Topical application of carbon dioxide and liquid nitrogen against the mountain pine beetle, *Dendroctonus ponderosae* (Coleoptera: Scolytidae)

S.P. TAYLOR
BRITISH COLUMBIA FOREST SERVICE, PRINCE GEORGE, BC, V2L 3H9

I.M. WILSON
PHERO TECH INC., DELTA, BC, V4G 1E9

K. J. WHITE
BRITISH COLUMBIA FOREST SERVICE, SMITHERS, BC, V0J 2N0

ABSTRACT

A small-scale field experiment was conducted near Prince George to evaluate the effectiveness of topical treatments with CO_2 and liquid N_2 for killing brood in lodgepole pine trees infested with the mountain pine beetle, *Dendroctonus ponderosae* Hopk. (Coleoptera: Scolytidae). CO_2 and liquid N_2 caused significant ($p < 0.05$) mortality of approximately 40% and 60 - 63 % of larvae and adults, respectively. About \$263 and \$67 worth of N_2 and CO_2, respectively, would be needed to treat 1.5 m of the trunk of an infested tree. The low mortality and high treatment costs make freezing uneconomical compared to the alternatives of monosodium methane arsonate or felling and burning.

Key words: mountain pine beetle, *Dendroctonus ponderosae*, liquid nitrogen, carbon dioxide, control techniques

INTRODUCTION

The mountain pine beetle, *Dendroctonus ponderosae* Hopk. kills many trees in the Prince George Region, affecting 25400 ha of lodgepole pine, *Pinus contorta*, in 1995 (Taylor 1996). Logging infested trees and treating individual trees are the most common direct control techniques. Two common treatments include the use of the systemic pesticide MSMA (monosodium methane arsonate) and "fall & burn"(Safranyik *et al.* 1982). MSMA must be applied within 3 weeks of attack for maximum effectiveness (Dyer and Hall 1979). In addition, opposition to the use of pesticide has sometimes precluded or limited its use, and current guidelines prevent the commercial use of trees treated with MSMA. Felling and burning infested trees is very costly and also prevents their commercial use. There is a need for inexpensive and non-toxic alternatives to both MSMA and "fall & burn", especially in parks and riparian areas.

The use of freezing to kill insect pests is well known, especially for stored product and structural pests (Forbes and Ebeling 1986). Promising results were also found in a trial against *Ips typograpus* L. in Romania (Hristea, personal communication 1996), in which liquid N_2 was pumped into a sleeve encasing an infested spruce tree. CO_2 and liquid N_2 come out of their containers at -79°C and -196°C respectively (Weast *et al.* 1984), and therefore can decrease the temperature of a surface well below the lethal level of -38°C for winter hardened larvae (Safranyik 1985). In summer the larvae would not be as cold hardy. We conducted a preliminary assessment of CO_2 and liquid N_2 as topical sprays to control the mountain pine beetle.

METHODS

On October 3, 1996, eight trees (mean diameter ± SD at breast height (1.3 m) = 48.6 ± 5.9 cm) infested with mountain pine beetle were selected near Prince George. The trees were felled and the infested portion of the bole identified. Three 20 x 20 cm (400 cm^2) treatment sites were marked 1 m apart on each tree and randomly given either: no treatment; a 30 second application of liquid N_2 (about 2.33 l); or a 30 second application of CO_2 (about 540 g). Liquid N_2 was applied using a 125 l cylinder or a 35 l cylinder (for transport to distant trees) coupled to a 4 m hose with a "snowhorn" nozzle attached. For the CO_2 treatment a 23 kg cylinder with a liquid withdrawal system was used[1]. Delaying treatment until 3 October allowed time for eggs to hatch and larvae to start developing after an unseasonably late attack in September. Samples were cut out with a chisel up to 4 days after treatment and the patches were allowed to warm up for 2 to 3 weeks at room temperature before examination. Larval, pupal and adult mortality was assessed as bark was removed from samples. Larvae were placed in 95% ethanol for measuring head-capsule widths. For each sample, thickness of the bark (phloem plus cortex) was measured in three places with a vernier calliper.

Mean percent mortalities for adults and larvae were compared by a one way analysis of variance (ANOVA). Linear regression analysis ($\alpha = 0.05$) was conducted to relate bark thickness to percent larval mortality for the three treatments using the equation:
$y = a + bx + e$, where y is the percent larval mortality, a is a regression constant, b is bark thickness in mm and e is an error term. To determine costs of both the CO_2 and N_2 treatments the cost of treating 400 cm^2 was extrapolated to a 1.5 m length of infested bole with a diameter of 50 cm.

RESULTS

Less than 10% of the larvae and adults were dead in the untreated bark. CO_2 killed 54.5% of the larvae and 54.7% of the adults, subtracting the control mortality. Liquid N_2 killed significantly more larvae (63.2%, $F(2,21) = 6.643$ $p = 0.006$) and adults (60.5%, $F(2,16) = 5.771$ $p = 0.013$) than the control treatment (Table 1).

