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Evaluation of damage to forest tree plantations by wild boar in the Czech Republic

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Abstract: Wild boar (*Sus scrofa*) populations in Central Europe have been growing long-term, and damages to crops and forests where boars damage freshly planted tree seedlings are growing too. In addition to having a significant economic impact, these damages worsen the prospect of successful restoration of bare land. This study presents an analysis of damage to tree seedling plantations caused by wild boar in the Czech Republic. We used data from an extensive questionnaire survey among forest owners, our own survey of the extent of damage in model areas, and experiments in locations with a large boar population. Damage to plantings is a widespread phenomenon, and up to 80% of planted trees may be damaged in heavily affected locations. The wild boar does not differentiate between bareroot or containerized seedlings or tree species. Trees were often simply pulled out, without any traces of damage to the root system. Wild boar preferences were not affected by the composition of the substrate of containerized seedlings. Seedlings were damaged most often during the 4 weeks after planting; after this period, the risk of damage fell considerably. Based on the obtained data, we estimated that the damage caused by wild boar rooting out seedlings in 2019 throughout the Czech Republic amounted to $3,199,200 USD, which is equivalent to $122 USD per km^2 of forest land. As we are not currently aware of any method of protection against this damage, the most expedient solution seems to be the reduction of the wild boar population, as well as to monitor and protect freshly established cultures, for a period of at least 4 weeks after planting.

Key words: damage, damage quantification, human–wildlife conflict, rooting out trees, seedlings, wild boar

The wild boar (*Sus scrofa*) is an autochthonous European species, which currently finds favorable living conditions in the landscape of Central Europe and is subject to very limited regulation mechanisms due to global climate changes and the absence of predation pressure from large predators (Barrios-García and Ballari 2012). The wild boar has high nutritional requirements. The species is easily adaptable to many environments, including human-dominated areas, reproduces at a young age, and produces large litters (Vetter et al. 2020). Practically the only significant regulatory mechanism applicable to the boar population is hunting, but despite many years of efforts to reduce the number of boar, this method is not sufficient, and the boar population throughout Central Europe continues to grow (Keuling et al. 2013, Massei et al. 2015). The high number of boar leads to a serious economic, biological, and social consequences. Most importantly, boar in many locations have become one of the most significant pests damaging agricultural production. Pork production and trade have also been endangered in recent years as a result of the spread of African swine fever among the wild boar population (Costard et al. 2015). The consequences of frequent traffic accidents involving wild boar are also significant. Wild boar populations living in towns have a negative impact on the everyday lives of these towns' inhabitants, and the food behavior of boar has a significant impact on biodiversity (Massei and Genov 2004).

The wild boar leads a hidden way of life and successfully makes use of fields where crops are grown as well as forests where it finds food and cover during the growing season. It is only after

the crops have been harvested that the wild boar moves into the forests, where it remains throughout the winter. The occurrence of boar in the forests is generally considered not very problematic, unlike that of herbivorous ungulates, for whom woody plants are a basic food element. Under specific conditions, the food behavior of boar is actually beneficial because by rooting in the soil and disturbing the sod, they facilitate the sprouting and growing of tree seeds and also consume insect and rodent pests (Mayer et al. 2000, Mori et al. 2020).

Despite this, there is an increasing number of regions where extensive boar populations have a significant impact on the success of reforestation and cause considerable economic losses. In higher numbers, boar may consume all surpluses of attractive seeds during the winter and thereby prevent natural forest renewal or growth (Kamler et al. 2016). Additional damages to growth result from gnawing on young trees and abrading trunks and roots; indirect damages to forests caused by damage to fencing and the surfaces of forest roads are also significant.

The spruce forest in Central Europe is collapsing, and enormous areas of forests should be renewed. Damage by wild boar, which are systematically destroying planted seedlings, is getting more and more significant (Fern et al. 2020). We have been aware of this boar behavior for some years, but it has only become significant in some places in recent years. This means that the boar has become another factor complicating forest renewal or growth, in addition to the reduced viability of seedlings due to lack of rain, frost, or gnawing by ruminants (e.g., Haaverstad et al. 2013).

