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Age and growth of wild service tree (*Sorbus torminalis* (L.) Crantz) in former oak coppice forests in southwest Germany

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Introduction

Wild service tree (*Sorbus torminalis* (L.) Crantz) is a rare species, but not uncommon in oak coppice forests of Central Europe. Like other minority tree species, *S. torminalis* is of high ecological value and contributes to social welfare on numerous levels (LFV 1987, Spiecker 2006). Furthermore, the species is appreciated because of its wood, since only a few other European tree species yield comparable economical returns for high quality wood (Franke et al. 1990, Drapier 1993, Uthoff 2002, LÖBF 2004). Although *S. torminalis* is, from a forestry point of view, considered to be the most important species among the genus *Sorbus* (Heß 1905) it has rarely received consideration by forest management. Early publications refer to the species as of subordinate importance (Käpler 1805, Drais 1807, Weise 1888) or describe, like more recent publications, the need for species conservation (see e.g. Burckhard 1870, Bednorz 2007).
Wild service tree is wildly distributed across Europe, from the northern extremity of Africa to the south of Sweden and from the east of Great Britain to the north of Iran (Demesure-Musch & Oddou-Muratorio 2004). It grows on all types of soil and is a post-pioneer tree that colonises disturbed areas and forest edges (Demesure et al. 2000). The species shows also rather broad amplitude in terms of community context. It is mainly found in calcareous beech and hornbeam forests, but it also occurs in acidic oak forests (Rassumssen & Kollmann 2004).
Major reasons for the rarity of *Sorbus* species today are changes in forest management practice and increasing browsing pressure. Because of *S. torminalis* need for light forest management systems like coppice, with and without standards, are thought to have favoured minority tree species such as wild service tree over centuries (Rackham 1980, Kleinschmit 1998, Angelone et al. 2007, Pietzarka et al. 2009). Therefore, the creation of high forests, especially by transformation and conversion of coppice forests into high forests, is considered to be a reason for continuous species loss (Röhrig 1972, LFV 1987). For aged coppice forests, it is uncertain whether *S. torminalis* populations can persist in the longer term or whether coppicing is needed to maintain the species.
Against this background this study aims to determine i) if *S. torminalis* regeneration is dependent on coppicing and ii) if diameter and height growth of *S. torminalis* indicate that the species might be an inferior competitor when compared to its companion species, mostly sessile oak.

Material and Methods

Because the establishment of one coherent research site was impeded by small-scale changes of landscape form (and the subsequent changes of stand composition and management) three separate 1 ha sub-sites were established near the city of Baumholder (49°36′50″N, 7 20′0″E), in the federal state of Rhineland-Palatinate (southwest Germany). Site specific climatic, edaphic and geologic site conditions were summarized by Schneider (2004). The three sub-sites are located in former oak (*Quercus petraea*) coppice forests, in which silvicultural activities ceased following the last harvesting ca. 85 ago. The maximal distance between all plots was less than 1 km and there are no difference between the sub-sites in terms of species composition, former management and stand age. The occurrence of *S. torminalis* was no priority stand selection criterion because other coppicing related studies were carried out on the same sites (see Pyttel et al. 2008). In addition to oak, other woody species are *Carpinus betulus*, *Prunus avium*, *Fagus sylvatica*, *Pyrus pyraster*, *Sorbus aria*, *S. domestica* and *S. torminalis*. None of these species had been released from the surrounding oak competition through thinning or protected against browsing.

To obtain information about how many *S. torminalis* individuals had established after the last coppicing we quantified species frequency of all individuals > 1.3 m in height in each plot. To describe species growth, height and diameter measurements were taken for each *S. torminalis* individual and for a subsample of the surrounding oaks.

The contemporary age structure of the *S. torminalis* population was reconstructed from 80 stem discs cut at ground level in July 2009. Sample trees represented the diameter variation of the population inventoried on all three sub-sites. A master chronology for the study area was developed from lager *S. torminalis* trees to provide a dating control for all remaining samples (*sensu* Rozas 2003).

Ring-width series along four radial lines were measured to the nearest 0.01 mm using of a scanner in conjunction with WinDENDRO™ software. Cross dating was accomplished with both visual and calculative checking (Schweingruber 1983).

