adults. *Oikos* **2001**, *95*, 537–543. [[CrossRef](#)]
81. Bernays, E.A.; Woodhead, S. Plant phenols utilized as nutrients by a phytophagous insect. *Science* **1982**, *216*, 201–203. [[CrossRef](#)] [[PubMed](#)]
82. Appel, H.M.; Martin, M.M. Gut redox conditions in herbivorous lepidopteran larvae. *J. Chem. Ecol.* **1990**, *16*, 3277–3290. [[CrossRef](#)] [[PubMed](#)]
83. Vourc'h, G.; De Garine-Wichatitsky, M.; Labbé, A.; Rosolowski, D.; Martin, J.L.; Fritz, H. Monoterpene effect on feeding choice by deer. *J. Chem. Ecol.* **2002**, *28*, 2411–2427. [[CrossRef](#)] [[PubMed](#)]
84. Welch, B.L.; Pederson, J.C. In vitro digestibility among accessions of big sagebrush by wild mule deer and its relationship to monoterpenoid content. *J. Range Manag.* **1981**, *34*, 497–500. [[CrossRef](#)]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.