Locally, the damages caused by boar in the field of forestry management are larger than those resulting from all other factors combined. Most often, boar cause damage to newly planted seedlings, which they pull or root out, sometimes gnaw on the roots, or leave them lying without any trace of damage. According to 1 hypothesis, the boar only chew on the roots to reach the sap and the starch (Wood and Roark 1980) and then spit out the damaged seedling. However, a bared root system means that it dries out and the seedling dies. Another attraction may be the aroma of some tree species or the method of site preparation before planting (Mayer et al. 2000). The intensity of damage to planted seedlings varies greatly, even within small forest complexes, where we can find areas that are completely undamaged next to areas with practically no seedling left untouched. Thus, it is very difficult to identify a clear cause. It can be expected that the intensity of damage to seedlings is affected by a specific combination of numerous conditions: available food, availability and age of seedlings, season, boar population density, hunting pressure, soil cover, and soil moisture (Fern et al. 2020). Young trees are most vulnerable to these effects during the first few years after planting (Sweeney et al. 2003, Mayer 2009).

The purpose of this descriptive study was (1) to establish the significance, scope, and distribution of damage to planted tree seedlings caused by boar in the Czech Republic, (2) to determine the extent of damage and the possible impact of selected environmental characteristics, and (3) to establish the risk of damage in relation to seedling parameters. We assumed that the higher intensity of damage to containerized seedlings (container-grown seedlings) was due to the presence of fertilized substrate.

Methods

We based the study on 3 groups of data obtained in 2019: questionnaire of forest owners throughout the country, our own survey mapping endangered regions, and experiments in localities of high boar density. The average annual Czech National Bank exchange rate for 2019 (i.e., 22.93 CZK [Czech koruna] to $1 USD), was used to convert economic losses. The data about numbers and prices of planted seedlings were obtained from the Czech Statistical Office, companies, and forest owners.

Questionnaire survey

We used electronic questionnaires to estimate wild boar damage to plantations throughout the Czech Republic. In 2019, we sent the interactive form to the large forest owners (public and private forests), who jointly manage approximately 75% of the forests in the Czech Republic. The basic spatial unit in the questionnaire was the hunting ground, which allowed for easier localization and for a more detailed data classification, and thus more accurate evaluation. We distributed 586 questionnaires and obtained data from 316 hunting grounds.

Table 1. Number of areas in regions selected for field research of wild boar (*Sus scrofa*) damage in the Czech Republic in 2019 and their main characteristics.

Area	Main type of forest	Average altitude (m)	Number of areas
Českomoravská vrchovina	Mixed forest	550	18
Brněnská vrchovina	Mixed forest	227	12
Středomoravské Karpaty	Deciduous forest	282	11
Západobeskydské podhůří	Mixed forest	353	13
Slovensko-moravské Karpaty	Mixed forest	404	14
Západní Vněkarpatské sníženiny	Deciduous forest	237	9

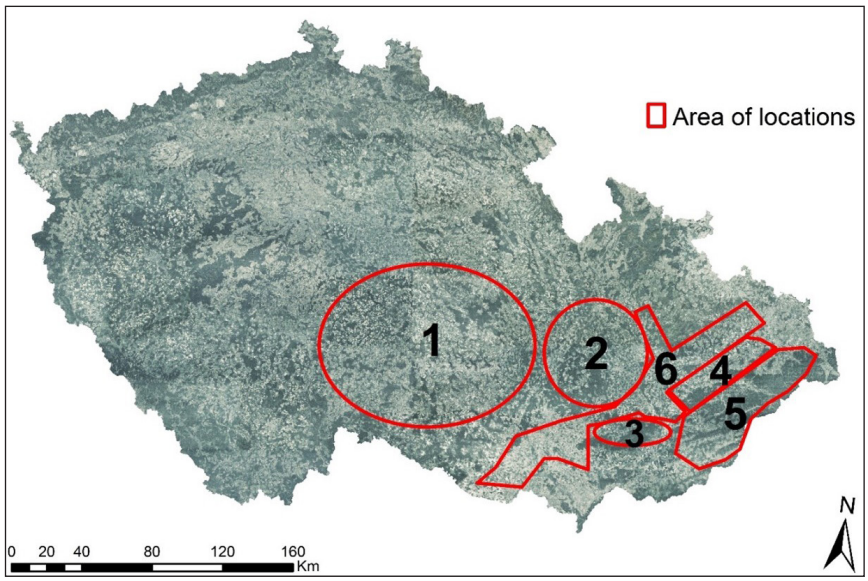

Figure 1. Selected regions for field survey of wild boar (*Sus scrofa*) damage in the Czech Republic in 2019. Area of locations: (1) Českomoravská vrchovina, (2) Brněnská vrchovina, (3) Středomoravské Karpaty, (4) Západobeskydské podhůří, (5) Slovensko-moravské Karpaty, (6) Západní Vněkarpatské sníženiny.

