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ORIGINAL PAPER

The natural resistance of the yew wood *Taxus baccata* L. to destruction by subterranean termites *Reticulitermes lucifugus* var. *santonensis* De Feytaud

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ABSTRACT

This study tested the resistance of heartwood and sapwood of yew trees *Taxus baccata* L. in relation to feeding by subterranean termites *Reticulitermes lucifugus* var. *santonensis* De Feytaud. The assessment of common yew wood resistance to termite feeding has not been clearly defined in the PN-EN 350: 2016-10 standard. The experiments were carried out under compulsion conditions in the lab, according to ASTM D 3345-08: 2009 standard methodology. Yew wood from three approx. 40 year-old trees were compared to the sapwood resistance of Scots pine (*Pinus sylvestris* L.). Five yew heartwood blocks, seven yew sapwood blocks and seven pine sapwood blocks (25.4×25.4×6.4 mm) were used. Each block was placed individually at the bottom of a glass vessel and covered with 200 g of moist sand. The amount of water needed to moisten the sand was empirically determined. The vessel was filled with 1 ±0.05 g of termites, with pseudergates accounting for over 90% of the individuals. The test time was four weeks in an incubator at 27°C. The degree of damage to the wood was assessed according to ASTM D 3345-08: 2009 standards. Additionally, the blocks' weight losses and the average weight loss for each wood category were calculated. Various degrees of wood damage were found. Yew heartwood showed high resistance to termite feeding and block weight losses were small. Yew sapwood was moderately damaged, while the sapwood of Scots pine was damaged to a degree between 'heavy' and 'failure'. Total termite mortality was observed in yew heartwood, with low mortality seen in yew and pine sapwood. Significant differences in the results were statistically verified using the Chebyshev inequality.

KEY WORDS

biodeterioration, toxic wood properties, subterranean termite

Introduction

Yew *Taxus baccata* L. is a long-lived, slow-growing tree found in western, central and southern Europe, as well as the Caucasus, Asia Minor, Northern Iran and North Africa. The eastern range margin of yew trees lies in North-Eastern Poland and in the southeast their distribution extends beyond the present Polish border. In the past, yew was over-exploited in Polish forests for its valuable wood. In recent years, a range expansion of this species has been observed, as it is planted for ornamental, medicinal and timber purposes.

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Yew wood is generally considered to be very durable. The best evidence of the durability of yew wood is the good condition of English longbows found in the wreck of 'Mary Rose', Henry VIII's ship that sunk in 1545 (Rule, 1983). According to the PN-EN 350: 2016-10 standard, yew heartwood is classified as resistant (durable) to damage by European beetles. Despite this, laboratory studies have shown that the development of European old house borer larvae *Hylotrupes bajulus* L. in yew sapwood is possible (Dominik, 1965). The distribution of yew trees often coincides with the occurrence of subterranean termites *Reticulitermes lucifugus* var. *santonensis* De Feytaud. However, the standard assessment of common yew wood resistance to termite feeding has not been clearly defined and there are no reports in the literature describing the resistance of yew sapwood and heartwood to termite attack. In this research, the natural resistance of yew wood to the feeding of subterranean termites *R. lucifugus* var. *santonensis* will be evaluated.

Materials and methods

All tests were conducted in accordance with the ASTM D 3345-08 standard, which aims to test the resistance of wood and wood-based materials to subterranean termites.

The sapwood and heartwood of three approx. 40-year old yew trees were used in this research, with Scots pine sapwood *Pinus sylvestris* L. as reference material. Five yew heartwood blocks, 7 yew sapwood blocks and 7 pine sapwood blocks were used. The yew wood was sourced from Falenica in Warsaw. All test blocks had dimensions of 25.4×25.4×6.4 mm and a moisture content of 7 ±1%. The density of the dry yew wood was 0.65 g/cm^3 and the Scots pine density was 0.51 g/cm^3. In order to determine the dry weight of the wood prior to the experiment, all blocks were freeze-dried.

During the experiment, each block was placed individually at the bottom of a 450 ml glass vessel and covered with 200 g of sand which was sieved, rinsed and heat sterilised. The sand was moistened with water to 7% of the sand's saturation point. Each vessel was then filled with 1 ±0.05 g of termites, of which at least 90% of the individuals were pseudergates. The test vessels with wooden blocks and termites were placed in an incubator at 27°C for 4 weeks. The water content of the vessels was replenished weekly.

After a period of four weeks, the wooden blocks, sand and termites were removed from the test vessels. Approximate termite mortality rate was determined and scored as 'slight' (0-33%), 'moderate' (34-66%), 'heavy' (67-99%) or 'total' (100%). The wooden blocks were weighed and then freeze-dried in order to determine the final dry weight. The blocks were photographed to determine the extent of the termite damage. The degree of damage was visually assessed and scored: 10='sound', surface nibbles permitted; 9='light attack'; 7='moderate attack', penetration; 4='heavy'; 0='failure'. In ambiguous cases, the value between two categories was recorded: 10/9=9.5; 9/7=8; 4/0=2.

