University of Tennessee – Center for Renewable Carbon

RESEARCH REPORT

Research on the control of thousand cankers disease and the vector species Pityphthorus Juglandis and the investigation of the strength loss in railroad ties treated with DOT borate wood preservative against other native wood damaging factors

performed in the degree course

Forest Products Technology and Wood Constructions

at the Salzburg University of Applied Sciences

submitted by

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Julia-Katharina Neier

List of abbreviations

TCD	Thousand cankers disease
WTB	Walnut twig beetle
P. juglandis	Pityphthorus juglandis
G. morbida	Geosmithia morbida
J. nigra	Juglans nigra
TN	Tennessee
mm	millimeter
°C	degree Celsius
DOT	disodum octaborate tetrahydrate
sec	second
ml	milliliter

Abstract

Nonnative, invasive species pose a significant threat to native biodiversity in ecosystems across the globe. To protect economically important wood species from invasive insects and fungi, treatments are used for wood products, and also to prevent the movement of insects and fungi globally.

The Thousand cankers disease is a recently recognized pest complex, which appears to be transported in black walnut (*Juglans nigra*) wood or plant materials as a result of commerce or firewood movement. DOT solute with at least 30% in combination with heat treatment seems to be an effective way to prevent further contamination in black walnut products. The same treatment is used for railroad ties, a wide range of wood is used for the production, like pine or oak.

The DOT treatment on railway ties already showed to be effective, still some research is necessary to figure out the highest protection with the least strength loss, for long lasting railroad ties.

DOT treatment seems to have a broad spectrum of insecticidal and fungicidal efficacy with low mammalian toxicity on a wide range of wood species.

Keywords:

Railroad ties, disodum octaborate tetrahydrate (DOT), Thousand cankers disease, *Juglans nigra*, strength loss

1 Introduction

The internship at the University of Tennessee was performed between July and September 2015. The research was about the control of thousand cankers disease and the vector species *Pityphthorus Juglandis* and the investigation of the strength loss in railroad ties treated with DOT borate wood preservative against other native wood damaging factors.

Nonnative, invasive forest insect pests and fungi are a significant threat to the health of global forest resources.

The objective of this project is to assess the ability of disodum octaborate tetrahydrate (DOT) wood preservative against a range of fungi and insects in wood products made from native wood species like oak, pine and black walnut from Tennessee.

Special focus was laid on the thousand cankers disease and the vector species *Pityphthorus juglandis* and the strength loss of railroad ties. *Juglans nigra* and railroad ties can both be treated with DOT against a wide range of fungi and insects.

DOT showed in former studies high results in the protection of native wood species in Tennessee. Borates have been used as a preservative against insects and fungi for the last 70 years. It is an inexpensive product, with low mammalian toxicity. (Nix, 2013/ Audley, 2015)

The thousand cankers disease caused a high black walnut mortality in Tennessee and other states in the United Stated of America, which is an economically important wood specie. The disease is the result of an invasive insect-pathogen complex in which the walnut twig beetle (*Pityophthorus juglandis*) is a vector to the associated fungal pathogen (*Geosmithia morbida*).

Wooden rail road ties are an important product of the hardwood forest products industry in the United States. They have been used since 1831 and account more than 30% of the volume of the whole treated wood products marked (Chow et al., 1987, ASTM, 2000).

Different tests to show the effectiveness of DOT treatment on different wood species and against different invasive pest complex were performed.

The tests are separated in the emergence of insects in treated wood bolts and the strength loss of railroad beams. Both procedures show the characteristics of a DOT treatment.

2 State of the art

Nowadays different wood damaging factors are known to cause problems in alive trees and processed wood products. Especially in the United States the research works on figuring out different solutions to protect their wood economy, with different treatments on both, the tree and wood products. The following chapter defines the basic knowledge to the research.

2.1 Thousand cankers disease

The thousand cankers disease is a recently recognized pest complex which infests black walnut trees, *Juglans nigra*. It is caused by the walnut twig beetle, *Pityophthorus juglandis*, and an associated fungus, *Geosmithia morbida*. The beetle vectors the fungal pathogen. Especially black walnut and butternut are highly susceptible to TCD. The trees are often killed as a result of infection.

Pityophthorus juglandis is native to the southwestern U.S. states, historically known from Arizona, New Mexico and northern Mexico and caused a high mortality in *Juglans nigra* since decades. The disease was first described in 2001 in Boulder, Colorado. By fall of 2008, 700 black walnuts had died and were removed from the Boulder area alone, representing the majority of the black walnuts in that area. At that time the thousand cankers disease was thought to only threaten *Juglans nigra* in the western states, however since 2010, the disease was discovered in Knoxville, TN, as well as Virginia, Pennsylvania, North Carolina, Ohio and Maryland. The first recorded case outside of the United States was in the fall of 2013 in Italy.

