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THE USE OF PERIODIC MOISTURE STESS TO INDUCE VEGETATIVE BUD SET IN DOUGLAS FIR SEEDLINGS

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Abstract. Periodic moisture stress of up to -16 bars prior to irrigation was not effective in inducing vegetative bud set in Douglas fir seedlings. Increasing stress decreased terminal bud dimensions, root weight and shoot weight and caused slight increases in shoot/root ratio but did not result in reduced shoot growth after outplanting.

An additional -8 bar stress treatment with 8-hour photoperiod and low nitrogen nutritional regime showed the smallest bud size, root and shoot weight, and root collar diameter in the experiment; however, no practical effect on shoot growth was observed.

REVIEW OF LITERATURE

The induction of vegetative bud set in the production of containerized Douglas fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings is a means of regulating when the seedling enters the first stage of dormancy, as well as controlling seedling height and root development. Proper dormancy induction and conditioning are tremendously important to the attainment of high survival and growth potential, yet are often overlooked in nursery cultural programs (6). One of the management procedures most often used in inducing vegetative bud set in seedlings is reduction of irrigation to induce moisture stress. Short photoperiods have been used experimentally but most nursery managers regard shortening the photoperiod to be too expensive for large scale usage. One commonly used procedure is to remove nitrogen from the nutritional schedule and to reduce the amount of watering during the late summer. This creates a condition of nitrogen level reduction and moisture stress during a period of naturally shortening photoperiods.

The literature on control of shoot growth in temperate climate conifers suggests that moisture stress during the period of vegetative bud set can be correlated with reduced shoot growth the following year (5,9). This raises the question whether moisture stress is an advisable and effective management procedure for the induction of vegetative bud set in order to condition seedlings for high growth potential. What level of moisture stress will effectively induce bud set without detrimentally affecting shoot growth potential the following year? This study was designed to quantitatively answer this question as a basis for developing specific managerial procedures that would allow the production of seedlings with a predictably high growth potential.

MATERIALS AND METHODS

Two seedlots of coastal Douglas fir, one from 500 ft. elevation near Sekiu, Washington and one from 1000 ft. elevation near Seaside, Oregon were sown into Styroblock 4 containers filled with 1/1 peat/vermiculite in March, 1977. The seedling containers were arranged in units 5.8 ft. × 6 ft. in size. Each of four greenhouse benches contained five of these units, one unit per bench receiving each of the five treatments. the assignment of treatments to units on a bench was done at random. The units were separated by 3 feet of open bench to prevent accidental overspray during treatment.

The seedlings were cultured until December, 1977, utilizing the nutritional regime developed by the British Columbia Forest Service (personal communication with Helmut Mueller, Koksilah Forest Nursery, Duncan, British Columbia). On August 1, when seedling height over all the units reached approximately 18 cm. the moisture stress and photoperiod treatments were initiated. Prior to the initiation of the treatments the seedlings were irrigated excessively with water to leach out excess fertilizer salts. The first four treatments were -4, -8, -12, -16 bar moisture stress, all on the 0-52-34 nutritional solution. The fifth treatment was -8 bars moisture stress, an 8-hour photoperiod and the 10-52-16 nutritional regime. Moisture stress treatments consisted of monitoring the predawn moisture stress of each unit of seedlings using a Scholander pressure bomb (PMS Instruments, Corvallis, Oregon), sampling three seedlings per unit per day. The operation of the pressure bomb has been described by Waring and Cleary (11). When the mean predawn moisture stress of all four replicate units reached the treatment level they were watered to field capacity with the designated treatment solution. Photoperiod adjustment was done by putting Simshade fabric tents over the designated units late in the afternoon and removing them in the morning to allow the 8 hour photoperiod.

Table 1. Nutrition Schedule

Plant Condition	Week	Nutrition Schedule, NPK	g/1000 liters
Use Until Roots Well Developed	4-5	10-52-16*	625
Rapid Shoot Growth	6-16	20-20-20** + ferrous sulfate	500 155
Dormancy Induction***	17-18	0-52-34	625
Root Growth and Stem Diameter Development	19-Shipping	10-52-16 + ferrous sulfate	625 155

* Contains microelements.
** Occasionally replaced by 12-0-0 at 500 g/100 liters.
*** Except for short photoperiod -8 bar stress treatment which was given 10-52-16.

