RELATIONSHIP OF FALL WATERING PRACTICE TO WINTER INJURY OF CONIFERS[1]

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To reduce incidence of winter injury, it has been a long standing recommendation and practice of tree maintenance specialists that trees, especially evergreens, be given ample soil moisture prior to soil freezeup (8). If not stated, it is implied that the critical time for watering is just prior to freezeup and that the purpose is to provide ample soil moisture to allow the trees to replace the moisture that is lost through transpiration in mid-winter.

A few years ago we began to question the validity of this practice or at least the implications that accompany the recommendation. Our reasons for questioning the implications are two-fold: (A) In climates such as ours in Minnesota it seems highly unlikely that trees could replace water lost from the tops during mid-winter since the upper layer of soil remains constantly frozen from late November until March. Thus water would need to pass from the roots through frozen tissue to reach the top. (B) Cold hardiness research has shown that slight moisture stress accelerates cold acclimation (1, 2, 4) and lower tissue water levels frequently correspond to greater cold tolerance (3). McKenzie, et al. (5) and Parsons (6) demonstrated that plant root tissues actually become more resistant to water uptake and/or translocation during the onset of cold accimlation.

In previous research Pellett, et al. (7) found that there was no uptake and translocation of water from the roots to the tops of arborvitae in mid-winter when soil was frozen. The purpose of this research was to determine the value of fall water after water stress on the winter survival of evergreens.

Materials and Methods

Experiment 1: Container grown pyramidal arborvitae, *Thuja occidentalis* 'Pyramidalis', were given water stress treatments during the fall of 1977. In order to prevent natural rainfall from interfering with the desired soil moisture levels, test plants were grown under a clear fiberglass roof. The soil moisture treatments consisted of watering each 2 gallon container as follows: (A) 400 ml/pot (control plants), (B) 100 ml/pot, and (C) 50 ml/pot at each watering. Soil moisture treatments were started August 16. Initially all plants were watered daily but as the season advanced watering frequency was decreased to every two or three days or longer depending on temperature conditions. On November 2 half of the stressed plants (50 ml and 100 ml/pot) were rewatered to field capacity and maintained at the higher level (400 ml/pot) until freezeup. All treatments were replicated with five plants. Periodic plant tissue moisture levels were determined throughout the study and plants were visually evaluated for winter injury in the spring.

Cold hardiness levels were determined in the laboratory on October 6, October 27 and November 2. To determine cold hardiness, stem pieces from 3 plants of each treatment were placed in plastic bags, a thermocouple for measuring tissue temperature was inserted into one stem per bag, and the bags sealed and placed in a deep freeze at 0° C. Freezer temperature was lowered at a rate of 15° C per hr. with one bag removed at each 3° interval. After thawing the samples were stored at room temperature for 7 to 10 days and then rated for visual signs of injury of the foliage and stem tissue.

Experiment 2: Experiment 2 was conducted in the fall of 1978 to verify the results of experiment 1 and to determine the effect on winter injury of rewatering at different times after water stress. Experimental conditions were the same as those in experiment 1. The water stress treatments were initiated August 11, 1978. Five plants from each stress treatment were watered to field capacity on October 1, October 15, November 1,

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or not rewatered. These plants were maintained at the same water level as the control plants following rewatering.

Water content and water potential measurements were made on plants from all the treatments throughout this experiment. Water potential was measured with a pressure chamber apparatus (9). Water potential is measured in negative numbers and, like temperature, a larger negative number indicates the plant is under more water stress.

Plant injury was evaluated as in the previous experiment. In order to observe injury symptoms that might develop without exposure to severe mid-winter freezing temperatures, 5 plants each from the control and from the most severely stressed treatment were placed under greenhouse conditions on November 2. A field rating for visual signs of injury was also made on December 12 and again on May 15. Cold hardiness level was determined on October 2, October 16, November 13, December 14, and February 2 by laboratory procedures described previously.

