

Methyl bromide fumigation of lifted lodgepole pine seedlings for European pine shoot moth control

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Lodgepole pine seedlings can be stored up to 8 weeks before fumigation with methyl bromide; fumigated and then stored up to

16 weeks; fumigated and stored in closed boxes.

Distribution of the European pine shoot moth (*Rhyacionia buoliana* (Schiffermueller)) in British Columbia is mainly confined to the Vancouver Forest District (southwestern mainland and Vancouver Island). Consequently, lodgepole pine (*Pinus contorta* Dougl.) nursery seedlings grown for use within the District must be certified as being free of the pest, whereas those seedlings destined for use outside the District must be fumigated, at the appropriate time, with methyl bromide before leaving the nursery (3). Frequently, work schedules do not permit lifting, fumigating, and then immediate shipping of seedlings for planting. Thus it would be valuable to know the effects of pre- and post-treatment storage periods on seedling survival. For storage, seedlings are tied in bundles of 50 and are packed horizontally in paper-bag lined, cardboard boxes. Each box contains 500 to 800 seedlings, depending upon seedling size. Whether boxes and storage bags should be open during fumigation, or whether adequate methyl bromide would penetrate the seedling bundles if holes were punctured in the liner bag at the hand-hold openings in the cardboard boxes was unknown. The

latter procedure would eliminate opening the boxes before, and resealing after fumigation; the holes in the liner bag would be taped shut. An inherent disadvantage of this system would be that post-fumigation aeration might be inadequate and lead to problems with methyl bromide phytotoxicity or danger to persons handling the boxes shortly after fumigation. This study was made to determine the effects on seedling survival of (1) length of pre- and post-treatment (methylbromide fumigation) storage periods, and (2) open vs. closed (holes in liner bag) boxes (luring fumigation).

Materials and Methods

Fumigation was done in a metalframed, polyethylene (10-mil thick) covered chamber at the rate of 1 lb (453 g) of methyl bromide (Dow Chemical Co.) per 250 ft³ (ca. 71 m³). Liquid methyl bromide was vaporized by heating it to 180°F (82°C); the gas was introduced via a rubber tube into the chamber where it was further distributed by an eightoutlet "octopus". During fumigation, a small fan and electric heater continuously circulated and heated, when needed, the air-methyl bromide mixture; a hygrothermograph was used to monitor temperature and relative humidity changes. The general fumigation procedure used here has been described in detail elsewhere (1, 2). Specific chamber conditions at various fumigation dates are given in table 1; these followed the approved

recommendations (3). After packing into boxes, either before or after fumigation, i.e., until planting, the seedlings were stored in a cold room at approximately 34° to 36°F (1° to 2°C).

To determine the effect of length of pre-treatment storage period on seedling survival, dormant, 1-1 lodgepole pine seedlings at the B.C., Forest Service nursery at Surrey were lifted in February 1974, and tied into bundles of 10 seedlings each. Five bundles of seedlings were placed in each of 20 boxes. Because insufficient lodgepole pine seedlings were available to fill all the boxes required, cull 2-0 Douglas-fir seedlings, tied in bundles of 50 seedlings each, were used as fillers and the pine bundles were interspersed at random. Ten of the boxes were open (both cardboard box and liner bag) during fumigation; the remaining 10 were closed (holes punctured in the liner bag at the hand-hold holes at each end of the cardboard box) when fumigated. On February 26, four boxes (two open and two closed) were fumigated. Subsequently, additional lots of four boxes each were treated after 4, 8, and 16 weeks' storage. Following fumigation, the boxes were allowed to aerate for 21 hours, whereupon 5 bundles of 10 pine seedlings each from each of the treatments (open and closed) were transplanted into a nursery bed, and 5 more bundles from each treatment were planted into 6-inch clay pots, containing equal parts of sand and peat, and kept in a

greenhouse. The effects of the various treatments were determined by recording the percentage of field and greenhouse planted trees that were dead or alive in late July 1974.

The procedures for determining the effects of post-treatment (fumigation) storage time on seedling survival were the same as for the pre-treatment experiment, except that 2-0 lodgepole pine were used and 25 bundles of seedlings (interspersed among the Douglas-fir filler bundles)

were placed in each of 8 boxes (4 open and 4 closed during fumigation). All boxes were fumigated as soon as possible after packing; 10 randomly-selected lodgepole pine seedling-bundles for each treatment were removed from the boxes and the trees were planted in the nursery transplant bed and greenhouse after 0, 2, 4, 8, and 16 weeks' storage. Controls for both experiments were unfumigated, 2-0 lodgepole pine seedlings handled exactly in the same

way as the seedlings in the posttreatment experiment. Seedling survival in the field and greenhouse was expressed on a percentage basis for each replicate, and for analysis of variance, the data were transformed to the arcsin of the square root to correct for heterogeneity of variance. The Student-Newman-Keuls' test (4) was used to test the significance of mean differences.

To determine if sufficient amounts of methyl bromide to kill the insects would penetrate the bundles, lodgepole pine shoots heavily infested with shoot moth larvae were placed at the bottom, middle and top of several boxes prior to fumigation. These shoots were subsequently dissected and the dead and live larvae were recorded.