When vegetative bud set was completed (September 9), the moisture stress and photoperiod treatments were stopped and the seedlings were irrigated as needed with the 10-52-16 nutritional regime. The first week of October, 25 seedlings of the Seaside seed source were sampled from each replicate of the -12 bar treatments and put into 2°C storage as a test of the effects of early storage on shoot growth the following year. The second week of December, 12 seedlings to be used for measurement were selected at random from each seed source in each replicate, totalling 48 seedlings per treatment per seed source. The four rows of seedlings closest to the edge of each unit were eliminated from sampling to reduce edge effects. Height, root collar diamete, length and diameter of the terminal bud, and dry weight of the shoot and root were measured on each seedling. Twenty-five seedlings of each seed source to be used for field tests were selected at random from each of the four replicates of each treatment. These seedlings were tagged, placed in polyethylene lined boxes, and stored at 2°C until randomization just prior to outplanting.

Field plantations were installed in February near Sekiu, Washington and near Seaside, Oregon. At each location 100 replicate single tree plots of each treatment were installed in a totally randomized design. In the plantation near Seaside each seedling was surrounded with Vexar tubing to prevent animal damage. The site index (a productivity index consisting of height at age 100 years) of the Seaside plantation is 160 and the index of the Sekiu plantation is 155.

In September, 1978, after vegetative bud set, the total height and 1978 height growth was measured on each tree in each plantation. Seedlings damaged by animals were eliminated from growth measurements.

The data were subjected to analysis of variance procedures utilizing the Statistical Analysis System Version 76.6 program (SAS Institute, Box 10066, Raleigh, North Carolina 27605).

RESULTS

The analysis of variance of seedling size parameters (Table 2) indicates that differences in all of the characteristics measured before planting except height were related to treatment (Figure 1).

There was a reduction in root weight with increased moisture stress during vegetative bud set (Figure 2). There was also an overall reduction of shoot weight with increasing stress; however, there was not a definite trend due to a decreased shoot weight in the -8 bar treatments. The shorter photoperiod-low nitrogen treatment had lower shoot and root weights than the same moisture treatment with natural photoperiod and without nitrogen in the nutritional solution.

The shoot/root ratio was lower for the low moisture stress treatments than for the higher stress levels (Figure 3). This was due to the pronounced trend toward reduced root weight at

Table 2. Analysis of Variance Calculations.

Variable	N	Error Mean Square	Error DF	Treatment DF	F	Probability of a Greater F
Shoot Weight	480	0.1393	27	4	2.4570	0.0689
Root Weight	480	0.0378	27	4	6.9422	0.0008
Shoot/Root Ratio	480	1.0435	27	4	1.7782	0.1617
Root Collar Diameter	480	0.0918	27	4	4.0024	0.0113
Bud Diameter	480	0.1686	27	4	11.3224	0.0001
Bud Length	480	0.4151	27	4	6.9422	0.0008
1978 Height Growth — Sekiu	480	21.9500	328	4	1.1800	0.3190
Total Height 1978 — Sekiu	480	29.8518	328	4	2.110	0.0791
1978 Height Growth — Seaside	480	62.7400	553	5	1.0400	0.3956
Total Height 1978 — Seaside	480	77.1290	553	5	2.3300	0.0407