Results and Discussion

The data in tables 1 and 2 indicate that plants subjected to water stress treatments had a much lower water content in late summer than the plants maintained under more optimal soil water conditions. The water content of all plants decreased as the season progressed; however, the plants that were given the highest water level decreased at a much faster rate. In Expt. 1 (Table 1) there were no apparent differences in water content between any of the treatments after early November while in Expt. 2 (Table 2), plants that were water stressed throughout the experiment (plants that were never rewatered) remained at a lower water content on all dates measured. Stressed plants that were rewatered increased in water content to the same level as that of the control plants. However, measurements (Expt. 2) of tissue water potential indicate the rewatered plants from the lowest soil water treatment (50 ml) continued to have lower water potential (greater stress) than those plants given optimum water throughout the experiment (Table 3). Plants given the 100 ml/pot (at each watering) treatment were under greater stress than those given more water but when shifted to the higher soil water treatment reached the same water potential as the plants given optimum water conditions throughout the study.

Freezing test results (Table 4) indicate that there were no major differences in hardiness level of plants subjected to different soil moisture treatments. In all cases plants were capable of tolerating temperatures much lower than the minimum air temperatures which might occur on the dates tested. Thus, injury due to minimum temperatures would not be expected regardless of the soil water treatments tested.

Visual rating of injury showed that plants subjected to the water stress treatments suffered considerable injury, with the amount of injury proportional to the severity of the stress treatment (Table 5). Rewatering of the stressed plants did not reduce the amount of visible injury exhibited

Table 1. Water content of arborvitae tissue from plants subjected to different soil water treatments in Experiment 1 (1977-78 study).

Water treatment (ml water/pot)	Water content percentage (fresh wt.—dry wt./fresh wt.×100)											
	Date evaluated											
	8/29	*9/10*	*9/26*	*10/6*	*10/17*	*10/27*	*11/4*	*11/11*	*11/22*	*12/2*	*2/27*	*4/14*
400	69.0	64.0	66.3	63.7	60.7	65.3	60.0	55.3	58.5	56.1	54.9	55.5
100	60.0	59.7	60.3	59.7	58.7	63.0	60.3	58.3	57.7	57.7	55.0	55.9
100—400 Nov. 2	—	—	—	—	—	—	59.3	57.3	59.3	59.1	54.6	55.5
50	59.7	59.3	59.3	59.0	58.7	61.3	60.3	60.4	58.0	58.0	54.5	54.7
50—400 Nov. 2	—						61.3	59.7	60.4	59.7	52.1	57.4

regardless of date of watering. We feel that the injury was caused as a direct result of the moisture stress, and cold temperatures contributed little if any to the injury. We base this conclusion on several pieces of evidence. Water stressed plants moved into the greenhouse in early November 1978 exhibited injury symptoms as severe as those on plants over-wintered outdoors under normal temperatures. Also in December 1978, upon close observation, signs of injury on stressed plants were apparent as exhibited by lighter foliage color. As indicated previously, determinations of cold hardiness levels indicated that there were no appreciable differences in hardiness levels and all plants were capable of withstanding temperatures considerably lower than any temperatures which might normally be encountered during the period of time in which the experiments were conducted.

Results of this research would indicate that watering during dry periods in late summer or early fall is beneficial to reduce incidence of injury to conifers. However, the timing of irrigation is very critical and must be applied to prevent water stress from becoming acute. Watering in late fall prior to freezeup is not very beneficial in reducing

Table 2. Water content of arborvitae tissues from plants subjected to different soil water treatments in Experiment 2 (1978-79 study).

