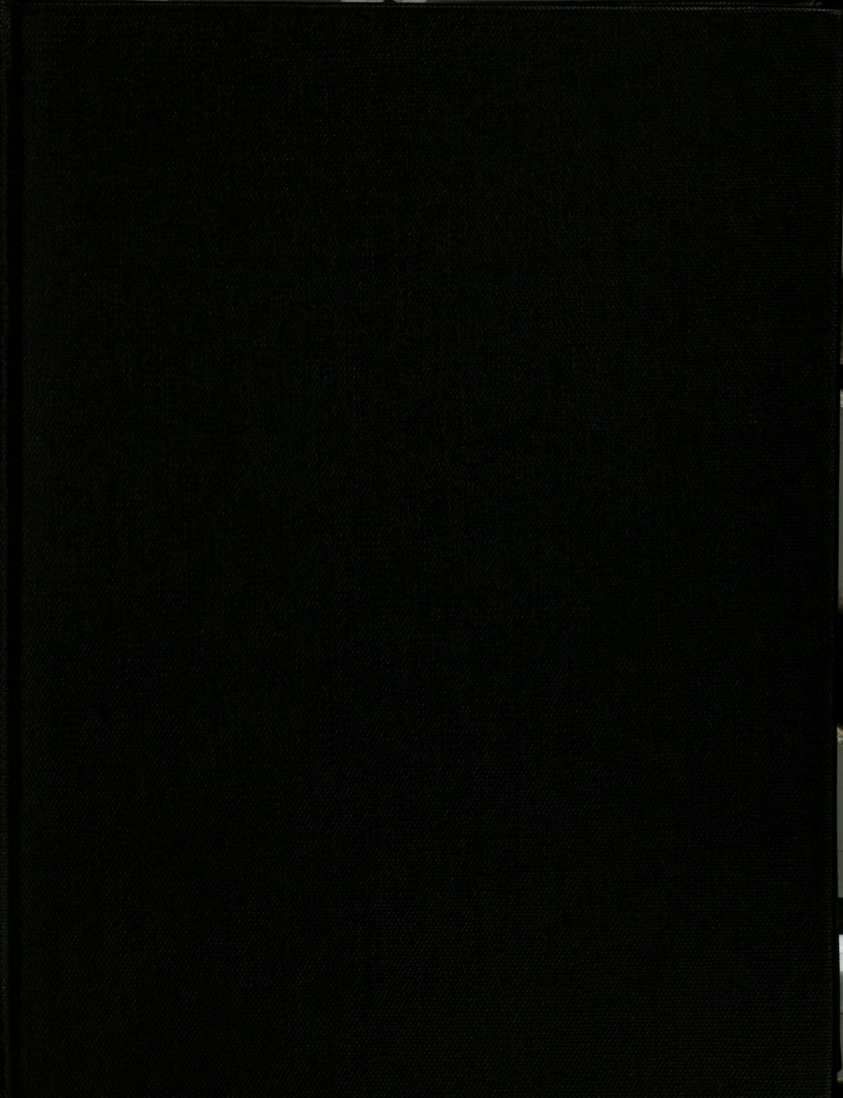






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MOISTURE LOSS DURING STORAGE AND NEW GROWTH
OF
BARE-ROOT CONIFER SEEDLINGS

presented by

Roy Edward Lefevre

has been accepted towards fulfillment
of the requirements for

Master of Science degree in Horticulture

A handwritten signature in dark ink, appearing to read "N. Curtis Peterson". The signature is fluid and cursive, with a long horizontal stroke at the end.

Major professor

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MOISTURE LOSS DURING STORAGE AND NEW GROWTH
OF
BARE-ROOT CONIFER SEEDLINGS

By

Roy Edward Lefevre

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE

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ABSTRACT

MOISTURE LOSS DURING STORAGE AND NEW GROWTH OF BARE-ROOT CONIFER SEEDLINGS

By

Roy Edward Lefevre

Various packages and 0 and 1 day delay at 20°C prior to storage were used to generate different amounts of moisture loss in seedlings stored at 0°C. Seedlings' percent weight loss varied from approximately 0 to 60 percent after 5 and 7 months storage depending on the treatment. New growth performance after storage, measured as percent survival and terminal growth and survival, was not reduced for any species when the percent weight loss was less than 15 percent. However, some plants survived up to 60 percent weight loss. Weight loss never exceeded 10 percent when plants were packed in polyethylene and stored at 0°C. New growth performance was not reduced when seedlings were held at 20°C for up to 4 days before storage provided the package was an effective barrier to moisture loss. Changes in moisture content were characterized during the storage period.

DEDICATION

To Dad, Mom and Carie for their constant support.

ACKNOWLEDGMENTS

I would like to thank Dr. Curtis Peterson, my major professor, and Dr. Arthur Cameron and Dr. J. J. Kielbaso, my committee members, for their guidance and support, while I have been at M.S.U.

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INTRODUCTION

Conifers are normally spring sown in prepared seed beds in the field. After two years of growth, the seedlings are mechanically harvested in the early spring or late fall. Growers usually plant-out seedlings in the spring. They prefer freshly dug seedlings in the spring instead of seedlings harvested in the fall. Significant losses have occurred with seedlings that were stored for several months after fall harvest.

Several factors have been identified which influence the successful storage of conifer seedlings. Research evaluations have been conducted on lift date, storage temperature and packaging methods to achieve satisfactory growth after transplanting. Researchers have investigated the moisture content of seedlings in storage (3, 4, 6, 7, 9, 22, 26). Moisture loss would be expected to influence seedling quality, and a cumulative water loss may be experienced by the seedlings during digging, handling, storage and replanting. Additional information is needed to compare the moisture loss of seedlings during storage with growth after transplanting. The purpose of this thesis is to examine the new growth performance of bare-root

conifer seedlings as affected by moisture loss before
and during storage.

LITERATURE REVIEW

Lift Date

Optimal lift date for storage has usually been studied by simply lifting seedlings at different times of the year including fall and winter lift dates and observing the new growth performance after storage (1, 8, 9, 21, 27). Williams and Rambo (27) lifted red pine and white pine seedlings on November 13 and December 3 in Northern Indiana and stored the seedlings until March 29. The seedlings lifted in December had 85 percent survival in June. The survival rate of the seedlings lifted in November varied with species. Red pine had no difference in survival, while the white pine seedlings had significantly lower survival when lifted in November. Hinesley (8) stored Fraser fir seedlings lifted November 28 and December 4 in North Carolina for up to 5 months and the seedlings had 100 percent survival, but he did not have any earlier lift dates for comparison. Hocking and Ward (9) concluded that lifting white spruce in Edmonton, Alberta on October 20 was better than October 13, but failed to show any statistical difference in new growth for the two lift dates. Cram and Lindquist (1) successfully stored Colorado spruce and Scotch pine lifted on

October 16 in the prairie region of Canada for 212 days. In Canada, seedlings had to be lifted in October because of a shorter growing season (9), while seedlings in North Carolina could be lifted in December (8). Generally, the latest possible lift date in a region was best. Research has also been conducted on seedlings lifted and stored in the spring. The researchers generally agreed that the seedlings should be lifted as early as possible before new growth (1, 14, 21, 27).

Since there were differences between conifers, region and weather from year to year, it was not always appropriate to set a specific lift date for seedlings. For this reason, some researchers have made an attempt to develop a technique other than date to determine the best harvest time for storage. One method which has been repeatedly investigated has been degree-hardening-days (DHD) which involves the summation of chilling hours (12, 15, 16, 17, 23). However, in all cases, when DHD was compared to storage survival, no reliable prediction model could be developed (12, 15, 16, 17, 23).

Storage Temperature

Temperatures ranging from -18 to 4°C have been tested to determine an optimum range for storage of conifer seedlings. Many temperatures were found to be

satisfactory. Mullin (13) successfully stored white pine and white spruce at -2 and 2°C . Cram and Lindquist (1) successfully stored Scotch pine and Colorado spruce at 2°C for 212 days. Hee (5) described Weyerhaeuser's practices and suggested that both 2 and -2°C are satisfactory, but mold was sometimes a problem at 2°C . At -2°C storage he recommends a moisture barrier to avoid desiccation. Mullin (15) found white pine and red pine could be stored at -3°C , but showed no data. Mullin and Bunting (20) successfully stored white pine, red pine and white spruce at 1.5 and -3°C for 4 months. Hinesley (8) found that -3 and 4°C were acceptable temperatures to store Fraser fir. Morby and Ryker (11) stored ponderosa pine, Douglas-fir, lodgepole pine and Englemann spruce at -2.2 and 0.56°C . Mullin and Parker (16) found -4°C to be acceptable depending on packages.

Some seedlings have been reported to store poorly at temperatures between 4 to -4°C . Red pine had less storage survival at -2°C when compared to 2°C (13). White spruce stored in bales or open tray and white pine and red pine stored in bales in polyethylene or open tray had reduced survival at 1.5°C (20). Also, white spruce in bales and white spruce, red pine and white pine in open trays did not survive well at -3°C .

Some of the temperatures tested were also too low for the storage of conifer seedlings. A temperature of

-18°C was too cold for the storage of white spruce and jack pine. (16) Mullin (15) found white pine and red pine could not withstand -12°C. Cram and Lindquist (1) attempted to store Scotch pine and Colorado spruce at -5°C without success.

Packaging

There are many types of materials which can be included in the package to maintain the moisture level for seedlings. Hinesley (8) packed Fraser fir in kraft polyethylene bags with hydromulch, Canadian peat, sterile Canadian peat, sphagnum moss (all moist) and mud slurry dip at 4°C verses bare-root in kraft polyethylene bags. The hydromulch was the only material that caused a decrease in survival. He concluded that there were no benefits from the packing materials compared to bare-root seedlings in kraft polyethylene bags. Hocking and Ward (9) stored white spruce for 7 months at -3°C, using six packing methods: 1) heeled-in with peat, 2) jelly roll bales, 3) plastic bags with moist peat, 4) plastic bags with moist steamed peat, 5) plastic bag only and 6) the current Alberta tree nursery method (same as 3 except bag is covered with burlap). Seedlings with the tops exposed had significantly lower survival and the addition of peat did not improve the survival for the seedlings. Mullin (15) stored red and white pine in kraft polyethylene

bags after dipping the roots of half the seedlings in water and packing moist moss around the roots and half of the seedlings were not dipped in water. No difference in new growth, after 7 months of storage, was found in white pine, but better survival was achieved in red pine without dipping the roots. Data was collected in this experiment after five years of growth in the field. Racey and Hutchison (24) stored red and white pine and white spruce in kraft polyethylene bags at -3°C , with or without damp moss packed around the seedlings. They concluded that the damp moss was of no benefit to seedlings. Mullin (12) tested water dipping (dipping the roots in water before packaging) of red pine in both polybin and kraft polyethylene bags. The seedlings had approximately 77 percent survival in both packages. He concluded the water dipping was unnecessary based on data collected after five years of growth in the field. Mullin (13) also stored white spruce and white and red pine with no moss, moss in the bottom of the bag, moss in the top or moss in the top and bottom. He stored the seedlings for different lengths of time and temperatures and concluded that neither location nor the presence of the moss in the package had a significant influence on survival. Mullin and Myland (18) either dipped white spruce seedlings in water before packaging in kraft polyethylene bags or packed the seedlings without the

water dip. After 7 months of storage, they did not find a difference in seedling performance between dipping and not dipping seedlings.

Many tests on packaging methods have been made without an emphasis on the packing material. Mullin and Bunting (19) tested open tray (an open slatted wooden tray with roots inward toward the center and packed in sphagnum moss) at 1.5°C , seedling bale at 1.5 and -3°C , polyethylene bag at 1.5 and -3°C , seedling bale placed in a polyethylene bag at 1.5 and -3°C using red pine seedlings to determine the optimal temperature and packaging method. The seedlings were stored in refrigerated storage. His data suggested that those seedlings stored in trays had visible signs of desiccation after 5 months of storage, while seedlings stored in a bale in a polyethylene bag had severe mold at 1.5°C . Mullin et al (21) stored red pine, white pine and white spruce in either a standard seedling bale or kraft polyethylene bags for 1 or 2 weeks in a work shed (temperature and humidity unknown). Only the white pine seedlings stored in kraft polyethylene bags had the best survival after 2 years growth. Morby and Ryker (11) stored seedlings in either crates lined with waterproofed paper or kraft polyethylene bags at -2.2 or 0.56°C . The seedlings stored for 6 months in crates at -2.2°C had poor survival. Darby (2) described the advantages of a "wraparound" crate (like a standard

seedling bale except a wirebound box is used instead of reinforced waterproofed paper) compared to a standard seedling bale to be: 1) no special tools are needed, 2) increase packing output, 3) packages are easy to open, 4) seedlings are easy to remove, 5) partial packages can be resealed easily, 6) crates are reusable and 7) cost is reduced because less labor is needed. However, he did not conduct any experiments to support his conclusions. Lanquist and Doll (10) tested polyethylene bags and regular packing (alternate layers of seedlings and packing material in crates). They conducted this experiment for two consecutive years and found no difference between survival which ranged between 84 and 94 percent after 5.5 months of storage. Racey et al (25) packed white spruce in polybin, polybin sealed with freezer tape, kraft polyethylene bag (2 ply with poly laminated coating), kraft polyethylene bag (2 ply with polyethylene insert) and kraft polyethylene bag (3 ply with polyethylene insert) and stored them for 6 months. They found no differences in survival (95.8 to 99.5 percent survival) with the package treatments. Mullin and Myland (18) packed black spruce in kraft polyethylene bags and cardboard cartons lined with wax paper and observed no difference between packages.

Those packages which gave the best seedling survival were the packages that protected the seedlings

from moisture loss. Polyethylene bags, kraft polyethylene bags and polybins (a polyethylene container 30 by 45 by 55 cm with a pegdown cover) are the most common of these packages. Kraft bags and polybins have the extra advantage of adding more protection against damage, during storage and handling, by placing a protective layer around the moisture barrier to prevent punctures.

Storage Moisture Level

Hermann (7) measured moisture content (oven-dry basis) of Douglas-fir seedlings at the time of lifting (November, January, March) and after 2 hours of exposure at 32°C and 30 percent relative humidity. He found many differences between seedlings and the value for the critical maximum moisture loss (amount of moisture loss resulting in death) varied. Hellmers (6) lifted Jeffrey pine and ponderosa pine at three times in the winter and measured water content on freshly dug seedlings and after 11 and 26 weeks in storage. He provided no data but stated that the plants which were stored had a 10 percent higher water content than freshly dug stock in the spring. He thought this may have been due to the drying conditions outdoors or the moist packing material used in packaging.

Nyland (22) stored Scotch pine, red pine and Norway spruce seedlings in jelly roll bundles with the

tops exposed or completely enclosed in plastic bag. After 28 weeks the moisture content of seedlings with exposed tops fluctuated from 75 to 200 percent for all species, while the moisture content was higher and more constant with seedlings whose tops were enclosed in plastic bags.

Deffenbacher and Wright (3) bundled Douglas-fir, ponderosa pine, noble fir and sitka spruce and placed these bundles in cold storage (temperature unknown). They took top and root moisture content (method not stated) after seedlings were removed and found that the stock stored for 4 and 6 months had a higher percentage of moisture in the roots than in the tops. Between 6 and 12 months, less moisture was measured in the roots than the tops. After 12 months in storage the moisture content in the roots dropped to 50 percent or less.

Hocking and Ward (9) found that seedlings which were stored with tops exposed lost moisture throughout storage (started with moisture content of 120 percent of dry weight and ended at approximately 40 percent). The seedlings packed in polyethylene lost little or no moisture (moisture content remained about 120 percent).

Tarrant (26) measured moisture content of Douglas-fir in storage. He packed the seedlings in moist cedar shavings in a bundle then measured the moisture content immediately after lifting and at 4 week intervals during the experiment. For the first 8 weeks the

seedlings were stored at 35°F and 95 percent relative humidity. After 8 weeks the storage conditions were not maintained in order to allow drying. The moisture content of the roots and tops started about the same at 190 and 195 percent oven dry weight. After 4 and 8 weeks the moisture content increased significantly to 209 percent for the tops and 223 percent for the roots. After 8 weeks the moisture in the roots dropped lower than the tops. He concluded that the moisture content did not decrease during two months of storage. He did not relate seedling moisture content to new growth performance.

Conclusion

Research conducted thus far on lift date and storage conditions with different conifer seedlings provides some guidelines for growers. Current recommendations are to harvest seedlings as late in the fall as possible and to store the seedlings in packages containing a moisture barrier, such as polyethylene and without packing material at temperatures between -3 and 0°C. Lift dates will vary with species and location. There are no guidelines concerning the influence of moisture loss in storage and new growth performance of seedlings. At this time recommendations about the relationship between moisture loss and new growth

performance of seedlings placed in storage are not available.

CHAPTER I

**THE INFLUENCE OF MOISTURE LOSS DURING STORAGE
ON NEW GROWTH OF CONIFER SEEDLINGS**

Introduction

Conifer seeds are normally spring sown in prepared ground beds. The seedlings are grown in the field in 48 inch wide beds and 24 inch tractor paths between each bed. If the nursery has a storage facility the 2+0 seedlings may be lifted in the fall. The seedlings are harvested by a tractor with a rigid undercutting blade and agitators to disturb the soil and lift the seedlings for manual collection. After harvest the seedlings are graded, packaged and placed in storage. The seedlings may be in storage for several months depending on planting dates.

There is no question that excessive loss of water will ultimately reduce the new growth performance of evergreen seedlings. At the present time, there is no research evidence which compares the actual relationship between moisture loss and new growth performance.

Various techniques have been employed to reduce moisture stress. Such techniques include regularly spraying water on the seedlings, applying moistened packing materials to the roots of seedlings or placing seedlings in packages with a moisture barrier. There are generally two methods of packaging. The first method of packaging protects the roots, while the tops of the seedlings are exposed to the storage environment. The second method of packaging protects

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the whole seedling from water loss. Examples of the open package method which have been tested are open tray (19), bale (19, 21), wraparound crate (2), and crates (10). Examples of packages with barriers to water loss that have been tested are polyethylene bags (19, 10), kraft bags with polyethylene insert or poly laminated (kraft paper coated with polyethylene) (11, 25, 18), crates lined with waterproofed paper (11), polybin (a polyethylene container 30 by 45 by 55 cm with a pegdown cover) (25), and cardboard cartons lined with wax paper (18). In general, it can be concluded that an increased barrier to moisture loss will increase storage success. However, it is still not clear how much if any water loss can be tolerated during the storage period, which can extend for several months.

The following treatments were used to determine the relationship between moisture loss and new growth performance of seedlings after storage. The seedlings were placed in storage with 0 day delay and 1 day delay in four different packages at 0°C for 5 and 7 months.

Materials and Methods

In the 1986 experiment Picea pungens glauca Reg. 'Misty Blue', 2+0 seedlings, were harvested on December 6, 1985 from Armintrout's West Michigan Farms, Inc. in Allegan Michigan. In the 1987 experiment, seedlings of Picea pungens glauca Reg. 'San Juan', Pinus sylvestris L. 'Lake Superior Blue', and Pseudotsuga menziesii (Mirb.) Franco 'Lincoln' were harvested from the same location on January 7, 1987. The seedlings were harvested by a tractor with a rigid undercutting blade and agitators to disturb the soil and lifted the seedlings for collection by hand. The seedlings were transported to Michigan State University in East Lansing, Michigan, in polyethylene lined cardboard boxes. Immediately upon arrival, seedlings were removed from the polyethylene bags and graded to height (only the tops were considered during grading). The Picea pungens glauca Reg. 'Misty Blue' tops were 15 to 25 cm; Picea pungens glauca Reg. 'San Juan' tops were 15 to 25 cm; Pinus sylvestris L. 'Lake Superior Blue' tops were 10 to 20 cm; and Pseudotsuga menziesii (Mirb.) Franco 'Lincoln' tops were 20 to 30 cm. The seedlings were randomly bundled into groups of ten. Each bundle was weighed and placed in a burlap bag, burlap bag in a cardboard box, 4 mil perforated polyethylene bag or 4 mil polyethylene bag. The packages were approximately 1 ft x 1 ft x 2 ft.