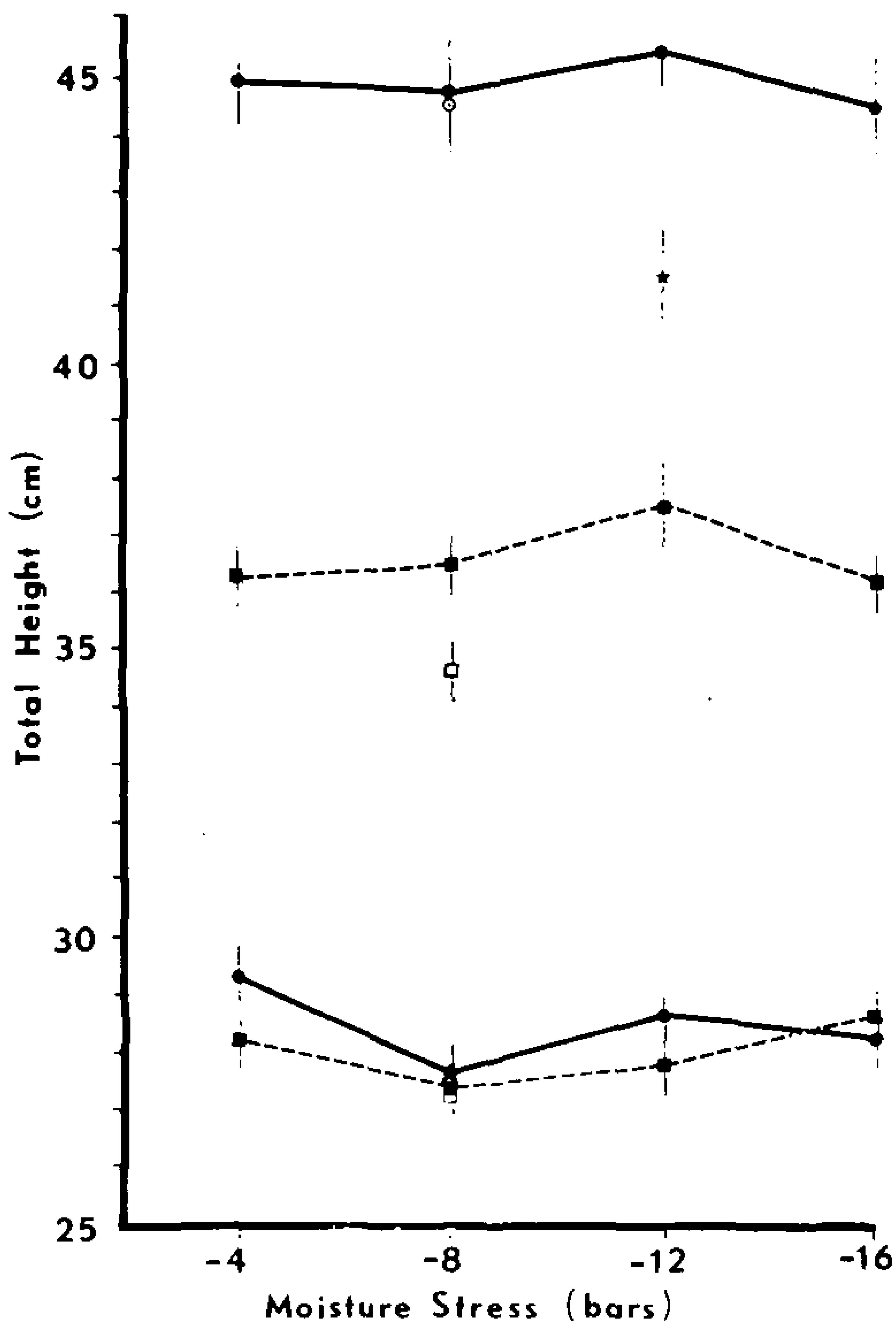

Figure 1. The total height of seedlings from Seaside, Oregon, ————, and Sekiu, Washington, -------. Seed sources after nursery culture (lower lines) and after one year in the field (upper lines).

Treatment during vegetative bud set: four levels of moisture stress + a 0-52-34 nutritional regime, Seaside, ● ; Sekiu, ▪ ; -8 bar moisture stress, 8-hour photoperiod - 10-52-16 nutritional regime, Seaside, ○ ; Sekiu, □ ; -12 bar moisture stress, 0-52-34 nutritional and early storage treatment on the Seaside seed source, ★ .

