The Use of Disodium Octaborate Tetrahydrate to Control Conifer Butt Rot Caused by *Heterobasidion annosum*

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Abstract

The efficacy of disodium octaborate tetrahydrate (DOT) used as a stump treatment against *Heterobasidion annosum* was determined at different application rates and at different levels of inoculum. The viability of mechanized application was assessed with particular emphasis on the cold temperature solubility characteristics of DOT solutions. Soil contamination was determined in the immediate vicinity of treated stumps and the effect of treatment during clear felling on ground water was investigated.

It was found that DOT could be effectively applied in commercial operations to control *H. annosum* and that such application would have no obvious detrimental effect on the environment or ground water. With the advent of this technology, the choice of alternative strategies in controlling this important forest pathogen have been increased. DOT is a viable, safe, and cost-effective alternative option to other prophylactic control measures.

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Introduction

Conifers in the northern hemisphere are susceptible to a root and butt rot caused by *Heterobasidion annosum* (Fr.) Bref. The fungus spreads over long distances (300 km) (10) by aerial dispersion of basidiospores, which in Britain are released throughout the year from fruit bodies on rotted wood. In managed forests and plantations, freshly cut stump tops are created during thinning and clear-felling, and these are susceptible to infection by *H. annosum* basidiospores. The fungus is a primary colonizer of wood, and the infection of a stump top may lead to complete colonization of a stump. This saprophytic phase is of no economic significance *per se*. However, the fungus can infect healthy intact roots of standing trees where tree and diseased roots are in close contact. Cortical lesions may be so prolific as to kill the distal portion of a living root, and thus provide *H. annosum* entry into the central xylem of the living tree. Heartwood in both root and stem can then be decayed following colonization by the fungus. This increases the risk of premature wind-blow and renders the valuable butt sawlogs useless, often to a height of several meters. The heartwood decay is cryptic and large numbers of trees can be diseased with no outward symptoms until they are felled. Stumps of decayed trees are themselves potent sources of infection, since the fungus can remain viable within them for many decades. Infection arising from such stumps can spread into replacement crops even before thinning provides more stumps as access for infection. The disease can therefore increase both within and between rotations.

The disease can, however, be controlled by destumping (3) or by treatment of stump tops to prevent their infection by basidiospores. While the former can be an effective method of eradication, it is expensive, limited by topography, and is impermanent. Since the fungus cannot survive freely in the soil and only has access to the stump for a short time, the treatment of stumps is an economically viable and effective strategy. For the past 30 years, stump treatment has been used in the United Kingdom to prevent the establishment of the disease. Trials by Phillips and Greig (7) have shown that 17 percent w/v urea was effective, and it was selected for general use in 1970. However, a significant change in felling techniques occurred in the early 1980s with the introduction of mechanized harvesters. Systems of automatic treatment of stumps were developed within a few years but it rapidly became clear that urea was not well suited to these machines because of its low solubility at required concentrations and its corrosiveness. Furthermore, its efficacy on stumps of some species was found to be less than satisfactory (8).

Borax ($Na_2B_4O_7 \cdot 10H_2O$), which demonstrates good efficacy against *H. annosum*, was adopted in the United States for this use and was applied as a solid to stump surfaces. However, borax is also unsuitable for mechanized liquid application because of its solubility characteristics. Other borates of higher solubility are available, and this paper details the results of testing one of them, namely disodium octaborate tetrahydrate (DOT, available commercially as Tim-bor Industrial Wood Preservative, from Borax Europe Ltd.).

DOT is a spray-dried product approximating $Na_2B_8O_7 \cdot 4H_2O$ and has been specifically formulated to give the highest concentration of boron at the maximum possible solubility and rate of dissolution. It has an approximately neutral pH and is noncorrosive to metals. DOT is used commercially as a plant food and wood preservative. Borates, which are ubiquitous in the environment, essential plant micronutrients and of importance in mammalian nutrition (1), are also generally perceived as environmentally benign. On this basis and because of favorable results in the United States (4), DOT was a good candidate for testing as a control agent against *H. annosum* in Britain. For a full review of the use of borates in controlling *H. annosum*, the reader is directed to Pratt (9).