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The seedlings were stored at 0°C. Half of the seedlings were placed into storage immediately after packaging (0 day delay) and half after one day at 20°C and 35 percent relative humidity in the packages (1 day delay). Separate packages were used for the 0 and 1 day delay seedlings.

After 5 and 7 months of storage, bundles were removed from the packages and reweighed to determine percent weight loss on a fresh weight basis. The seedlings were then planted in 10 cm pots containing a mixture of 50% sandy loam:30% peat:20% torpedo sand (v:v:v) and placed on benches in a greenhouse with no supplemental lighting. The greenhouse was set at 16°C night temperature and 22°C day temperature. Measurements of percent plant survival, percent terminal survival, terminal length (new growth only) and lateral length (new lateral growth only) were made every two weeks during new growth in the 1986 experiment. The 9th week data were chosen as representative and were used in all calculations. In 1987 new lateral length was not taken.

There were 6 replicates and 10 seedlings per replicate. For statistical analysis a 3 way AOV was used for each species. There were 4 packages, 2 delays and 2 durations, with a total of 60 plants per treatment.

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Results

Spruce Performance for 1986

Percent weight loss of the seedlings was influenced by storage duration, package and delay (Figure 1.1). The seedlings packed in burlap, cardboard, perforated polyethylene or polyethylene averaged 53, 49, 27 or 4 percent weight loss respectively. The moisture content of seedlings which were stored in burlap with a one day delay and those seedlings stored in perforated polyethylene or polyethylene without a delay before storage was not affected by storage duration. After 5 months of storage the seedlings packaged in burlap had a greater percent weight loss with one day delay than with no delay, while seedlings packaged in cardboard or perforated polyethylene had a lower percent weight loss when they were held for a 1 day delay. There was no effect of delay on percent weight loss when seedlings were stored for 7 months.

There was no difference between the survival rate of the spruce seedlings stored for either 5 or 7 months. Seedling survival ranged from 0 to 100 percent depending on package and delay treatment (Figure 1.2). All seedlings packed in burlap performed poorly and averaged only 7 percent survival (averaged over 5 and 7 months). The seedlings packed in cardboard, perforated polyethylene or polyethylene averaged 43, 82, or 100

Figure 1.1. Effect of package and delay treatments on percent survival of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and POLY represents polyethylene.

Picea pungens glauca

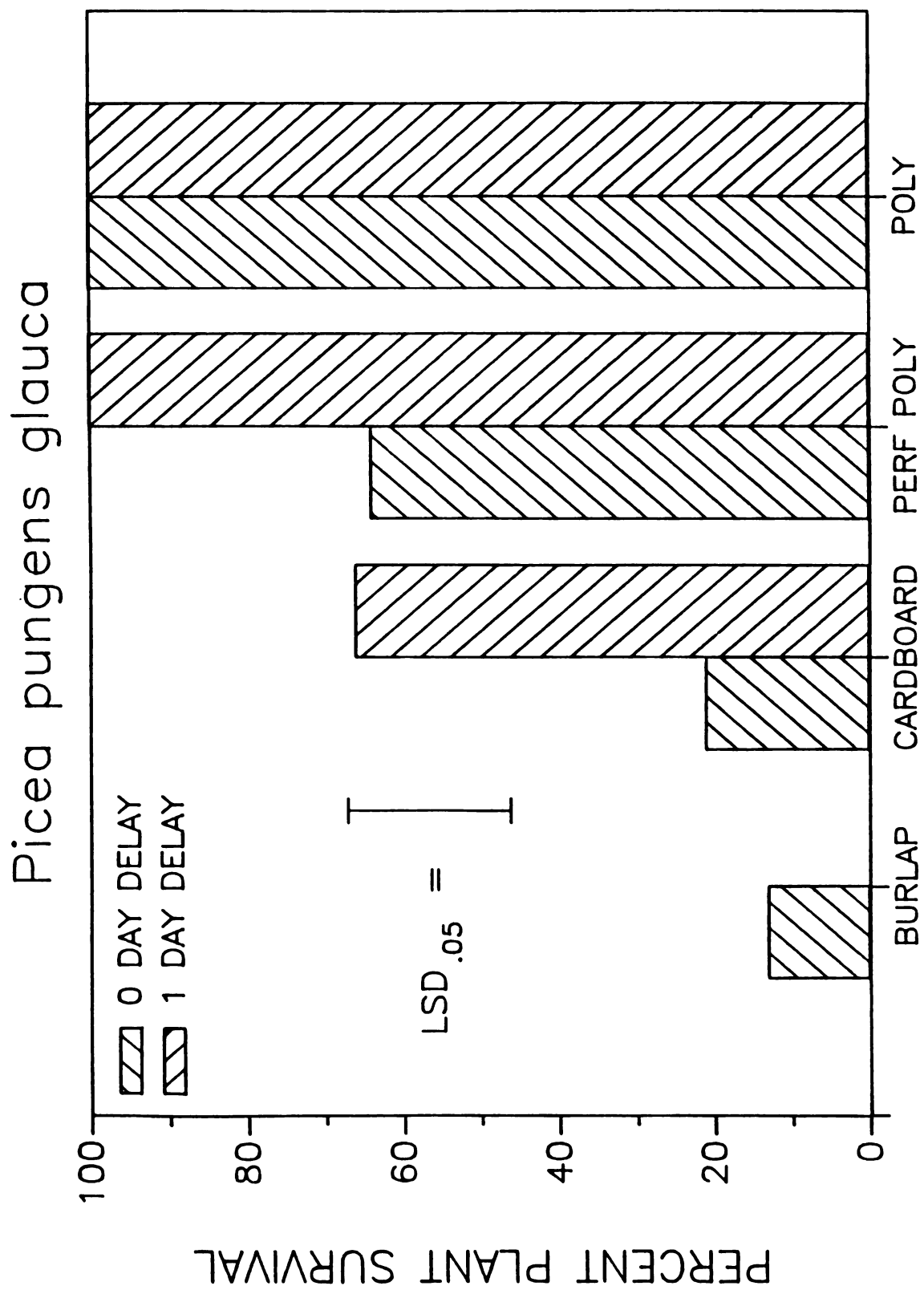
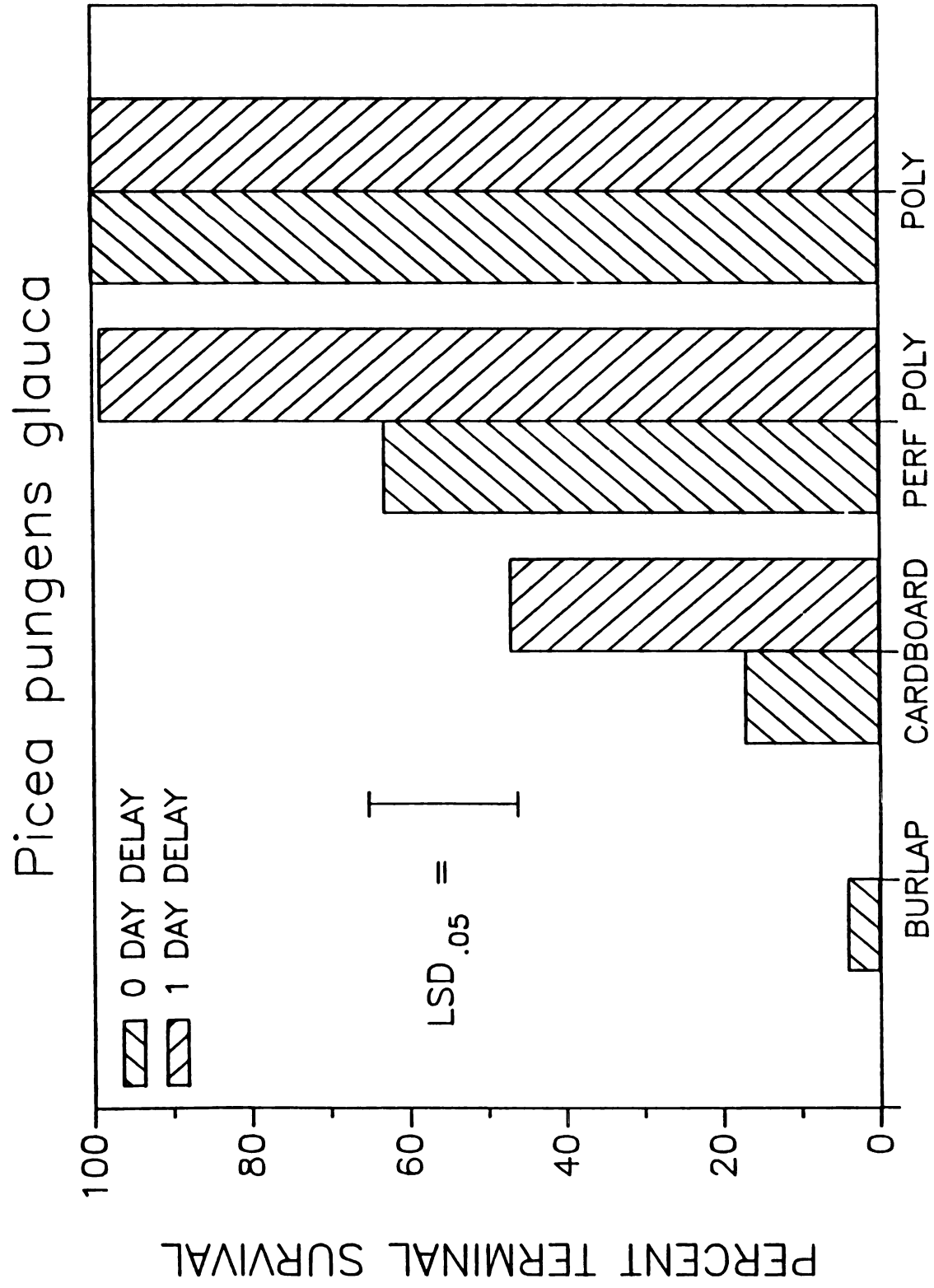


Figure 1.2. Effect of package and delay treatments on percent terminal survival of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and POLY represents polyethylene.



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percent respectively. One day delay at 20°C before storage increased the percent survival for seedlings packaged in cardboard from 21 to 66 percent and in perforated polyethylene from 64 to 100 percent. There was no effect of delay period on survival for seedlings packaged in burlap or polyethylene bags.

Seedling growth responses were influenced by package and delay treatments, but not by duration. Percent terminal survival (Figure 1.3), new terminal length (Figure 1.4) and new lateral length (Figure 1.5) were best when seedlings were stored in polyethylene. One day delay at 20°C before storage increased the subsequent performance of the seedlings packed in cardboard and perforated polyethylene.

Seedling survival for all treatments was influenced by percent weight loss (Figure 1.6). Survival was 100 percent when seedlings had less than 25 percent weight loss. However, as percent weight loss increased from 25 to 60 percent, seedling survival varied from 0 to 100 percent. When the seedlings had over 60 percent weight loss, there was no survival. The relationship between weight loss and percent terminal survival, terminal length, and average lateral length were similar to that described for percent survival (Figures 1.7, 1.8, and 1.9).

Figure 1.3. Effect of package and delay treatments on terminal length of Picea pungens glauca seedlings. PERF POLY represents perforated polyethylene and POLY represents polyethylene.

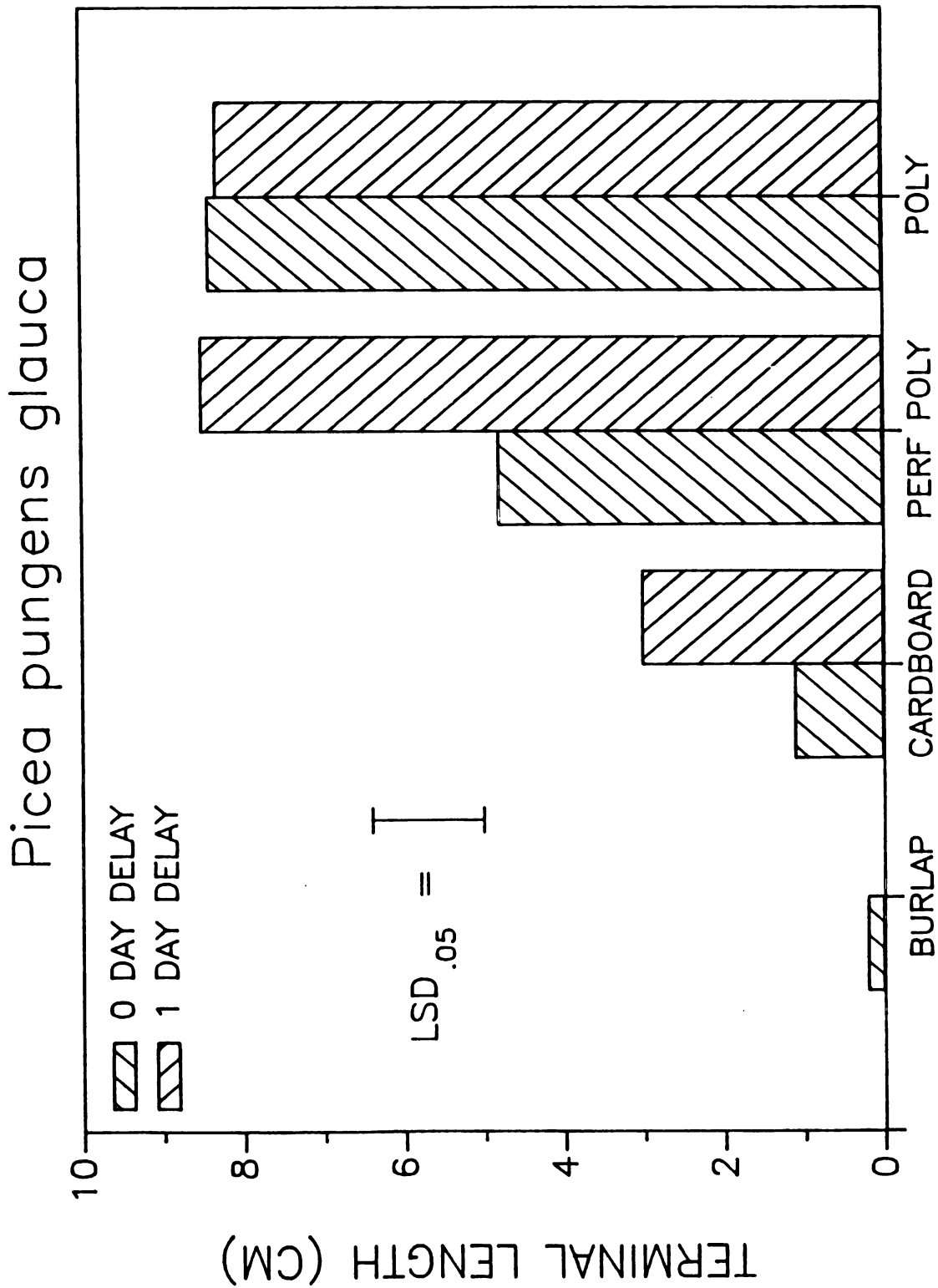


Figure 1.4. Effect of package and delay treatments on new lateral length of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and
POLY represents polyethylene.

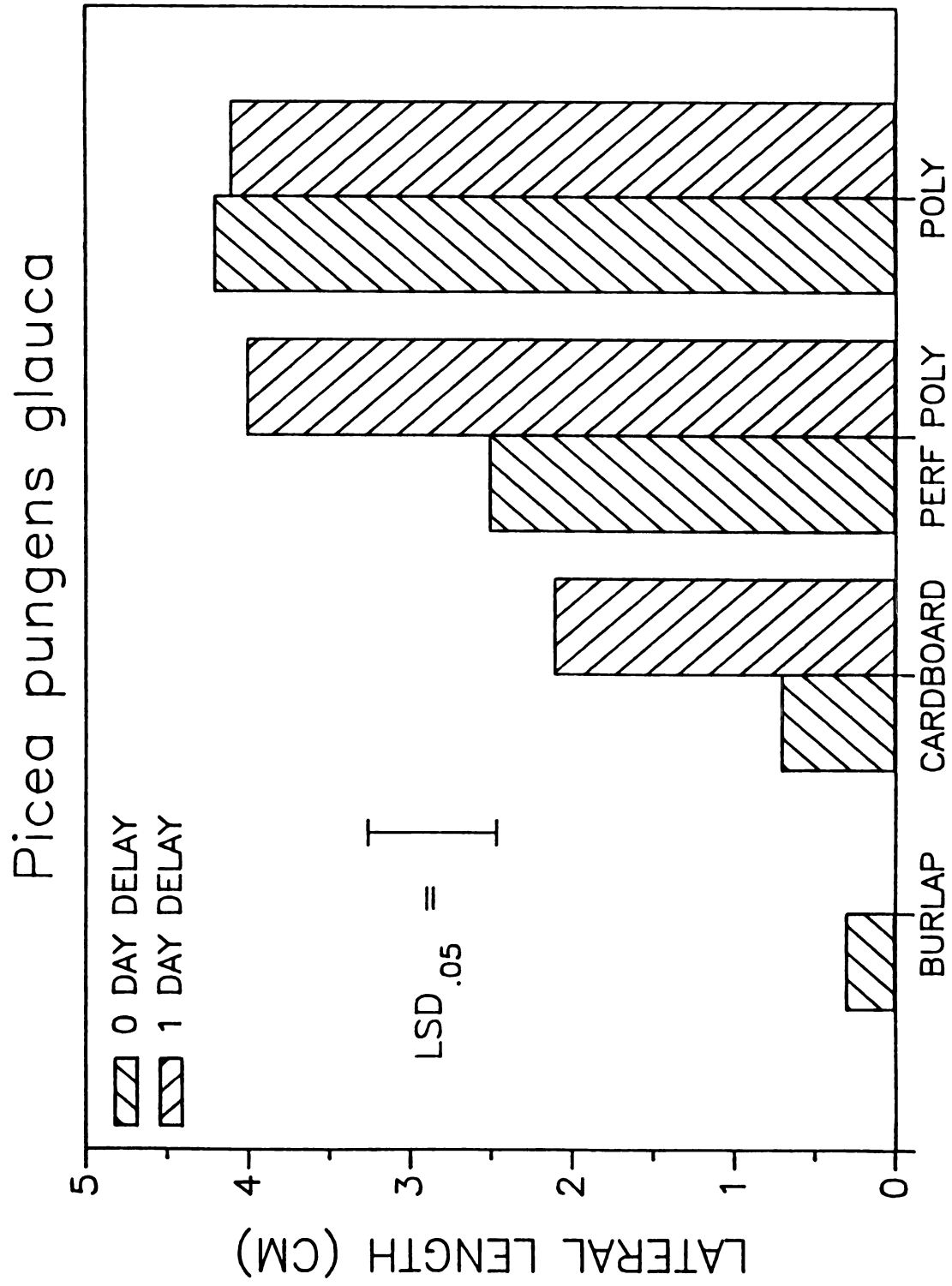


Figure 1.5. Effect of storage duration, package and delay treatment on percent weight loss of Picea pungens glauca seedlings. Shaded bars represent 5 months of storage and empty bars represent 7 months of storage. PERF POLY represents perforated polyethylene and POLY represents polyethylene.