To reconstruct periodic diameter and height growth, 20 trees representing the populations' upper diameter limit were selected for stem analyses in combination with the counting of bud scale scars (Telewsky & Lynch 1991, Schweingruber 1996). Stem discs were cut at ground level, breast height and at 1 m intervals along the stem.

S. torminalis belongs to the diffuse- to slightly semi-ring porous woods and therefore offers a challenge for dendrochronology (Kahle 2004). In the sampled trees, the wood was very pale and it did not show contrasting coloration between early- and latewood. Partially absent rings (ring wedging) and indistinct year ring boundaries were common. The tendency of ring counting to underestimate age in *S. torminalis* trees was reduced by applying various methods of sample preparation. Year ring identification was improved with very fine polish and by using colorant (such as ordinary high lighters). Finally, questionable year rings were checked against microscopic analysis using microtome sections.

Results

On the three study plots, we found on average of 241 *S. torminalis* trees per hectare. In total 724 individuals higher than 1.3 m were inventoried. The number amount of *Q. petraea* individuals amount totals on average 1377 trees per hectare. Percentage of *S. torminalis* trees on total stand tree layer ranged between the sub-sites from 1.4 to 4.3 until 6.3%.

Mean DBH of all recorded *S. torminalis* trees was 6.6 cm. Even 85 years after the last coppice cut DBH of almost 65% of all inventoried wild service trees was below the solid wood threshold of 7 cm (Fig. 1a). Corresponding to the high number of trees with low diameters, most of *S. torminalis* trees were smaller than 10 m in height. Only few wild service trees reached a height of 15 meters or more, while most oak trees were higher than that. Consequently, sessile oak was the common tree species in the upper tree canopy (Fig. 1b).

Age determination showed that tree age within the *S. torminalis* population varied (Fig. 1c, 2). Most of the trees established over a period of 70 years before destructive sampling. Only a few trees were found to be younger than 19 or older than 80 years. As few as six trees older than 70 years were found. Interestingly, many of the trees with a diameter below 7 cm were older than 40 years (Fig. 1c). However, no distinct establishment phase was identified.

Stem analyses showed that average radial increments at 1.3 m height ranged between 1.9 and 2.2 mm during the first 8 years after tree establishment (Fig. 3a). Thereafter, radial increment of all trees decreased continuously with increasing tree age. Until a tree-age of 25 years, the average radial increment dropped below 0.7 mm and remained fairly constant until the time of sampling. At the individual tree level, increment of some trees surged spontaneously and far above the average. These positive growth trends lasted for a few years until growth declined again to an average level.