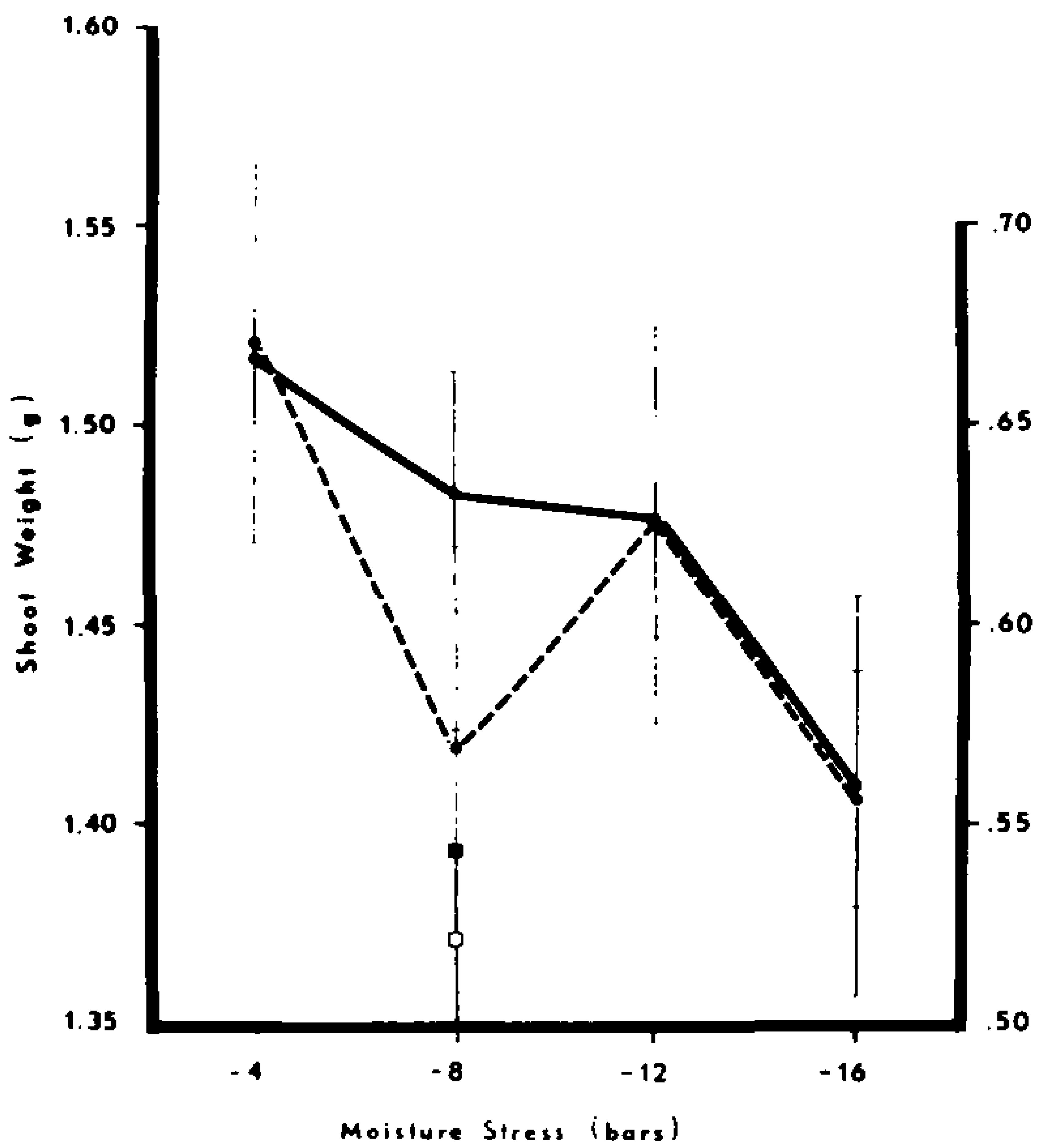

Figure 2. The shoot weight, -----, and root weight, ————, of seedlings receiving various moisture stress - 0-52-34 nutritional regime treatments, ● . Shoot weight, □ , and root weight, ■ , of seedlings receiving -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional regime treatment.

higher stress levels (Figure 2). The 8-hour photoperiod-low nitrogen treatment had the highest shoot/root ratio.

Root collar diameter followed the same trend as shoot dry weight (Figures 4 and 2). The -8 and -16 bar treatments had the lowest diameters in the moisture stress treatments, and the 8-hour photoperiod-low nitrogen treatment had the lowest diameter over all treatments.

Terminal bud dimensions decreased with increasing stress with the exception that the -8 bar stress-low nitrogen treatment had the smallest buds overall (Figure 5).