Picea pungens glauca

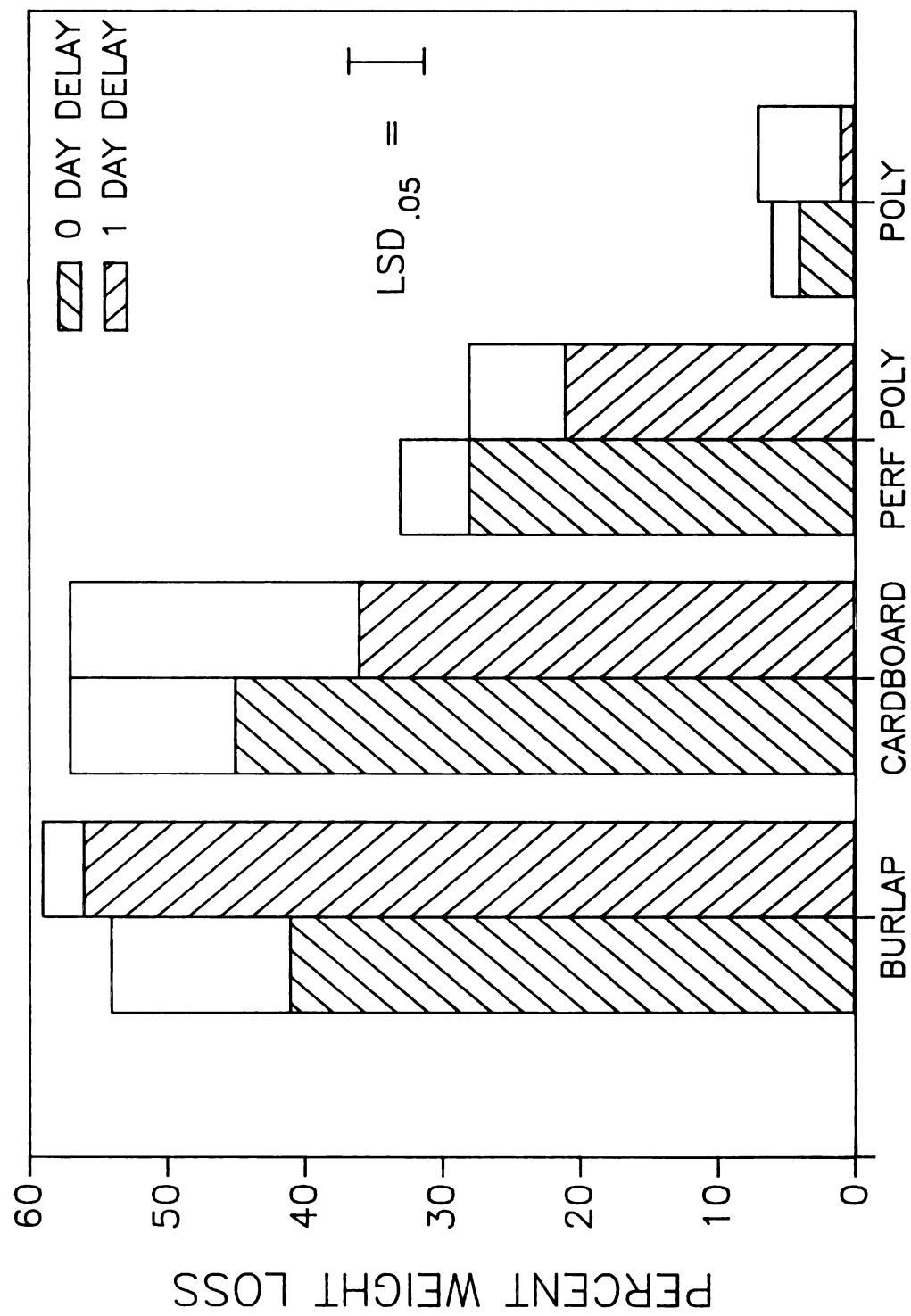


Figure 1.6. Effect of percent weight loss on percent plant survival of Picea pungens glauca seedlings.

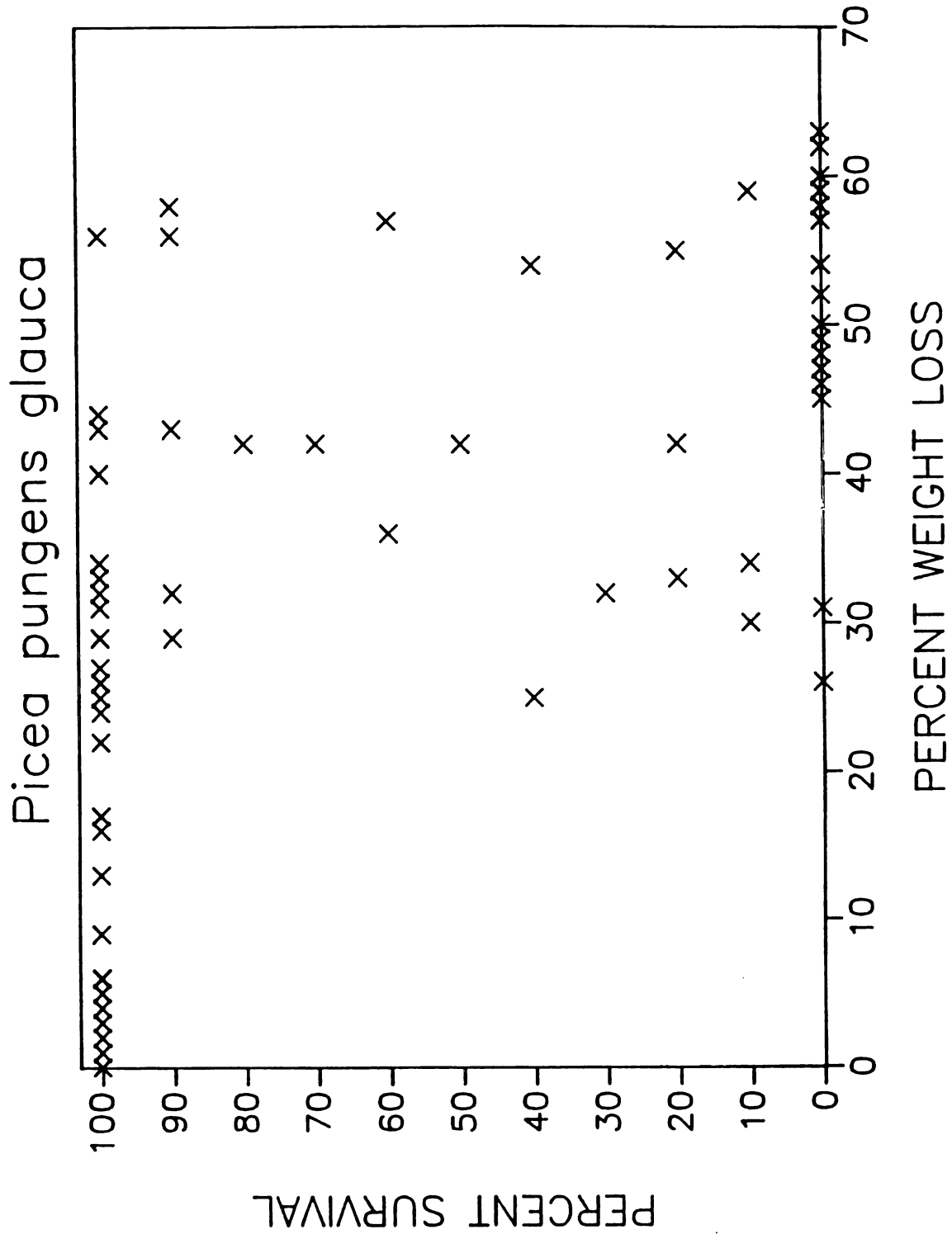


Figure 1.7. Effect of percent weight loss on Picea
pungens glauca seedling terminal survival.

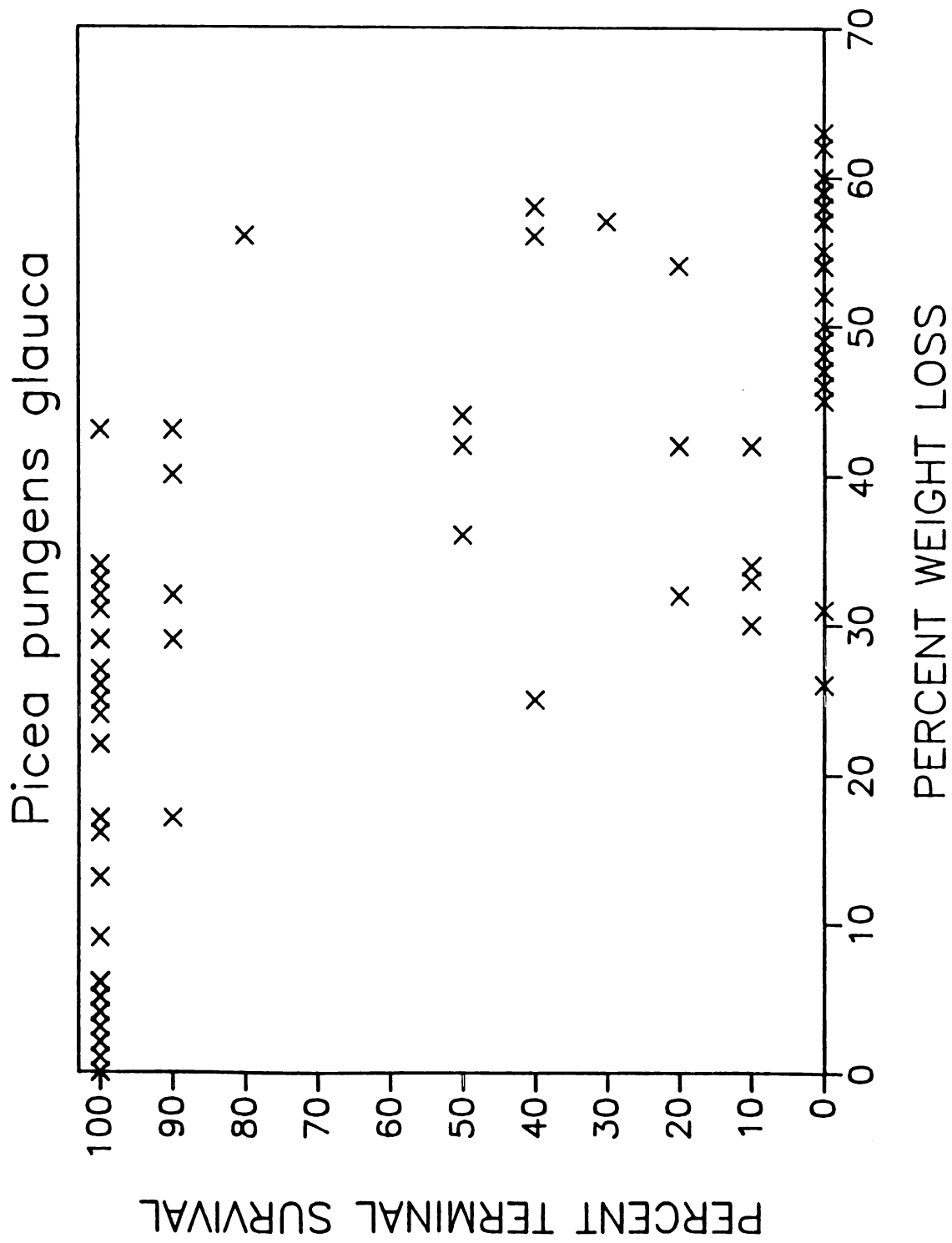


Figure 1.8. Effect of percent weight loss on Picea
pungens glauca seedling terminal length.

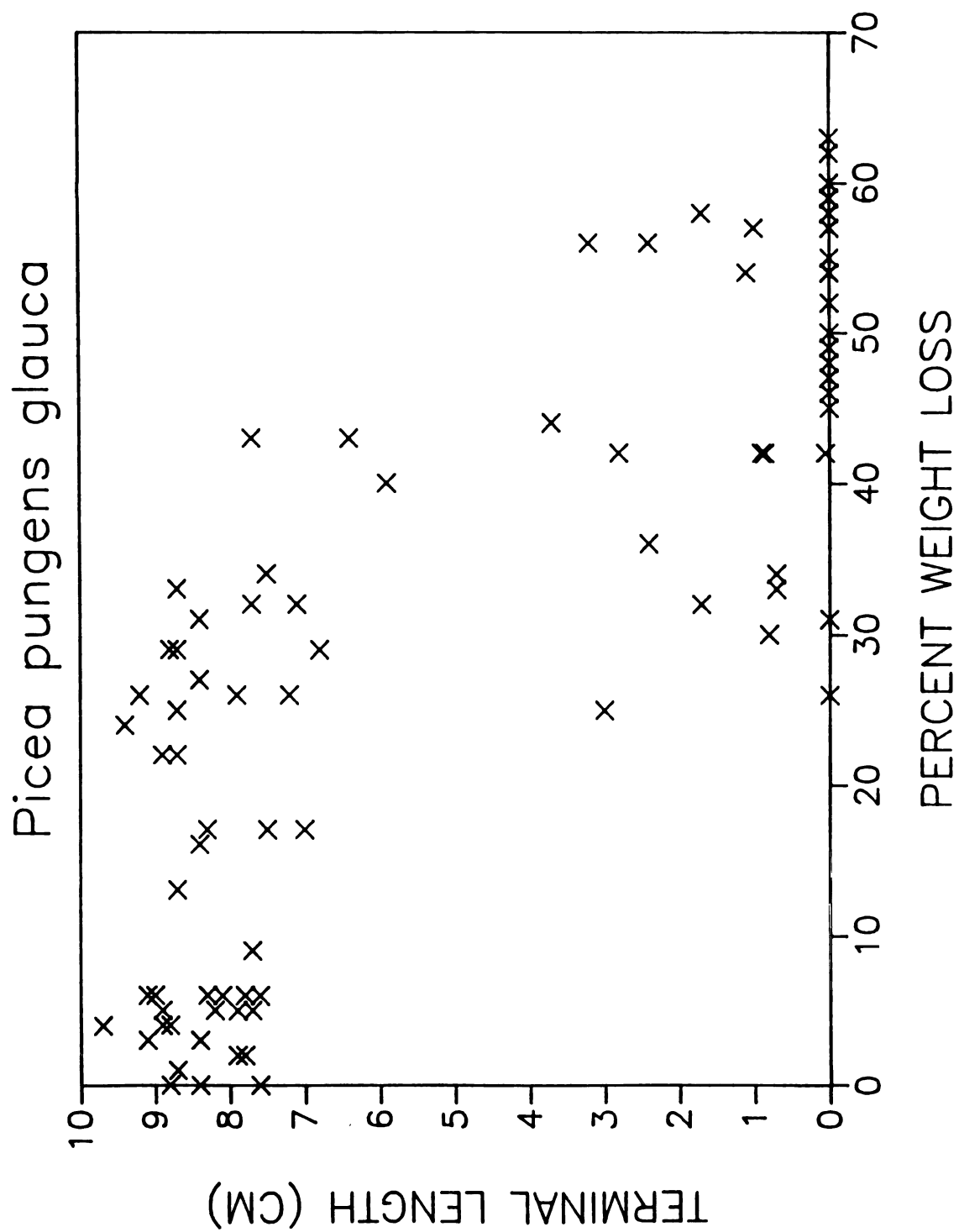
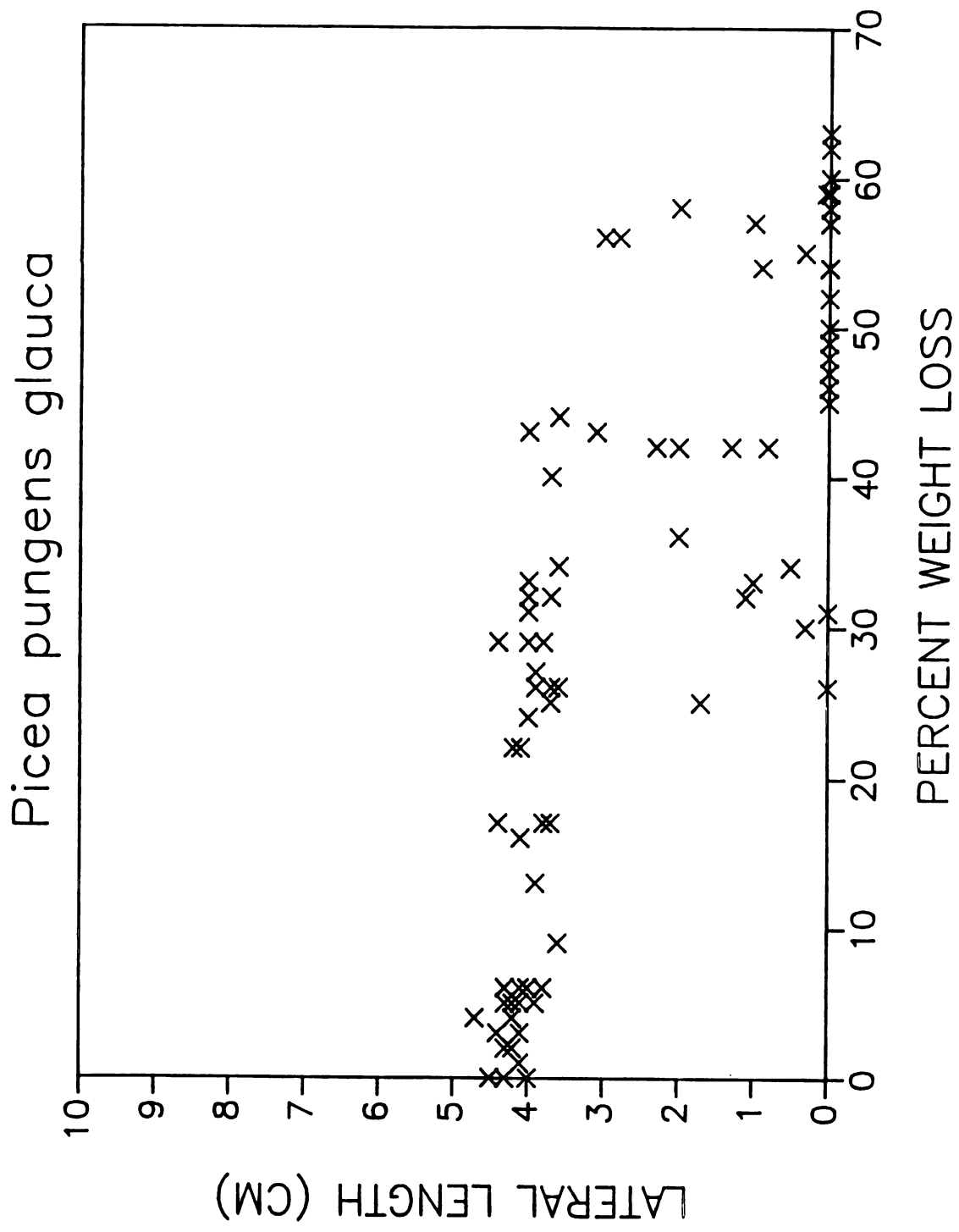


Figure 1.9. Effect of percent weight loss on Picea
pungens glauca seedling lateral length.



Spruce Performance for 1987

There was no difference in survival between seedlings placed in storage immediately after packaging and those held at 20°C for one day before storage. Bare-root spruce seedlings stored in burlap averaged only .4 percent survival (Figure 1.10). Seedling survival in cardboard was 74 percent for 5 months of storage and 0 percent survival after 7 months of storage. Perforated polyethylene or polyethylene package treatments produced 100 percent seedling survival when stored for 5 or 7 months.

Similar results in the response of seedlings to package and storage duration were measured for percent terminal survival (Figure 1.11) and new terminal growth (Figure 1.12). Seedling performance was best in perforated polyethylene and polyethylene. There was no difference in seedling performance between 5 and 7 months when packaged in polyethylene.

Package and storage duration treatments influenced the weight loss of seedlings (Figure 1.13). The seedlings stored in cardboard or perforated polyethylene had an increase in percent weight loss when stored for 7 months. Storage duration did not affect the percent weight loss when the seedlings were stored in burlap or polyethylene.

Seedling survival for all treatments was influenced by percent weight loss (Figure 1.14).

Figure 1.10. Effect of storage duration and package treatment on plant survival of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and
POLY represents polyethylene.