The objectives of these trials were to assess the suitability of DOT for stump treatment in Britain, in relation to:

- the minimum application rate which provides adequate control of *H. annosum*;
- the suitability for commercial mechanized application; and
- the environmental impact of application.

Methodology

Laboratory trials are of limited value in determining efficacy of treatment materials because of the inherent, unpredictable variability in stumps. Thus, most efficacy trials are carried out on specially cut fresh stumps in plantations of even-aged trees with known history. In the trial reported here, the treatments under test were applied in aqueous form at different application rates to fresh stumps. Treated stumps were inoculated the following day with basidiospores of *H. annosum* in freshly made aqueous suspensions, the viable spore concentration being determined retrospectively. After a suitable period (3 to 24 months), stumps were sampled by cutting from one to three serial discs of constant thickness from stump tops. These discs were washed with cold tap water to remove surface detritus, allowed to drain for >3 hours, wrapped in newspaper and moist-chamber incubated at 12°C ± 3°C for 7 to 10 days. After this time, conidiophores of *H. annosum* are readily visible at ×10 magnification and their distribution on the disc cross-section provides a measure of the success of treatment. It should be noted that there has been little research carried out into the relationship between the severity of this initial colonization and the final infectiveness of a stump. It has been assumed that at least 10 percent of the stump surface needs to be colonized at the time of assessment for there to be a reasonable chance of disease spread. The effect of inoculum potential on stump colonization was also determined.

The freezing point of DOT aqueous solutions is close to that of water and the solubility is such that temperatures of about 10°C are thought necessary to maintain a 10 percent solution concentration, although the solubility of DOT is complicated by the formation of supersaturated solutions. Because of the need to apply treatment throughout the year, problems may arise with the storage and use of DOT in sophisticated harvesters during cold weather. Thus, for the months December 1994 to March 1995, DOT at 5 percent and at 10 percent solution concentrations were used in the Buchan area of northeast Scotland. Cold mixes of solution were made as required in an agricultural mixing tank (2,000 liters), and used for routine treatment. Temperatures of DOT within the harvesters' tanks were recorded and could be compared to comments in the machine operator's log where system failures are recorded. Bulk storage was simulated in 800-liter polypropylene tanks. These were filled with either 5 or 10 percent DOT solutions and remained undisturbed throughout the trial. Solution strengths were measured at the beginning and end of the trial.

The effect of DOT application, from two harvesting machines, on soil background levels was determined in an alkaline sandy soil in an area of low rainfall (<600 mm); a situation where reduced boron mobility could be expected. Four samples of 0.05 kg each were taken, at locations north, south, east, and west, 5 cm from 40 treated stumps and 10 untreated stumps, 4 weeks after treatment with 4 percent DOT applied at 1 lm^{-2}. The samples for each stump were pooled and analyzed for boron content using ICP-AES after extraction under reflux.

TABLE 1.—Effect of DOT application on incidence of stump infection.

DOT		Species	No. of stumps	Infection
(% w/v)	(g/m^2)			(%)
10	100	Sitka spruce	40	0
5	50	Sitka spruce	40	0
3	30	Sitka spruce, Scots pine	212	24.5
1.5	15	Sitka spruce, Scots pine	140	74
0	0	Sitka spruce, Scots pine	287	84

TABLE 2.—Effect of DOT application and spore inoculum density on the incidence of stump infection.

DOT		Mean inoculum density (viable spores m^2)		
		2.5×10^8	2.0×10^6	2.5×10^3
(%)	(g/m^2)		(%)	
3	30	51	12	0
1.5	15	83	55	14
0	0	87	77	28

The effect on water quality was investigated in a 31-ha clear-fell site in a high rainfall area (2,200 mm/yr.) of west Scotland. Both the site and the timing of operations were chosen to maximize the risk of chemical wash-off. Stream water draining a discrete 18-ha water catchment within the clear fell was sampled for boron analysis, weekly before and after the treatment, and daily during treatment.

Results

The effect of five different DOT concentrations in seven trials has been summarized in Table 1, where application rate is weight of DOT per m^2 of stump surface. The stumps were inoculated with approximately 2×10^8 viable spores per m^2.

The effect of reducing the inoculum density is demonstrated in Table 2, in which the incidence of infection in six trials on Sitka spruce was clearly related to DOT application rate and inoculum density. The effects of inoculum density and of DOT application rate on the incidence of infection were significant ($P<0.001$): the numbers of infected stumps rose with increasing spore loads, and decreased with increasing DOT application.

