EVALUATION OF AN INSULATED CANOPY FOR SEEDLING TRANSPORTATION

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SR-66

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Abstract

In the spring of 1989, the Forest Engineering Research Institute of Canada (FERIC) received funding support through a Forestry Canada FRDA contract to build an insulated seedling-transportation canopy for use on a pickup truck. The objective of the study was to compare the thermal and operational effectiveness of the canopy to conventional methods of seedling transportation and field storage. In the summer of 1989, FERIC tested the insulated canopy by using it to transport cold-stored seedlings on one planting contract and hot-lift seedlings on a second contract.

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Funding for construction of the canopy was provided by the Canada/British Columbia Forest Resource Development Agreement (FRDA), through the Pacific Forestry Centre of Forestry Canada.

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Disclaimer

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Summary

Approximately 200-280 million tree seedlings are planted annually in British Columbia. The immediate consequences of poor stock handling practices are not easily detected but the effects are cumulative and can influence the ability of seedlings to establish and grow vigorously. In the spring of 1989, the Forest Engineering Research Institute of Canada (FERIC) received funding support from the Canada/British Columbia Forest Resource Development Agreement (FRDA) through the Pacific Forestry Centre of Forestry Canada to build an insulated seedling-transportation canopy for a pickup truck. Project cooperators included Horizon Fiberglass Products Ltd., Brinkman & Associates Reforestation Ltd., and Pacific Forestry Centre of Forestry Canada.

The canopy is a completely enclosed unit designed to slip into a standard pickup truck bed. The canopy ceiling, walls, and floor are constructed of panel urethane foam insulation sandwiched between layers of fiber glass. Five centimetres of insulation were contained in the roof panel and 2.5 cm elsewhere. In addition, removable panels with 2.5 cm of insulation were constructed for the front, roof, and sides of the unit for the purpose of testing different levels of insulation.

The objective of the study was to compare the thermal and operational effectiveness of the canopy to the conventional method of using insulated tarps to transport and store seedlings in the field. In the summer of 1989, FERIC conducted two tests with the canopy; one using cold-stored stock, and a second using hot-lift stock.

When tested with cold-stored seedlings, the insulated canopy clearly maintained an interior ambient temperature below that of the conventional system. By late afternoon, temperature of the seedling environment under tarps in the main cache reached 7-11°C, which is at the prescribed 10°C upper limit. However, the temperature of the seedling environment in the insulated canopy reached only 6-8°C, and boxes stored on the bottom near the front of the unit were still at 2-3°C by late afternoon. Other benefits were also realized. Seedlings transported and stored in the insulated canopy required less handling. Supervisory time normally spent loading, unloading, and caching seedlings in the conventional system could be spent supervising the planters and checking planting quality.

When tested with hot-lifted seedlings, the insulated canopy maintained the temperature of the seedling environment at the same level or below that of the conventional system. At no time did the temperatures in either method of transportation and storage reach critical levels. Again, seedlings transported within the canopy benefitted from reduced handling, as well as from increased air circulation as the seedling boxes were open at all times.

With a few minor modifications, the insulated canopy will be a useful and economical tool for a reforestation program. The level of insulation was adequate to maintain seedling temperatures well below specified upper limits.

INTRODUCTION

Approximately 200-280 million tree seedlings are planted annually in British Columbia.[1] The planting season now extends from early spring to late fall because both cold-stored and hot-lift seedlings, and a variety of stock types, are utilized. Historically, research on seedling survival and growth has focused on the relationship of field performance to nursery culture and site preparation. However, focus has now shifted to studying the influence of external factors on the seedlings between the time of lifting and planting. The protection of seedlings from extreme temperature and moisture, and physical damage—each of which could lead to shock, stress, and the depletion of carbohydrate reserves—has been identified as the key element in preventing loss of seedling vigour and mortality (Storey 1989). The immediate consequences of poor stock-handling practices are not easily detected, but the effects are cumulative and can influence the ability of tree seedlings to establish and grow vigorously.

Research has shown that insulated tarps are useful in protecting seedlings from heat stress caused by exposure to direct sunlight (DeYoe, Holbo, and Waddell 1986). These tarps consist of reinforced white vinyl on one side and metallized mylar on the other. The white side is placed upwards to reflect and reradiate incoming solar radiation, while the metallic side is placed downwards to block reradiation of heat through the tarp towards the stored seedlings. These insulated tarps are widely used in tree-planting operations.

Custom-made insulated canopies for pickup trucks have been used successfully by forest companies and planting contractors (Dorion 1988); however, no comparative study has been done to quantify the benefits of such a unit over conventional methods of using insulated tarps to transport and store seedlings in the field. FERIC surveyed its members to determine the need for, and design parameters of, an insulated seedling-transportation canopy. In the spring of 1989, FERIC received funding support from the Canada/British Columbia Forest Resource Development Agreement (FRDA), through the Pacific Forestry Centre of Forestry Canada, to build an insulated seedling-transportation canopy for a pickup truck.

The objective of the study was to compare the thermal and operational effectiveness of the canopy to the conventional method of seedling transportation and field storage. This project involved several cooperators. Horizon Fiberglass Products Ltd. manufactured the canopy; Brinkman & Associates Reforestation Ltd., the planting contractor, suggested design parameters for the prototype unit and implemented the use of the canopy; and the Pacific Forestry Centre of Forestry Canada was the scientific authority administering the contract funding.

[1] Charles von Hahn, Planting Program Specialist, B.C. Ministry of Forests, Victoria; pers. comm., December 1989.

THE CANOPY

The canopy (Figures 1 and 2), fabricated by Horizon Fiberglass Products Ltd. of Delta, B.C., was a modification of a current canopy design. The canopy is a completely enclosed unit, i.e. complete with an insulated floor (Figure 3), and is designed to slip into the bed of a standard pickup truck. Canopy walls are constructed of panel urethane foam insulation sandwiched between layers of fiber glass. Five centimetres of insulation were contained in the roof panel and 2.5 cm elsewhere. In addition, removable panels with 2.5 cm of insulation were constructed for the front, roof, and sides of the

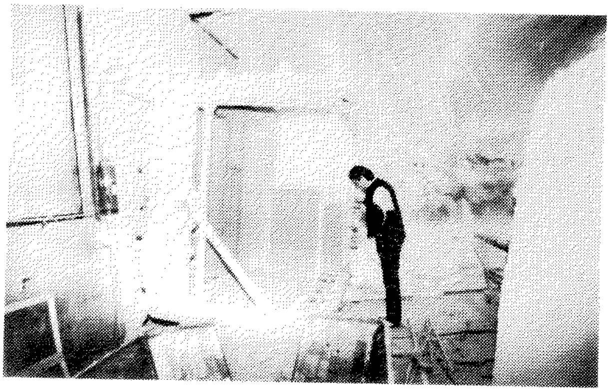

Figure 1. Upper portion of the canopy unit in the mold.

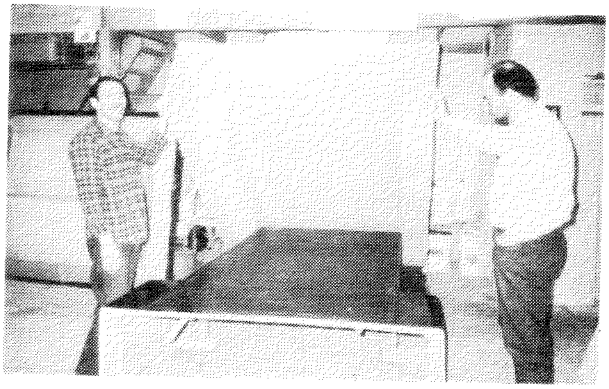

Figure 2. Bedliner (bottom) of the canopy unit being removed from the mold.

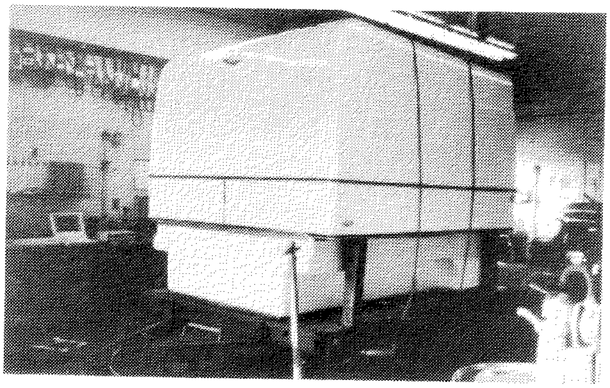

Figure 3. Assembled insulated canopy.

unit (Figure 4). Two-and-a-half centimetres of new insulation have an "R value" of 7.0 but may deteriorate to 5.5 with time.[2]

The canopy was designed to have an inside height of 1.8 m and a width and length to fit a standard, full-size, 2.4-m pickup truck bed. Small vents were installed in the front and sides of the unit for air exchange, if required. Two full-height cargo doors were installed at the rear. These doors also contained 2.5 cm of insulation. The canopy was installed on a pickup truck provided by Brinkman & Associates Reforestation Ltd. and was attached to the truck bed by four large bolts. Wooden frame shelves were constructed for stacking open boxes of hot-lift stock.

