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Response of beech and oaks to wounds made at different times of the year

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Abstract Tree care, especially pruning, is still mostly done in the dormant time. Such treatments expose live inner bark, the vascular cambium, and functioning outer sapwood to harsh external influences followed often by infection of pathogens. Investigations about response reactions of beech and oak to wounding made in different times of the year showed that wound closure was significantly slower for December and February wounds than in April and October. The length of discoloured sapwood was in October and December wounds greater than in February and April. Sapwood reaction expressed by the soluble phenol concentration index indicated however no significant differences among wounding dates. Overall, woundings in the vegetation period will be more effectively compartmentalized than in the dormant season. Consequently, tree care like pruning with many woundings should not be done in the winter period.

Keywords Beech · Oak · Time of wounding · Wound reactions · Discoloration · Phenol concentration

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Introduction

Tree care, especially pruning, is still mostly done in the dormant time. Such treatments expose live inner bark, the vascular cambial zone, and functioning outer sapwood to harsh external influences followed often by infection of pathogens (Shigo 1984). On this base SHIGO developed the CODIT model as "Compartmentalization Of Decay In Trees". Since such a discoloration develops also without fungal activity, CODIT was expanded towards "Compartmentalization of Damage in Trees" (Liese & Dujesiefken 1996). The phloem as well as the sapwood have an effective defence system to secure their vital function of transport and storage, to restrict the embolism of air and in later stages also the spread of pathogens. The response capacity is primarily influenced by the physiological state, e.g. the prevailing season (Shortle 1979, Dujesiefken et al. 1991, Trockenbrodt and Liese 1991, Shortle et al. 1996).

Among the trees studied regarding their defensive system, species of the Fagaceae have received little attention. Beech and oak are common urban trees, as well as important forest tree species. Arborists inflict wounds during standard tree care practices (pruning, injections). The purpose of the study was to determine how European beech, white oak and red oak respond to wounds made at different times of the year. The main focus was set to the wound closure, the extention of the discoloration and the soluble phenol content.

Materials and methods

Twenty beech (*Fagus sylvatica* L.), ten white oaks (*Quercus robur* L.) and eight red oaks (*Quercus rubra* L.) trees, 80–100 years old, were selected in Hamburg, Germany (beech in parks, white oaks along the roadsides, red oak in parks and cemetery). All trees appeared well developed and were "co-dominant". The stems were wounded at the beginning of October, December, February, and April. The wounds consisted of holes

1.8 cm diameter and 10 cm deep. The rate of wound closure was measured after one growing season in November as the horizontal width (w) between the wound wood ridges and expressed as the closure index = 1.8 − w/1.8×100.

Two trees of each species were felled, the wounds were dissected and evaluated regarding cambial dieback, extent of columns of discolored and decaying wood for the extent of cambial dieback. The horizontal and vertical distances of necrotic tissue along the vascular cambial zone from the wound-hole were measured. The vertical distance of discolored wood was determined at a depth of 15 mm of the column. The sapwood response was also measured by the amount of phenols at the boundary of the column and the outer sapwood. Since felling of the further trees was not permitted, only the growth of their wound wood could be measured.

A pair of small wood chips (1×1×10 mm, 8–12 mg weight) was taken from the sapwood 5 mm outside the column boundary and from the boundary itself 5–15 mm above the wound-hole. The chips were oven-dried at 55°C, weighed, and extracted with 1 mL of 76% aqueous ethanol by heating at 70°C for 1 hour. The soluble phenol concentration of the alcoholic extract was determined by the Folin-Ciocalteu procedure expressed as mmol gallic acid/ kg dry wood. From the paired values a phenol concentration index = phenol concentration of the column boundary layer/phenol concentration of the sapwood was used to determine the sapwood reaction to infection; a greater index indicates stronger reaction.

For light microscopy small blocks (1×1×1 cm) were cut near the chip samples and 20 μm sections stained with safranin/astrablue to observe the transition of sapwood into wound-initiated discoloration.