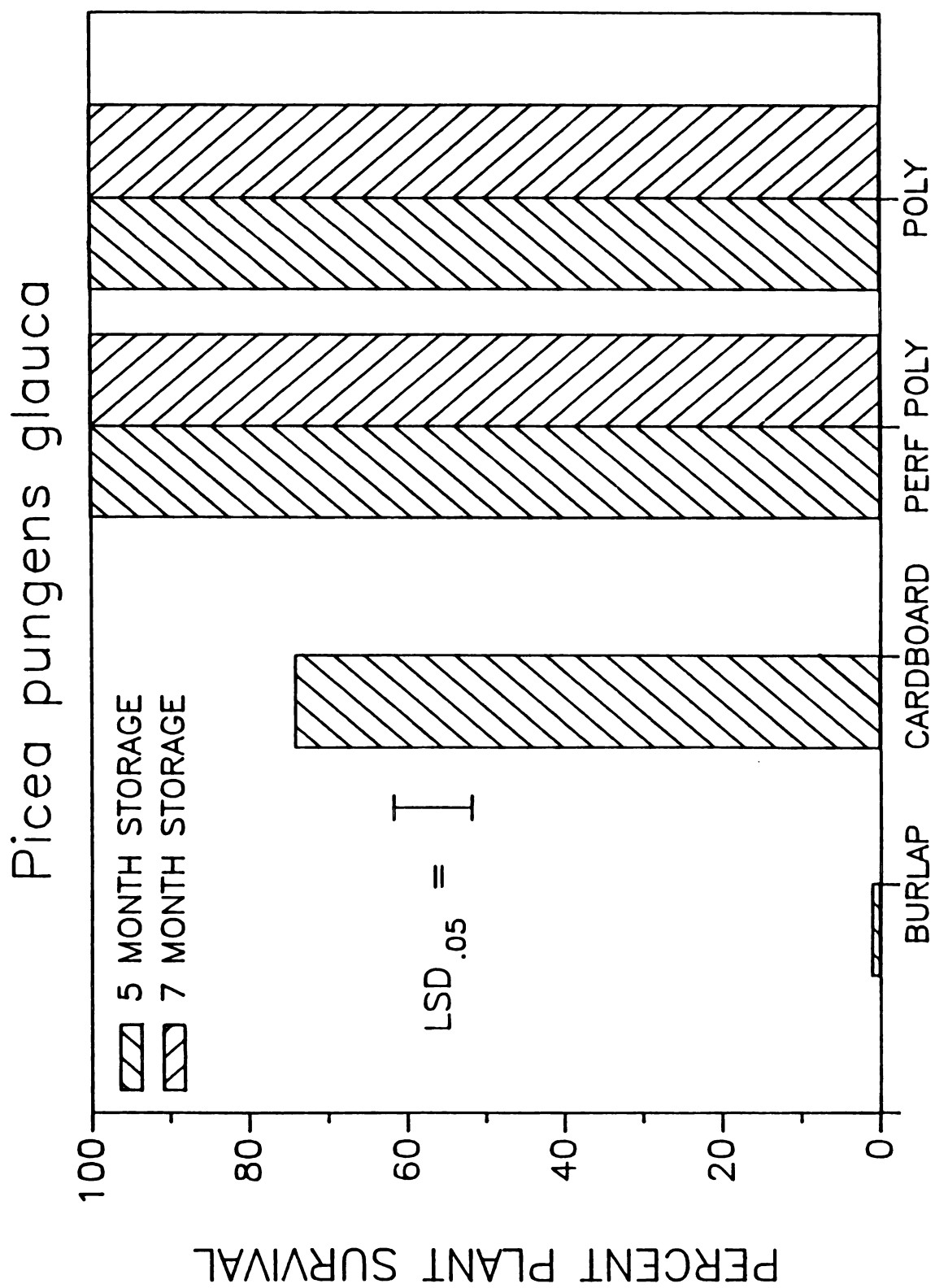


Figure 1.11. Effect of package and storage duration treatment on percent terminal survival of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and POLY represents polyethylene.

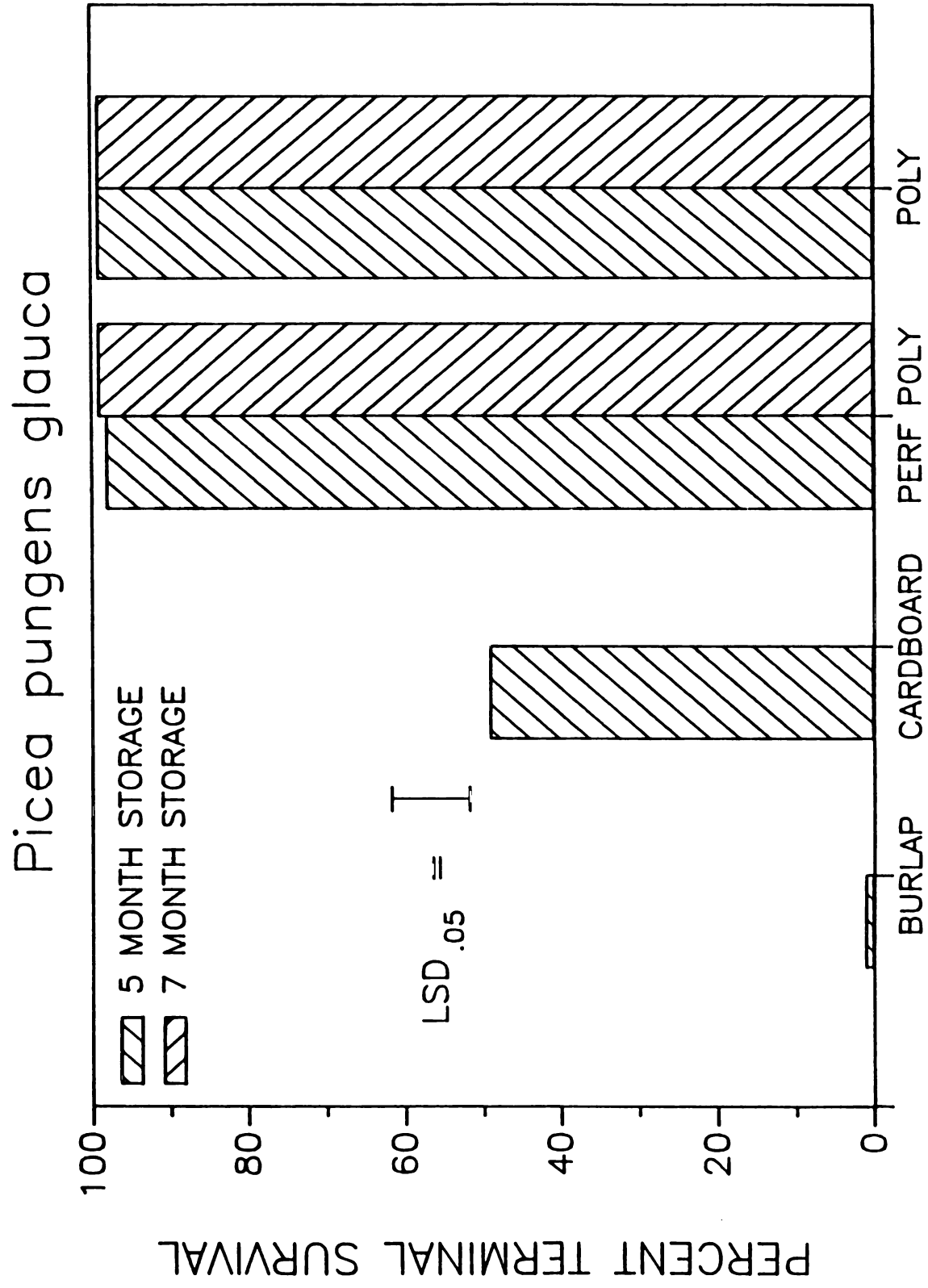


Figure 1.12. Effect of package and storage duration treatment on new terminal growth of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and
POLY represents polyethylene.

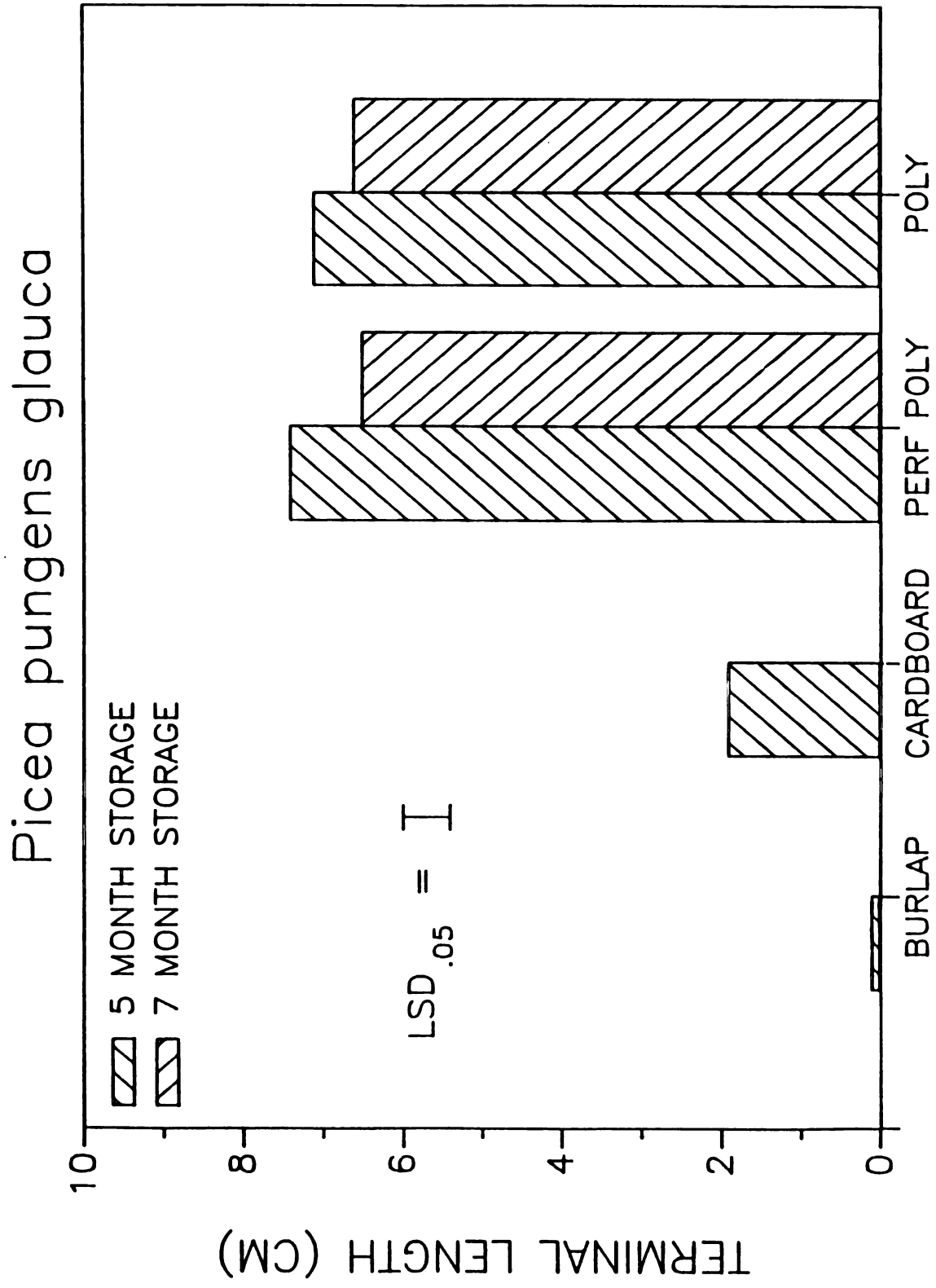


Figure 1.13. Effect of package and storage duration on percent weight loss of Picea pungens glauca seedlings.
PERF POLY represents perforated polyethylene and
POLY represents polyethylene.

Picea pungens glauca

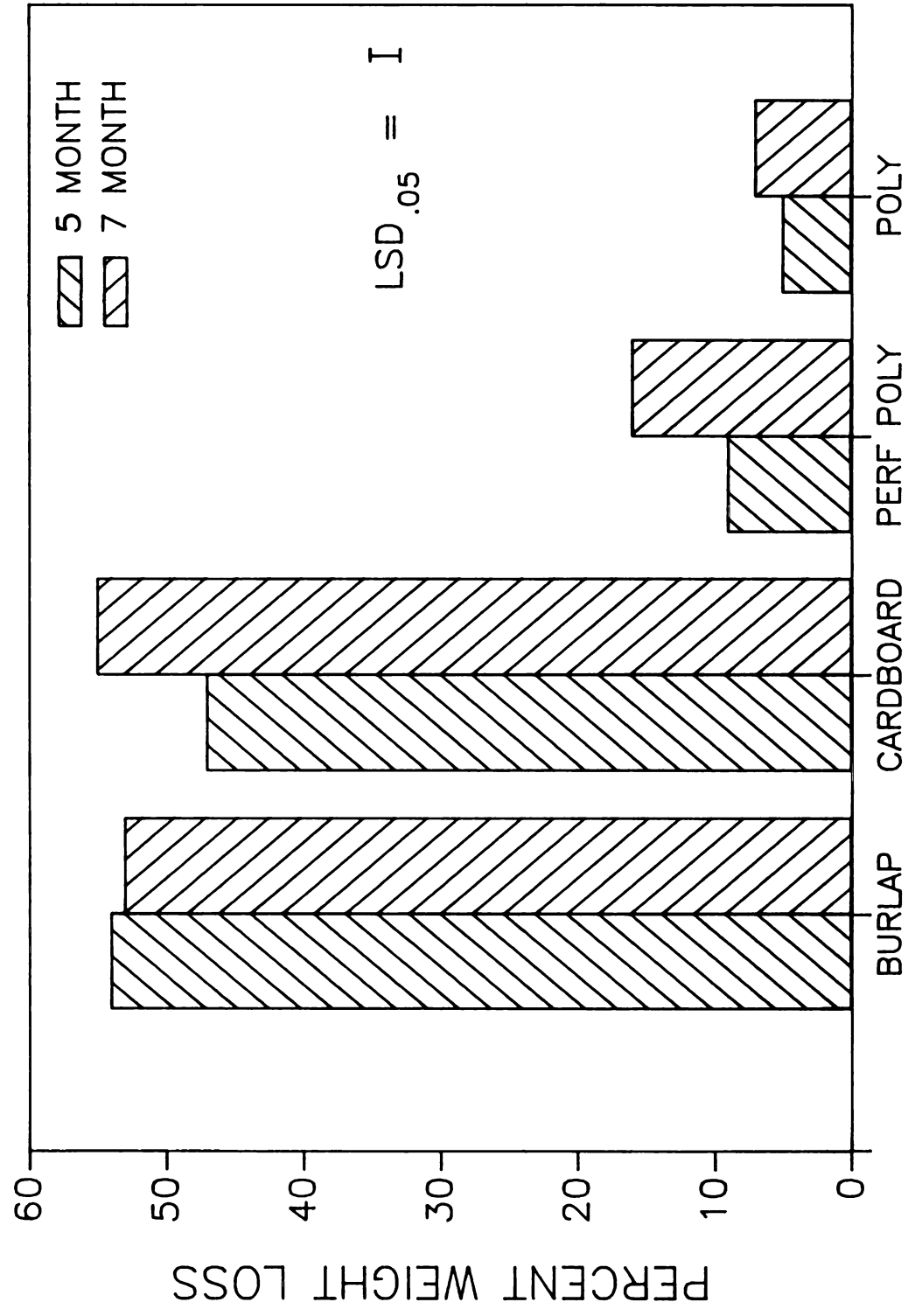
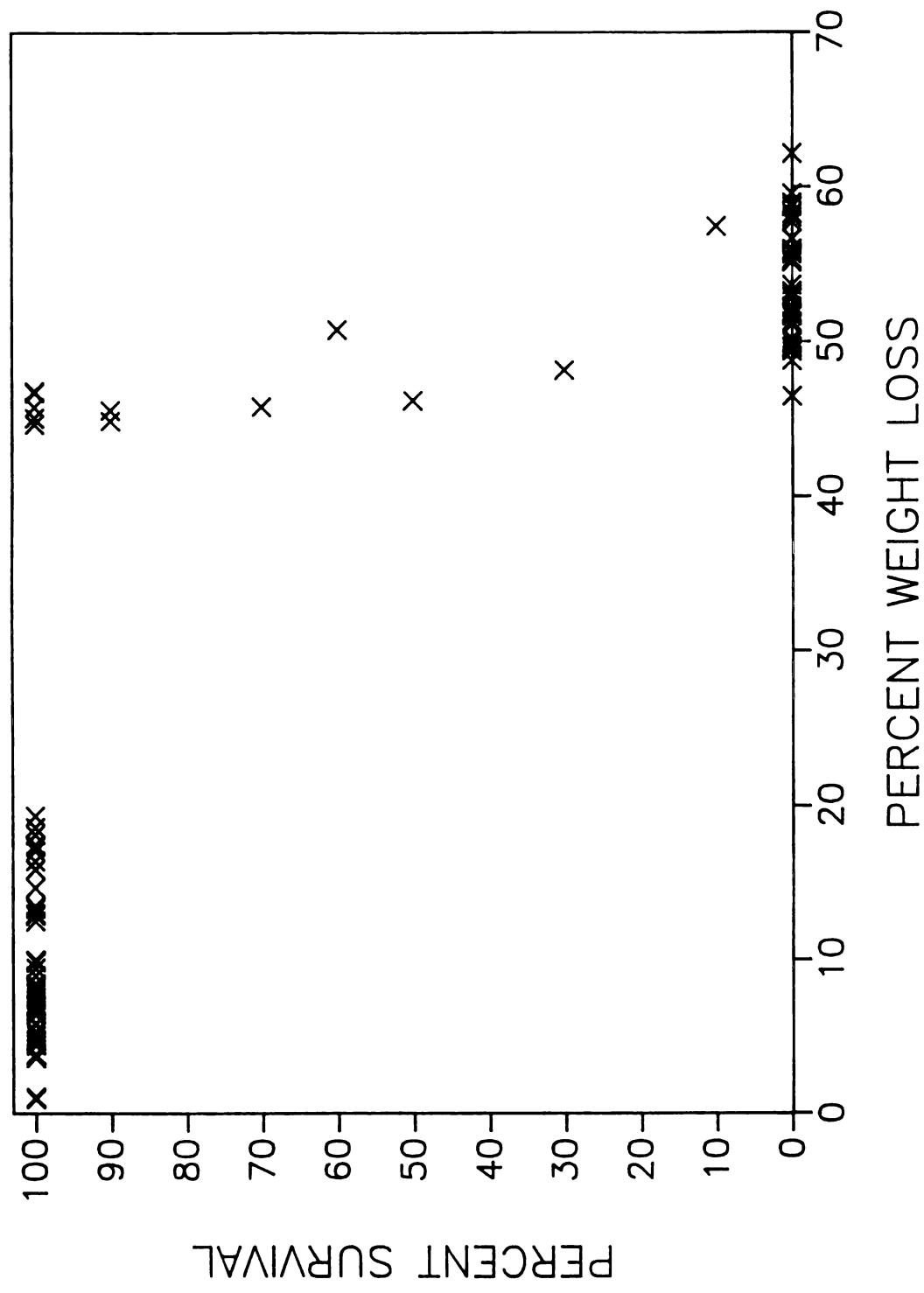


Figure 1.14 Effect of percent weight loss on Picea
pungens glauca seedling survival.

Picea pungens glauca



Survival was 100 percent when seedlings had less than 20 percent weight loss. When percent weight loss ranged from 45 to 60 percent, seedling survival varied from 0 to 100 percent. There were no data from 20 to 60 percent weight loss. The relationship between percent weight loss and percent terminal survival or terminal growth were very similar to that described for percent survival (Figures 1.15 and 1.16).