The exact method of introduction is not known, however, it appears likely that the beetle is transported in walnut wood or plant material as a result of commerce and/or firewood movement. (Newton and Fowler, 2009)

TCD is characterized by a progressive top-down mortality, beginning in the crown and moving down the main stem, often killing the tree. The adult walnut twig beetle carries spores of G. morbida, by excavate galleries for mating and feeding, damage to the phloem tissue results and the fungus G. morbids is introduced into the tree where it subsequently germinates and grows and causes a tissue necrosis.

The eponymous cankers occur beneath the bark and are associated with beetle galleries. Each time a beetle tunnels into a tree a canker is initiated, numerous attacks severs the nutrient flow within the tree, causing die off of parts of the tree. (Audley, 2015)

Visible symptoms of TCD begin with premature yellowing and wilting of leaves in the crown. During the progress of the disease black staining and/ or bark cracking may be visible at the surface, a thinning of foliage occurs, as well as branch and crown dieback.

Figure 1: Invested walnut tree in Tennessee with wilting of leaves in the crown (Camp, 2015)

2.2 Walnut twig beetle *(Pityophthorus juglandis)*

The walnut twig beetle (*P. juglandis*) belongs to a group of bark beetles, this genus is widespread in the United States with more than 100 species, which are feeding and reproducing within the phloem or pith of a host species (normally *Juglans nigra* in Tennessee). The beetle is native to the western states, however, *P. juglandis* has greatly expended its range is now found too in several eastern states like Tennessee.

Pityophthorus juglandis is a yellowish to dark brown bark beetle with a length of 1.5 mm to 2.0 mm (fig. 2 and 3). Characteristic are the 4-6 concentric rows of the asperities on the anterior of the pronotum. (Bright, 1981)

The females differ from the males with a distinct tuft of yellow setae on the area of the head between the eyes (frons).

The *P. juglandis* beetles are active during an average air temperature of 18°C to 19°C and overwinter under the bark. Beetles have been observed attacking apparently healthy tree, stressed trees and cut logs. (Tisserat et al. 2009, Mayfield 2014)

Localized spread could be facilitated via the transport of logs and firewood.

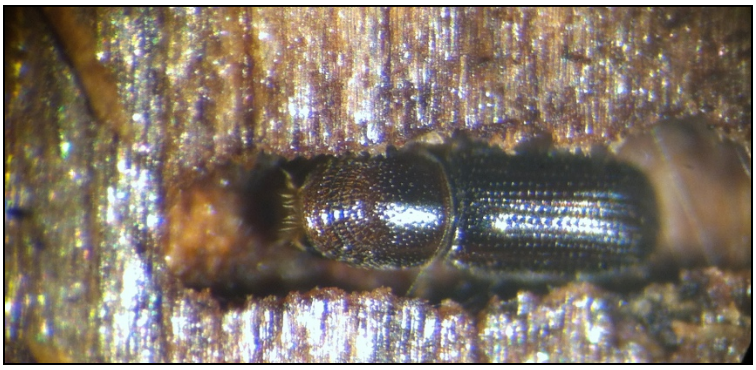

Figure 2: Female walnut twig beetle in tunnel (Camp, 2015)

Figure 3: Female walnut twig beetle from the side (Camp, 2015)

2.3 Oak ambrosia beetle *(Platypus quercivorus)*

The oak ambrosia beetle (*P. quercivorus*) is a wood boring beetle with a wide host range and is considered as a significant pest of oaks in Japan. It attacks different species of the family *Fagaceae* but can attack also trees from other families. The beetle originates from Japan and Taiwan but is now also native to California and other parts of the western United States, under the name *Monarthrum spp.* (Dreistadt; Clark; Flint, 2004)

Platypus quercivorus adults are reddish brown to dark brown in color with a cylindrical, elongated body that averages 5 mm (fig. 5) long. These insects have a concave declivity armed with spines. The front legs are adapted for excavation. (Dreistadt; Clark; Flint, 2004)

The beetles are active between March and October and cause a damage which is associated with the galleries in the wood of the host trees during breeding attacks. The results can be loss of structural integrity of the wood and loss of lumber quality. In combination with its associated ambrosia fungus *Raffaelea quercivora*, the beetle is able to cause extensive tree mortality on oak forests.