Results and Discussion

Tables 1 and 2 give the results of the experiments. In the pre-treatment storage study (trees lifted, then stored for 0 to 16 weeks before fumigation), no effect of storage period was evident until the trees had been stored for 16 weeks (tables 1 and 2), and then only when fumigation was done in open boxes (table 1). Why survival was lower in open boxes, we do not know, but mortality was not attributable to desiccation. The overall results (table 2) reveal that: (i) seedling survival was not affected by the boxes being either open or closed during fumigation, (ii) survival was better in the greenhouse than in the field, and (iii) survival decreased significantly after 8 weeks' storage. Results of this experiment indicate that lodgepole pine seedlings should not be stored longer than 8 weeks before being fumigated, especially if the treatment is to be done in open boxes.

Results of the post-treatment experiment (trees lifted, fumigated and

Table 1.—Survival of greenhouse and field-planted lodgepole pine seedlings fumigated with methyl bromide¹

	Percentage survival			
	Greenhouse planted		Field planted	
	Boxes open	Boxes closed	Boxes open	Boxes closed
Pre-treatment storage period (weeks) ²				
0	xy80a	x92a	x100a	x100a
2	x96a	x86a	x90a	x100a
4	x92a	x88a	x94a	x100a
8	x94a	x84a	x96a	x100a
16	y56ac	x80ab	b46c	x94b
Post-treatment storage period (weeks) ³				
0	x94a	x93a	y81b	y76b
2	x99a	x92a	x69b	x62b
4	x96a	x94a	z94a	z99a
8	x94a	x94a	z100a	z100a
16	x99a	x100a	z98a	z97a
Control storage period (weeks) ⁴				
0	x95a	x99a	x100a	x81b
2	x91ab	xy91a	x95a	x79b
4	y78a	y85ab	x100c	y92bc
8	x93a	y80b	x100a	y100a
16	x100a	x100a	x100a	y100a

¹ Boxes were open or closed during fumigation; reading across, means followed by the same letter (a,b,c,) are not significantly ($P = .05$) different; reading down, means within each of the three experiments (pre-treatment, post-treatment, and control preceded by the same letter (x,y,z) are not significantly ($P = .05$) different.

² Weeks storage before fumigation; values for this treatment are means of five replicates of 10 observations each, the temperature and relative humidity (percent R H) ranges and lengths of the fumigation periods were: 0 weeks, 10–14°C, 38–68 percent R H, 3 hours; 2 weeks, 12–29°C, 36–90 percent R H, 3 hours; 4 weeks, 10–17°C, 90 percent R H, 3 hours; 8 weeks, 26–37°C, 55–95 percent R H, 2.5 hours; 16 weeks, 10–14°C, 90 percent R H, 3 hours.

³ Weeks storage after fumigation; values for this treatment are means of 10 replicates of 10 observations each, the temperature and relative humidity (percent R H) ranges and length of the fumigation period was: 10–14°C, 38–68 percent R H, 3 hours.

⁴ Values for the controls are means of 10 replicates of 10 observations each.

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then stored for periods of up to 16 weeks) showed no significant ($P=0.05$) differences in survival between fumigated and non-fumigated ($F=0.8NS$, $df=1,80$) seedlings. No trends (table 1) were evident to indicate that any of the factors studied had any practical effect on seedling survival. As in our first experiment, survival was slightly higher (table 2) in greenhouse than in field-planted stock and, while seedlings fumigated in open boxes performed better than those treated in closed boxes, the differences were too small to be of practical importance. In this experiment, the longer storage period improved seedling survival (table 2). The results indicate that neither of the two important factors studied, i.e., fumigation in open or closed boxes, and length of storage period following fumigation, had any effect

on survival of lodgepole pine seedlings.

Dissection of shoot moth infested twigs showed that no larvae survived the fumigation, confirming that adequate methyl bromide gas had penetrated both open and closed boxes. We see no reason why the closed box method can not be used in nursery practice.

Our studies show that lodgepole pine seedlings can be: (i) stored for periods up to 8 weeks before being fumigated with methyl bromide, (ii) fumigated and then stored for intervals up to 16 weeks, and (iii) that no reduction in seedling survival occurs when seedlings are fumigated in closed boxes.

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Table 2.—Overall effects of various factors on survival of methyl bromide fumigated lodgepole pine seedlings

	Percentage seedling survival ⁴	
	Pre-treatment experiment	Post-treatment experiment
Planting location ¹		
Field	85 a	91 a
Greenhouse	92 b	93 b
Boxes ²		
Open	84 a	94 a
Closed	92 a	91 b
Weeks seedlings ³ stored		
0	93 a	90 a
2	93 a	85 b
4	94 a	92 a
8	94 a	95 c
16	69 b	99 d

¹ Values are means for all seedlings planted in the two localities and include all seedlings from open and closed boxes and for all storage periods.

² Values are means for all seedlings fumigated in open and closed boxes and include all seedlings planted in both field and greenhouse and for all storage periods.

³ Values are means for all seedlings planted at the specific storage time and include all seedlings planted in the field and greenhouse and fumigated in open and closed boxes.

⁴ Reading down each column, values followed by the same letter are the same ($P = .05$); valid comparisons can only be made within individual factors such as planting location.