Statistical analysis for wound closure, dieback, column length, and sapwood reaction expressed by the soluble phenol concentration index related to time of wounding were determined by 2-way analysis of variance. Mean differences in parameters among dates of wounding were indicated by least significant difference ($P < 0.05$).

Results and discussion

Wound closure was maximum for April wounds with white oak closing more rapidly than red oak or beech, probably because the white oaks were growing faster (Figure 1). By the end of the second season, both oak species were fully closed and beech nearly so (Figure 2). Once the wounds are closed and the infection no longer aerated, the activity of wood-destroying pathogens is greatly suppressed and likely terminated, although bacteria and budding spores of fungi can persist producing wetwood rather than woodrot (Jensen 1967, 1969). Wound closure was minimum in February and December with white oak again closing more rapidly than red oak and beech (Figure 1). After the second season white oaks were closed, but beech and red oak remained exposed to aeration (Figure 2) with decay fungi likely to remain active. Regarding wounding time wound closure in October was equivalent to February in beech and to April in red oak after the first season. At the end of the second season the wound closure index was the same for all times.

Cambial dieback was not related to wound closure in February and December wounds. Horizontal dieback was only 1–2 mm with no significant differences among dates of wounding, where as vertical dieback with 0–35 mm was highly variable. The only significant dif-

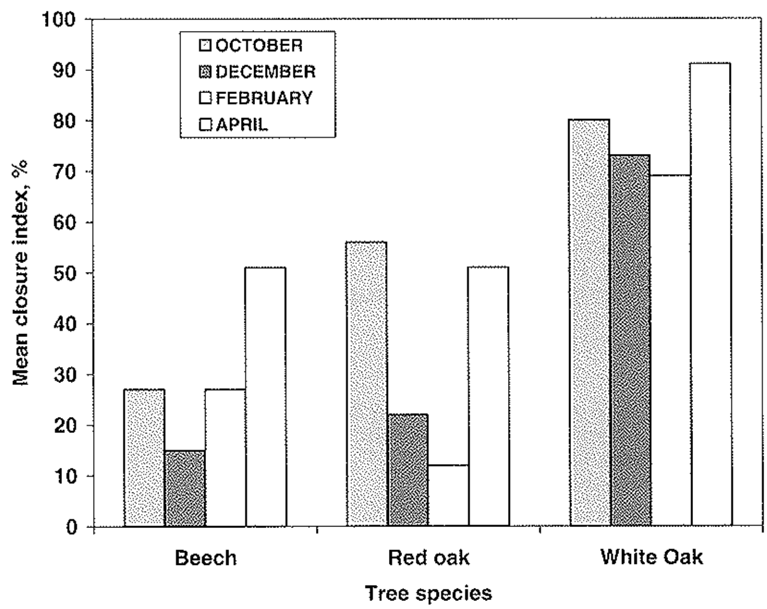
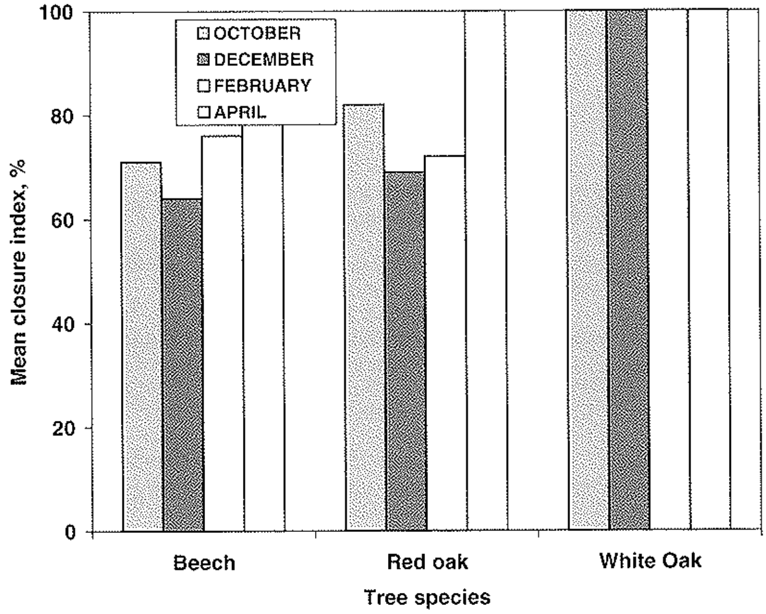