Douglas-fir Performance for 1987

Seedling survival ranged from 0 to 100 percent depending on package and storage duration treatments (Figure 1.17). Seedlings packaged in burlap or cardboard performed poorly and averaged only 14 percent survival after 5 months of storage (averaged over 0 and 1 day delay) and 0 percent after 7 months of storage. The seedlings packaged in perforated polyethylene or polyethylene had 100 percent survival for both 5 and 7 months of storage.

The seedlings packaged in burlap or cardboard averaged 1 and 3 percent terminal survival respectively, while those packaged in perforated polyethylene or polyethylene had significantly higher averages of 99 and 98 percent respectively. New terminal growth was also affected by package treatment. Seedlings packaged in burlap, cardboard, perforated

Figure 1.15. Effect of percent weight loss on Picea
pungens glauca seedling terminal survival.

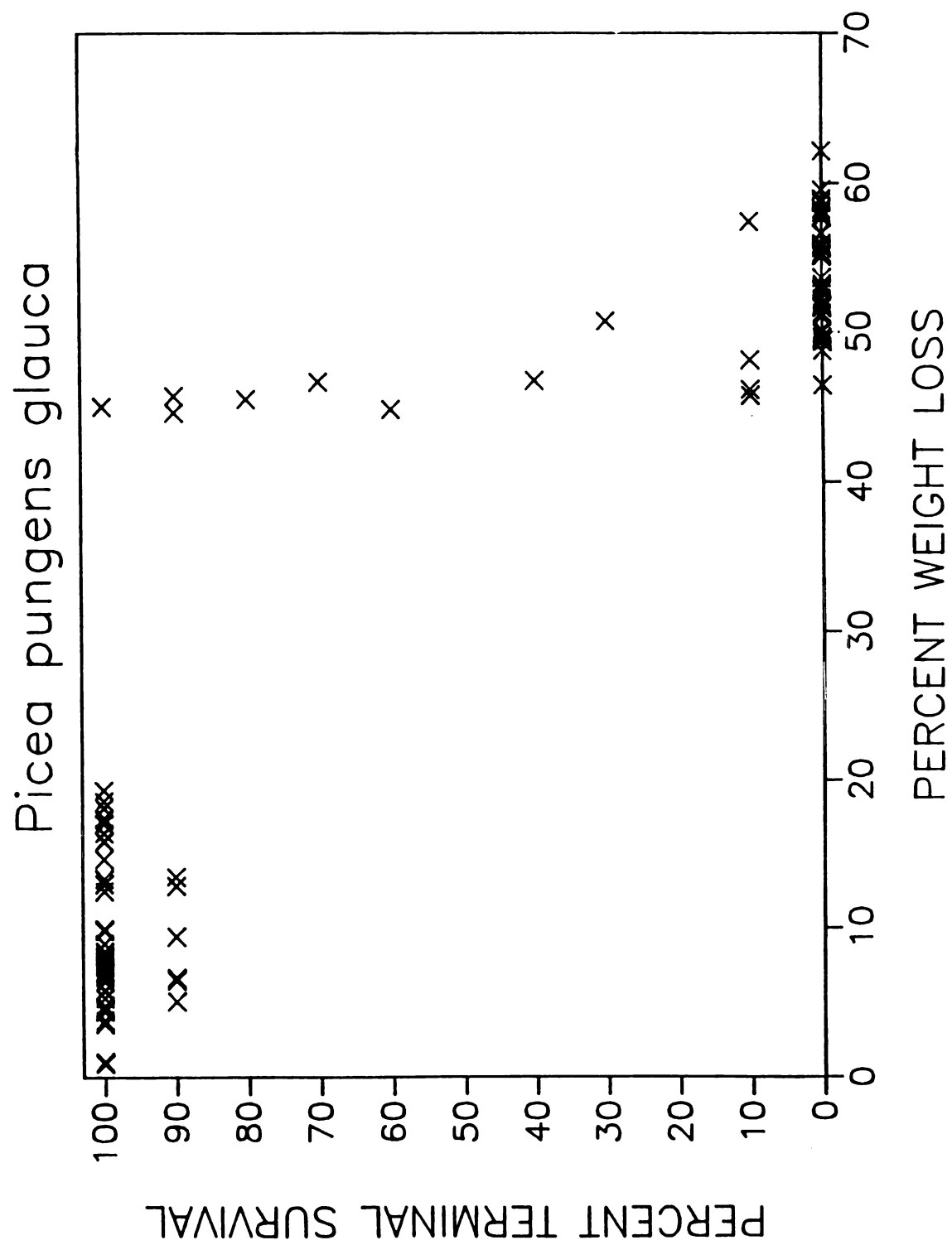


Figure 1.16. Effect of percent weight loss on Picea
pungens glauca seedling terminal length.

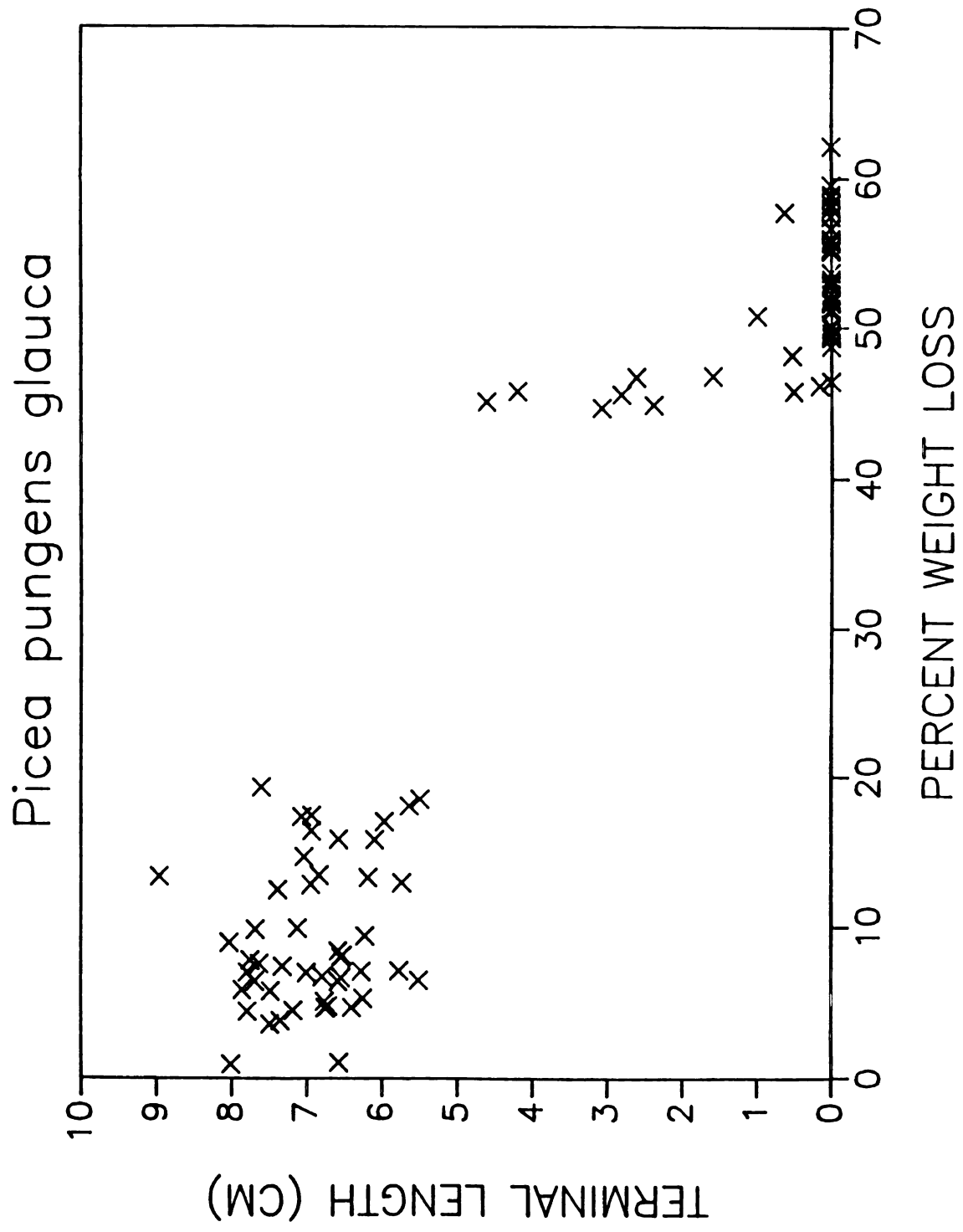
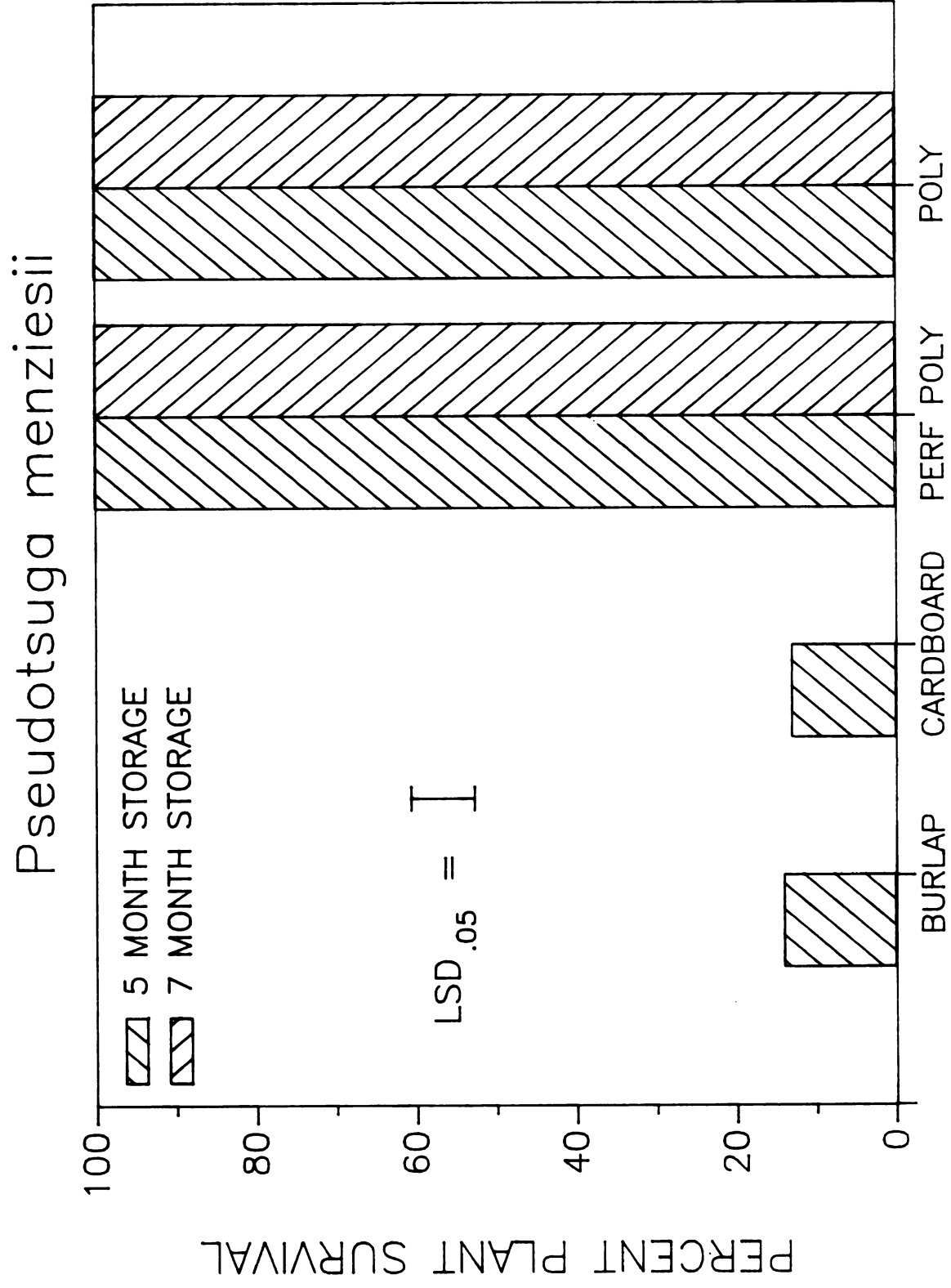


Figure 1.17. Effect of package and storage duration on Pseudotsuga menziesii seedling percent survival. PERF POLY represents perforated polyethylene and POLY represents polyethylene.



polyethylene, or polyethylene averaged 0, 0, 5, and 5 cm growth respectively.

Seedling survival for all treatments was influenced by percent weight loss (Figure 1.18). Survival was 100 percent when seedlings had less than 15 percent weight loss. Seedling percent survival ranged from 0 to 90 percent as the percent weight loss increased from 45 to 65 percent. There was no data from 15 to 45 percent weight loss. The relationship between percent weight loss and percent terminal survival or terminal growth were very similar to that for percent survival (Figures 1.19 and 1.20).

Scotch Pine Performance for 1987

Seedlings packaged and stored in burlap or cardboard did not survive, while seedlings packed in perforated polyethylene or polyethylene had 100 percent survival. Similar results in the seedling response to package treatment were measured for percent terminal survival and new terminal growth (no data shown).

Package and storage duration treatments influenced the amount of weight loss by the seedlings (Figure 1.21). The seedlings stored in cardboard or perforated polyethylene both increased in percent weight loss from 5 to 7 months storage. Storage duration did not affect the percent weight loss when the seedlings were stored in burlap or polyethylene.

Figure 1.18. Effect of percent weight loss on
Pseudotsuga menziesii seedling survival.

Pseudotsuga menziesii

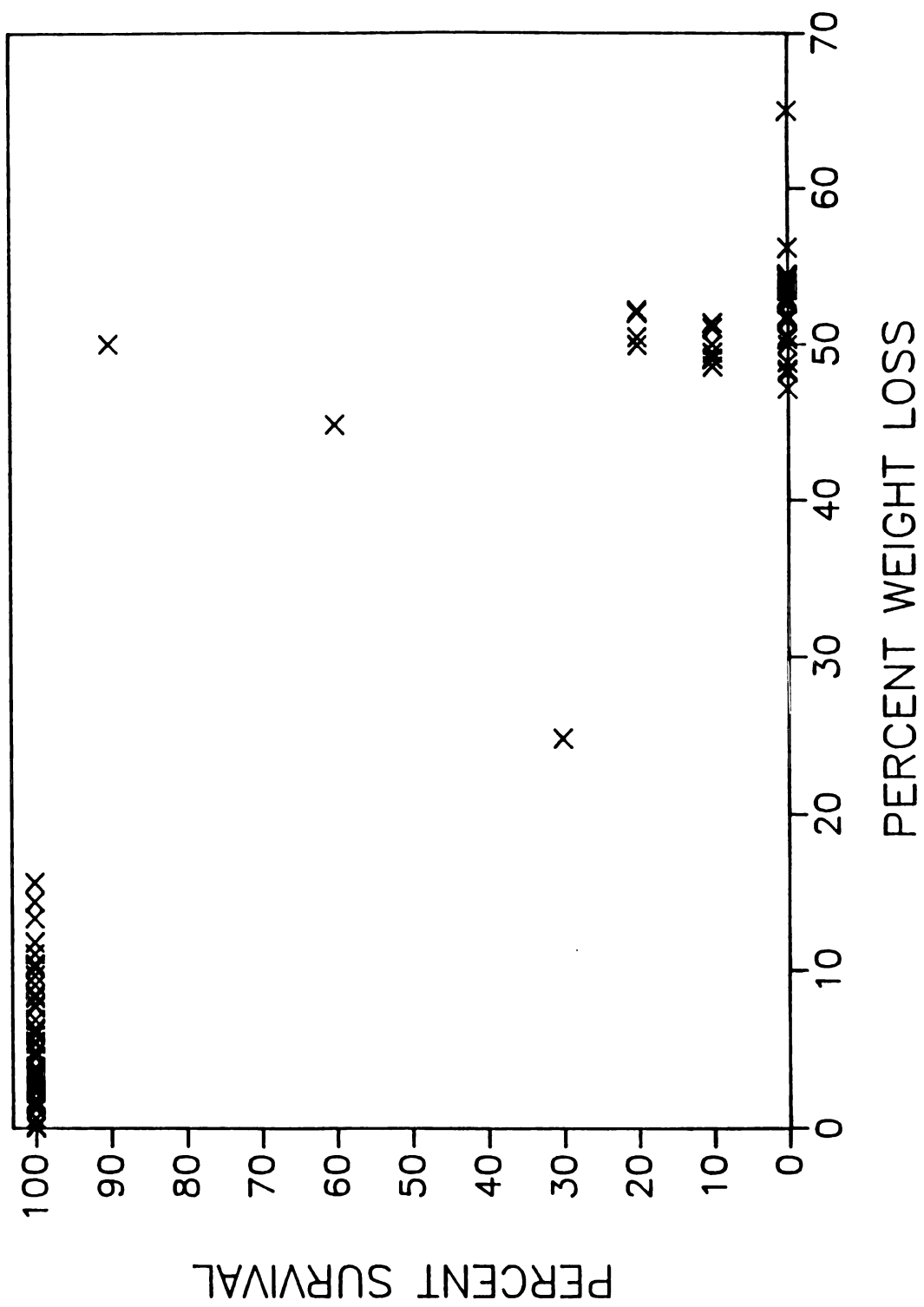


Figure 1.19. Effect of percent weight loss on
Pseudotsuga menziesii seedling terminal survival.

Pseudotsuga menziesii

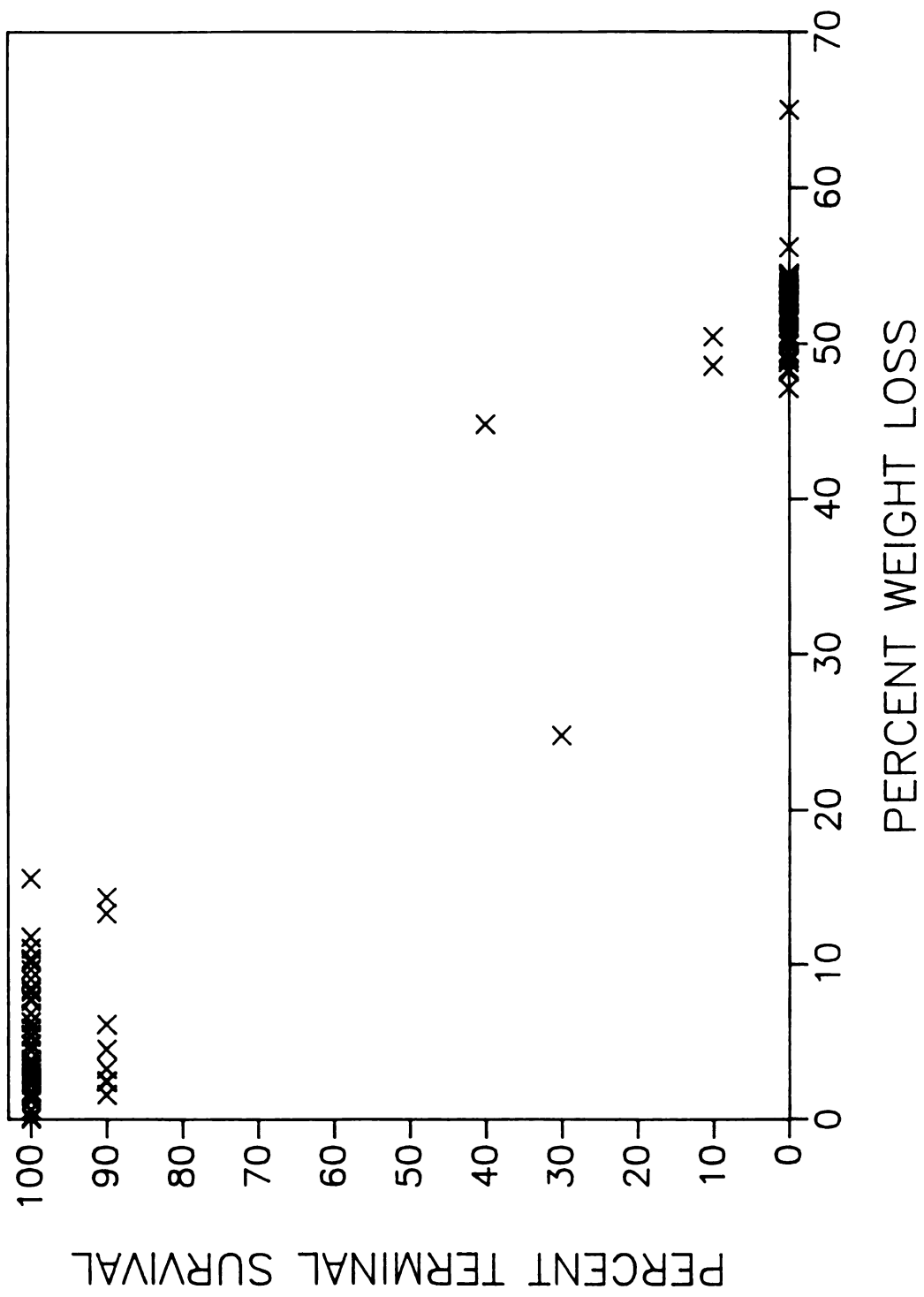


Figure 1.20. Effect of percent weight loss on
Pseudotsuga menziesii seedling terminal length.