International trading of crating, pallets or dunage made out of oak can result in the intercontinental spread of all life stages of ambrosia beetles. Localized spread could be facilitated via the transport of logs and firewood. (Dreistadt; Clark; Flint, 2004)

Figure 4: Adult oak ambrosia beetle (Camp, 2015)

2.4 Geosmithia morbida

The pathogen in the TCD complex in species of walnut trees is *Geosmithia morbida*, an anamorphic fungus, which was described as new to science in 2010. *G. morbida* is described as having yellowish conidia en masse with distinctly verrucose conidiophores (fig. 5). Conidia inside the beetle galleries appear whitish and have been observed lining the tunnels of both adults and larvae. (Tisserat et al., 2009; Nix, 2013)

P. juglandis is the only known vector of *G.morbida.*

The fungus *G. morbida* is not moving systemically within the host. What means that *Geosmithia morbida* is not spreading within the host or from host to host directly. The pathogen must be repeatedly introduced into the host by numerous beetle attacks. Each time *P. juglandis* enters the phloem, the spores come into contact with viable phloem material. (Tisserat et al., 2009; Kolařík et al., 2011)

Figure 5: Geosmithia morbidia in a walnut twig beetle tunnel (Camp, 2015)

2.5 Railroad ties

A railroad tie is a rectangular support for the rails in railroad tracks. Ties transfer loads to the track ballast and subgrade, hold the rails upright and keep them spaced to the correct gauge.

Railroad ties were traditionally made of wood, in North America still over 90% of all track applications are wooden, because it can be easily spiked or drilled for rail fastening system and its durability with proper treatment.

The Railway Tie Association (RTA) was founded in 1919 with the purpose to promote the economical and environmentally sound use of wood crossties. They are for example involved in research into wood preservation, conservation of timber resources and more. (Railway Tie Association, 2015)

For the railway tie production 4% to 6% softwood species are used, but the vast majority of species utilized today are hardwoods.

The most popular used wood is oak with 55% to 65%, other like pines and walnuts are just occasionally used.

The impregnation with DOT takes place via drilled holes in the railway ties, the treatment is inserted in the drill hole and spread through the tie (fig. 6).

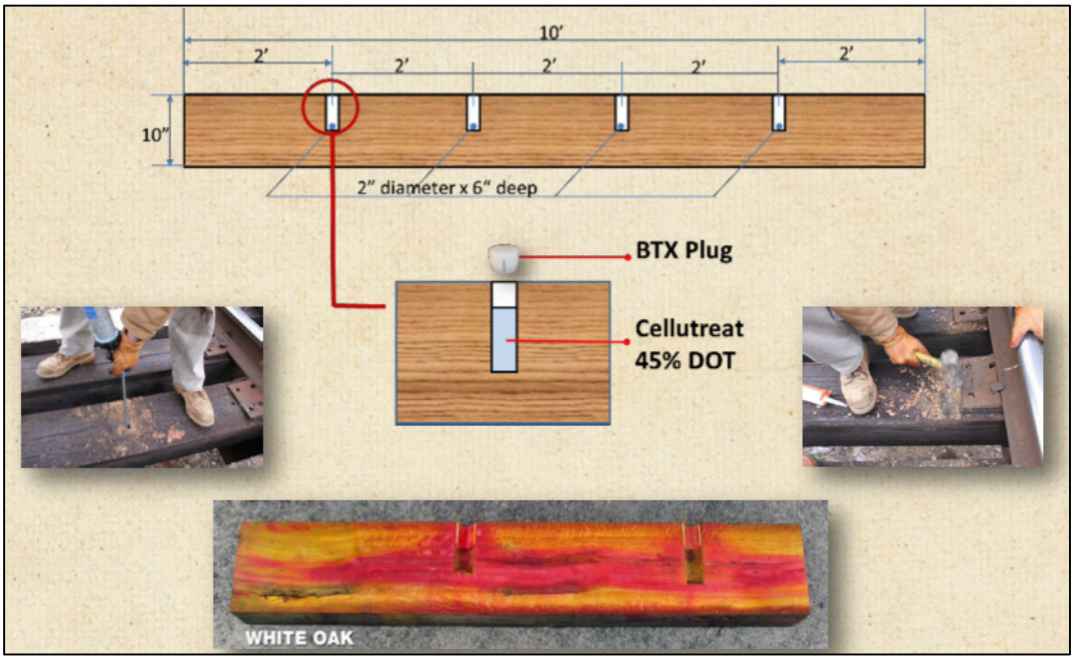

Figure 6: Railway ties treated with DOT (Nisus Corp., 2015)

3 Materials & Methods

This chapter describes the procedure of the research, beginning with the used materials and going further to the test procedure.

3.1 Economical important wood species in Tennessee

3.1.1 Black walnut (*Juglans nigra*)

Black walnut (*J. nigra*) is one of the most economically valuable North American hardwood species. It is a prized furniture and carving wood because of its color, hardness, grain and durability. As well is walnut wood the timber of choice for gun stocks. Veneer quality logs are exceptionally valuable.

The *Juglans nigra* nuts are edible and are sold commercially, which offers an economic dual use. Due to the abrasive properties of the shell they are also used in several industrial applications. Especially in Europe the black walnut is planted as a landscape tree.