Fig. 1 Mean closure index after one growing season

Fig. 2 Mean closure index after two growing seasons



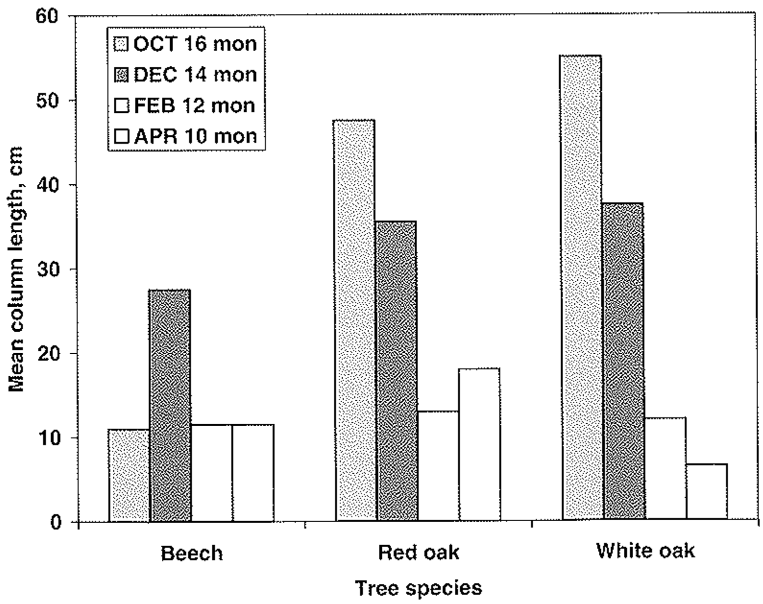
ference with greater vertical dieback occured in December wounds of red oak.

The **Column length** varied between 9 and 65 cm; the longest discoloration occurred at the October and December wounds of the oaks and at the December wounds of beech (Figure 3). The extention at all February and April wounds amounted to around 10 cm. The column length of beech was not significantly related to duration of exposure. Oak columns were longer with white oak being strongly related to duration of exposure (adjusted $r^2 = 0.93$, $P = 0.02$) and also red oak (adjusted $r^2 = 0.72$, $P = 0.10$).

The rate of wound closure depends primarily on the growth rate of the stem. The influence of growth respectively supply of nutrients are also shown by Herms and Mattson (1992) and Stamp (2003). Trees with broad tree rings close faster than slow growing trees (Dujesiefken et al. 1989). Rapid closure reduces oxygen access which is necessary for the development of decay (Boddy & Rayner 1983, Jensen 1967, 1969).

The results have shown that time of wounding can delay closure. Wounding in December results the slowest closure, more dieback, larger discoloration columns, April wounds the fastest closure, less dieback and smaller columns. However, December wounds have been exposed four months longer than April wounds and this may contribute to differences, especially in size of discoloration. October and February wounds were