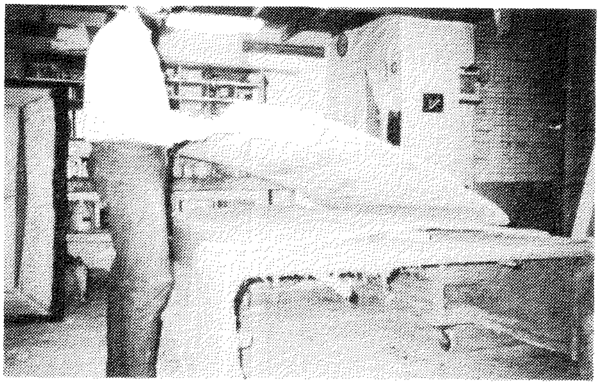

Figure 4. Removable insulated panel.

COMPARATIVE TESTING USING COLD-STORED STOCK

The comparative test took place in June 1989 on a planting contract with the participation of Brinkman & Associates Reforestation Ltd., Crestbrook Forest Industries Ltd., and Myers Woods Services (planting contract implementor). Cold-stored seedlings were held in Crestbrook Forest Industries Ltd.'s reefer in Canal Flats, B.C. at a temperature between 1 and 3°C. Under normal operations the seedlings were transported 50 km to a main field cache that was central to the planting blocks. This main cache held enough seedlings to meet the daily requirements of the 35-member planting crew. Boxes were withdrawn from the main cache two or three times each day and taken to smaller field caches located on the planting blocks. Planters filled their planting bags, i.e. bagged up, with seedlings drawn from these small field caches. At the end of the day, unplanted seedlings were placed in the main cache and used for the first bag up the following day. The upper temperature for the seedling environment within their storage boxes was specified as 10°C during both transportation and field storage. Figure 5 summarizes the various phases of transport and storage involved in the conventional (tarp) system and canopy system.

Tarp

Using the conventional system, boxes of seedlings were transported daily from the reefer to the main cache either in the bed of a pickup truck (Figure 6) or in an open-topped plywood trailer (Figure 7) covered with a Silvacool®[3] tarp. Seedling boxes transported in the pickup truck were placed on slats to provide an insulating barrier of air between the boxes and the heat generated by the pickup's running gear and exhaust. Boxes of seedlings were unloaded from the reefer to the pickup truck at 07:00 and delivered to the main cache 1-1.5 h later. The main cache was located at a sheltered, shaded spot near a large stream and central to the planting blocks (Figure 8). Here, boxes of seedlings were unloaded and again placed under Silvacool tarps. Boxes of seedlings were withdrawn periodically and taken to smaller field caches located directly on the planting blocks. The tarps used in the study were in good condition, i.e. they were almost new and had no visible signs of deterioration.

Canopy

With the insulated canopy system, seedlings were transported daily from the reefer as well. Boxes of seedlings were unloaded from the reefer to the canopy in the morning and again delivered to the site 1-1.5 h later. However, they were not unloaded at the main cache. Instead, the loaded canopy was driven directly to the planting block where it served as a mobile main cache. Planters could then bag up directly from the canopy. Boxes of seedlings were also withdrawn periodically from the canopy and taken to smaller field caches, or the pickup was moved as seedlings were required. Usually, however, the canopy remained parked at a central landing (Figure 9). Unlike the main cache in the conventional system, this was usually in an open, sunny location. At the end of the day unplanted seedlings were placed in the main cache and used for the first bag up the following day.

COMPARATIVE TESTING USING HOT-LIFT STOCK

Another comparative test was conducted in July 1989, in northern B.C., on a planting contract with the participation of Brinkman & Associates Reforestation Ltd. and Canadian Forest Products Ltd., Chetwynd. Hot-lift spruce seedlings were transported by reefer directly to a main cache located at the planters' camp, southwest of Tumbler Ridge. The reefer contained enough seedlings to meet the 35-member planting crew's requirements for approximately one week. The main

[2] Brad Engelland, Horizon Fiberglass Products Ltd., Delta, B.C.; personal communication, December 4, 1989.

[3] Silvacool® is a registered trademark of Brushpro Supplies Inc., Vancouver, B.C. Silvacool tarps are constructed of reinforced white vinyl on one side and metallized mylar on the other.

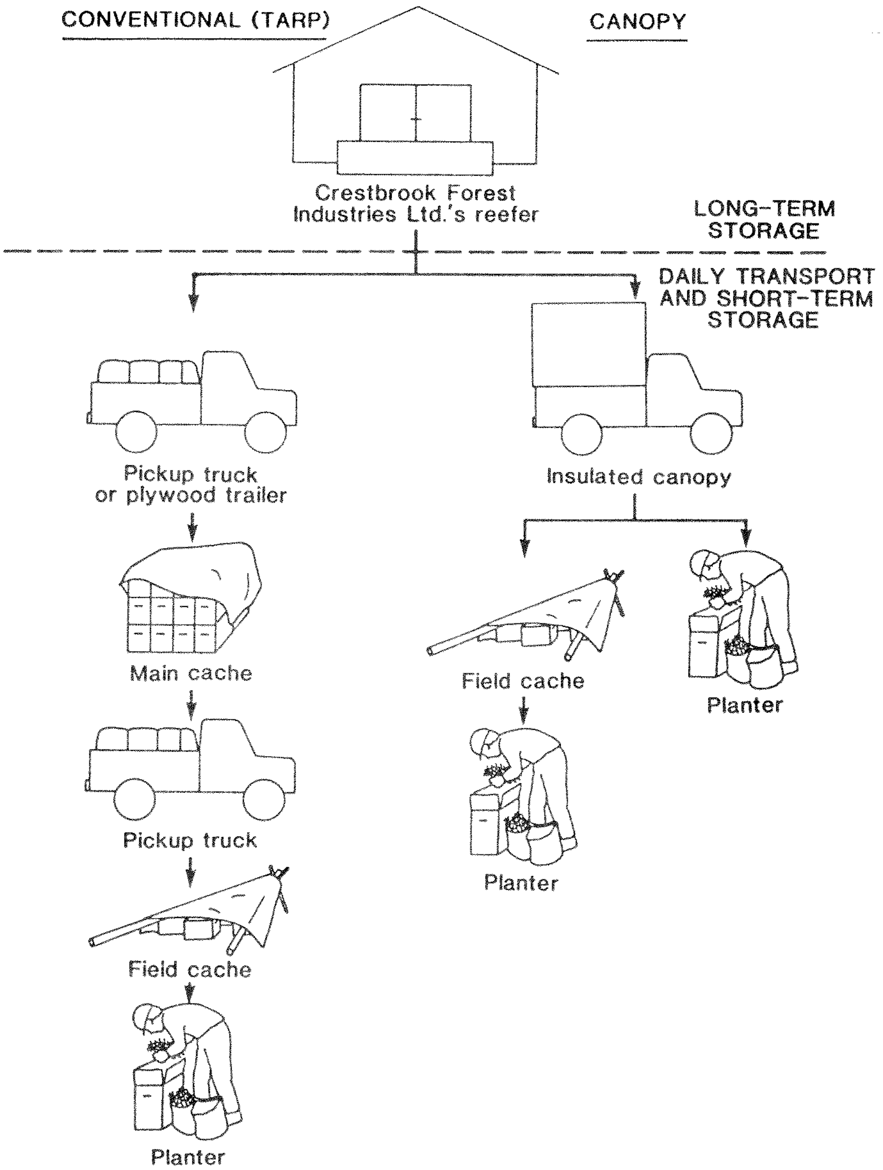

Figure 5. Seedling transport and storage: Cold-stored stock.

Figure 6. Seedling boxes loaded in the pickup truck and covered by a Silvacool tarp.