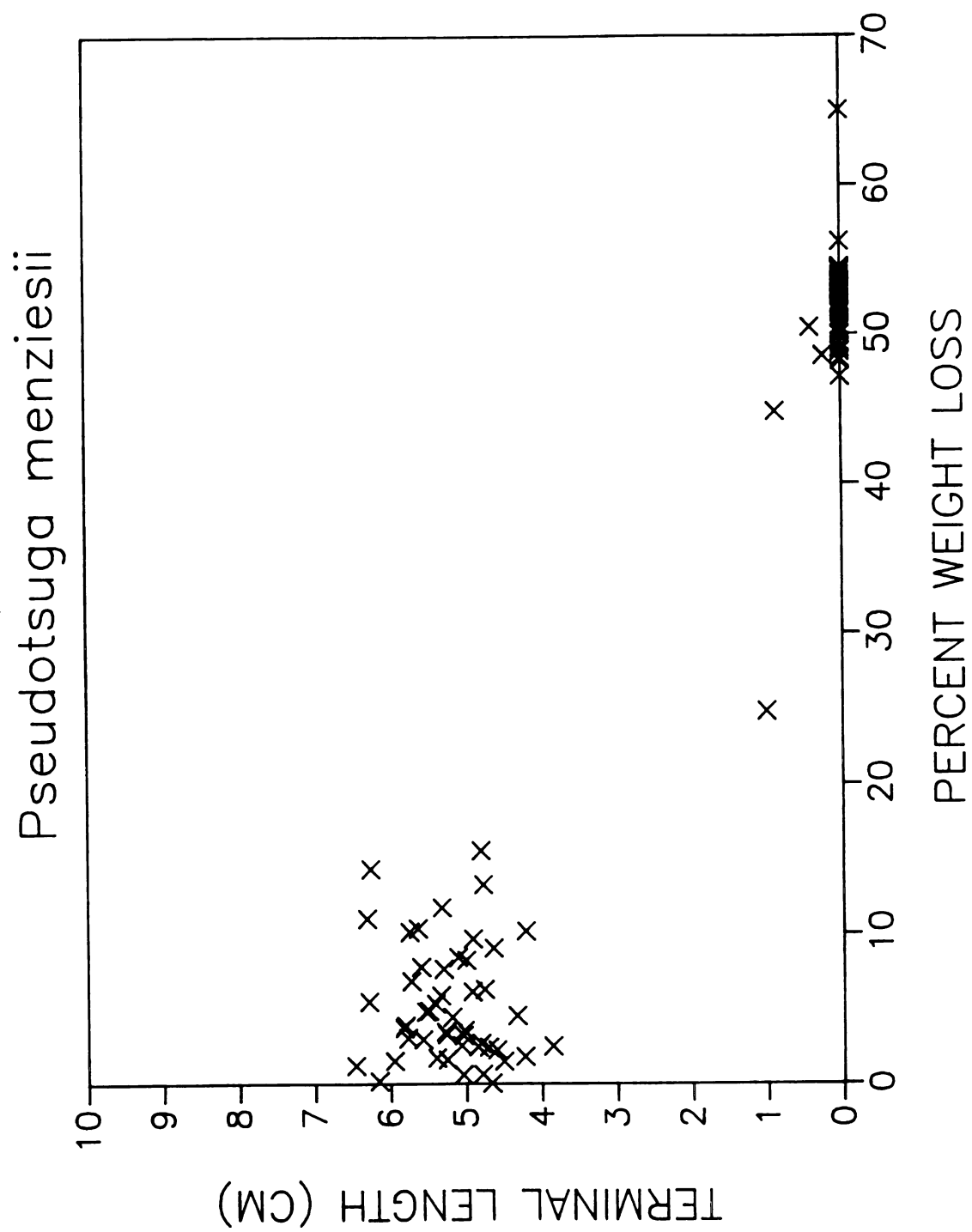
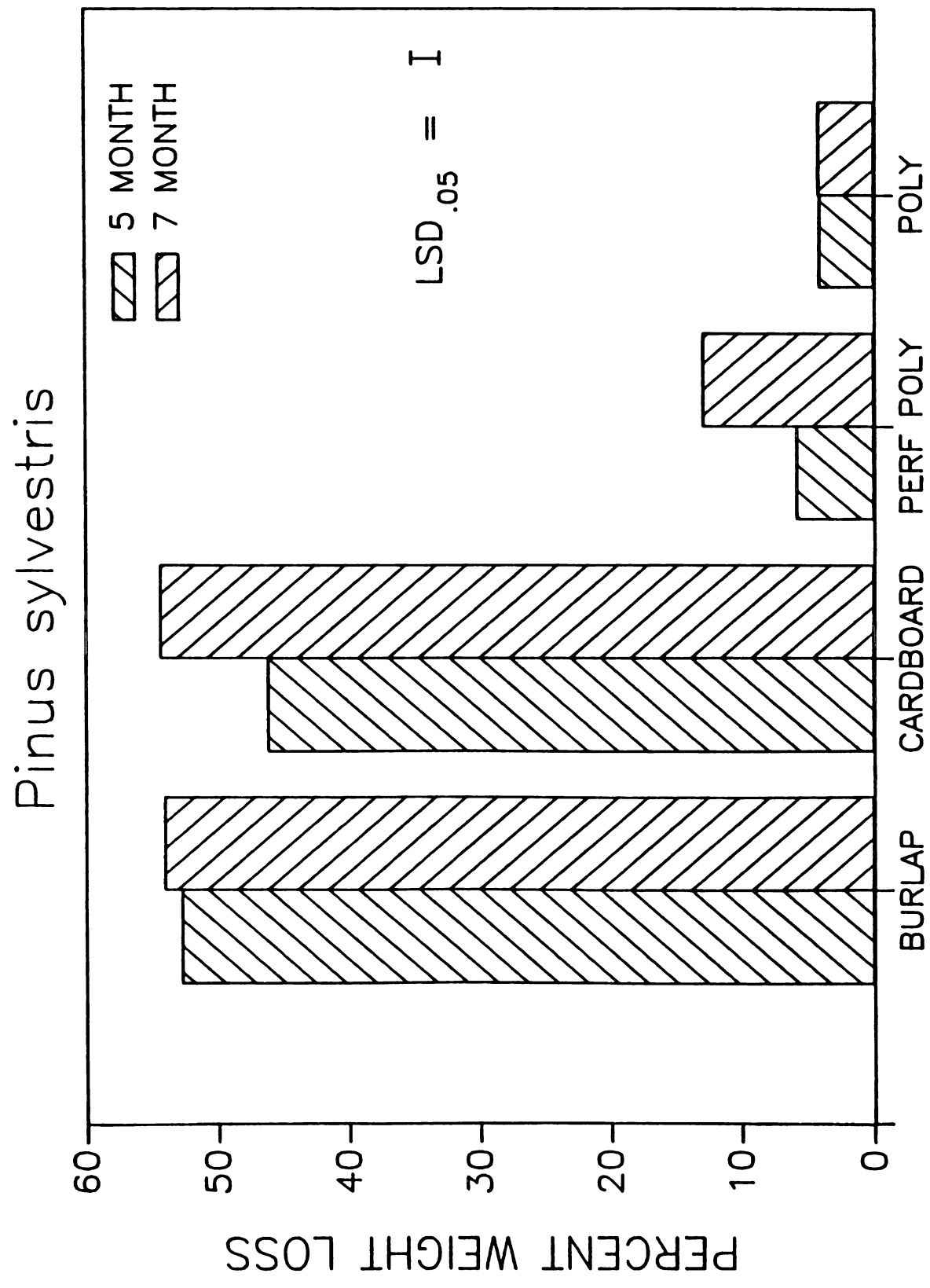


Figure 1.21. Effect of package and storage duration on percent weight loss of Pinus sylvestris seedlings. PERF POLY represents perforated polyethylene and POLY represents polyethylene.



Seedling survival for all treatments was influenced by percent weight loss (Figure 1.22). When the seedlings had less than 16 percent weight loss there was 100 percent survival and seedlings with more than 39 percent weight loss did not survive. There was no data from 16 to 39 percent weight loss. The relationship between percent weight loss and percent terminal survival or new terminal growth were similar to that described for percent survival (Figures 1.23 and 1.24).

Figure 1.22. Effect of percent weight loss on Pinus
sylvestris seedling survival.

Pinus sylvestris

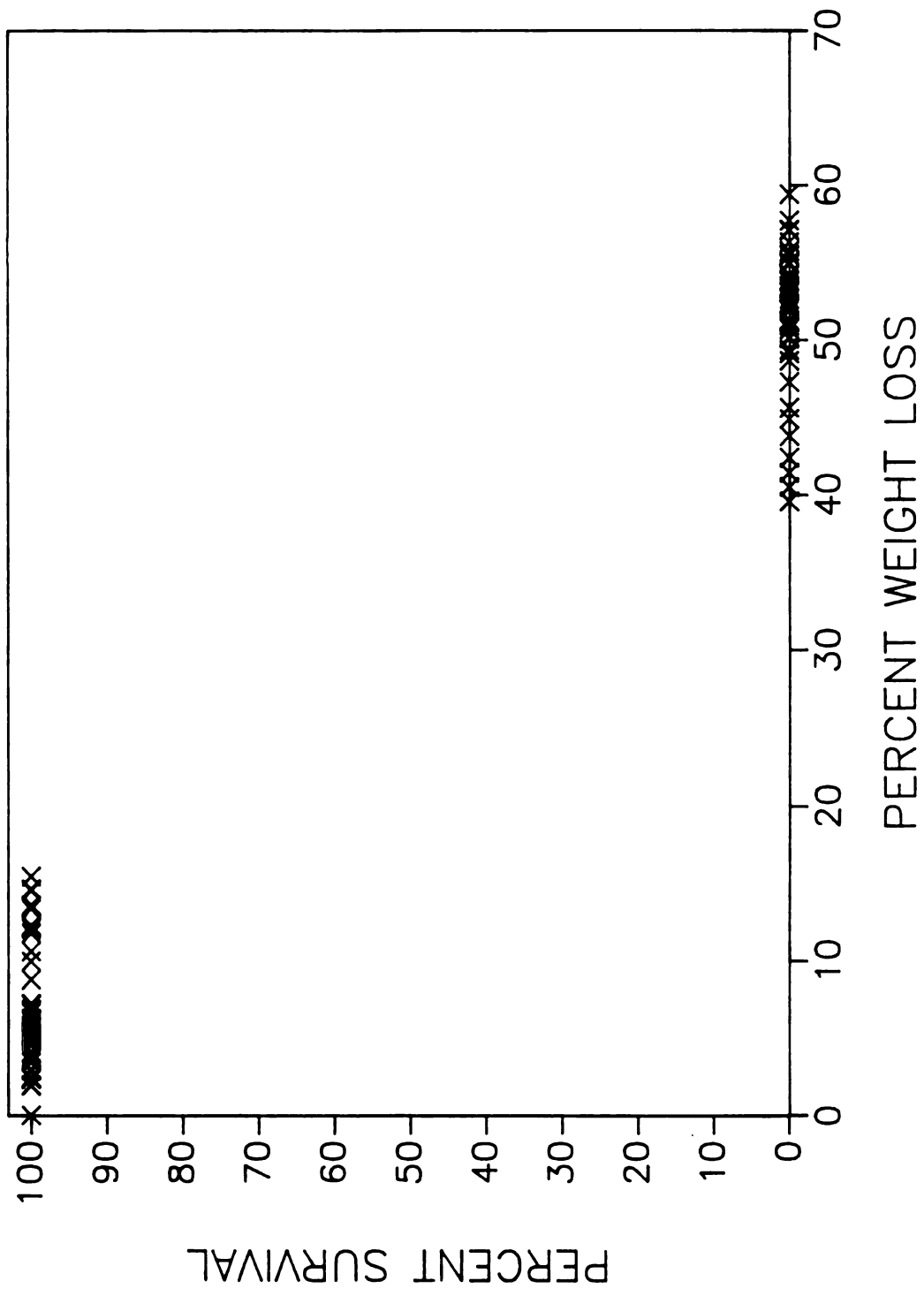


Figure 1.23. Effect of percent weight loss on Pinus
sylvestris seedling terminal survival.

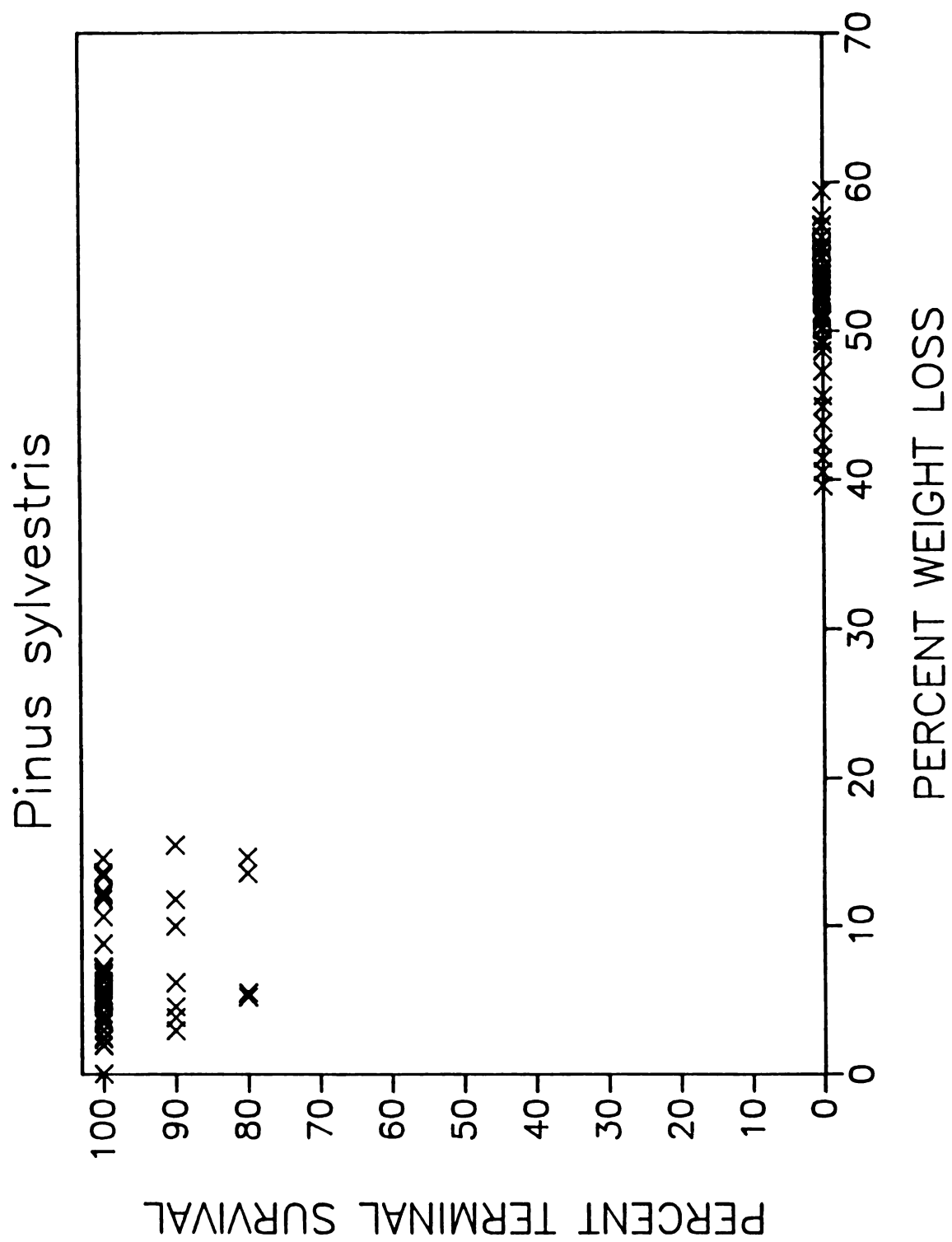
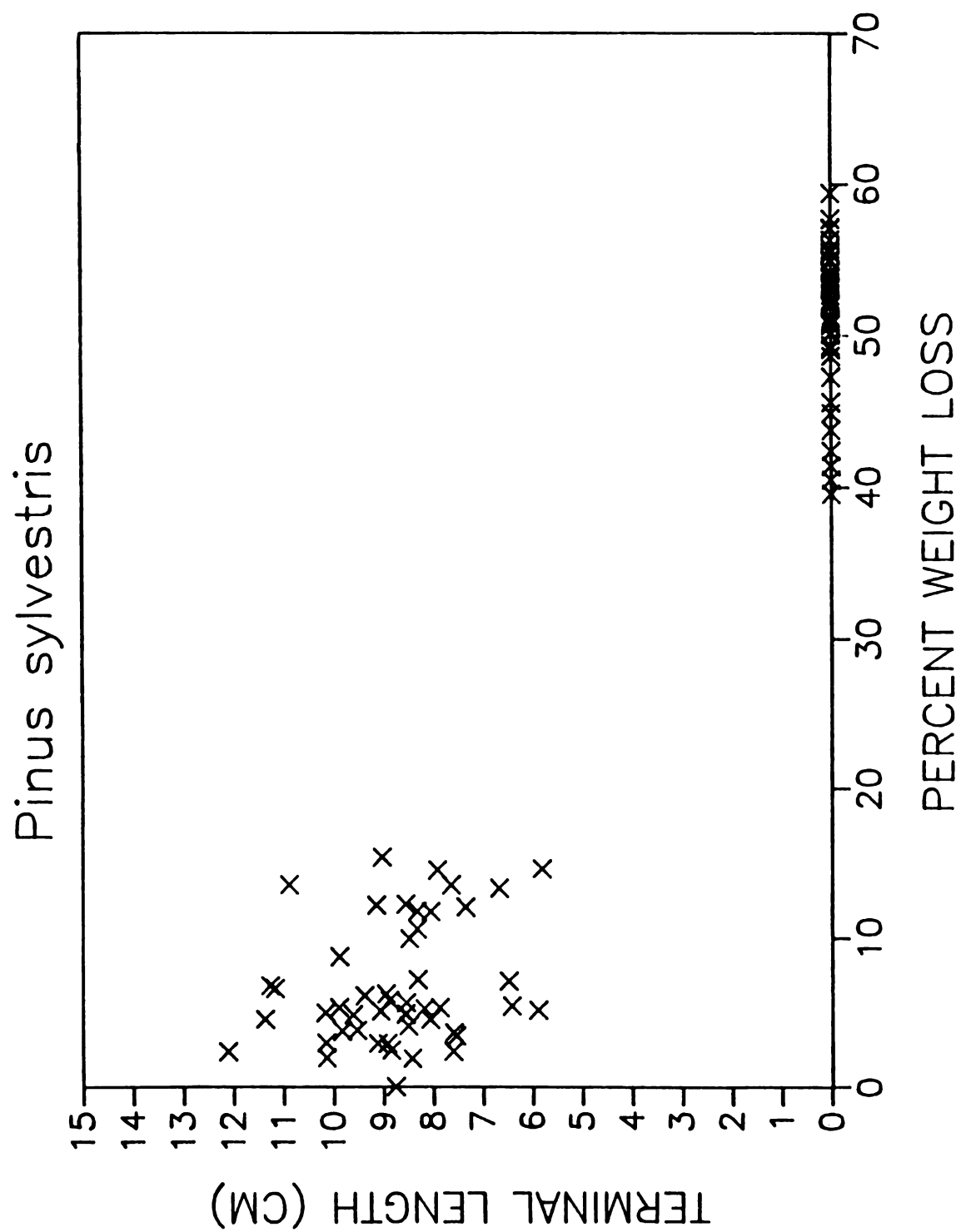


Figure 1.24. Effect of percent weight loss on Pinus
sylvestris seedling terminal length.