Table 1

Comparison of mean mortalities caused by topical sprays of CO_2 and liquid N_2 on the outer bark of trees infested by mountain pine beetles

Life Stage	Treatment	No. of replicates	No. per m^2 (± SD)[a]	% mortality (± SD)[a]
Larvae	Untreated control	8	37.9 ± 17.9 a	8.7 ± 7.8 a
	Carbon Dioxide	8	30.9 ± 17.9 a	40.1 ± 27.0 ab
	Nitrogen	8	57.6 ± 25.3 b	63.2 ± 43.7 b
Adults	Untreated Control	7	3.0 ± 1.5 a	4.8 ± 12.6 a
	Carbon Dioxide	5	1.0 ± 0.0 b	40.0 ± 54.8 ab
	Nitrogen	7	2.9 ± 1.3 ab	60.5 ± 44.7 b

[a] Means for each life stage followed by the same letter are not significantly different, Tukey's test, p=0.05.

[1] Praxair, Delta, BC, gases and equipment.

There was an inverse relationship between bark thickness and percent larval mortality for the N_2 treatment. The regression for mortality was 148.8 - 17.9 x (bark thickness in mm), $r^2 = 0.744$, adjusted $r^2 = 0.479$, $F(1,6) = 7.439$, $p = 0.034$ (Fig. 1). The regression was not significant for the control ($F(1,5) = 1.369$, $p = 0.295$) or the CO_2 treatments ($F(1,5) = 1.881$, $p = 0.228$).

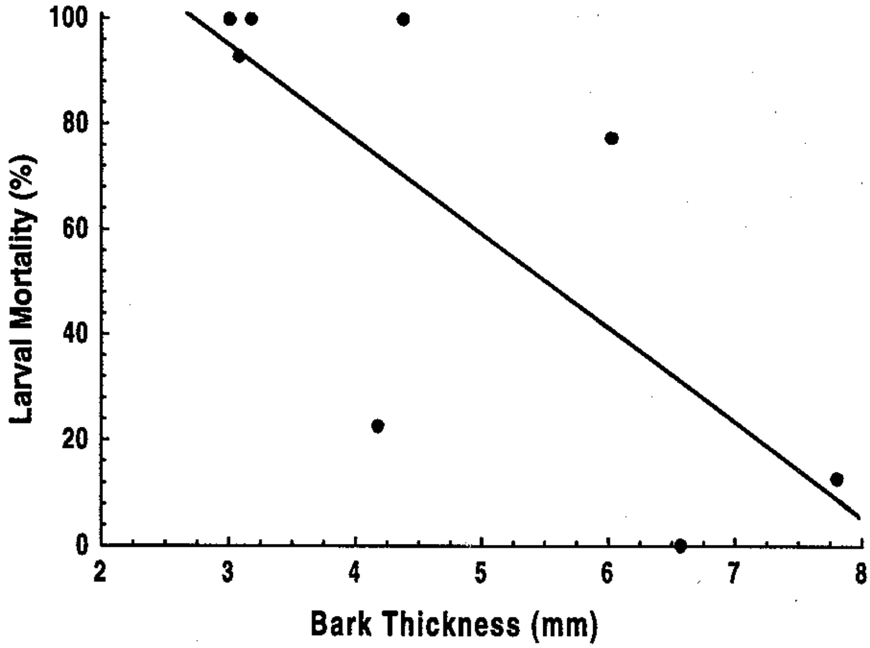

Figure 1. The relationship between bark thickness and larval mortality for the liquid N_2 treatment. Line plotted from the regression y = 148.8 - 17x, ($r^2 = 0.744$, adjusted r^2 = 0.479, $p = 0.034$).

DISCUSSION

Treatment with liquid N_2 causes significant mortality of both adult and larval mountain pine beetles. However, mortalities are about the same as those caused by a late MSMA treatment, which was 55% four weeks after attack (Dyer and Hall 1979). Moreover, the lower larval mortality under thick bark (Fig.1) shows: that liquid N_2 treatment may be ineffective on the large-diameter lodgepole pine trees with thick bark that are selected by the mountain pine beetle.

To treat about 2.3 m^2 of bark on the basal 1.5 m of the bole of the average tree in this study would require 128 l of N_2 or 30 kg of CO_2, costing \$263 and \$67, respectively. A further labour cost of \$60 per tree would result in total application costs of \$323 per tree for liquid N_2 or \$127 for CO_2. In comparison, MSMA and fell & burn treatments, cost about \$50 and \$100, respectively. Unless their application rates can be reduced, or their efficacy increased, neither CO_2 nor N_2 is likely to be used operationally. One way to increase the effectiveness might be to delay treatments until spring when the brood may be less cold hardy than in the fall.

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