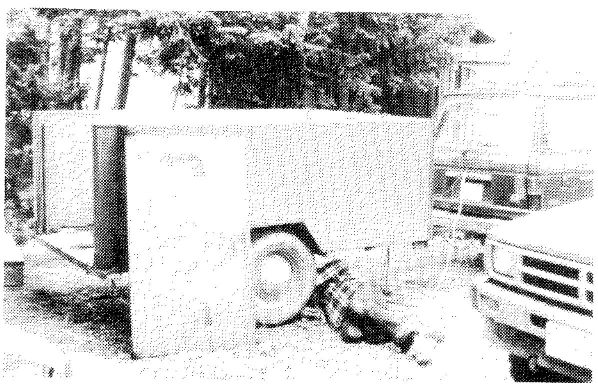

Figure 7. Open-topped plywood trailer used to transport seedlings.

Figure 8. Seedling boxes stored under tarps at the main cache, cold-stored planting contract.

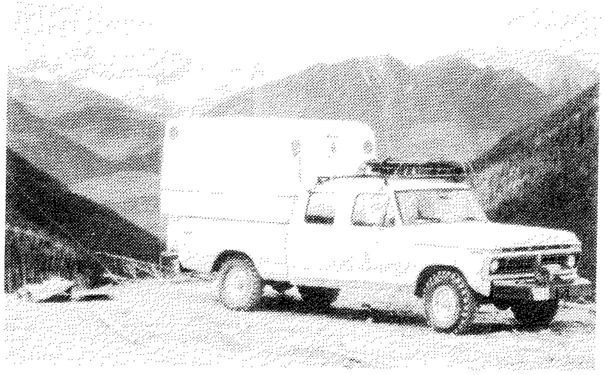

Figure 9. Insulated canopy loaded with seedlings and parked at a central landing.

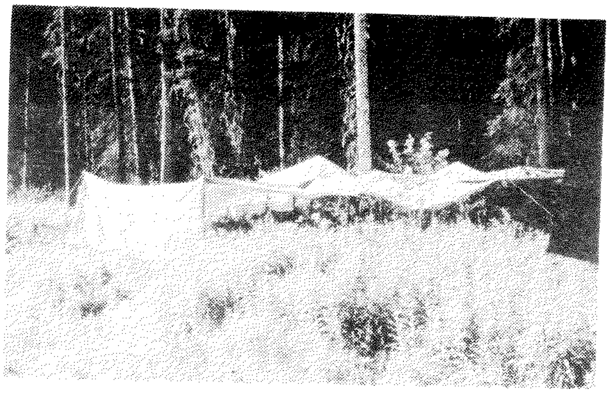

Figure 10. Main cache, hot-lift planting contract.

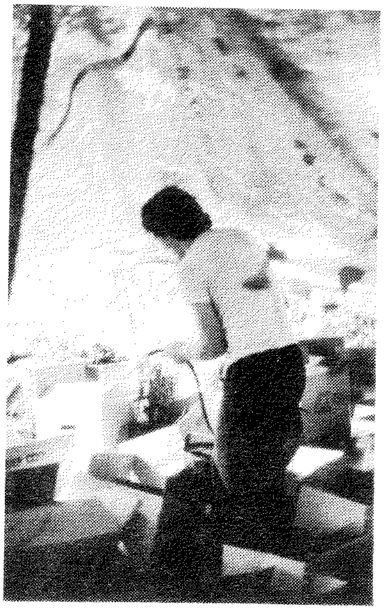

Figure 11. Watering seedlings stored in the main cache, hot-lift planting contract.

cache consisted of a large, tarped area; it was located off the road and was partially shaded by surrounding trees (Figure 10). The reefer was unloaded, the boxes were opened, and the seedling bundles were placed upright. Seedlings were watered periodically as required (Figure 11). Seedlings were transported two to three times per day to the planting sites for immediate bag up or short-term storage in small field caches. Distance to the various planting blocks from the main cache varied from 15 to 40 km. The critical upper temperature for the seedling environment during transportation and storage was specified as 35°C. Figure 12 summarizes the various phases of transport and storage involved in the conventional (tarp) system and canopy system.

Tarp

In the conventional system, seedlings were covered with Silvacool tarps and transported in pickup truck beds. For the first trip of the day, closed and stacked boxes of seedlings were loaded at approximately 05:00. At the planting block, the majority of the seedlings were bagged up, while the remaining boxes were opened and stored under tarps in field caches. In subsequent trips, seedling boxes were not stacked and were left open on the truck, covered with Silvacool tarps (Figures 13 and 14). At the planting site, these boxes were placed in small field caches (Figure 15). On occasion, the pickup truck bed was covered with additional tarps and served as the field cache.

Canopy

Seedlings were transported in the insulated canopy using a racking system to allow the boxes to remain open at all times (Figure 16). A full load of 34 open boxes was again loaded at approximately 05:00 and transported to the site during the first trip of the day. Approximately half were bagged up immediately. After the second bag up, the remainder were cached under tarps on site and the canopy returned to the main cache for a second trip at approximately noon. The second canopy load stayed on site and served as the field cache for the remainder of the day, and planters bagged up directly from it.

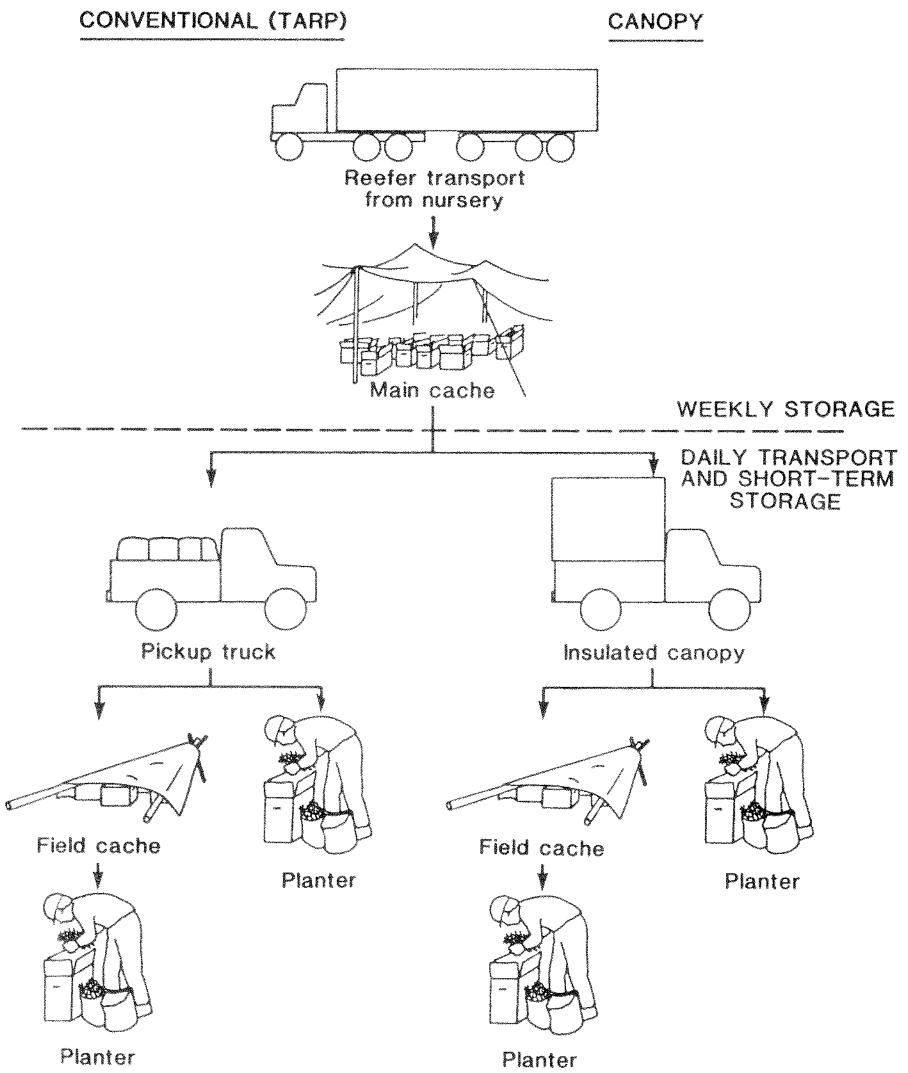

Figure 12. Seedling transport and storage: Hot-lift stock.

Figure 13. Loading open boxes of hot-lift stock into a pickup truck.