The average block weight loss and average degree of block destruction was calculated for each tree species and wood category. Significant differences between tree species and wood categories were statistically verified using the Chebyshev inequality. If the difference in average values was greater or equal to three times the standard error of that difference, then the average values were recognised as statistically significant.

Results

The results of the visual assessment of the wood destruction, weight loss of wood, and the mortality rate of termites are presented in Table 1. An example of the condition of wood blocks after 4 weeks of termite feeding is shown in Fig. 1.

Table 1.

Visually rates of wood destruction, loss of wood weight [g] and termite mortality

Species of wood	No of block	Visual rates of destruction	Loss of wood weight [g]	Termite mortality
Sapwood of *P. sylvestris*	1	4	0.75	slight
	2	0	0.83	slight
	3	0/4=2	0.81	slight
	4	4	0.82	slight
	5	0/4=2	0.77	slight
	6	0/4=2	0.83	slight
	7	0	0.87	slight
	average	2	0.81	slight
Sapwood of *T. baccata*	1	4/7=5.5	0.48	slight
	2	4/7=5.5	0.37	slight
	3	4/7=5.5	0.41	slight
	4	9/7=8	0.76	slight
	5	9/7=8	0.34	slight
	6	9	0.53	slight
	7	9	0.65	slight
	average	7.2	0.51	slight
Heartwood of *T. baccata*	1	10	0.09	complete
	2	10	0.06	complete
	3	10	0.03	complete
	4	10	0.09	complete
	5	10	0.10	complete
	average	10	0.07	complete

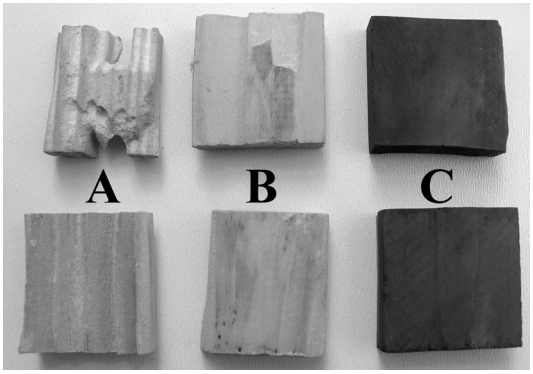

Fig. 1.

An example of the wood condition after 4 weeks of termite feeding:
A – sapwood of *P. sylvestris*, B – sapwood of *T. baccata*, C – heartwood of *T. baccata*

Yew heartwood blocks showed a high natural resistance to termite feeding, with only the edges of the blocks bitten and a complete mortality of insects after 4 weeks. The resistance of yew sapwood was moderate and the termite mortality rate was slight. By comparison, the average score for Scots pine sapwood damage was heavy or failure, and termite mortality was also slight.

When comparing the mean values of wood destruction between species (5.2) to the threefold value of the standard error of the difference (2.64), a significant difference was detected. Comparing the mean value of the block weight loss (0.3) to the threefold value of the standard error of the difference (0.01) also showed significance. The differences in mean values between yew wood and Scots pine were thus considered statistically significant.

Discussion

The natural resistance of wood to subterranean termite feeding can be assessed using either the ASTM D 3345-08: 2009 or PN-EN 117: 2013-04 standards. The ASTM D 3345-08: 2009 test has two advantages: the procedure is twice as short as in PN-EN 117: 2013-04 and it does not require the onerous counting of individual termites, as only collecting 1 g of termites per block of wood is necessary. Due to its advantages, this study used the ASTM D 3345-08: 2009 standard. In both procedures, the assessment of wood resistance to termite feeding is performed visually based on an appropriate visual scale. However, this assessment may contain a certain amount of subjectivity (Krajewski *et al*., 2018, 2021). For this reason, the assessment of the condition of the blocks was supplemented with the weight loss of wood after termite feeding. Despite this, the obtained results were similar in both evaluation criteria.

In the PN-EN 350: 2016-10 standard, the sapwood of all European species of trees is classified as susceptible to destruction by termites (class S). Furthermore, the classification of durability of wood species in this standard is based only on heartwood. Among European species, only heartwood of oak *Quercus* sp. is rated as being medium-durable (class M) and other domestic wood species are rated class S (susceptible). According to PN-EN 350: 2016-10, to date there has been no sufficient data on the resistance of yews wood to termites (n / s). Based on the results obtained in the current research, the heartwood of yew should be assigned a durable grade (class D).

The natural resistance of wood to termite feeding is to some extent related of its hardness, as harder wood is more difficult to drill into. Higher density, and therefore greater hardness, allows insects to collect more wood weight for the same volume of wood loss. However, high hardness without the presence of toxic substances does not significantly affect the natural resistance of the wood. This is confirmed by comparing the feeding effects of subterranean termites in hornbeam wood *Carpinus betulus* L. and yew. The hardness of yew wood using the Brinell method was 65-71 MPa along the grain and about 31 MPa across the grain, while the hardness of hornbeam was higher at 71-89 MPa along the grain and 29-36 MPa across the grain (Wagenführ and Scheibler, 2007). In comparison, the visually assessed degree of resistance in hornbeam wood was lower at 8 (Krajewski *et al*., 2016) than the resistance index of yew heartwood was 10.