In the winter machine trial of DOT at concentrations of 5 and 10 percent, the 10 percent solution fell to 7 percent over the 3-month period (confirmed by analysis). However, although the freezing point of the DOT solutions was exceeded on a number of occasions when the vehicles were immobile overnight, there was no significant time lost the following morning due to freezing in the pipes and nozzles, even with the 10 percent solution. It is thought that this was because of their inherent design which allowed them to quickly warm up as a result of neighboring hydraulic pipes, which rapidly heat up.

The maximum and mean measured soil boron levels for both treated and untreated stumps has been given in Table 3 for the two harvesting systems used. The results from the water analysis showed that there was an immediate response to the treatment, with the boron level reaching a peak of 0.14 mg/ℓ following a period when the harvesting was at its

TABLE 3.—Soil boron concentration around treated and untreated stumps.

	Maximum	Mean	SED
		(mg/kg)	
Harvester 1, treated	37	8	8
Harvester 1, untreated	4	3	0.6
Harvester 2, treated	70	14	16
Harvester 2, untreated	5	4	0.9

most intense. The baseline boron level rose steadily during the treatment and returned to background levels of approximately 0.02 mg/ℓ within a period of 7 months following its cessation.

Discussion and conclusions

As can be seen from the results shown in Tables 1 and 2, both the application rate and the level of inoculum are of relevance in determining the efficacy of DOT and the minimum rate at which the product can be applied to give satisfactory control. In the experiments summarized in Table 2, stumps that had not been treated with DOT showed a significant reduction in the areas of heartwood colonized by the fungus with decreasing inoculum (mean areas colonized 18.6, 9.0, and 0.3%, respectively), demonstrating that the severity of disease is associated with spore load. There is little data on levels of natural inoculum beyond some exposures made in the United Kingdom over 30 years ago (5,10) which suggested that spore loads in excess of 1×10^{-4} m^2/hr. would be considered high. Assuming that stumps remained open to infection for 2 weeks, a total load of around 2.0×10^6 would be a more reasonable approximation than the higher or lower densities used in these studies. At this density, a dose rate of 15 g/m^2 DOT was ineffective. At a 30 g/m^2 application rate, 12 percent of stumps were infected, with an average area of diseased heartwood of approximately 3 percent. This is likely to be an acceptable level of control. A 30 g/m^2 DOT application can be achieved by applying a concentration of 3 percent at 1 ℓ/m^2.

A possible alternative is to apply the same DOT loading by using a higher concentration and a lower solution volume. This has considerable appeal to the manager of harvesting machines, since the costs associated with the logistics of supply represent a considerable portion of the overall cost of treatment. However, at higher concentration, the solubility of DOT at low temperatures becomes more critical. As can be seen by the results of the machine trials, DOT can be used with reasonable confidence at concentrations up to 10 percent in most British winters, albeit that storage of working-strength solutions over the same period without heat or stirring may lead to precipitation and the requirement for redissolving. A 10 percent solution could still be used if the product were mixed directly into machine tanks prior to application. The dissolution/solubility characteristics of DOT may lend itself to this approach.

The mean results from soil contamination and the results from the water contamination demonstrate that these did not exceed levels typically found in soil, which ranges from 2 to 100 mg/kg (11) or those recommended for the protection of drinking water and freshwater fish (2 mg/ℓ) (6). This data together with the known fate of boron in the environment (2) suggests that no detrimental effects of application, on the environment, could be expected. It should also be remembered that the levels applied in this study are similar to those used annually as micronutrients in agriculture and forestry although application in this case (clear felling) would be only every 40 to 80 years.

It was concluded from this work that:

1. A 3 percent DOT solution applied by mechanized harvester gives a satisfactory level of control at the normal liquid application rate of 1 ℓ/m^2 when natural levels of inoculum are considered.
2. Up to 10 percent DOT solution can be satisfactorily applied by a mechanized harvester during U.K. winter conditions, although long-term storage of solutions at concentrations higher than 5 percent DOT cannot be recommended.
3. There was deemed to be no significant environmental impact from the resulting levels of boron in both soil and water. Long-term environmental problems from commercial application would not be expected.

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