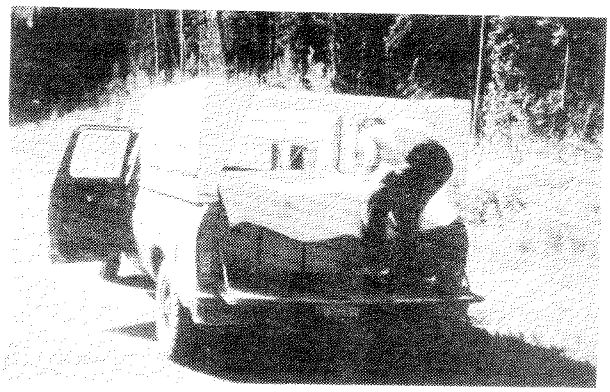

Figure 14. Covering open boxes of hot-lift stock with a Silvacool tarp.

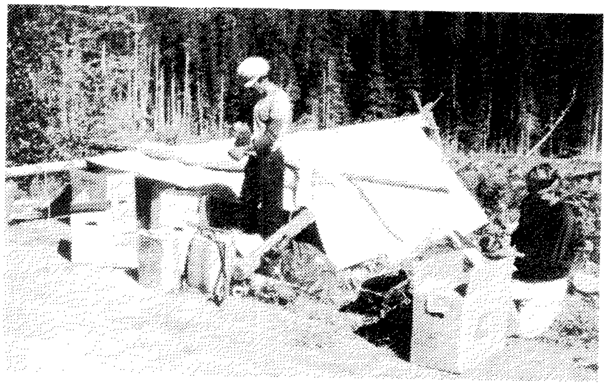

Figure 15. Small field cache located within the planting block.

Figure 16. Insulated canopy loaded with open boxes of hot-lift stock.

STUDY METHODS

The objective of the study was to quantify the temperature regimes of the seedling environment for both the conventional system and the insulated canopy, and to test the operational effectiveness of the insulated canopy under field conditions. Every effort was made not to interfere with normal operations and to test the systems under realistic conditions. To establish a baseline, temperature readings of the conventional seedling transportation system were taken during the first two or three days in different weather conditions. Similar readings were then taken for the insulated canopy, both with and without the extra insulating panels. Unfortunately, data for both systems could not be collected simultaneously because of the logistics of the planting operation and limited equipment availability.

Data were collected using a 12-channel datalogger connected to a laptop computer. Eight thermistors monitored the temperature every 30 seconds during data collection. In both systems, six thermistors were placed directly in the seedling boxes, sandwiched between seedling foliage in a central bundle, to measure the temperature of the seedling environment as accurately as possible. In the conventional transportation system, a thermistor was placed on top of the seedling boxes under the tarp, and another was taped directly on the top of the tarp. When testing the insulated canopy, one thermistor was suspended 30 cm below the ceiling of the canopy, and a second was taped directly outside on the canopy roof. Temperature readings from the thermistor on top of the tarp and the thermistor on the canopy roof were used to calculate "total temperature load," i.e. as a way of comparing the different daily weather conditions each system experienced. The total temperature load >5°C in degree-minutes was calculated as half the sum of the measured 30-second temperature readings minus 5°C. For both systems, thermistors were put in place when the seedling boxes were loaded in the morning; monitoring continued until the seedlings were required for bag up at periods throughout the day, at which time the thermistors were removed. In the case of the tarp system, thermistors were left in place when the boxes were being unloaded from the pickup bed or trailer into the main cache.

RESULTS

Cold-Stored Seedlings

Results of the cold-stored portion of the study are summarized in Table 1 and Appendix I. Weather ranged from cool and rainy, to sunny and warm, with ambient temperatures from 5 to 25°C.

Tarp. During the conventional portion of the trial, the measured temperatures on the tarp surface ranged from 7 to 34°C. Total temperature load on the tarp surface, in degree-minutes greater than 5°C, ranged from 396 to 1214 during the trip and from 743 to 2923 at the cache. Total temperature load, for the trip and cache combined, ranged from 1321 to 4137 degree-minutes greater than 5°C. Total temperature load at the main cache was low because the cache was in a shaded location. Ambient temperature measured by the thermistor placed on top of the seedling boxes under the tarp ranged from 7 to 20°C, and tended to fluctuate in accordance with tarp surface temperatures. The temperature of the seedling environment slowly rose from reefer temperature (1-3°C) to 7-11°C by late afternoon. The sheltered location of the cache, combined with cool soil temperatures, helped to keep temperatures down.

Canopy. The insulated canopy portion of the trial was conducted in two parts. When all the insulated panels were used, measured surface temperatures ranged from 7 to 32°C. Total temperature load greater than 5°C ranged from 3407 to 7363 degree-minutes for the trip and cache combined. Total temperature load was high because the locations where the canopy served as the cache were open and sunny. Ambient temperatures within the canopy ranged from 6 to 12°C and were characterized by a gradual rise, unlike the fluctuating surface readings. Temperatures of the seedling environment rose slowly from reefer temperatures to 3-6°C by late afternoon. When the canopy was used without the extra panels, surface temperatures ranged from 8 to

Table 1. Cold-Stored Seedlings

Date	Method	Weather	Range of surface temperature (°C)	Total temperature load on surface >5°C [a]			Elapsed time			Internal ambient temperature range [b] (°C)	Temperature of seedling environment	
				Trip (°min)	Cache (°min)	Total (°min)	Trip (min)	Cache (min)	Total (min)		Initial[c] (°C)	Final[c] (°C)
Conventional system												
June 16	Tarp and pick-up, 35 boxes	Rainy	7-12	396	1 395	1 791	90	343	433	7-11	3	7
June 17	Tarp and trailer, 30 boxes	Cloudy with sunny breaks, cool	12-34	1 214	2 923	4 137	99	306	405	10-20	3	8-11
June 18	Tarp and trailer, 30 boxes	Cool, sunny, partly cloudy	8-15	578	743	1 321	90	106	196	8-13	2-5	7
Canopy system: Fully insulated												
June 21	16 boxes	Cool, sunny, partly cloudy	8-15	n/a	n/a	3 407	n/a	n/a	438	6-8	1-3	3-6
June 22	30 boxes	Trip - overcast Landing - sunny with cloudy periods and windy	7-32	n/a	n/a	7 363	n/a	n/a	573	8-12	2	3-6
Canopy system: Panels out												
June 25	44 boxes	Sunny and warm	8-33	n/a	n/a	8 065	n/a	n/a	458	8-16	1.5-3	2-6
June 26	Small load, gas and water transported to camp	Sunny/cloudy and warm	16-24	n/a	n/a	1 988	n/a	n/a	144	14-16	3	3-8
June 28	28 boxes	Overcast	10-30	n/a	n/a	5 569	n/a	n/a	430	8-12	1-3	3-6

[a] Calculated as $\sum_{i=1}^{n} 0.5(x_i - 5.0)$ where,
n = number of 30-second temperature readings (logs)
x = measured surface temperature
[b] Measured underneath the tarp or within the canopy.
[c] The "initial" values represent initial reefer temperatures of the seedling environment prior to transport and field storage. The "final" values represent temperatures of the seedling environment reached by the end of the monitoring period.

33°C. Total temperature load greater than 5°C ranged from 1988 to 8065 degree-minutes and, again, was high because of the open, sunny locations. Ambient temperature within the canopy ranged from 8 to 16°C, and was again characterized by a slow rise. The temperature of the seedling environment also rose slowly from the reefer temperature to 3-8°C by late afternoon.

In general, location within the canopy accounted for differences in the temperature of the seedling environment. The highest temperatures occurred in the boxes on top and near the canopy door in the rear, but these were the boxes of seedlings which were used first. The lowest temperatures occurred in the boxes on the bottom near the truck's cab or on the bottom in the middle of the load. These boxes of seedlings were the last to be used or were left to go into the main cache overnight for the first bag up the following day.

Hot-Lift Seedlings

Results of the hot-lift portion of the study are summarized in Table 2 and Appendix II. Weather varied from overcast and rainy to hot and sunny, with ambient temperatures ranging from 10 to 30°C.