Fig. 3 Mean column length after one growing season



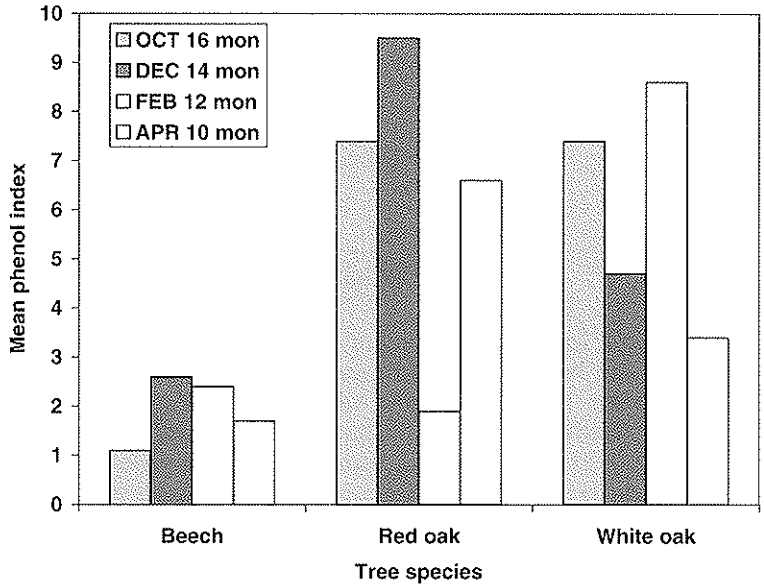


Fig. 4 Mean phenol index after one growing season

intermediate in overall effects with February wounds appearing somewhat less harmful than October wounds, but again wounds of October have been exposed four months longer than of February.

The **phenol index** (phenol concentration of boundary tissue/phenol concentration of sapwood) appeared to be generally greater in oaks than in beech after one growing season (Figure 4). However, the apparent difference was not significant due to the high variability in sapwood response. The boundary tissue indicates a response of sapwood to limit the inflow of air and the spread of infection by wood pathogens by enrichment of these substances in the boundary tissue (Shortle et al. 1995). The lower phenol index values in beech indicate a slower rate of infection in beech than oak in which consistently higher index values indicate a more active infection in discoloured wood of oak than beech after only one growing season.

The boundary tissue evinced microscopically dark contents in the lumen of parenchyma cells, which were filled nearly completely (Figure 5). The discoloured tissue however revealed only little contents.

Investigations in recent years have shown a strong seasonal influence on the wound reactions of trees (Armstrong et al. 1981; Dujesiefken et al. 1991). Defence reactions by tyloses and by plugs as well as the formation of accessory substances depend on the temperature and thus on the season. While age-related development of tyloses during heartwood formation occurs during the vegetation period, wound tyloses after injury can also develop in winter time. The influence of temperature on its development has sporadically been investigated. In felled beech trees tyloses emerge at temperatures above 5–10°C (Jurasek 1958). *Quercus serrata* in Japan formed tyloses in winter 30 to 45 days after felling, but during May to October after three days (Shibata et al. 1981). Trees are hardly able to react on an injury in winter time. Also the formation of protective substances occurs slowly at low temperatures. Stem injuries on different deciduous trees during winter lead to reduced

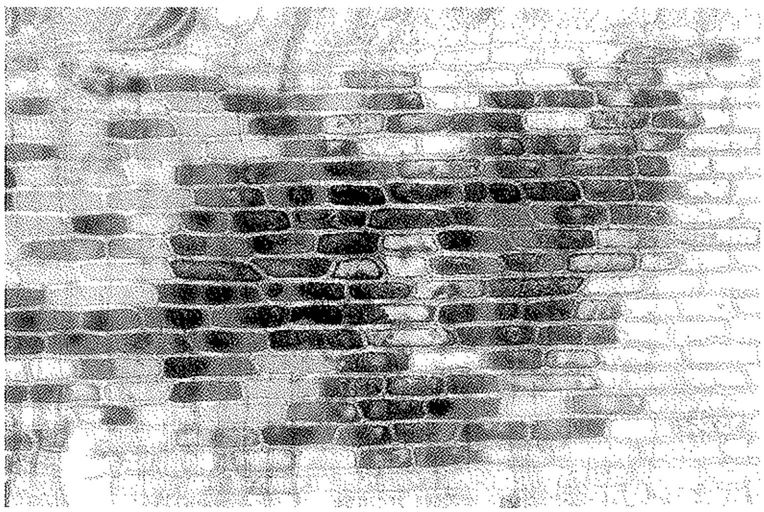


Fig. 5 Dark contents in parenchyma cell of column boundary layer

compartmentalization with extended columns of discoloration compared with the vegetation time. The time of wounding has therefore a strong influence on the effectives of the wound reactions. Consequently, tree care like pruning with many woundings should not be done in the dormant season.

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