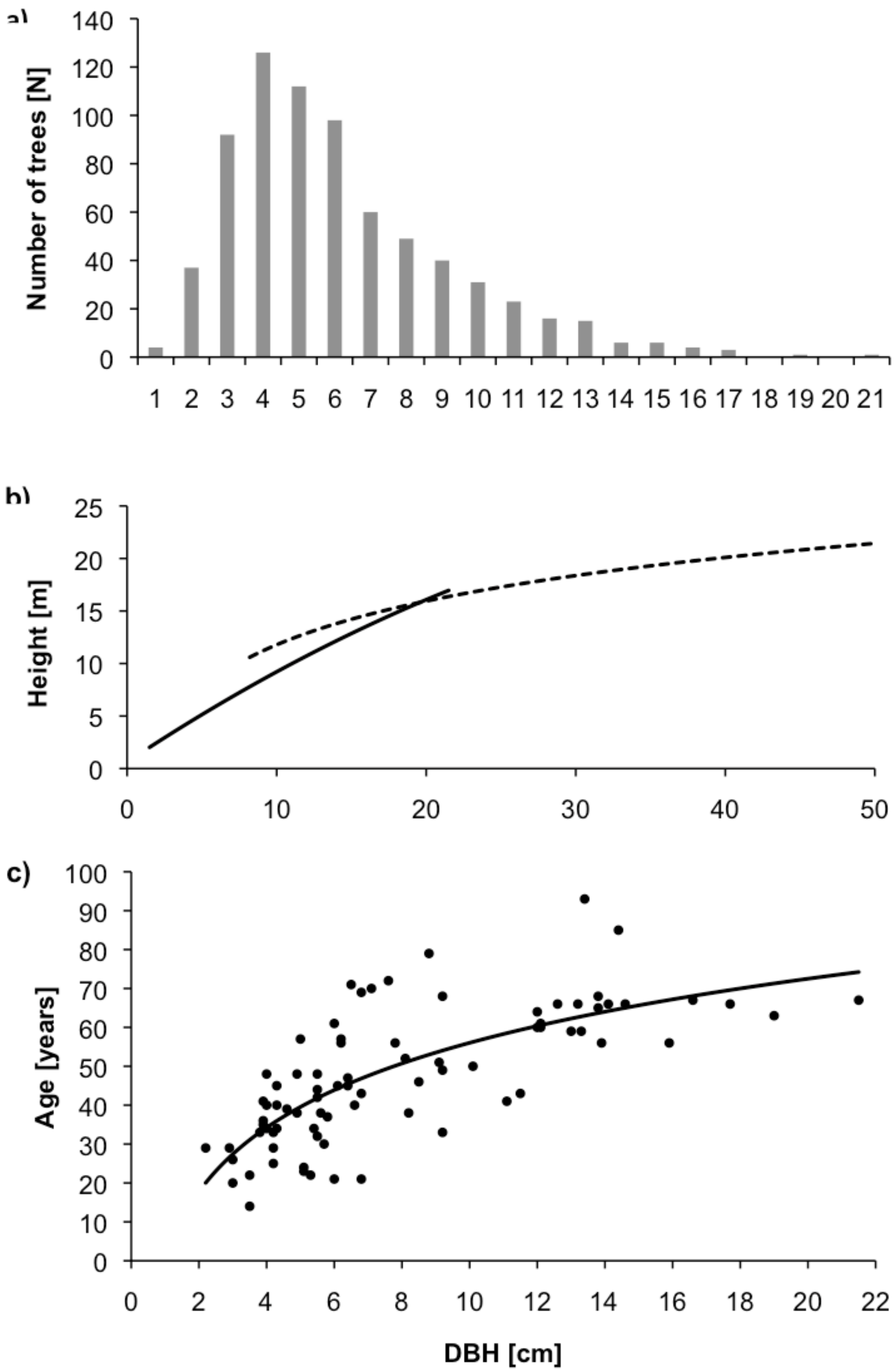

Figure 1: a) Diameter distribution of Sorbus torminalis *trees over all study plots (N=724, DBH classes cluster trees with same pre-decimal position).b)Tree height in relation to diameter at breast height (DBH) of* S. torminalis *(N=678) in comparison to Q. petraea (dashed line, y = 6ln(x) – 2.022, $R^2 = 0.61$, N=112) and c) relation between tree age and DBH of wild* S. torminalis *(y = 23.78ln(x) + 1.28, $R^2= 0.53$, N=80).*

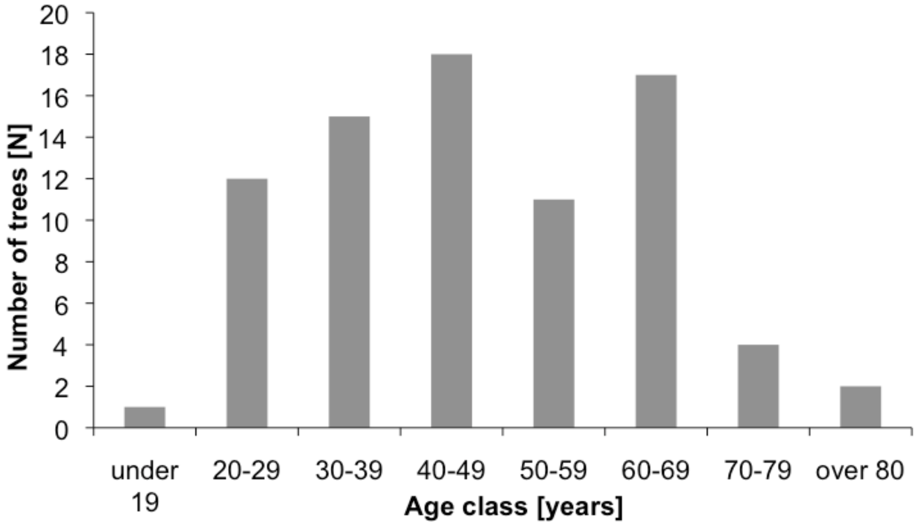

Figure 2: Age structure of S. torminalis *(N=80) in a former oak coppice forest. Trees younger than 19 and older than 80 years are summarized.*