Tarp. With the conventional tarp system, measured surface temperature ranged from 13 to 45°C. Total temperature load greater than 5°C ranged from 400 to 5089 degree-minutes. Ambient temperature measured by the thermistor placed on top of the seedling boxes under the tarp ranged from 14 to 26°C and tended to fluctuate with surface temperatures. The measured

Table 2. Hot-Lift Seedlings

Date	Method	Weather	Range of surface temperature (°C)	Total temperature load on surface >5°C [a] (°min)	Elapsed time (min)	Internal ambient temperature range [b] (°C)	Temperature of seedling environment (°C)
Conventional method							
July 21	Tarp - trip and cache	Sunny and warm	15-28	2 389	161	15-22	10-15
July 22	Tarp	Windy, partly cloudy					
	Noon - trip only		13-21	400	39	14-20	11-18
	Afternoon - trip and cache		16-40	2 760	163	14-26	12-17
July 23	Tarp	Sunny and hot					
	Noon - trip and cache		25-45	5 089	178	20-25	12-16
Canopy system: Panels out							
July 24	First trip	Clear and sunny	11-29	1 894	153	11-13	10-11
	Second trip and cache	Overcast and showers	11-28	5 020	334	14-16	12-14
July 26	First trip - early	Clear and sunny	2-26	2 363	173	8-14	8-14
	Second trip and cache	Sunny and warm	24-37	6 646	263	18-21	12-15
Canopy system: Fully insulated							
July 27	First trip - early	Cloudy with showers	12-15	503	59	14-15	12-15
	Second trip only	Sunny with cloudy periods	21-31	1 051	50	18-20	13-16

[a] Calculated as $\sum_{i=1}^{n} 0.5(x_i - 5.0)$ where,

n = number of 30-second temperature readings (logs)

x = measured surface temperature

[b] Measured underneath the tarp or within the canopy.

temperatures of the seedling environment remained fairly steady, ranging from 10 to 18°C.

Canopy. For the canopy portion of the study, both with and without the extra insulating panels, measured surface temperatures ranged from 2 to 37°C. Total temperature load greater than 5°C ranged from 503 to 6646 degree-minutes. With the panels removed, interior temperatures ranged from 8 to 21°C, and the temperature of the seedling environment varied from 8 to 15°C. With the panels in, interior temperatures ranged from 14 to 20°C, and temperatures of the seedling environment ranged from 12 to 16°C.

DISCUSSION

Seedlings depend upon carbohydrate reserves from the time they are lifted until photosynthesis in outplanted seedlings can meet the demands of growth and respiration. Even low levels of stress have been found to severely retard the ability of plants to regenerate roots (Rietveld 1989). Prompt establishment of root/soil contact is crucial for avoiding moisture stress after outplanting. Respiration in lifted seedlings should be minimized because it depletes the stored carbohydrates. Research has shown that storage temperatures between -2 and +5°C minimize the consumption of stored carbohydrates (Rietveld 1989), and that the rate of respiration is an exponential function of temperature, doubling every 10°C (Sweeten and Fraser 1989).

Research has also shown that rough handling of seedlings causes increased metabolic activity which accelerates depletion of reserve carbohydrates. Mechanical shock to seedlings, or rough handling, reduces root growth potential, depresses the development of mycorrhizae, and induces water stress (Tabbush 1986).

In the cold-stored portion of the trial the insulated canopy clearly maintained interior ambient temperatures below those of the conventional system. By late afternoon, the temperature of the seedling environment in the boxes under tarps in the main cache was near the 10°C upper limit, i.e. it ranged from 7 to 11°C. Temperature of the seedling environment in boxes in the insulated canopy reached temperatures of 6-8°C, and boxes stored on the bottom near the front of the unit were still at 2-3°C by late afternoon. Seedlings in the canopy that were not planted during the day were still close to reefer temperature (1-3°C) when placed in the main cache that evening.

Temperature increase in the seedling boxes was influenced by the number of boxes in the load, as the boxes themselves were a source of cooling. A larger load would reduce the average number of exposed sides per box and increase the source of cooling for the air contained within the canopy or below the insulated tarp. Temperatures monitored in seedling boxes surrounded by other boxes on all sides were lower than those with one or more surfaces exposed. The insulated canopy method proved to have an advantage in this respect in that the load of seedling boxes remained intact until individual boxes were withdrawn by the planters for immediate use. Even small loads of 10-15 boxes remained below 10°C because it was not necessary to transfer them to a main cache before bag up. Transferring seedling boxes into the main cache using the conventional system of transport and storage increased the air flow around the seedling boxes and inhibited the mutual cooling benefits of maintaining an intact load.

In the cold-stored portion of the trial, the seedlings benefitted from both lower temperatures within the insulated canopy and reduced handling. Using the conventional system, seedlings were unloaded at the main cache, reloaded onto trucks and moved to the planting site, and unloaded and cached before finally being bagged-up by the planters. Supervisory time spent loading, unloading, and caching seedlings ranged from 1.0 to 1.5 h/day. Seedlings transported in the canopy, however, were driven directly to the planting site and the planters bagged up directly from the unit; supervisors were able to spend more time supervising planters and checking quality.

In the hot-lift portion of the study, the insulated canopy maintained the temperature of the seedling environment at temperature levels at or below those of the conventional system. Again, seedlings transported with the canopy benefitted from reduced handling as well as increased air circulation because the seedling boxes were open at all times. The canopy's dark interior had no effect on the stored seedlings. Hot-lift seedlings can be stored in total darkness for one or two days with no harmful results.[4] As well, the relative humidity was probably higher within the canopy than under the tarp, but this was not measured in this study. At no time did seedling temperatures in either test reach critical levels.

FERIC believes the insulated canopy system will provide a more consistent level of protection for the seedlings than the tarp system. The manufacturer, Horizon Fiberglass Products Ltd., estimates that the canopy will last five field seasons with little reduction in insulating ability. Insulated tarps may provide reduced protection if great care is not taken when tying down the load and covering the field caches. Insulated tarps do not give a consistent level of protection during the season because they deteriorate with use and, generally, need to be replaced every year. Brinkman's experience suggests that tarps are not designed to withstand the rippling and flapping which occurs when the pickup truck is travelling on the highway. The resulting delamination has given these tarps a life span of one season or less when used for seedling transport. In contrast, tarps that are well cared for and used only for cache building can last for several seasons.[5] The tarps used in this study were in good condition.

The final retail price of the canopy has yet to be determined; however, it should be available at a cost of C$3000-3500. This is comparable to the purchase of three 4.6-m x 5.5- m Silvacool tarps per year, over five years, at a cost of C$230 each.[6] Cost benefits to the planting contractor resulting from use of the canopy system also include potential increased planting productivity and quality as a result of increased planter supervision. The canopy will also be available in a lease program.

RECOMMENDED DESIGN MODIFICATIONS

The experiences of the study and comments from the planting contractors and crews were used to quantify design parameters for a production unit.

Temperature monitoring data show that the 5.0 cm of insulation in the roof and 2.5 cm elsewhere were sufficient to maintain the temperature of the seedling environment below the 10°C level required for the cold-stored seedlings. Measurable benefits were, however, shown by the addition of the 2.5-cm panels to the roof, front, and sides of the unit. The manufacturer believes that additional insulation would also extend the canopy's working life. This suggests that using 5.0 cm of insulation throughout the unit would be desirable if the extra manufacturing costs are not prohibitive. This extra insulation would ensure that temperatures of the seedling environment would remain close to reefer temperature throughout the day; seedlings could also be stored with little or no temperature stress for a second day thus further reducing travelling time and stock handling.

Weight and unit dimensions were also discussed with the planting contractor. The 360-kg prototype canopy was considerably heavier than desirable. Extra fiber glass was required to make the removable panels and to make it possible to produce this prototype from existing molds, but the manufacturer feels that a pro-

[4] D.P. Lavender, Department Head, Department of Forest Sciences, Faculty of Forestry, University of B.C., Vancouver; personal communication, April 1990.

[5] D. Brinkman, President, Brinkman & Associates Reforestation Ltd., New Westminster, B.C.; personal communication, April 1990.

[6] Brushpro Supplies Inc., Jan. 10, 1990 price list.

duction unit made specifically for seedling transportation would be significantly lighter. The contractor has suggested a target weight of 160-180 kg.

The prototype unit was designed to fit a standard 2.4-m pickup truck bed and, because of its weight, it would have been more suited for use on a 1-ton pickup. Generally a four-door, 3/4 ton crew cab pickup is preferred by planting contractors, and a 2.1-m canopy would be more widely acceptable. Currently, B.C. seedlings are shipped in 30 x 60 x 45 cm boxes, a standard size that is not likely to change. A 2.1-m model which maintains the 1.83-m inside clearance of the prototype could store up to 45 closed, stacked boxes or 20 250 seedlings (at 450/box). Equipped with a racking system, the unit could hold 39 open boxes or 17 550 seedlings. These volumes are adequate for most planting operations. Some provision must be made for transporting planters' gear. A compartment with separate access is recommended.