Discussion

Sometimes growers are not able to store seedlings on the same day as harvest. Delays before storage may be caused by such things as labor problems or equipment failure. In the 1986 experiment, a 1 day delay at 20°C before storage decreased the percent weight loss and actually improved the new growth performance of seedlings packaged in cardboard or perforated polyethylene. The one day delay allowed the seedlings to be more resistant to water loss. The seedling roots may have suberized and/or the outer cells may have desiccated creating a protective barrier against further moisture loss, with the 1 day delay. However, seedling new growth performance in the 1987 experiment did not improve with a 1 day delay. The difference in performance between years may have been due to the different species used or the fact that the seedlings for the 1986 experiment were lifted in December, while in the 1987 experiment the seedlings were lifted in January. The soil temperature in December may have been higher than in January, thus the roots may have been in a different physiological condition. An additional experiment was conducted in 1987 to verify the increase in seedling new growth performance caused by the 1 day delay in the 1986 experiment. A delay at 20°C before storage was of no benefit to the seedling new growth performance (data not shown). If the

seedlings were protected against moisture loss the delay did not affect the seedlings.

To successfully store conifer seedlings it is important to use a package that prevents moisture loss. Of the seedlings studied in these experiments 100 percent survival was consistently achieved for all species when they had less than 15 percent weight loss. As expected, polyethylene proved to be an effective barrier against moisture loss of the seedlings during storage. Seedlings packed in polyethylene bags had 100 percent survival and less than 10 percent weight loss when stored for 5 and 7 months. These results agree with other researchers who reported that seedlings stored in containers with a moisture barrier, such as polyethylene, performed well after extended storage (10, 11, 18, 19, 25). Most of the treatments with seedlings stored in perforated polyethylene bags had 100 percent survival even though the perforations allowed for a higher percent weight loss than polyethylene bags without perforations.

Storage duration is also a concern of growers. Several months of storage may be necessary before the seedlings can be replanted. In 1986 the seedling performance was not affected by the storage duration treatment, while in 1987 the seedlings stored in cardboard were affected by the longer storage duration. Seedlings stored for a longer duration in cardboard

had additional moisture loss, which affected the new growth performance. Seedlings stored in polyethylene were not influenced by storage duration treatments and were successfully stored for up to 7 months. Seedlings could lose moisture anytime during storage and for this reason they need to be protected from moisture loss. Therefore the use of polyethylene bags for the long term storage of conifer seedlings would be highly recommended.

CHAPTER II

CHARACTERIZATION OF THE MOISTURE CONTENT OF CONIFER SEEDLINGS DURING STORAGE

Introduction

Conifers are usually field sown in prepared seed beds in the spring and harvested in the late fall after two growing seasons as 2+0 bare-root seedlings. After grading, the seedlings are stored bare-root for up to several months by the growers until orders are ready to be shipped. As soon as the buyer receives the seedlings, the seedlings are either placed back into storage or planted.

The optimum conditions for storage are not well established and growers still have concerns regarding handling and storage conditions. In the previous experiment (Chapter 1) a difference in the percent weight loss occurred on seedlings held before storage for 1 day delay at 20°C and stored for 5 or 7 months. However, all Picea pungens glauca Reg 'Misty Blue', Picea pungens gluaca Reg 'San Juan', Pinus sylvestris L. 'Lake Superior Blue' and Pseudotsuga menziesii (Mirb.) Franco 'Lincoln' seedlings with less than 15 percent weight loss survived storage. If a grower harvests too many seedlings per day in the fall, it may become difficult to grade and package the seedlings during the same day. Current information provides no guidelines on moisture loss by seedlings before storage. Information on the rate of moisture loss by seedlings before and during storage is needed by growers for the proper handling of seedlings.

Nyland (22) stored Scotch pine, red pine and Norway spruce below freezing for 28 weeks. He packaged the seedlings by two methods with only the roots protected versus the whole seedling protected from moisture loss. Moisture content of the tops and roots was taken every 5 weeks during storage. The moisture content of the tops and roots fluctuated between 75 and 200 percent throughout storage for exposed tops in the storage environment, compared to the seedlings that were totally enclosed in a polyethylene bag in storage.

Tarrant (26) measured the moisture content of the tops and roots of Douglas-fir seedlings every 4 weeks. The roots were packed in moist cedar shavings in a bundle. He concluded that the moisture content did not decrease after 8 weeks of storage.

Two experiments were designed to monitor the moisture loss of the seedlings during storage. The purpose of the first experiment was to measure the percent weight loss of seedlings before and during storage. The seedlings were packaged in cardboard, perforated polyethylene, and polyethylene and placed in storage immediately after packing or after 1, 2, 3, or 4 days of delay at 20°C before storage. The seedling percent weight loss was determined before being placed into storage and every month for 5 months during storage. A second experiment was conducted to monitor the moisture content of the tops and roots throughout

storage. The seedlings were packaged in burlap, cardboard, perforated polyethylene or polyethylene and placed in storage immediately or after 1 day delay at 20°C. Moisture content of the tops and roots were determined before and after 1, 3, 5 and 7 months of storage.

Materials and Methods

Experiment 1

Picea pungens glauca Reg. 'San Juan', 2+0 seedlings, were harvested on January 7, 1987, from Armintrout's West Michigan Farms, Inc. in Allegan, Michigan. The seedlings were harvested by a tractor with a rigid undercutting blade and agitators to disturb the soil and lift the seedlings for collection by hand. The seedlings were transported to Michigan State University in polyethylene lined cardboard boxes. Immediately upon arrival, seedlings were removed from the polyethylene bags and graded to a height between 15 and 25 cm. The seedlings were randomly bundled into groups of ten. Each bundle was weighed and placed in a burlap bag in a cardboard box, 4 mil perforated polyethylene bag or 4 mil polyethylene bag.

The seedlings were stored in a temperature controlled room at 0°C. The seedlings were placed into storage immediately after grading and bundling (0 day delay) or after 1, 2, 3, or 4 days of delay at 20°C in the packages. The bundles were removed from storage every month for 5 months and reweighed to determine percent weight loss on a fresh weight basis (always based weight loss of original day). After the weight was recorded the seedlings were returned to storage. After 5 months of storage the seedlings were then planted in 10 cm pots containing a mixture of 50% sandy

loam:30% peat:20% torpedo sand (v:v:v) and placed on benches in a greenhouse with no supplemental lighting. The greenhouse was set to 16°C night temperature and 22°C day temperature. After 9 weeks of growth in the greenhouse, percent plant survival, percent terminal survival and terminal length (new growth only) data was collected.

There were 6 replicates and 10 seedlings per replicate. For statistical analysis a 2 way AOV was used. There were 3 packages and 5 delays with a total of 60 plants per treatment. There was also a 3 way AOV used with 3 packages, 5 delays and 6 monthly readings.

Experiment 2

Picea pungens glauca Reg. 'San Juan' and Pinus sylvestris L. 'Lake Superior Blue', 2+0 seedlings, were harvested at the same time and location as the seedlings used in previous experiments. The Picea pungens glauca Reg. 'San Juan' were graded to sizes between 15 to 25 cm and the Pinus sylvestris L. 'Lake Superior Blue' were graded to sizes between 10 and 20 cm. The seedlings were bundled in groups of ten. Each bundle was placed in either a burlap bag, a burlap bag in a cardboard box, perforated 4 mil polyethylene bag or 4 mil polyethylene bag.

The seedlings were stored in a temperature-controlled room at 0°C. Half of the seedlings were

placed into storage immediately after packaging (0 day delay) and half after one day delay at 20°C in the packages. The seedlings were cut at the root collar in order to take the top and root moisture content.

Moisture content was determined on a fresh weight basis before storage and after 1,3,5 and 7 months of storage. The seedlings were dried for 24 hours at 60°C.

Results

Experiment 1 Spruce

The seedlings packaged in cardboard had a higher percent weight loss with each additional day of delay at 20°C before storage at 0°C (Figure 2.1). The loss of water was essentially linear over the 4 day period with approximately 12 percent weight loss per day. After 4 days of delay, seedlings experienced a 47 percent weight loss. The seedlings packaged in perforated polyethylene or polyethylene had approximately 5 percent weight loss the first day and an increase of approximately 1 percent per day thereafter. After 4 days of delay seedlings packaged in perforated polyethylene or polyethylene experienced 8 or 7 percent weight loss, respectively. Within each package there was no difference in seedling percent weight loss between delay treatment after 5 months of storage (Table 2.1). The seedlings packaged in cardboard, perforated polyethylene or polyethylene averaged 61, 19, or 14 percent weight loss respectively after 5 months of storage.

Package treatment influenced seedling new growth performance (Table 2.2). None of the seedlings packaged in cardboard survived, while the seedlings packaged in perforated polyethylene or polyethylene had 100 percent survival.

Figure 2.1. Effect of delay at 20°C before storage on percent weight loss of Picea pungens glauca seedlings.

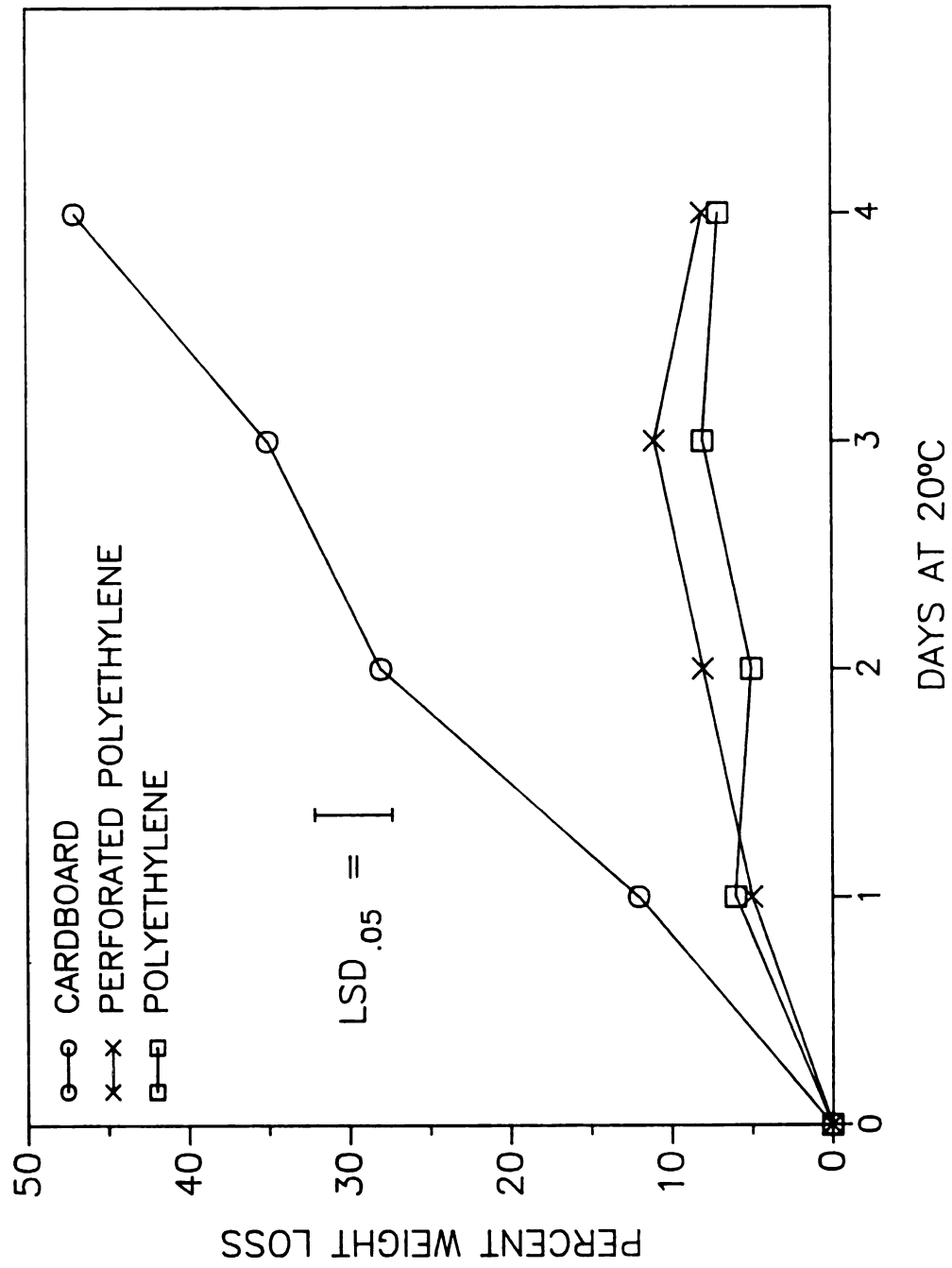
Picea pungens glauca

Table 2.1. Effect of package, delay and duration on percent weight loss of Picea pungens glauca seedlings.

		DAYS DELAYED					
DATE		0	1	2	3	4	
CARDBOARD	1-10	0	12	28	35	47	* 24
	2-10	43	34	41	43	54	* 43
	3-10	56	47	53	52	57	* 53
	4-10	55	55	55	57	60	* 56
	5-10	58	58	58	60	62	* 59
	6-9	59	60	59	62	63	* 61
		-----	-----	-----	-----	-----	* -----
		45	44	49	52	57	* 49
PERF POLY	1-10	0	5	8	11	8	* 7
	2-10	8	8	10	14	11	* 10
	3-10	13	11	14	16	12	* 13
	4-10	19	14	16	18	14	* 16
	5-10	21	16	18	20	16	* 18
	6-9	22	17	19	21	18	* 19
		-----	-----	-----	-----	-----	* -----
		14	12	14	17	13	* 14
POLY	1-10	0	6	5	8	7	* 7
	2-10	4	9	7	10	9	* 8
	3-10	8	12	8	12	10	* 10
	4-10	11	13	11	15	12	* 12
	5-10	13	14	12	16	13	* 14
	6-9	13	15	13	17	14	* 14
		-----	-----	-----	-----	-----	* -----
		8	12	9	13	11	* 11
		=====	=====	=====	=====	=====	* =====
		22	23	24	27	27	* 25

LSD.05

DAYS DELAYED ----- 1.15
 PACKAGE ----- .9
 PACKAGExDELAY ----- 1.99
 DELAYxREADING ----- 2.81
 PACKAGExMONTHLY READING --- 2.18
 PACKAGExDELAYxREADING ----- 4.87

Table 2.2. Effect of package on Picea pungens glauca seedling new growth performance.

	CARDBOARD	PERF POLY	POLY	LSD.05
PLANT SURVIVAL (%)	0	100	100	
TERMINAL SURVIVAL (%)	0	99	97	1.91
TERMINAL LENGTH (CM)	0	6.7	6.4	.35
WEIGHT LOSS (%)	61	19	14	2.24

Experiment 2 Spruce

Seedlings averaged 57 percent moisture content before being placed in storage. After 7 months of storage seedlings packaged in burlap, cardboard, perforated polyethylene or polyethylene had 34, 39, 57 or 60 moisture content, respectively. The seedlings packed in burlap or cardboard lost moisture over the 7 months to levels of 20 or 25 percent respectively (i.e., less than 1/2 what they started). The seedlings packed in perforated polyethylene and polyethylene remained relatively constant or even increased slightly after 7 months.

Tops of seedlings delayed 0 or 1 day had a higher moisture content than the roots when first placed into storage (Figure 2.2). After 7 months of storage, there was no difference in moisture content between tops and roots within each treatment and the roots lost more moisture with 1 day delay than with no delay.

Delay, package and storage duration affected seedling moisture content (Figure 2.3). The seedlings stored in burlap lost moisture with 1 day delay at 20°C prior to placement in 0°C storage and by the end of 7 months of storage, there was no difference in moisture content between treatments. The seedlings packed in cardboard had no difference in moisture content between 0 and 1 day delay until the 7th month of storage, when seedlings with 0 delay had a higher moisture content.

Figure 2.2. Effect of delay and storage duration on top and root moisture content of Picea pungens glauca.