This corresponds to an area of approximately 3,745 km^2. In the questionnaire, we established whether damages occurred in the specific location, their intensity, the most frequently damaged tree species, the differences between damages to bareroot and containerized seedlings, the effect of the planting time on the value of damages, and how long this type of damage had been occurring in practice.

The questionnaire contained a solemn declaration by the respondents about their consent to participate in the research and the use of all the provided data to objectively evaluate the answers obtained. The questionnaire did not ask for any confidential or otherwise protected information.

Survey of damage in selected regions

From the questionnaire responses, we chose regions where boar damages were more extensive and performed our own survey of planting. We chose the individual control areas randomly while driving through the location in a vehicle. The characteristics of the regions are described (Table 1; Figure 1). In each newly planted clearing, we examined 500 seedlings in each commenced hectare, and at the time the examined seedlings were uniformly distributed throughout the entire area of the clearing. The obtained data were recalculated for the entire area and then statistically analyzed. We monitored the proportion of damaged seedlings in relation to planting time (spring/autumn),

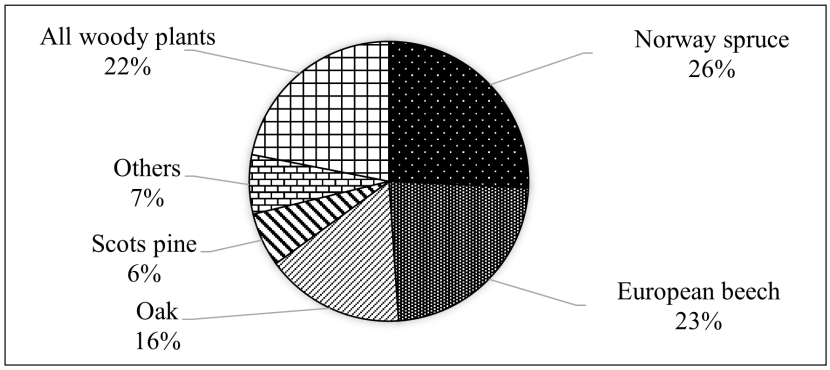

Figure 2. Woody plants most frequently damaged by wild boar (*Sus scrofa*) in the Czech Republic in 2019, according to the evaluated questionnaire (%).

method of growing the seedlings (bareroot/containerized planting), and tree species.

Experimental planting

We planted an experimental area to record some aspects of rooting, which required regular monitoring—in particular, root system attractiveness, highest risk period, and age of boar involved in rooting. To carry out this experiment, we chose a location with a high concentration of wild boar and red deer and planted the seedlings inside fenced bare land, which was accessible to the boar through openings in the fence fitted with sliding gates (49°3.05433'N, 16°24.78545'E). The boar regularly used the fence gates, and the effect of other wild animals was eliminated. This fenced area was 0.5 km^2 large and was located at an altitude of 250 m above sea level, with mostly oak (*Quercus robur* and *Q. petraea*) forests located in its vicinity. There, we planted bareroot and containerized oak and beech (*Fagus sylvatica*) seedlings in several phases. The individual rows were spaced 1 m apart, and there were 50 seedlings in each row. For easier inspection, the seedlings were marked with a specific color for each individual variant. Evaluation took place at weekly intervals for a period of 4 weeks.

To test the root system attractiveness, we inserted pegs approximately 30 cm long and with a diameter of 1 cm, made from cut willow branches. Another option used for testing was empty holes without any seedlings. We marked these with a cross painted over the center of the hole to allow inspection of whether pigs had rooted there. We had photo-traps permanently installed in the location, which monitored boar movement and behavior in short video sequences.