3.1.2 Red oak (*Quercus rubra*)

Oak is one of the most economically valuable North American hardwood species. Particular importance has oak in the production of railway ties, oak is the most used wood in this field of business. It is as well used as veneer, cabinetry, furniture and flooring wood.

3.1.3 Pine (Pinus)

Pinus trees are the most valuable commercial timber sources and continues to be used for construction, furniture, pulpwood, land management and more. Pine naturally grows straight, and tapers less, especially longleaf trees (yellow pine) is resistant to disease and insect injury and wind damage from hurricanes. White pine is often used for black walnut mixed tree plantations as protection from harsh winters and the pine will help to control pests.

3.2 Borat wood preservative

Boric acid, oxides and salts are effective and commonly used wood preservatives. Borates have been shown to have broad spectrum insecticidal and fungicidal efficacy across agricultural and domestic applications with low mammalian toxicity. One of the most common compounds used is disodium octaborate tetrahydrate (DOT).

Hot borate immersion treatment could combine the benefits of heat treatment with the long-term advantages of borate treatment. (Taylor; Lloayd, 2009)

3.3 Test procedure

The emergence of walnut twig beetles in *Juglans nigra* bolts (3 cm to 5 cm in diameter) was tested as well as the strength of railway ties true to scale (336 mm length, 20 mm width, 20 mm depth) with drilled holes (12 mm depth, 4 mm in diameter) for the DOT treatment.

3.3.1 Treatment of black walnut bolts with DOT

This study evaluated the efficacy of DOT insecticide in reducing *P. juglandis* survival rates and colonization activity on *J. nigra* bolts, 3 cm to 5 cm in diameter, following dip treatment applications.

There were two trials performed. Trial 1 with 15% DOT, Trial 2 with 30% DOT (Nisus Crop.). The solute was dissolved in 1892.7 ml of water at room temperature (20°C).

For trial 2 a 30% solution of DOT was made by dissolving 566.98 g in 1892.7 ml of water at 50° C, water was heated to increase the solubility in order to attain the 30% concentration (Nisus Corp., 2015)

Each bolt was submerged into the solution and held submerged with tongs for 120 sec to ensure complete coverage of the bark surface. All bolts were allowed to dry overnight prior to beetle introductions.

The treated black walnut samples were placed into sealed plastic containers with a hole covered up with a web for air supply. To observe the emerge of walnut twig beetles 2 males and 2 female beetles were added to the bolts and observed for 120 hours.

Two observations per 24 hour period were made during the first 72 hours after exposure, followed by a single observation per 24 hour period for the remaining 48 hours. During each observation, all live and dead beetles were counted. Beetles were confirmed dead by gently probing with the bristles of a fine tipped paintbrush under the stereo microscope. Mortality was recorded as a proportion of beetles per sample and the time of observation (expressed as the number of hours post-exposure) was used to estimate the time to mortality for each individual.

3.3.2 Treatment of pine and oak railway ties

Two typical wood species for railway ties were used, pine and oak. The samples were true to scale (336 mm length, 20 mm width, 20 mm depth). 120 sample for oak and 180 sampled for pine were prepared. Each sample group contained 30 samples. The DOT treatment diffuses into ties via drilled holes in the ties and the moisture in the wood (fig. 7 and 8).

The railway ties were prepared through drilling 8 holes in the bottom, top and side for oak (30 samples each) and another 30 samples as control group without any holes. It was the same procedure for pine but with another 30 samples with an extra hole in the middle (9 holes) and 30 sampled without dap and any holes.

The holes (12 mm depth, 4 mm in diameter) are filled with 45% DOT and covered with BTX plug. Through the moisture in the wood, the treatment diffuses into the ties and protect the wood against a wide range of fungi and insects.