Periodic moisture stress during vegetative bud set had no practically important effect on height growth the following year in the field (Figure 1). In both locations the -12 bar treatments had the greatest mean height and the early stored seedlings had the smallest mean height in the Seaside plantation (Figure 1).

DISCUSSION

The results of this study suggest that periodic moisture stress of up to -16 bars has little or no effect on bud set in the nursery. Perhaps higher stress levels would be more effective in that regard. Hahn (2) has recently suggested that withholding water until the seedling wilts then watering it back to field ca-

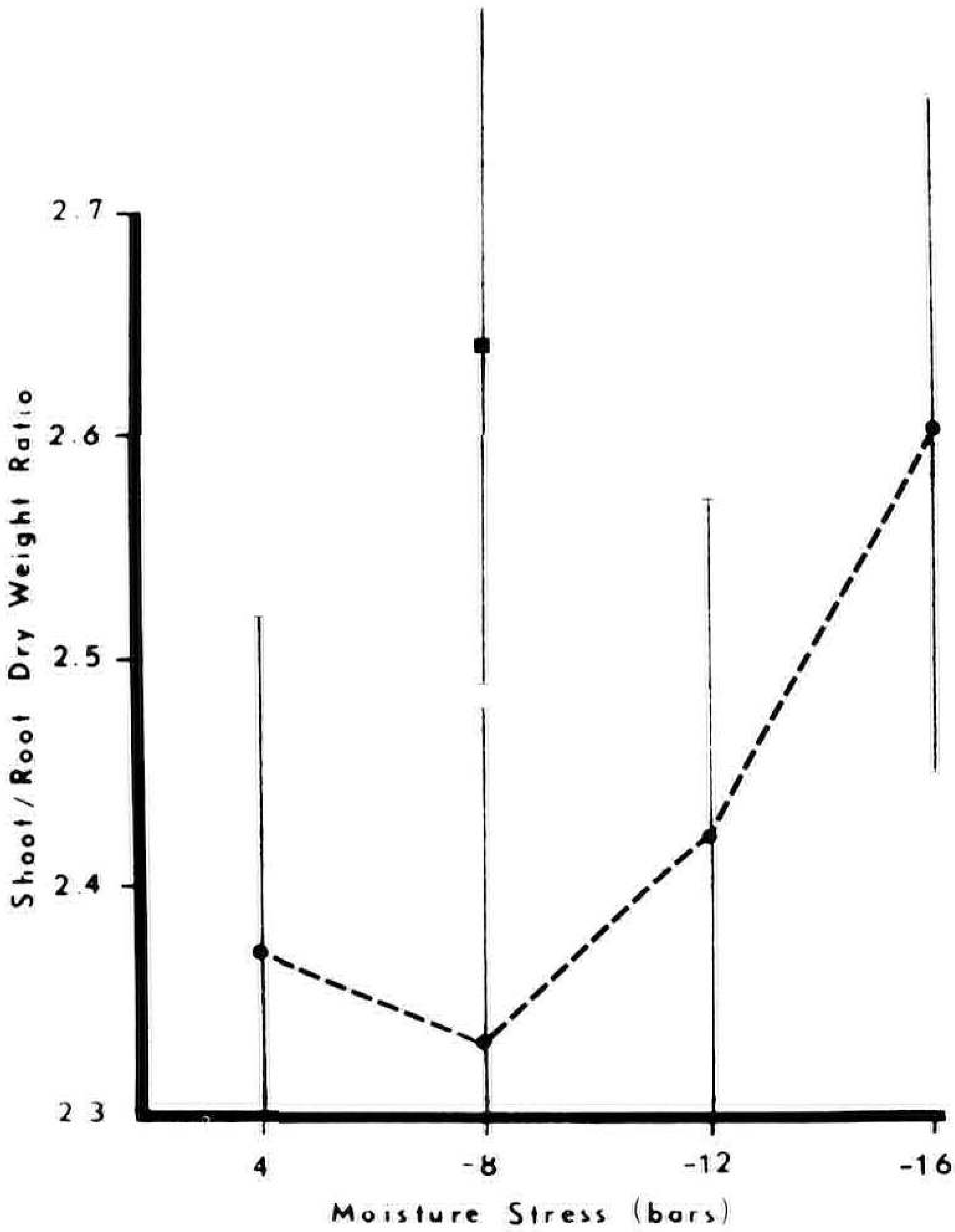

Figure 3. The mean shoot/root ratios of seedlings treated with one of four moisture stress levels and an 0-52-34 *nutritional regime,* ● ; *treated* with a -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional regime, ■ .