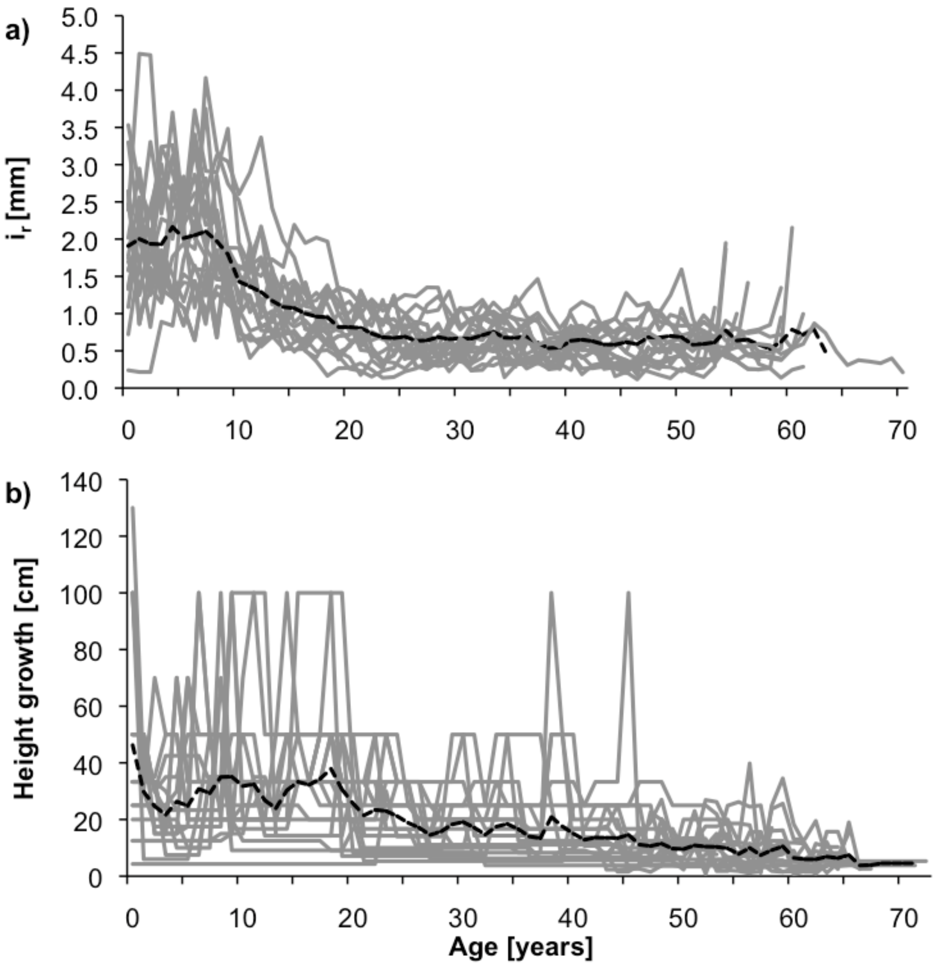

Figure 3: a) Radial increment measured at 1.3 m height and b) height increment in relation to tree age of Sorbus torminalis *grown in aged oak coppice forests. Grey lines indicate increments of single trees, the dashed black line shows the mean of all sampled trees (N=20).*

Average height increments fluctuated between 21 and 43 cm per year until the trees were 18 years old (Fig. 3b). During early growth phases, individual trees reached annual height increments of 1.3 m. In the subsequent years, mean height increment declined strongly, a pattern comparable to that of radial growth. However, changes in height growth were less abrupt. With increasing tree age, mean height increment declined to a level of only 5 cm at the age of 70 years. However, short burst in height increments of 50 and 100 cm were observed for individual trees in later growth phases.
As expected, growth of *S. torminalis* depended on canopy position (Fig 4). In accordance to Kraft's classification, co-dominant trees showed a comparably strong growth in the first decades after establishment. As in the given example, phases of reduced radial and height increment can follow (Fig. 4a). However, 50 years after establishment, co-dominant trees can show a consistent increase in radial growth increment along the whole stem axis.
The effect of tree suppression through competition is indicated through the continuously decreasing height and radial growth (Fig 4b). The co-dominant tree reached its final height of 10 m after 35 years, while it took the suppressed tree 55 years to reach a height of 9 m. Persistence or life expectancy was found to be independent of canopy position. Even suppressed trees persisted over a long period under the canopy of surrounding oaks.