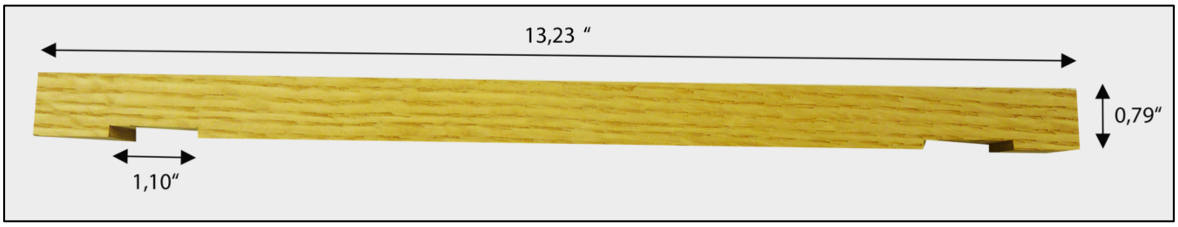

Figure 7: Oak railway tie sample true to the scale

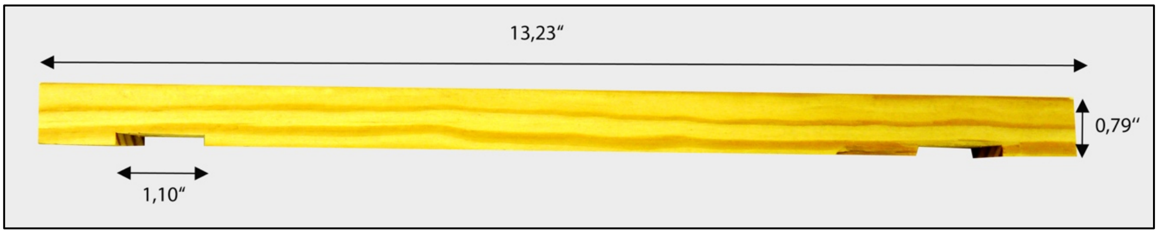

Figure 8: Pine railway tie sample true to the scale

3.3.3 4 point bending test with pine and oak railway ties

For the calculation of the maximum load of the railway ties a modified 4 point bending test was performed with the before prepared and described railway ties samples (30 samples each group) (fig.9).

The samples were true to scale (336 mm length, 20 mm width, 20 mm depth), 180 samples were drilled with 8 holes (12 mm depth, 4 mm in diameter) each sample and two daps on each side (28 mm wide, 4 mm deep). 30 sampled with 9 holes (12 mm depth, 4 mm in diameter), the extra one was placed exactly in the middle of the beam and again with daps. 60 sampled with no holes at all and daps. 30 sampled with no daps and no holes.

The railway ties are dapped on the beam support location. For the test, loading plates in the size of the beam flange and rail plates are placed on the loading frame supports.

The performed test is described in D 143-14, Standard Test Methods for Small Clear Specimens of Timber under the secondary method with a speed of 1.3 mm/min. All calculations were performed automatically. The only relevant number for this research purpose was the maximum load.

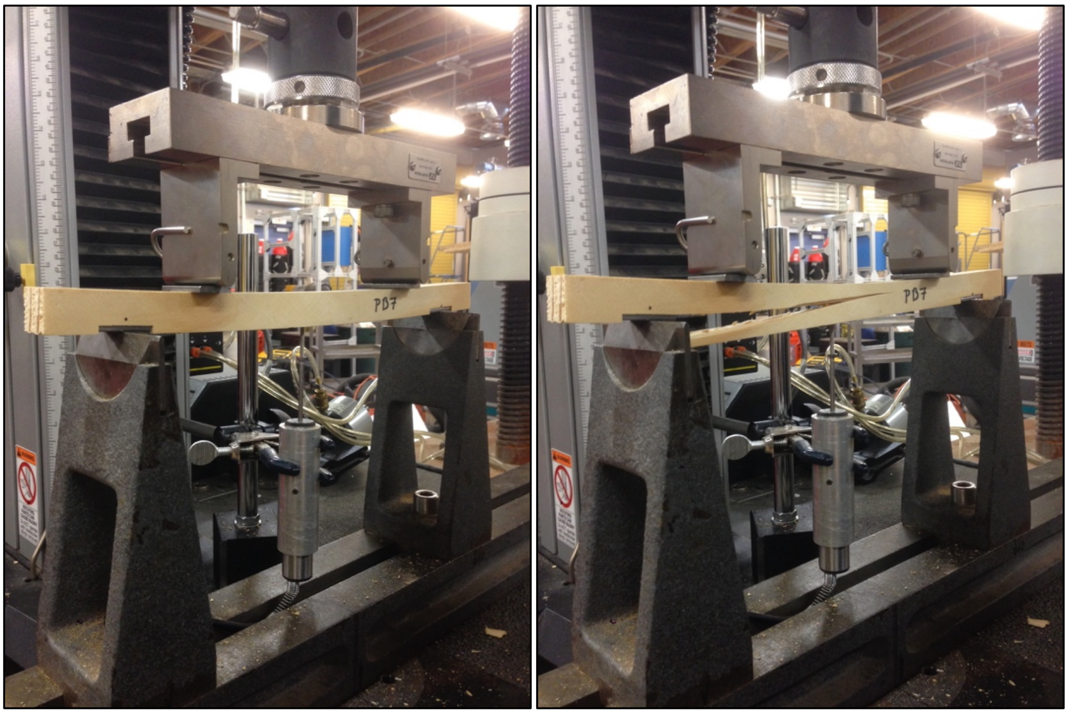

Figure 9: Pine sample with holes on the bottom during 4 point bending test (D 143-14)

4 Results

This chapter follows up with the results of the previous described tests. All tests were performed at the University of Tennessee at the Center of Renewable Carbone. The results of the studies show the behavior of the DOT treatment in different wood species.

4.1.1 Treatment of black walnut bolts with DOT

There were no differences in beetle survival rate among DOT and control treatments in Trial 1. Unlike in Trial 1, however, the increased concentration of DOT decreased beetle survival rate to a level significantly below that of the control treatment.