Statistical analysis was performed in STATISTICA 12. One-way ANOVA was used to establish the dependence of the number of planted seedlings on qualitative variables (presence/absence of seedling covering, groups of trees, tree species). The level of significance was 0.05, so $P < 0.05$ meant rejection of the null hypothesis (significance).

Results

During the monitored year of 2019, the total area of forest land in the Czech Republic was 26,138 km^2. Nearly 180 million forest tree seedlings were planted, and the average price was $0.40 USD per 1 seedling. The average area of the hunting ground was 11.8 km^2.

Questionnaire survey

The most important indicator in the questionnaire was the total annual volume of damage. On average, 4.49% of the planted seedlings were damaged, according to the responses. To quantify the number of destroyed seedlings in the Czech Republic, we applied this percentage to the total number of planted trees. It is clear from this calculation that approximately 7,998 seedlings were damaged in 2019. This is $3 million USD, when expressed in monetary value. We recalculated the data for the total area of forest land in the Czech Republic, and the result was damages of $122 USD per km^2.

Another result we obtained from the questionnaire was damage to seedlings according to tree species (Figure 2). The most frequently damaged species was Norway spruce (*Picea*

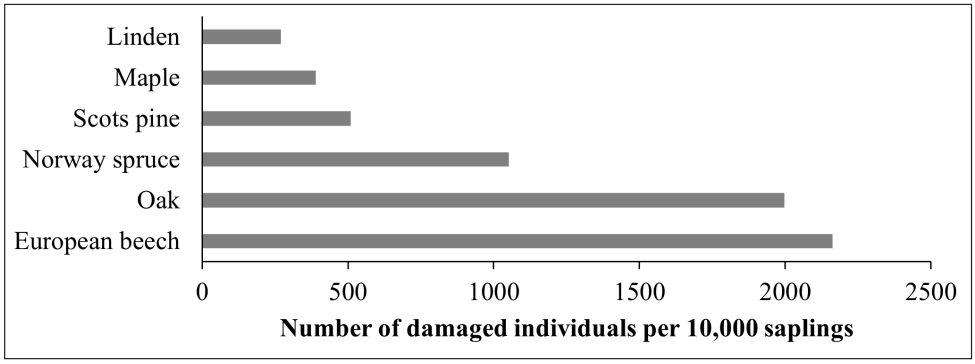

Figure 3. Intensity of wild boar (*Sus scrofa*) damage to selected woody plants in the Czech Republic in 2019.

abies), which was mentioned in 26% of the responses. It was followed by European beech with 23%, oak with 16%, and Scots pine (*Pinus sylvestris*) with 6% of the responses. Seven percent of the people questioned specified other tree species: fir (*Abies alba*), cherry (Prunus avium), alder (Alnus glutinosa), and Douglas fir (Pseudotsuga menziesii). A significant number of the respondents (22%) stated that all planted seedlings were damaged regardless of species.

The questionnaire also indicated that the seedlings were damaged regardless of whether they were bareroot or containerized seedlings. Regarding the season when damages occurred, seedlings planted in spring were more susceptible (59%) than seedlings planted in autumn (38%). The remainder of the responses stated winter as the most critical period. An interesting finding was that 78% of the respondents stated the seedlings were only rooted out, without further damage. The roots and root ball were damaged in only 17% of the cases, and the above-ground parts were damaged in only 5% of the cases. In practice, forest managers have been encountering this type of damage for an average of 24 years. The longest indicated period was 40 years. This phenomenon is not linked to a specific area or altitude but appears throughout the entire country to a lesser or greater degree.

Surveying

During our own survey, we assessed data from 6 regions (77 locations), with a total area of 0.925 km^2. We found no difference in damage intensity between the regions (P ⊚ 0.05).

The intensity of damage to seedlings fluctuated considerably (0.5–80%), and on average 17.5% of seedlings were damaged. No preference for deciduous seedlings over conifers was proven, although the results were very close (ANOVA, $F_{7,167} = 3.82$, $P = 0.052$). There were no differences between species ($P = 0.47$). Beech was the tree species that was most often damaged (Figure 3). An average of 2,160 out of 10,000 planted seedlings of this species were rooted out. The second most frequently damaged species was oak. Other species suffered much less damage.