The proposed production racking system for hot-lift seedlings consists of four 1.1-m x 1.5-m sheets of wire mesh, supported on the sides by angle iron fixed to the unit's inside walls. Mesh sheets could be stored on the floor of the unit when not in use and would take up little space. The mesh sheet would provide sufficient support while allowing free air flow around the seedling boxes. Horizon Fiberglass Products Ltd., the manufacturer, is designing removable shelves.

The full-size cargo doors on the rear of the unit are a desirable feature for easy access when loading and unloading. However, the doors and fastenings need to be strengthened. A plastic strip curtain door inside the cargo doors would restrict the loss of cooled air from the canopy when withdrawing seedling boxes.

After the pickup with canopy reached the planting site, the pickup remained stationary as a cache. A detachable canopy, with camper-style jacks, would allow the truck to be used for other tasks. In some operations, a towed trailer might be an alternative. However, a trailer unit would be limited to travelling on roads suitable for two-wheel-drive vehicles, and seedlings may receive more shock loading than those transported in a pickup with canopy. Helicopter lifting eyes can also be installed for air transportation to limited access blocks.

CONCLUSIONS

In the cold-stored portion of the trial, the insulated canopy, both with and without the extra panels, clearly outperformed the conventional tarp system in maintaining lower and more stable temperatures within the seedling boxes. On this operation, the seedlings transported within the canopy incurred less chance of physical damage because less handling was required. The planting contractor benefitted from having more of his supervisors' time available to monitor planting quality and productivity.

In the hot-lift portion of the trial, the insulated canopy, both with and without the extra panels, provided temperature control comparable to the conventional system. Benefits are not as clearly defined as with the cold-stored seedlings; however, the seedlings transported with the canopy again benefitted from less handling. Again, the planting contractor benefitted from having more of his supervisor's time available to monitor planting quality and productivity.

With a few minor modifications, the insulated canopy will be a useful and economical tool for reforestation programs. The level of insulation, whether with or without the extra panels, was adequate for maintaining seedling temperatures well below specified maximum limits.

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APPENDIX I

Representative Temperature Profiles From Comparative Testing Using Cold-Stored Stock

Representative temperature profiles are presented in Figures I-1 to I-5. All figures present measured surface temperatures, measured internal ambient temperatures, and an average temperature of the seedling environment (calculated from the six seedling boxes monitored) plotted over the duration of transport and storage for the day. This ranged from 7 to 9.5 h. The number of seedling boxes transported varied daily.

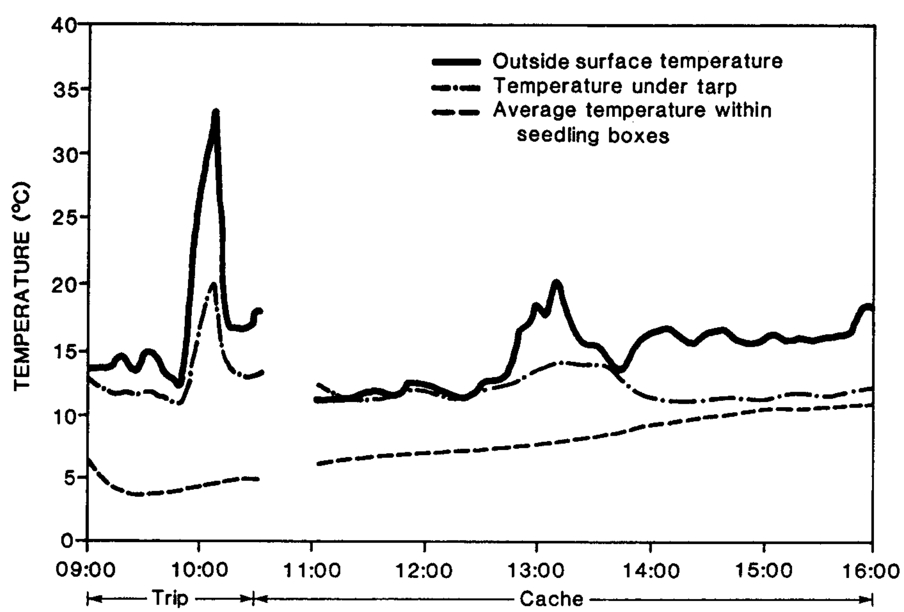

Figure I-1. Surface, internal, and seedling temperature profiles resulting from transportation of 35 seedling boxes with a plywood trailer and Silvacool tarp, June 17, 1989. Monitoring continued for 25 boxes stored in the main cache. Seedling boxes were withdrawn from the main cache periodically throughout the day. Weather was cloudy with sunny breaks and cool temperatures. The temperature peak at 10:00 occurred when the trailer sat in camp for 10 min during a sunny break. A second sunny break occurred at 13:00 while the seedlings were in the main cache. Note the matching rise in temperature beneath the tarp following these events. Average temperature of the seedling environment was characterized by a steady rise unaffected by the fluctuating ambient temperature beneath the tarp. This suggests that the seedling boxes provided some insulation. By 15:00, temperature of the seedling environment had reached the specified upper limit.

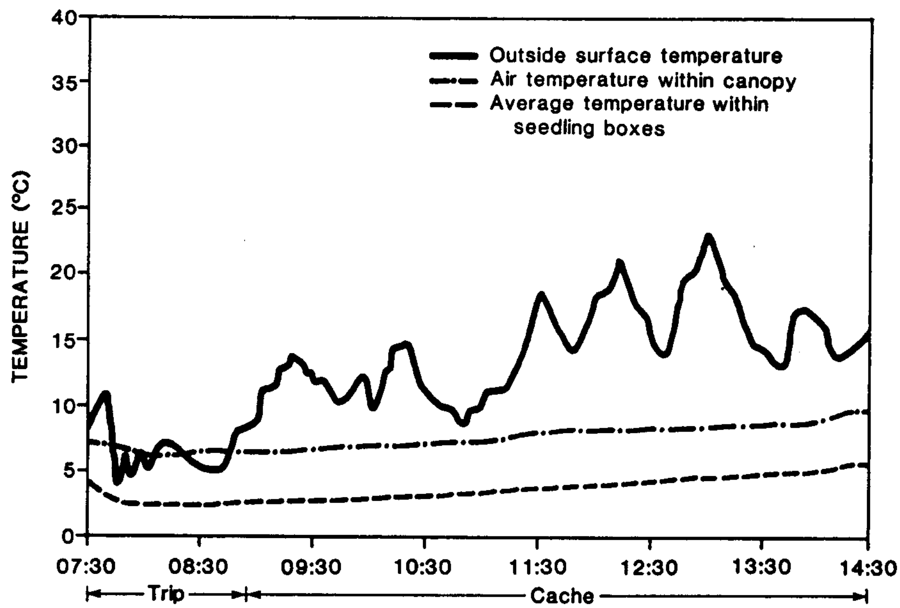

Figure I-2. Surface, internal, and seedling temperature profiles resulting from transportation of 16 seedling boxes, directly to the planting block, with the canopy, fully insulated, June 21, 1989. Surface temperature during transportation dipped due to brief rain showers. Weather throughout the remainder of the day was cool, sunny, and partly cloudy. Temperature within the canopy remained quite steady with slight increases at 11:30 and 14:30 when seedlings were withdrawn from the unit. Temperature of the seedling environment was characterized by a gradual rise to an average of 5-6°C by late afternoon.

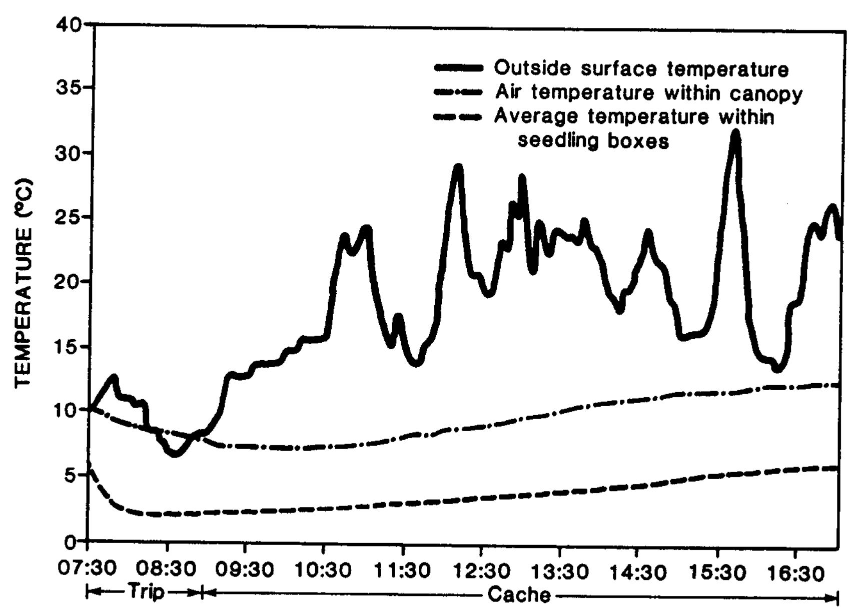

Figure I-3. Surface, internal, and seedling temperature profiles resulting from transportation of 30 seedling boxes, directly to the planting block, with the canopy, fully insulated, June 22, 1989. Weather during transport was overcast but changed to sunny with cloudy periods and windy for the remainder of the day. The canopy's internal ambient temperatures were characterized by a gradual rise to 12°C by late afternoon. Average temperature of the seedling environment gradually rose to 5°C by late afternoon.