The durability of heartwood in many tree species is essentially determined by the content of toxic and repellent substances (Becker and Petrowitz, 1971; Becker *et al*., 1972; Deon *et al*., 1980; Yatagai and Takahashi, 1980). The relatively high content of lignin in certain wood (Syafi *et al*., 1988; Rana *et al*., 2010), e.g. *Erythrophleum* sp. (Wagenführ and Scheibler, 2007) and *Hopea* sp. (Rana *et al*., 2017; Krajewski *et al*., 2019), may cause additional termite mortality. A similar phenomenon was found in the case of strongly degraded European beech *Fagus sylvatica* L. (Krajewski *et al*., 2015). In comparative studies, the lignin content in Neolithic beech wood was relatively higher than in modern *F. sylvatica* wood, resulting in total termite mortality (Krajewski *et al*., 2015). The taxines found in yew heartwood could possibly be a natural wood preservative (Wagenführ and Scheibler, 2007). However, no precise conclusions can be drawn from this as no chemical determination of taxine content was performed in this experiment.

Conclusions

- *Taxus baccata* heartwood is naturally durable and highly resistant to termite deterioration. The loss of weight in yew heartwood was negligible. Yew heartwood in the termite feeding test was assessed as sound with only surface nicks on the wood blocks. Termite mortality rate was complete.

- *T. baccata* sapwood resistance was rated as moderate against termite attack, which was one degree better than Scots pine sapwood. Termite mortality in both yew sapwood and Scots pine sapwood was rate was slight.

Authors' contributions

A.K., P.W. – concept, conducting experiments.

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Conflicts of interest

The authors declare no conflicts of interest.

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STRESZCZENIE

Naturalna odporność drewna cisa pospolitego *Taxus baccata* L. na niszczenie przez *Reticulitermes lucifugus* var. *santonensis* de Feyteaud

W obowiązującej w Polsce normie PN-EN 350:2016-10 nie określono jednoznacznie odporności drewna cisa pospolitego *Taxus baccata* L. na żerowanie termitów ze względu na brak dostatecznych danych (wpis n/a). W związku z tym przeprowadzono badania odporności jego twardzieli i bielu zgodnie z procedurą opisaną w normie ASTM D 3345-08:2009. W wariancie porównawczym użyto bielu sosny zwyczajnej *Pinus sylvestris* L.

Pobrano próbki drewna (klocki) o wymiarach 25,4×25,4×6,4 mm z 3 różnych drzew. Drewno miało wilgotność 7%. W ramach każdego wariantu doświadczenia przeprowadzono 5 powtórzeń. Każdą próbkę umieszczono na dnie w oddzielnym pojemniku testowym – szklanym naczyniu o objętości 450 ml – i przysypano czystym piaskiem rzecznym (200 g). Piasek w każdym naczyniu testowym zwilżono wodą o pojemności polowej gruntu pomniejszonej o 7% tej wielkości. Nie zastosowano środka antyseptycznego.

Doświadczenia biologiczne przeprowadzono w teście przymusu na glebowym termicie *Reticulitermes lucifugus* var. *santonensis* de Feyteaud. W każdym pojemniku testowym z 1 próbką drewna umieszczono 1 ±0,05 g termitów. Pseudergaty stanowiły ponad 90% osobników w każdym pojemniku. Pojemniki z termitami i próbkami drewna trzymano przez 4 tygodnie w cieplarce w temperaturze 27°C, kontrolując co tydzień wilgotność piasku w pojemnikach.

Decydujący o ocenie odporności/podatności drewna na uszkodzenie przez termity stopień uszkodzenia próbek klasyfikowano na podstawie cyfrowego systemu oceny wizualnej i ubytku masy drewna. W przypadkach niejednoznacznych przyjmowano indeks średni. Istotność różnicy uzyskanych średnich wyników dla bielu cisa i sosny poddano weryfikacji statystycznej przy pomocy nierówności Czebyszewa. Zgodnie z wymogami ASTM D 3345-08:2009 oszacowano także śmiertelność termitów.

Wyniki przedstawiono w tabeli 1 i na rycinie 1. Twardziel cisa wykazała naturalną trwałość, przejawiającą się wysoką odpornością na niszczenie przez termity. Straty jej masy były znikome (nie wyższe niż 0,1 g). Wizualnie została ona oceniona jako zdrowa (indeks 10), z niewielkimi ogryzieniami powierzchni w pojedynczych miejscach. Śmiertelność termitów była tu całkowita. Biel cisa wykazał umiarkowaną podatność na atak (średni indeks 7), mniejszą niż biel sosny zwyczajnej (średni indeks 2). Śmiertelność termitów była tu niewielka, podobnie jak w przypadku bielu sosny zwyczajnej.