The season of planting had no significant impact on the intensity of damages, and both spring and autumn plantings were damaged to the same extent. However, there was a significant difference in relation to the type of seedlings planted. Wild boar showed significant preference for containerized seedlings (ANOVA, $F_{1,167} = 16.66$, $P = 0.0007$), which were damaged in 80% of the cases. The preference for damaging containerized oak seedlings in comparison to bareroot seedlings of the same species was also proven (ANOVA, $F_{1,35} = 24.56$, $P = 0.00004$). No such preference was proven in relation to the second most frequently planted species, beech (ANOVA, $F_{1,76} = 1.71$, $P = 0.19$).

Wild boar behavior in experimental plantations

From the results of the survey in the regions, we established the highest risk period for occurrence of wild boar damage to plantations. This is the first week after planting, during which 38% of the total damages occurred. Thirty-three percent of the damages occurred

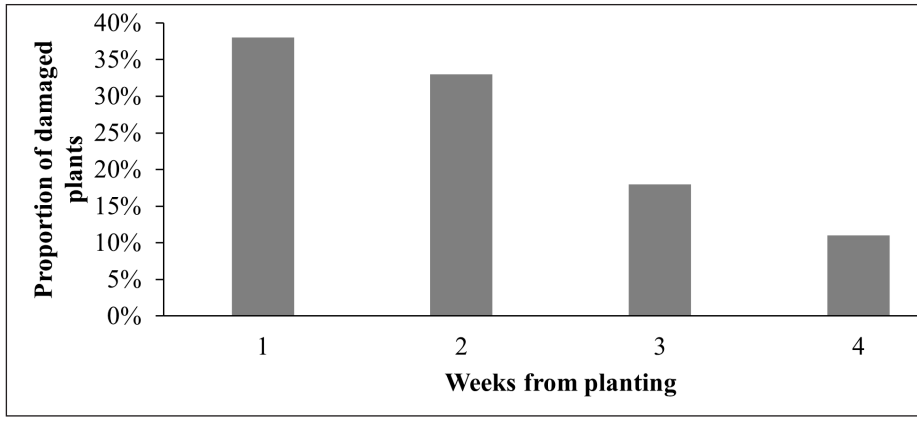

Figure 4. Intensity of wild boar (*Sus scrofa*) damage in the first 4 weeks after planting in the Czech Republic in 2019.

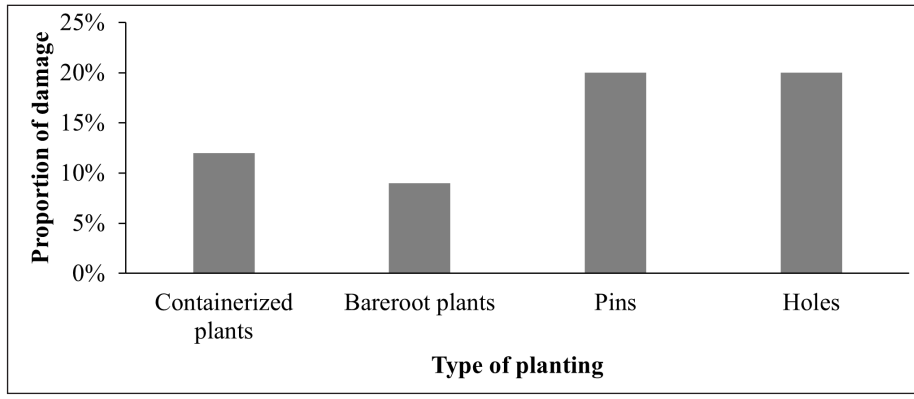

Figure 5. Intensity of wild boar (*Sus scrofa*) damage depending on the type of woody plants in the Czech Republic in 2019.

during the second week. This percentage continued to decrease, and damages that occurred >4 weeks after planting were practically negligible (Figure 4).

The dependence of rooting on the presence of a seedling root ball and root system is depicted (Figure 5). Classic seedlings, whether bareroot or containerized seedlings, were damaged roughly to the same extent (9% and 12%). Boar expressed more interest in the pegs inserted into the holes and the empty holes with loosened soil. Twenty percent of both variants were damaged at the time of inspection.