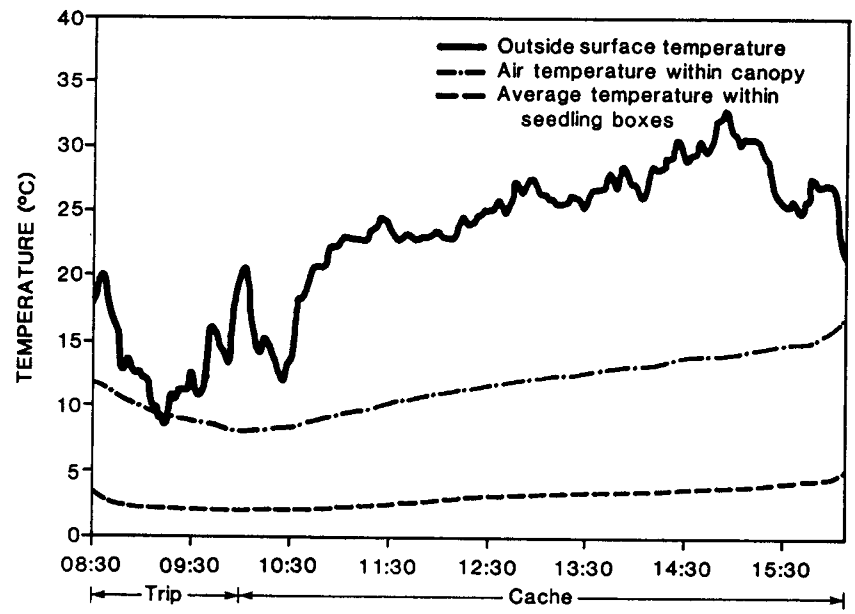

Figure I-4. Surface, internal, and seedling temperature profiles resulting from transportation of 44 seedling boxes directly to the planting block, with the canopy, with panels removed, June 25, 1989. Weather was sunny and warm. Ambient internal temperature was generally higher than when the extra insulating panels were used. The canopy's internal temperature was characterized by a gradual rise to 15°C by late afternoon. Average temperature of the seedling environment gradually rose to 5°C by late afternoon.

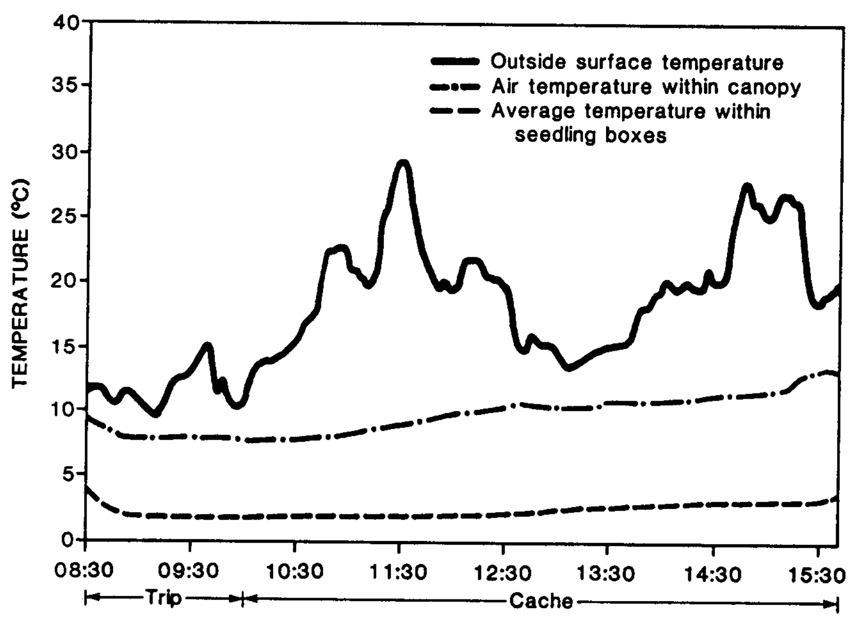

Figure I-5. Surface, internal, and seedling temperature profiles resulting from transportation of 28 seedling boxes directly to the planting block with the canopy, with panels removed, June 28, 1989. Weather was generally overcast but warm. The canopy's ambient internal temperature was characterized by a gradual rise; slight increases at 12:30 and 15:00 occurred because of seedlings being withdrawn from the unit. The slight rise at 12:30 may be the result of the rise in surface temperature from 10:30 to 12:30.

APPENDIX II

Representative Temperature Profiles From Comparative Testing Using Hot-Lift Stock

Representative temperature profiles are presented in Figures II-1 to II-5. All figures present measured surface temperatures, internal ambient temperatures, and an average temperature of the seedling environment (calculated from the six seedling boxes monitored) plotted over the duration of transport and storage for the day. This ranged from 45 min to 4.5 h. The length of time in transit varied as did the number of seedling boxes transported.

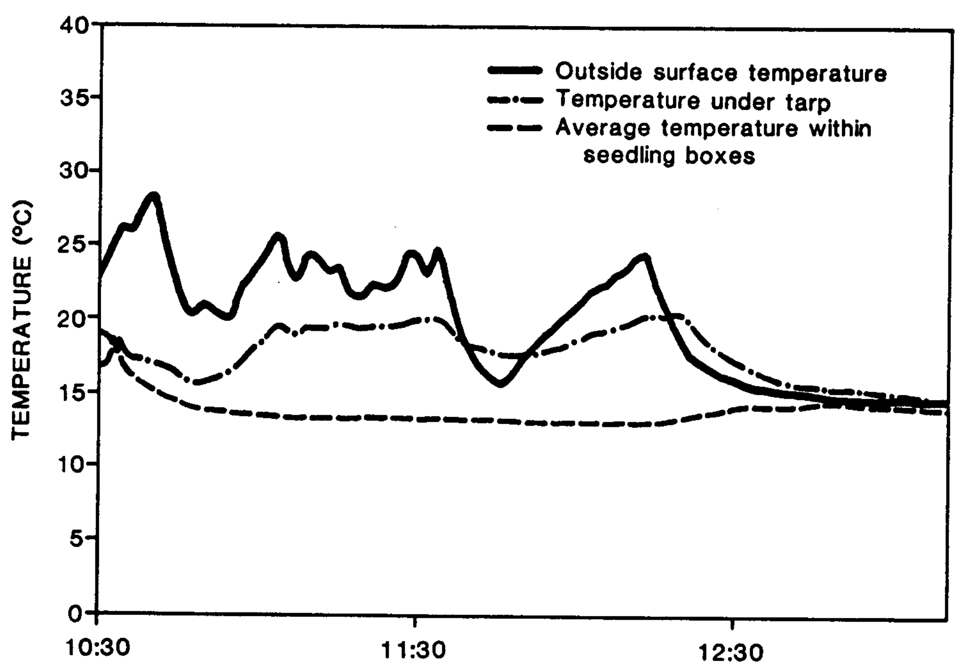

Figure II-1. Surface, internal, and seedling temperature profiles resulting from transportation of 25 seedling boxes covered with a Silvacool tarp, in a pickup truck bed, July 21, 1989. Seedling boxes were left in the truck bed which served as the field cache. Ambient internal temperature measured between the tarp and seedling boxes fluctuated with measured surface temperature. Ambient internal temperature remained below peaks in surface temperature but did not cool as rapidly as did surface temperatures. By 13:00 surface, internal, and average temperatures of the seedling environment were similar. Average temperature of the seedling environment remained fairly constant and well below harmful levels.