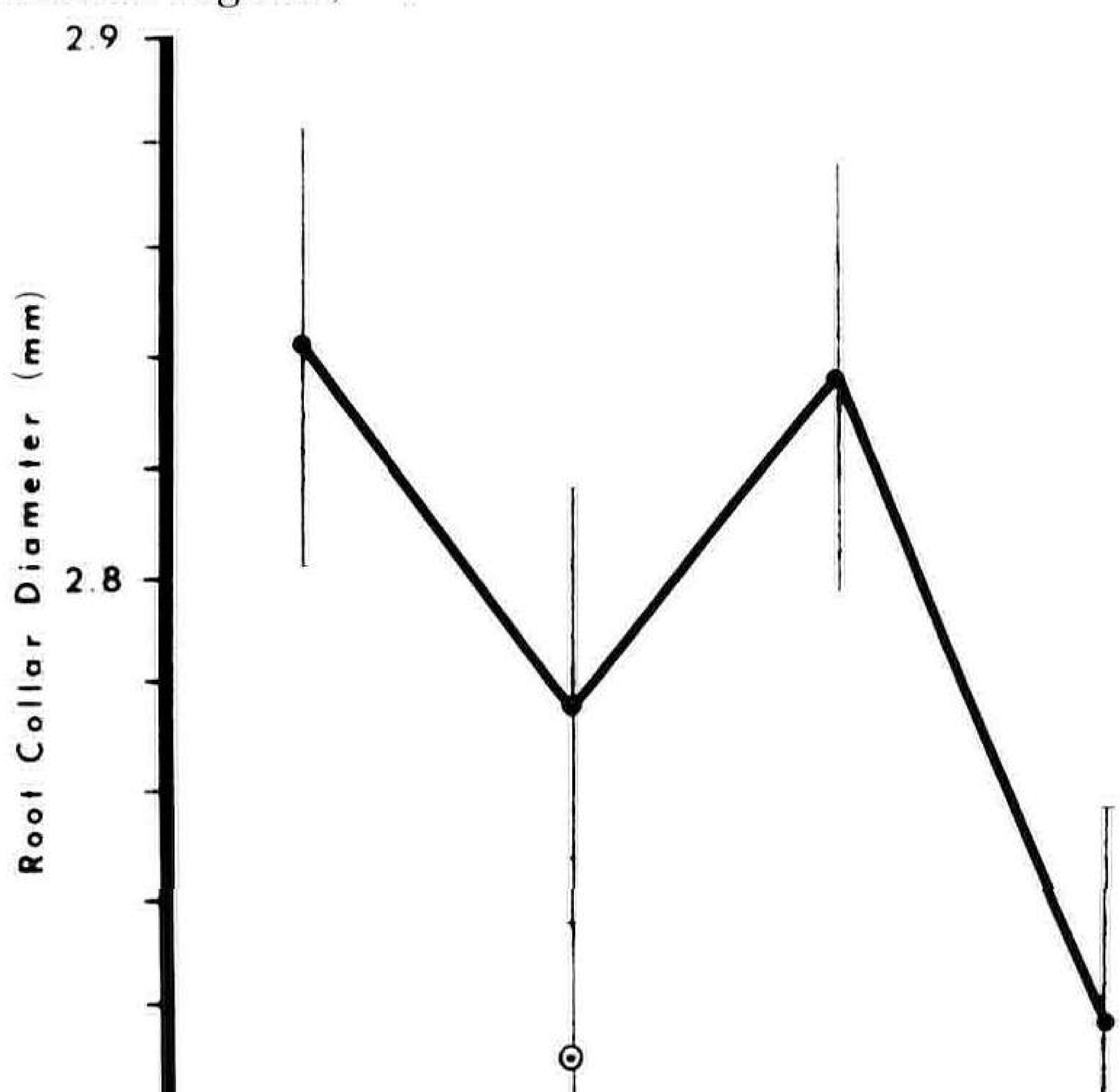

Figure 4. The effects of various moisture stress treatments and a 0-52-34 nutritional regime, ● , or an -8 bar stress, 8-hour photoperiod and 10-52-16 nutritional regime, ○ , during vegetative bud set on the root collar diameter of the seedlings.