The 15% DOT treatment in Trial 1 showed that it did not perform any better than the water control bolt. Increasing the DOT concentration to 30% in Trial 2 improved performance, and the observed beetle survival rate was significantly reduced compared to the control.

DOT showed to be only effective if ingested and thus some level of adult feeding must occur. Therefore, DOT may not provide an effective tool in preventing the spread of walnut twig beetles.

4.1.2 4 point bending test with pine and oak railway ties

The results were calculated with the program ANOVA and T-tests in Windows Excel.

The study showed that the dap influences the stability of the railroad ties more then the position of the holes (diagram 10). As seen in the diagram below oak shows as expected better results and the drilled holes on the side allows a higher maximum load on the railway tie. The control beams show similar results to the beams with drilled holes on bottom and top. Drilled holes on the top will certainly lead to weakness of the beam.

The pine beams show similar results as oak beams. One of the results is that beams with drilled holes on the side are able to resist a relatively high maximum load. Other than the tested oak beams, holes on the bottom deliver the same results as holes on the side. Drilled holes on the top will again certainly lead to weakness of the beam.

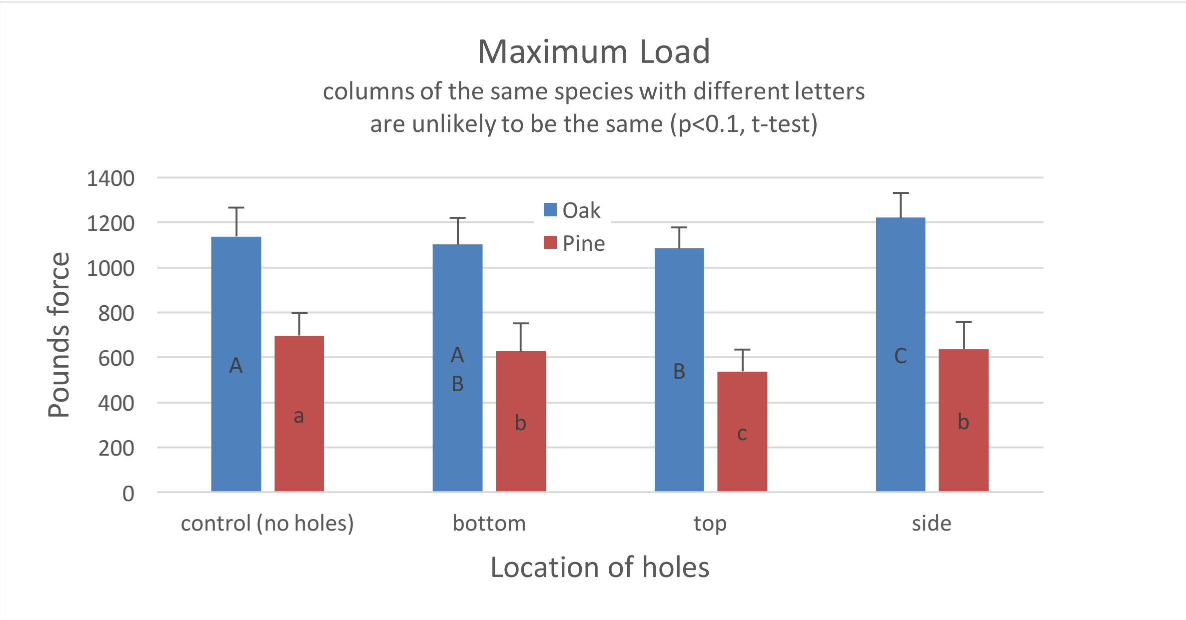

Diagram 10: Maximum load of tested railway tie samples, comparing oak and pine beams, with the same position of drilled holes

The results of the studies lead to the conclusion that the dap or the position of the holes must have a big influence on the strength of the beam. Tests on 30 samples with no holes and no daps and on 30 samples with another hole exactly in the middle of the bottom of the beam were performed.

The results of tests showed that the dap is in some way influencing the strength of the beam, especially in combination with the position of the holes. Against any expectations an extra hole in the middle does not have any influence (diagram 11).