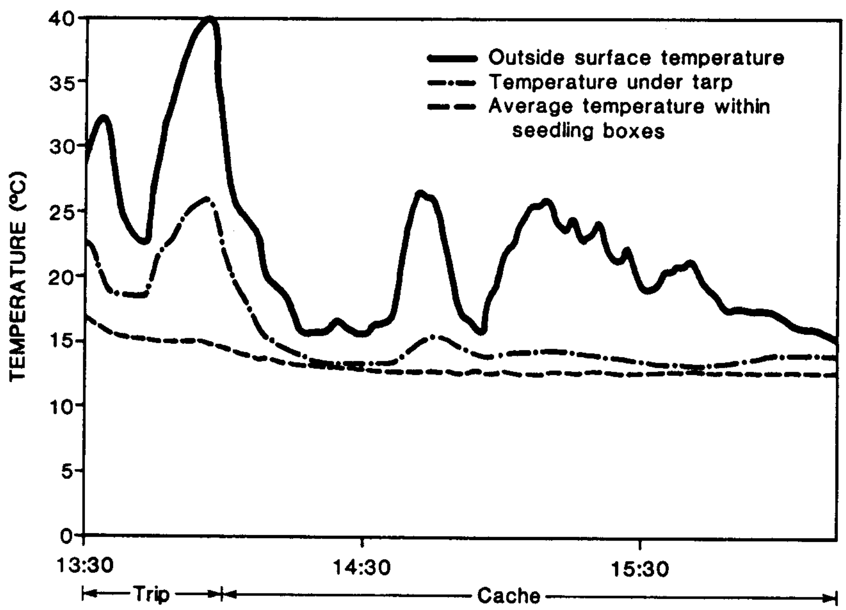

Figure II-2. Surface, internal, and seedling temperature profiles resulting from transportation of 25 seedling boxes covered with a Silvacool tarp in a pickup truck bed, July 22, 1989. Seedling boxes were left in the truck bed which served as the field cache. Ambient internal temperature measured between the tarp and seedling boxes fluctuated but remained below surface temperatures. Average temperature of the seedling environment remained fairly constant and well below harmful levels.

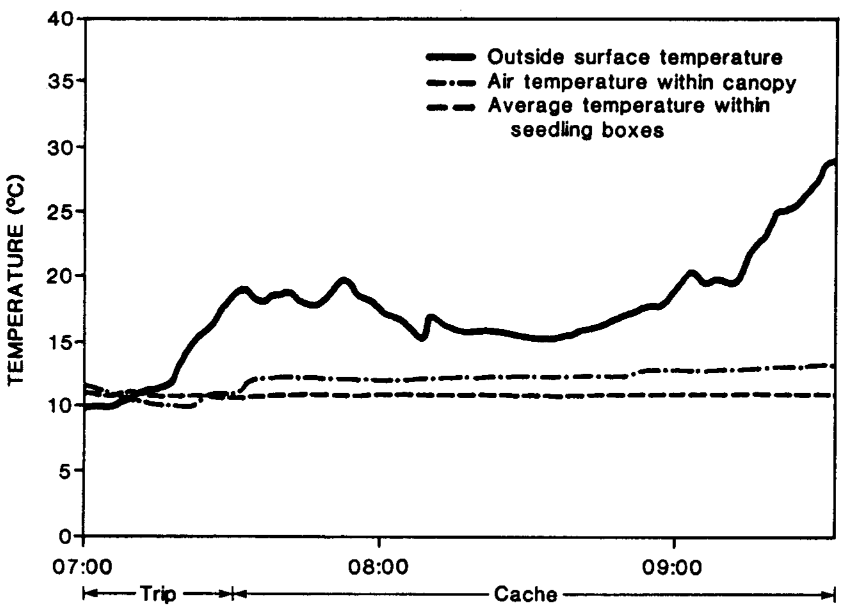

Figure II-3. Surface, internal, and seedling temperature profiles resulting from transportation of 39 open, seedling boxes with the canopy, with panels removed, July 24, 1989. Seedling boxes were loaded at 05:30 but not transported to the site until 09:00. Weather during transport and storage was clear and sunny. Ambient internal temperature remained fairly constant with slight increases when seedling boxes were withdrawn from the unit at 07:50 and 09:00. Average temperature of the seedling environment remained constant at 10°C.

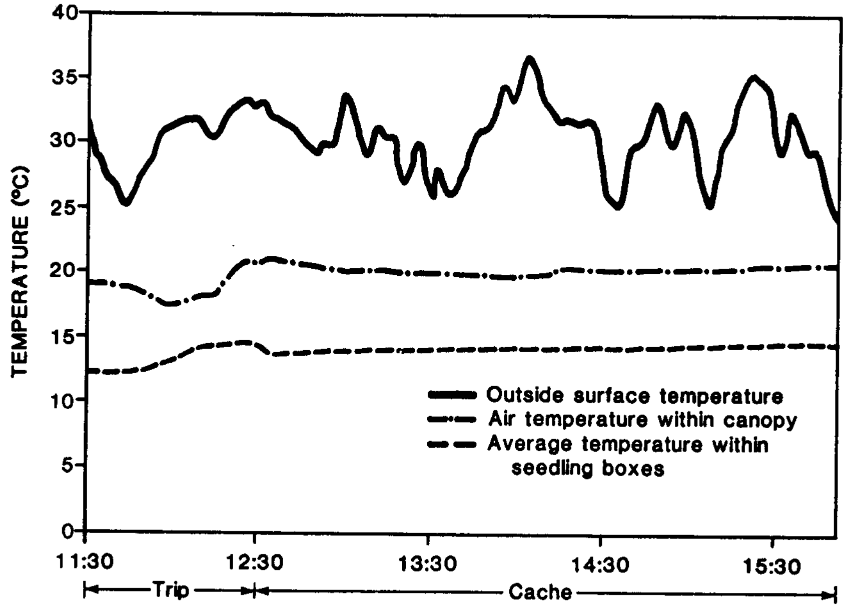

Figure II-4. Surface, internal, and seedling temperature profiles resulting from transportation of 39 open seedling boxes in the canopy, with panels removed, July 26, 1989. Weather during transport and storage was sunny and warm with surface temperatures ranging from 25 to 35°C. Ambient internal temperature remained constant with an increase at 12:30 due to large amounts of seedlings being withdrawn from the unit when it arrived at the planting block. Otherwise, temperature of the seedling environment remained constant and well below harmful levels.

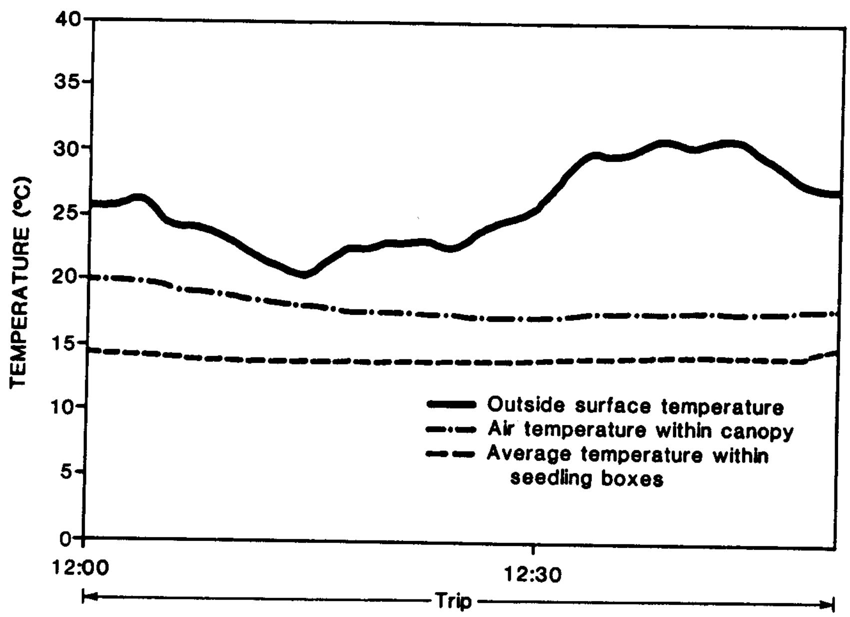

Figure II-5. Surface, internal, and seedling temperature profiles resulting from transportation of 39 open seedling boxes with the canopy, fully insulated, July 27, 1989. Weather during transport was sunny with cloudy periods. Surface temperature ranged from 20 to 30°C but ambient internal temperature remained constant. Average temperature of the seedling environment remained constant and well below harmful levels.