Water treatment (ml water/pot)	Water content percentage (fresh wt.—dry wt./fresh wt.×100)							
	Date evaluated							
	9/1	*9/27*	*10/6*	*10/13*	*10/23*	*10/31*	*11/7*	*12/12*
400	65.5	60.0	61.0	59.8	60.0	54.4	56.3	53.3
100	59.9	56.5	54.7	54.3	57.9	54.1	52.9	51.0
100-400 Oct. 1	—	—	59.1	58.2	59.6	55.3	55.6	55.4
100-400 Oct. 15	—	—	—	—	59.7	55.7	56.3	53.9
100-400 Nov. 1	—	—	—	—	—	—	54.9	53.7
50	54.9	57.2	54.5	54.8	53.1	52.2	50.8	47.4
50-400 Oct. 1	—	—	52.1	55.1	56.8	55.3	56.0	53.2
50-400 Oct. 15	—	—	—	—	59.3	55.5	55.1	53.9
50-400 Nov. 1	—	—	—	—	—	—	56.5	52.7

Table 3. Pressure chamber readings of water potential of arborvitae plants subjected to different soil water conditions. Experiment 2 (1978-79 study)

Water treatment (ml water/pot)	Water potential in Bars						
	Date evaluated						
	9/1	*9/27*	*10/6*	*10/13*	*10/23*	*10/31*	*11/7*
400	−15.2	−16.9	−12.8	−13.3	−10.1	−11.3	−14.3
100	−21.5	−19.7	−22.8	−22.2	−12.7	−20.6	−24.3
100-400 Oct. 1			−15.4	−13.2	−9.0	−10.6	−13.0
100-400 Oct. 15					−10.0	−13.9	−15.0
100-400 Nov. 1							−20.2
50	−27.2	−23.8	−25.7	−25.7	−28.8	−25.8	−29.7
50-400 Oct. 1			−24.4	−23.6	−20.8	−20.1	−21.1
50-400 Oct. 15					−16.4	−20.8	−23.2
50-400 Nov. 1							−22.6

Table 4. Cold hardiness level of arborvitae subjected to different soil water conditions

Cold hardiness level (expressed as lowest temperature °C tolerated without severe injury)

Water Treatment ml/pot	Experiment I (1977 study)			Experiment 2 (1978 study)				
	Date tested							
	10/6	*10/21*	*11/2*	*10/2*	*10/16*	*11/3*	*11/13*	*12/14*
400	−13	−18	−24	−9	−18	−27	−36[z]	−57[z]
100	−17	−18	−27	−12	−24	−24	−33	−57[z]
50	−10	−18	−24	−9	−18	−24	−36[z]	−48[y]
100-400 Oct. 1	—			—	−24	−27	−36[z]	−57[z]
100-400 Oct. 15					—	−24	−36	−57[z]
100-400 Nov. 1				—	—	—	−36[z]	−57[z]
50-400 Oct. 1				—	−18	−21	−36[z]	−57[z]
50-400 Oct. 15				—	—	−18	−36[z]	−57[z]
50-400 Nov. 1					—	—	−33	−51[x]

z — lowest temperature tested

y — considerable injury evident at −51 but not completely killed at −57.

x — considerable injury evident at −54 but not completely killed at −57.

Tab Average visual rating of injury of arborvitae subjected to different soil water treatments

Soil water treatment (ml/pot)	Average visual rating of injury[z]		
	Experiment 1 (1977-78 study)		Experiment 2 (1978-79 study)
	5/10/78	*12/12/78*	*5/15/79*
400	1.6	1.6	1.4
100	2.0	2.0	1.4
50	3.2	3.4	3.8
100-400 Oct. 1	—	1.4	1.4
100-400 Oct. 15	—	1.6	2.0
100-400 Nov. 1[z]	2.2	1.6	2.0
50-400 Oct. 1		3.2	3.0
50-400 Oct. 15	—	3.4	3.2
50-400 Nov. 1[y]	2.8	3.8	3.4

[z]Code of visual ratings: 1 = dark green foliage — no visual signs of injury; 2 = foliage lacks lustre — some tissue browning (10% brown); 3 = Moderate foliage injury 10-40% foliage brown; 4 = severe foliage injury — 40% foliage brown; and 5 = plants dead.

[y]plants rewatered on November 2 in 1977-78 study

winter injury of conifer stems and leaf tissue following fall droughts. However, because the temperature of moist soil does not drop quite as low as the temperature of dry soil, fall watering could reduce winter injury to root tissues.

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