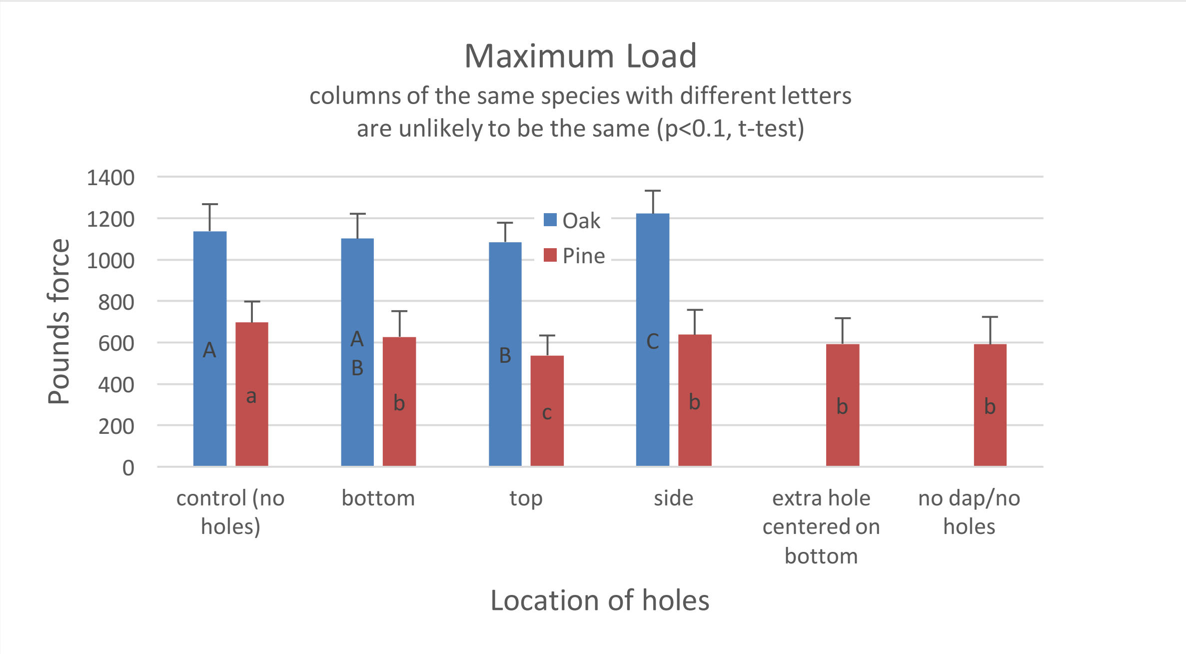

Diagram 11: Maximum load of all tested railway tie samples, inkluding extra tests of pine beams to underpin the importance of the dap

5 Interpretation of the results/resume

5.1.1 Treatment of black walnut bolts with DOT

The results of this study suggest to use an other treatment for balck walnut bolts. The 15% DOT didn't showed any effect on the beetles. It is suggested to use at least 30% to 45% of DOT as treatment to create an effect.

As in former studies showed, the use of permethrin when applied as a dip-treatment can be an effective tool in preventing the colonization on *J.nigra* logs.

Submerging logs into insecticide solutions may provide an effective and efficient means of protecting walnut logs from subsequent exposures to P. juglandis with limited regulatory interference of commercial operations.

In order to effectively manage the threat from thousand cankers disease, anthropogenic pathways of spread must be understood and managed (Newton and Fowler 2009, Moltzan 2011).

5.1.2 4 Point bending test with pine and oak railway ties

It was expected that oak railway ties with the holes on the top and bottom will achieve the best results. Against this expectation oak ties with the holes on the side achieved better results. A shortage of raw material didn’t allow further tests with a centered hole and no daps and holes at all.

The study showed that the dap on the bottom sides of the railway ties causes potential vulnerability, so the position of the holes becomes less important.

Against any expectation a centered hole does not influence the stability of the beam and the dap is from less importance as thought.

It is advised to drill the holes for the treatment on the bottom of the beam, for better diffusion it is also possible to put a hole exactly in the middle of the beam, without causing any weakness.

Further tests in this matter are advised, especially with beams without daps but with holes.

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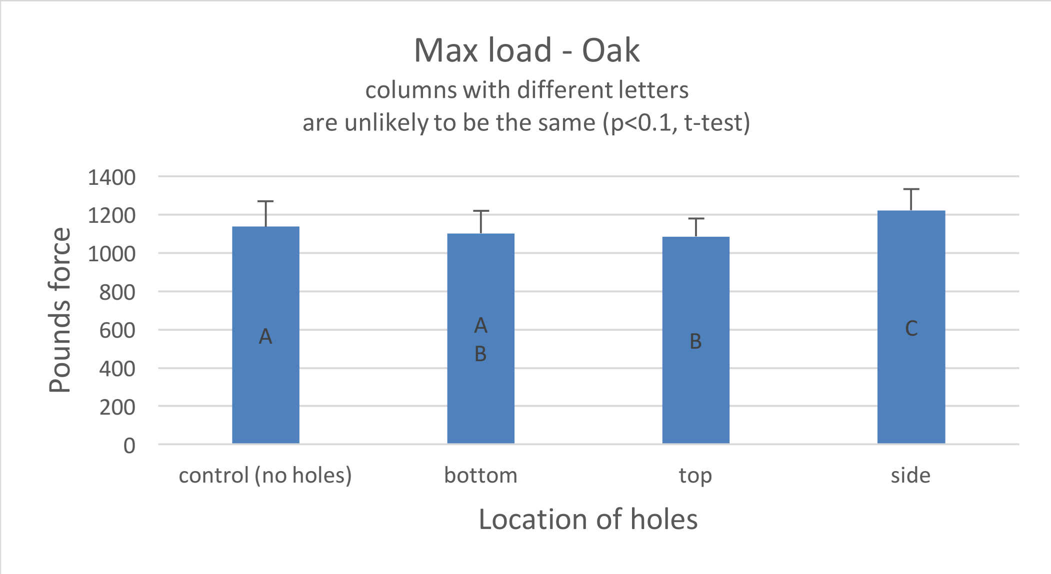
List of figures