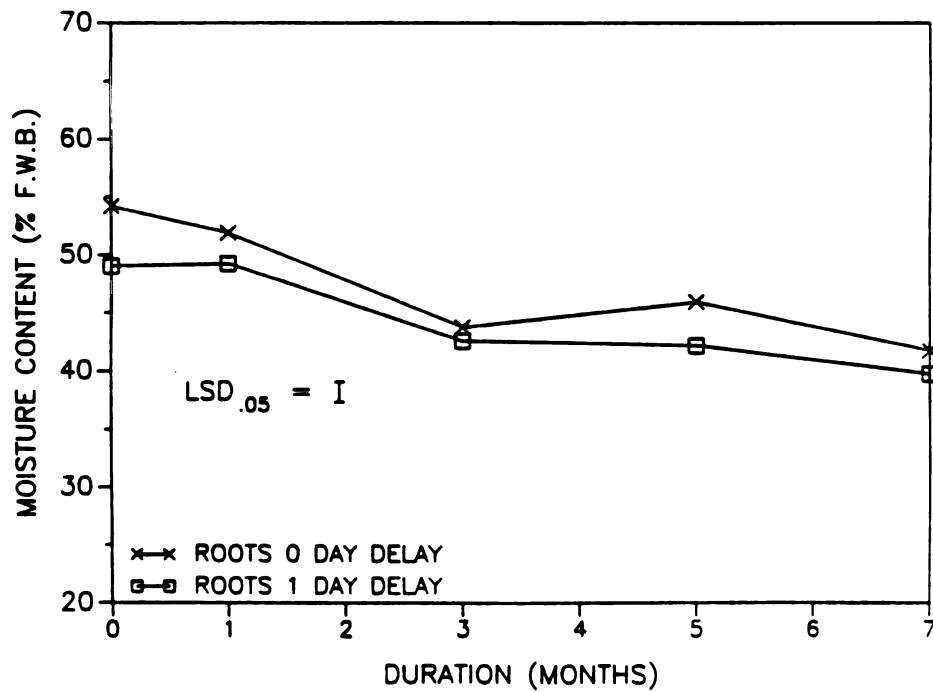
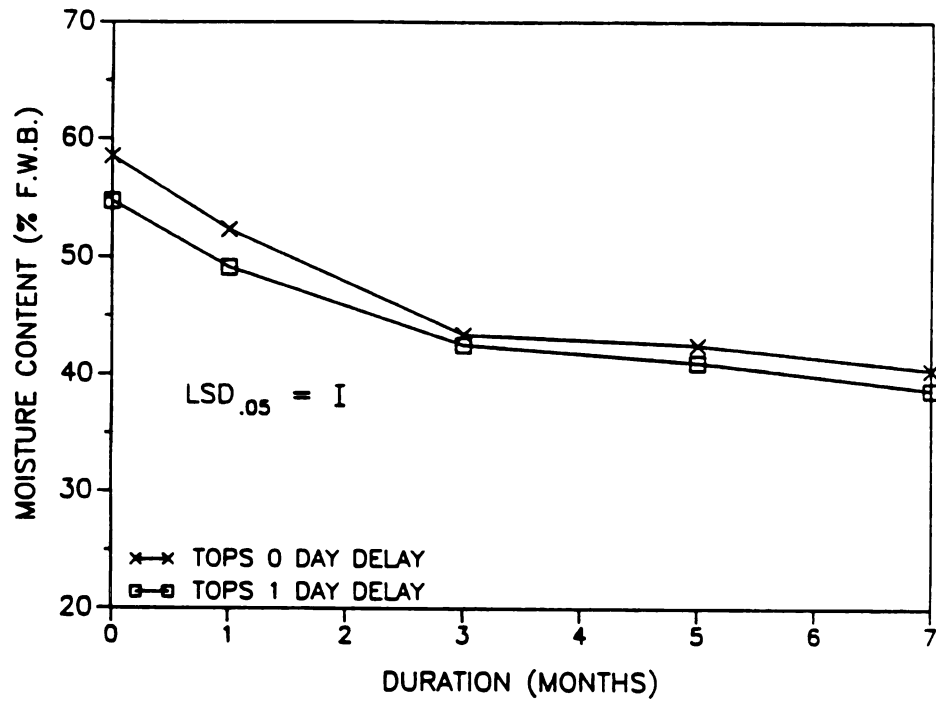
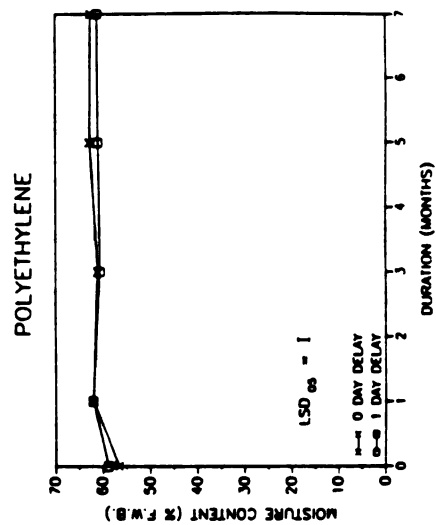
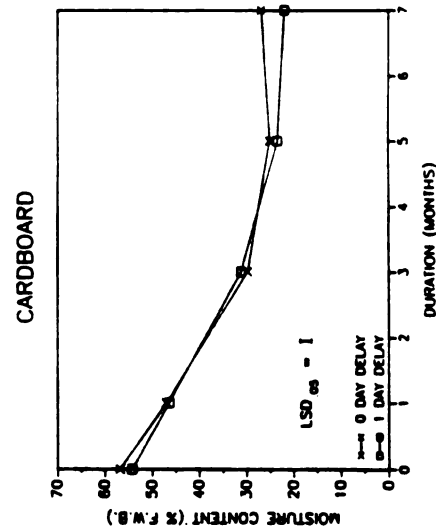
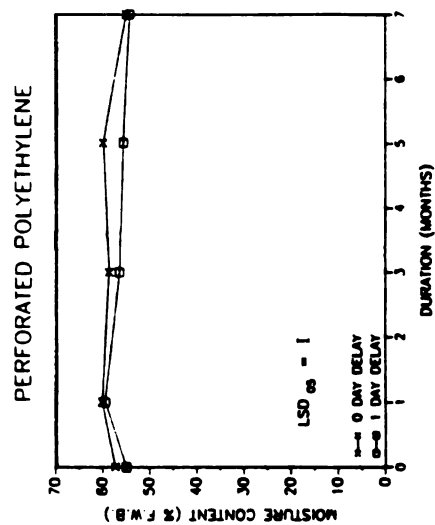
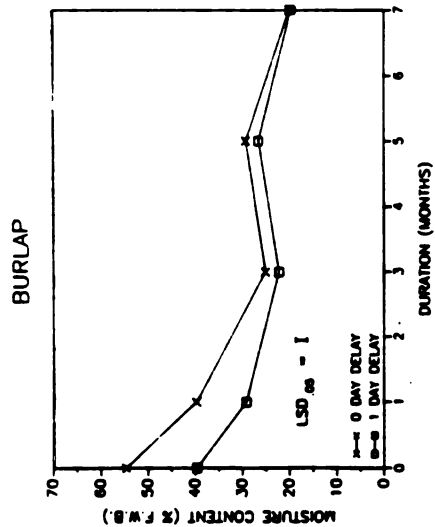
Picea pungens glauca

Figure 2.3. Effect of package, delay and storage duration on the moisture content of Picea pungens glauca seedlings.

Picea pungens glauca



Seedlings stored in perforated polyethylene or polyethylene had no difference in moisture content between 0 and 1 day delay after 7 months of storage.

The moisture content of the tops and roots were influenced by package and storage duration (Figure 2.4). Seedlings packaged in burlap had a higher moisture content in the tops than the roots when they were first placed into storage and by the end after 7 months of storage there was no difference in moisture content between the tops and roots. There was no difference in the moisture content of tops and roots packaged in cardboard until the 7th month when the roots had a higher moisture content. Seedlings stored in perforated polyethylene or polyethylene had no difference in top or root moisture content after 7 months of storage.

Experiment 2 Pine

Package, delay and storage duration influenced the moisture content of the Scotch pine seedlings (Figure 2.5). The moisture content of the seedlings packaged in burlap or cardboard decreased during 7 months of storage, while the moisture content of seedlings packaged in perforated polyethylene or polyethylene remained relatively constant. There was no difference in moisture content between seedlings packaged in burlap with 0 or 1 day delay before storage, but after 7 months of storage the seedlings with 0 day delay had

Figure 2.4. Effect of package and storage duration on top and root moisture content of Picea pungens glauca.

Picea pungens glauca

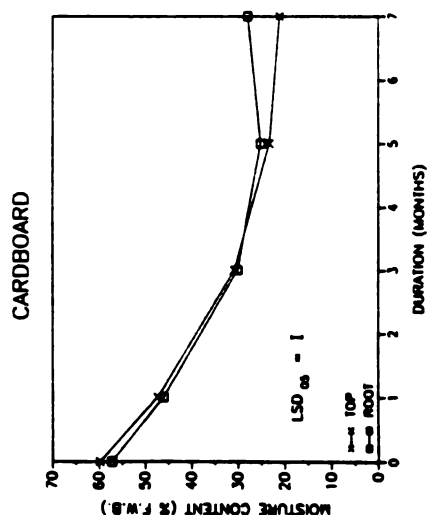
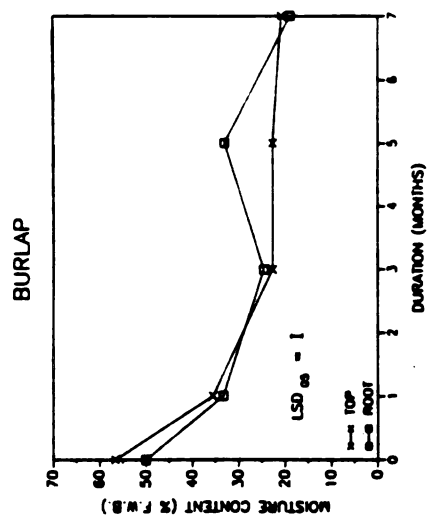
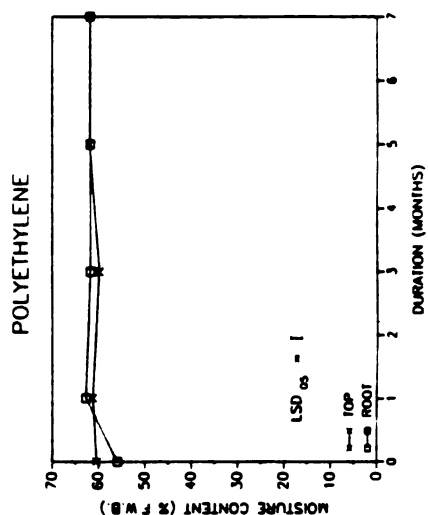
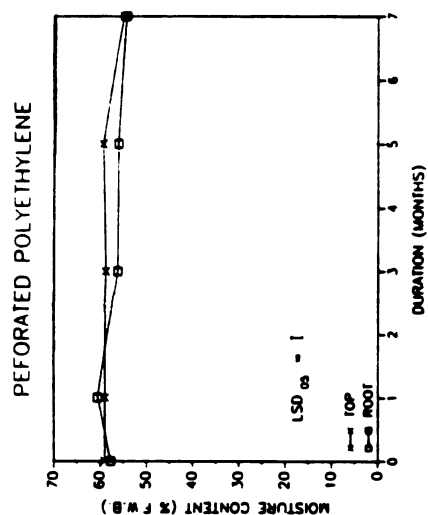
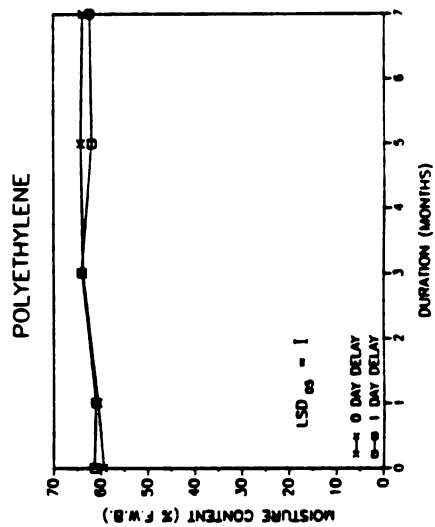
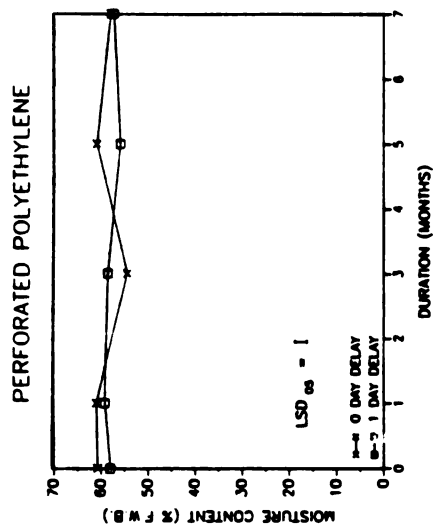
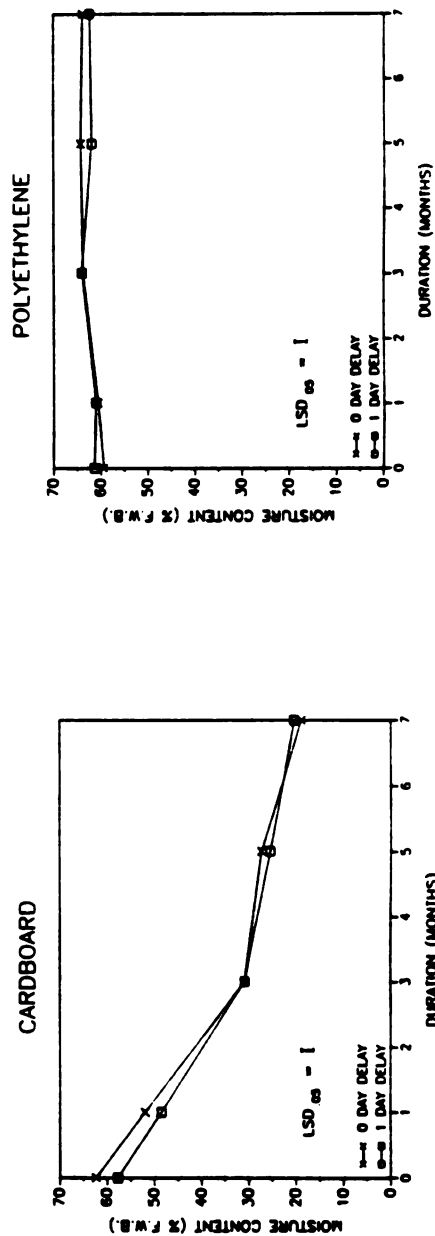
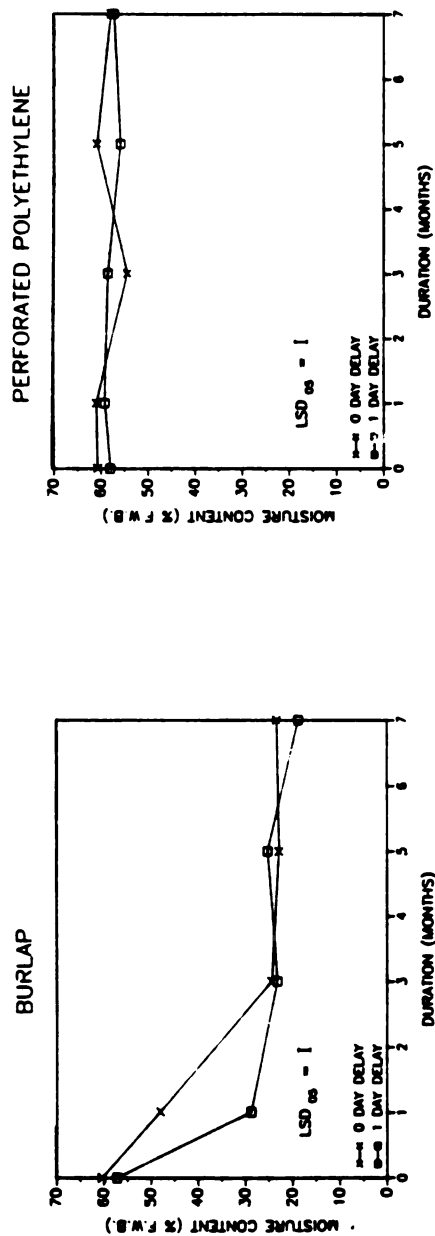


Figure 2.5. Effect of package, delay and storage duration on Pinus sylvestris seedling moisture content.

Pinus sylvestris

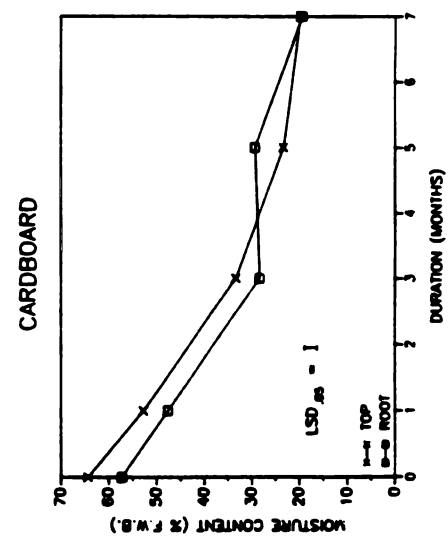
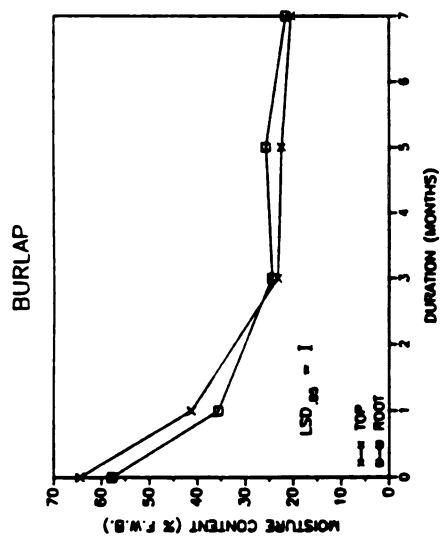
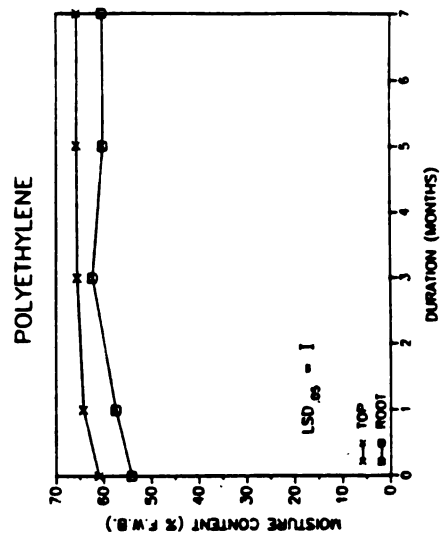
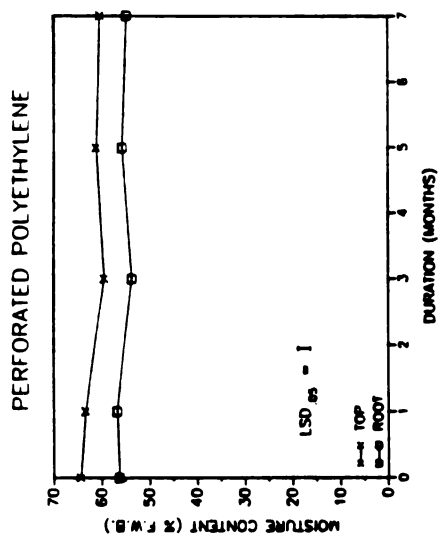


a higher moisture content than seedlings with a 1 day delay. The seedlings stored in cardboard, with 0 day delay had a higher moisture content before storage and by the end of 7 months of storage there was no difference in moisture content between treatments. There was some variability in the moisture content of seedlings stored in perforated polyethylene, but there was little difference in the moisture content between seedlings placed in storage with 0 delay or after 1 day at 20°C before storage. There was no difference in seedling moisture content between 0 and 1 day delay treatments when seedlings were packaged in polyethylene.

The moisture content of the seedlings packaged in burlap or cardboard decreased with 7 months of storage, while the moisture content of seedlings packaged in perforated polyethylene or polyethylene remained relatively constant (Figure 2.6). The tops of seedlings stored in burlap started out with approximately 5-6 percent greater moisture content than in the roots, but after 7 months of storage the tops had approximately the same moisture content as the roots. Seedlings packaged in cardboard started with a higher moisture content in the tops and by the end of 7 months of storage there was no difference between the tops and roots. The moisture content of tops of seedlings packed in perforated polyethylene or

Figure 2.6. Effect of package and storage duration on the top and root moisture content of Pinus sylvestris

Pinus sylvestris



polyethylene remained higher than the moisture content of the roots throughout storage by 5 to 6 percent difference.

Discussion

Sometimes growers are not able to store seedlings until a few days after harvest. Delays before storage may be caused by labor problems or equipment failure. In experiment 1 the seedlings stored in cardboard had a high percent weight loss when delayed at 20°C, because the cardboard box did not protect the seedlings from the room environment. Based on experiment 1, one might expect troubles after 2 days, because the seedlings had approximately 12 percent weight loss per day. The 20°C room had approximately 35 percent relative humidity and the seedlings were left to desiccate without protection. The perforated polyethylene and polyethylene packages were effective barriers to moisture loss and the seedlings were not damaged in the same way as seedlings packaged in cardboard. The perforated polyethylene and polyethylene packages continued to protect the seedlings in the storage environment throughout storage. The reason the seedlings within perforated polyethylene or polyethylene had the same percent weight loss after 5 months of storage, regardless of the delay treatment, may be that the seedlings within each package came to an equilibrium in the package environment. Seedling new growth performance was not affected by a 4 day delay at 20°C if the seedlings were protected from moisture loss. This is important information for

growers who may have troubles placing seedlings in storage the same day the seedlings are harvested. Growers should package the seedlings in polyethylene until they can sort and grade the seedlings before storage.

As a result of the ability of the packages to prevent moisture loss, the seedlings packaged in burlap or cardboard decreased with 7 months of storage, while the moisture content of seedlings packaged in perforated polyethylene or polyethylene remained relatively constant. Nyland (22) found that Scotch pine, red pine and Norway spruce seedlings stored in jelly roll bundles with the tops exposed to the storage environment lost more moisture than the seedlings completely enclosed in plastic bags. Hocking and Ward (9) found that seedlings stored with the tops exposed lost moisture throughout storage.

When the seedlings were packaged in perforated polyethylene bags or polyethylene bags the seedlings lost less moisture. A delay before storage at 20°C could occur without serious concern as long as the seedlings were protected from moisture loss. Therefore, the use of polyethylene bags for the handling and storage of conifer seedlings would be highly recommended.

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