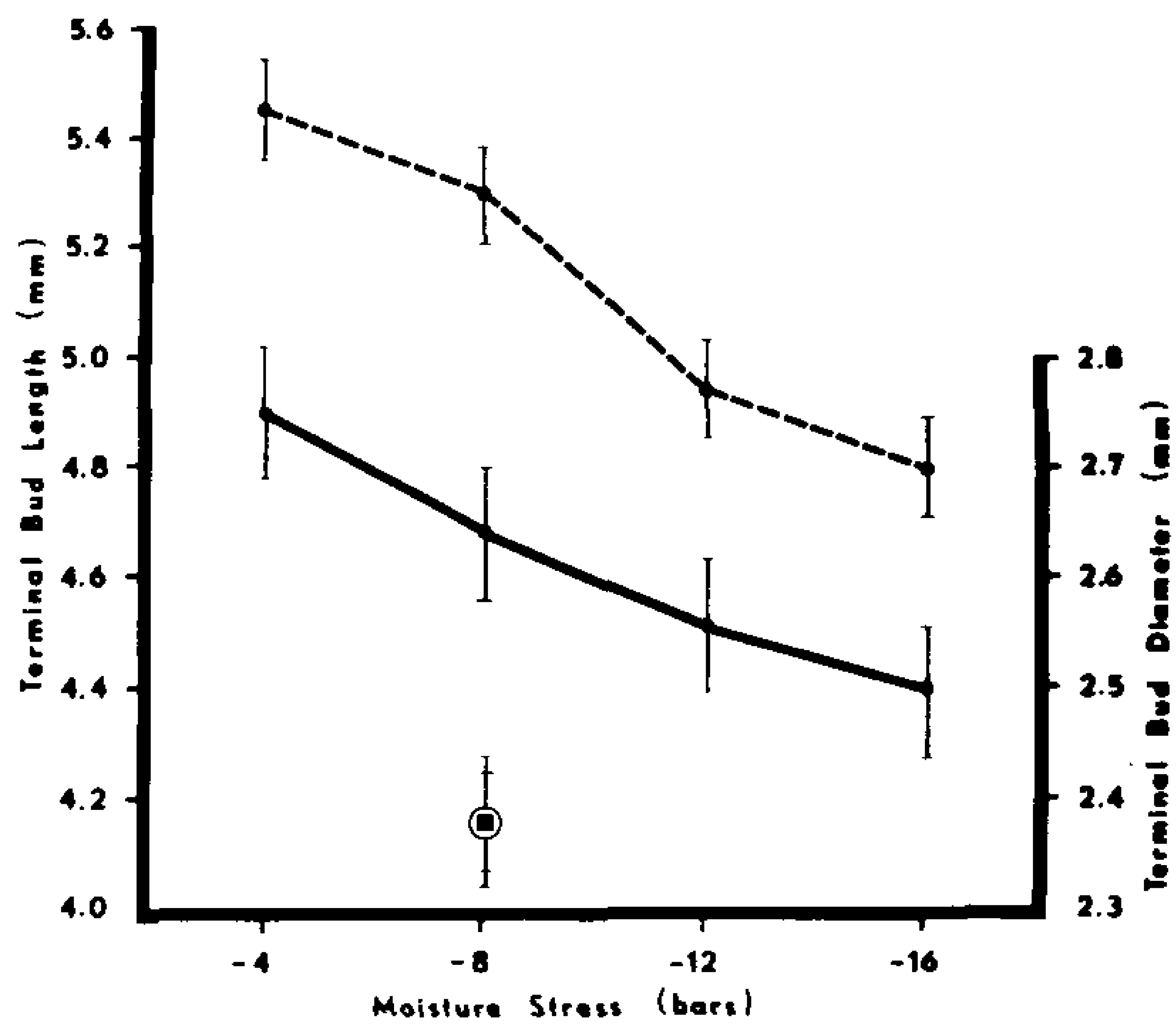

Figure 5. Terminal bud dimensions of Douglas fir seedlings treated with various levels of moistures stress and 0-52-34 nutritional solution, bud length, ------ ; bud diameter, ________ . Bud length, ○ , and bud diameter, ■ , of seedlings treated with -8 bar moisture stress, 8-hour photoperiod and 10-52-16 nutritional solution.