Appendix


Max load - Oak
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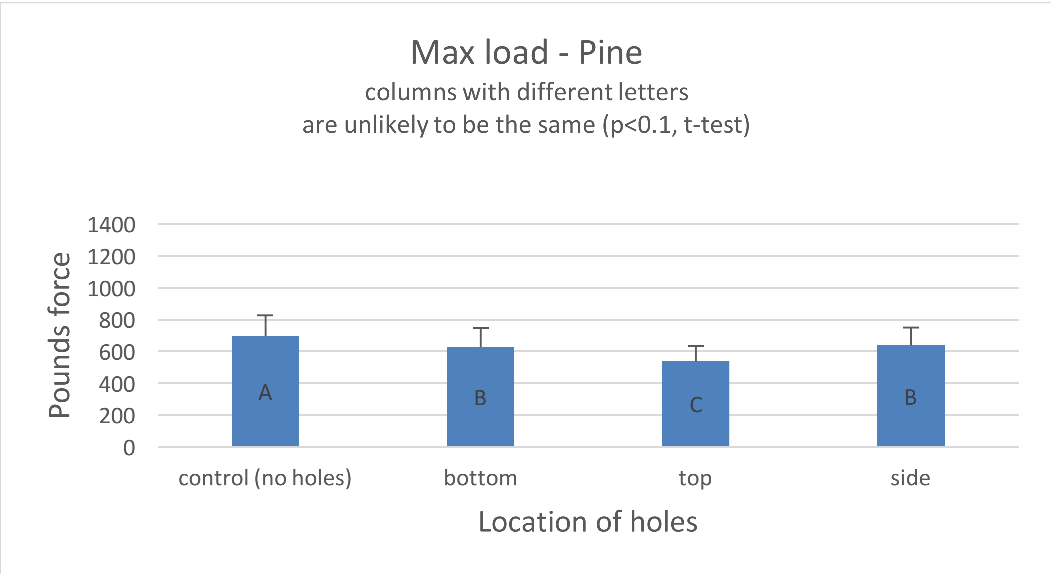
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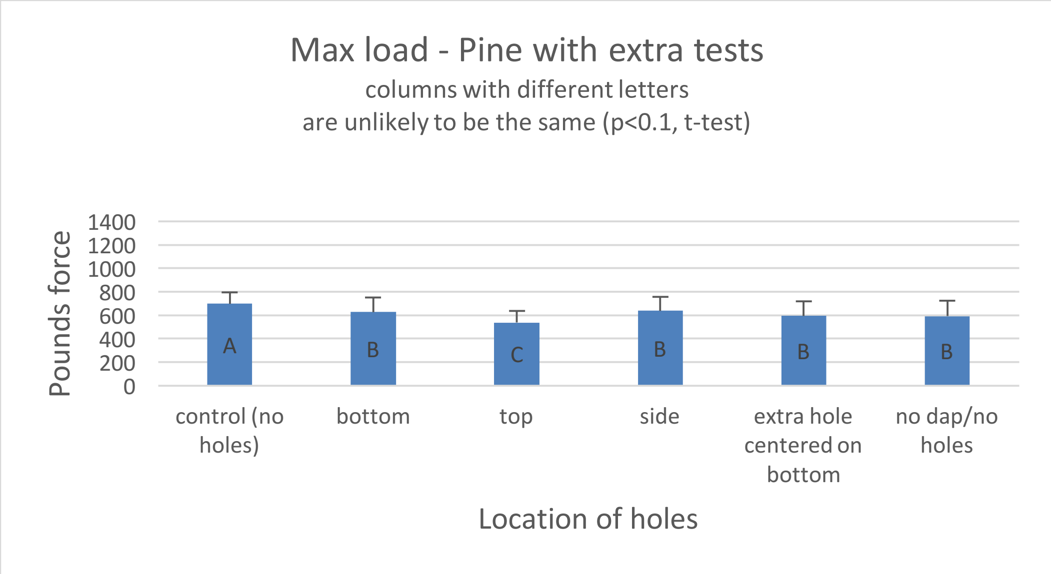
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Location of holes