Dependence of rooting on the age of the animals could not be fully proven, despite that we assessed >500 video recordings from this location. It is clear which individual caused the damage on only several of them. The data are not statistically assessable. However, 8 recordings on which the damage can be assigned to a specific individual show boar of all age categories, from piglets living in a group to adult individuals who appeared in the area separately.

Discussion

Rooting out of forest tree seedlings by wild boar is becoming a limiting factor for the forest renewal or growth in some areas. Up to 80% of the trees are repeatedly damaged in focal points. When the rooted out trees were replanted, they were rooted out again. Unfortunately, even after extensive investigation of this problem, we were unable to determine the precise reason for this behavior. According to Wood and Roark (1980), the reason for the damage is that boar are looking for sap and starch. However, this does not correspond to our findings for several reasons. Most of the planted tree species are damaged. Natural forest growth is attacked only exceptionally, despite the fact that these seedlings also

contain starch and sap. One partial explanation could be that artificially grown trees contain more nutrients and salts because they are fertilized. However, the low degree of damage to the root ball refutes this. We registered consumption of roots in only 2 locations, where the roots of oaks were gnawed on. We originally planned to evaluate damage in 5 categories, depending on the degree to which the roots had been chewed, but this was deemed unsuitable due to lack of data. We did not register this behavior in experimental plantations. The questionnaire survey also showed that 78% of trees were simply pulled out of the ground without subsequent damage. In general, we can agree with Fern et al. (2020) that the level of intensity of predation on seedlings is the result of a combination of environmental conditions and other factors (available food, availability and age of seedlings, season, boar population density, hunting pressure, soil cover, soil moisture, etc.). However, these factors are very difficult to assess. Upon comparison with our results, it is clear that 59% of the damage occurs to seedlings planted in spring, which does not indicate a clear link to the season. The relationship with wild boar population density and hunting pressure is a factor. This damage has been occurring to a greater extent in the last 20–25 years, which corresponds to the rise in wild boar numbers (Massei et al. 2015). Hunting pressure may also be crucial for protection of planted clearings. Hunters can affect the presence of animals on localities during risky periods. The greatest risk is during the first week after planting, and most damage occurs during the first 4 weeks. This means that fairly short-term, regular monitoring and subsequent shooting can be used as an effective tool to reduce these damages in the areas with a higher concentration of wild boar, which Fern et al. (2020) also states. Contrary to Sweeney et al. (2003) and Mayer (2009), we did not register any damage to older plantations.

Fern et al. (2020) state damage to pine (*Pinus palustris*) and hardwood seedlings. Our questionnaire indicates that the most frequently damaged tree species is spruce. It is followed by beech, oak, and pine. Our surveys indicate that oak and beech are at highest risk from damage. This roughly corresponds to the most frequently planted tree species. We also found damage to all monitored tree species (e.g., firs, maples, and birches). However, these are supplementary tree species, which are planted in small numbers. This also corresponds to the questionnaire findings, where 22% of respondents stated damage to all seedlings. Thus, the damage in the Czech Republic is not focused on a specific tree species or a group of species. Also, we did not find a species that suffered no damage at all. The preference for deciduous trees over conifers was also not statistically confirmed.

We did register a significant difference between our survey and the questionnaire in the preference of containerized seedlings over bareroot. While the questionnaire did not show any difference between these 2 types of seedlings, the survey clearly indicated the preference for seedlings with a root ball (80%). We found the greatest difference in damage between containerized and bareroot seedlings in relation to oak. This is why this discrepancy was monitored on artificial plantations with both types of oak seedlings in combination with plantations without a root system.

These experiments show that pegs without roots and empty holes are rooted out as much as or even more frequently than seedlings with roots. This does not point to damage due to food preferences, but we are not aware of a clear reason. Further research is needed, particularly to find out the exact time dynamics of the damage, differences in the environment, the effect of population density, and pig behavior.

Management implications

We recommend reduction of wild boar population in areas with high occurrence of damage, by means of shooting or trapping. At some locations, snares or toxicants can be used as well. Fencing and harassment can also be effective. We recommend daily inspection and targeted hunting at sites of occurrence of damage during the first 4 weeks after planting. Photo-traps have also been used successfully as a means of monitoring.

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