pacity with clear water is an effective technique. Our results in recent unpublished tests indicate that Douglas fir seedlings that have wilted for one day have a predawn stress of -22 bars.

Our tests up to -16 bars show only a small detrimental effect of stress on height growth the succeeding year. It is possible but in light of the data presented here not probable, that sustained stress leading to higher stress levels such as -22 bars at wilting could cause detrimental effects not observed up to -16 bars.

Hahn (2) suggests that reduced photoperiod makes moisture stress more effective in inducing bud set in Douglas fir. The data presented here indicate that while the -8 bar stress, 8-hour photoperiod-low nitrogen treatment did result in shorter seedlings the effect was small. It is possible that some low intensity light leaks reduced the effectiveness of our treatment (8).

Terminal bud size, shoot and root weight and root collar diameter were reduced by the -8 bar stress, 8-hour photoperiod-low nitrogen treatment. Reduced production of photosynthate due to decreased energy input could explain the general size reduction. Shoot weight was reduced considerably less than root weight. Timmis (10) noted increased root weights in seedlings deprived of nitrogen during bud set. It is possible that the low nitrogen level added to the -8 bar stress, 8-hour photoperiod treatment changed the allocation of photosynthate toward the shoot thus reducing root weight proportionately.

Terminal bud size was reduced by the moisture stress-no nitrogen and the -8 bar stress, 8-hour photoperiod-low nitrogen treatments; however, this was not reflected in a similar trend in reduced height growth. Perhaps the treatments affected reduced cellular elongation but did not otherwise alter bud development. This hypothesis is supported by the fact that the mitotic index[1] in the bud was not adversely affected by the stress treatments, whereas early cold storage, which caused cell division in the bud to be reduced to the December level in early October, did reduce shoot elongation the following spring. If stress treatments only reduced cellular elongation, then the shoot elongation rate in the next growing season would be expected to be similar in all of treatments because the small differences in bud size would be undetectable in the elongated shoot.

The Seaside plot in which each seedling was surrounded by Vexar tubing showed considerably more growth than the Sekiu plots even though all animal damaged seedlings were eliminated from the measurement group. The productivity index of the two areas is very similar. It is possible that the shade provided by the Vexar tubing allowed additional growth; however, other factors such as short term weather trends could be involved.

Root collar diameter, shoot/root ratio, and size of the root system are often used as quality parameters in culling seedlings on shipment from the nursery. The ranges of these parameters found in this study were small; however there was no detectable effect of their variation on shoot growth. Others have found that over a moderate range of shoot/root ratios, other quality parameters are more important indicators of shoot growth potential (4,7). Root growth potential is probably poorly described by root mass at time of planting. Hahn and Hutchinson (3) have suggested that with high quality container seedlings the root mass increases considerably prior to bud break. Large increases in root mass prior to shoot growth would probably minimize the effects of small differences in root mass at time of planting on shoot growth.

[1] The mitotic index portion of the study is to be published elsewhere after further work.

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ROOT SYSTEM CONFIGURATION IS IMPORTANT TO LONG TREE LIFE

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Abstract. Circling roots can stunt growth or increase susceptibility to wind breakage and blowdown. The problem can be largely avoided by growing tree seedlings in containers with vertical ribs or grooves, without sharp horizontal corners, and with an egress hole at the bottom for air pruning roots. Root configuration control is standard forest nursery practice in 30- to 700-ml containers, but now has been demonstrated in 10-liter containers intended to produce potted trees for the retail market. Additional egress holes near the pot surface may correct insufficient root production of outplanted trees.

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