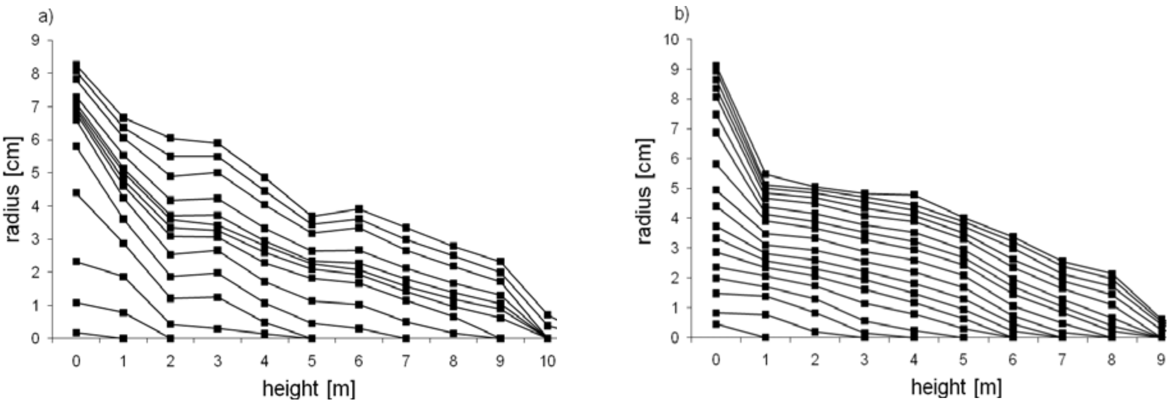

Figure 4: Height growth in relation to diameter increment of a) one co-dominant and b) one suppressed S. torminalis *tree. Lines represent 5 yearly increment periods.*

Discussion

Because *S. torminalis* is considered to be a rather rare tree species, the number of individuals > 1.3 m found in the studied aged oak coppice stands was surprisingly high. Age determination of trees indicated that that continuous recruitment of *S. torminalis* regeneration occurred over the last 80 years. Together, these data provide little support for the hypothesis that coppicing itself promotes the establishment of new *S. torminalis* cohorts. Obviously, the species has the capacity to establish beneath a closed canopy.
After 25 years, average annual radial increment of the studied trees dropped to 0.7 mm and remained constant. This growth reduction is far lower and more prolonged than reported previously (Hochbichler 2003, Kahle 2004). In those studies *S. torminalis* grew in high forests and was tended. No such measures took place at the research sites of this study, leading to impaired growth with increasing tree age and subsequent suppression. This is consistent with findings by Leder & Kahle (1998), who observed that natural growth potential of *S. torminalis* is often limited by concurrent tree species.
The average height increments during the first 20 years after tree establishment confirm findings of Röhrig (1972), Bamberger (1990) and Schüte (2001). However, bursts in height increments or sudden growth changes decades after tree establishment (see Fig. 3b) indicate that even after

enduring phases of suppression, increased height and radial growth can be observed. These spontaneous height and (less distinct) radial increments are neither related to tree age nor to silvicultural measures but presumably to changes in growth conditions through increased growing space. Thinning-induced growth increments of 80 to 100 year old *S. torminalis* trees were documented by Elflein et al. (2008). This late responsiveness is consistent with the results of this study but restricted to trees of co-dominant or dominant canopy positions (see Fig. 4).
We conclude that the status of *S. torminalis* is not threatened in the observed stands, ca. 85 years after the last coppicing. Furthermore, observed growth patterns confirm that *S. torminalis* is an extremely shade tolerant species that can survive long periods of intensive competition. In the absence of silvicultural measures, the fate of individual *S. torminalis* trees may depend on the frequency of disturbances and the duration of periods of release versus suppression.

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