IRRIGATION MANAGEMENT FOR HYBRID POPLAR PRODUCTION, 1997-1998

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Summary

Hybrid poplar (cultivar OP-367) was planted in April 1997 at the Malheur Experiment Station and submitted to six irrigation regimes. Irrigation regimes consisted of a combination of soil water potentials as thresholds for initiating each irrigation and water application rates. The irrigation system consisted of microsprinklers installed along the tree row. Wood volume at the end of September in both 1997 and 1998 showed a positive response to water applications. The wettest treatment (keeping soil water potential at 8-in depth wetter than -25 kPa and a total water application of 27 acre-in/acre in 1997 and 45 acre-in/acre in 1998) resulted in an average tree height of 9 ft, 11 in and 2.8 ft^3/acre of wood volume by the end of September in 1997 and an average tree height of 20 ft and 80 ft^3/acre of wood volume by the end of September in 1998. The results suggested that, at minimum, poplar trees should be irrigated at -50 kPa with 1.56 in of water applied at each irrigation. This treatment resulted, on average, in 23 and 32 acre-in/acre of applied water in 1997 and 1998, respectively. Estimated poplar evapotranspiration in 1998 totaled 34 acre-in/acre from May 1 to September 30.

Introduction

With timber supplies from Pacific Northwest public lands becoming less available, sawmills and timber products companies are searching for alternatives. Hybrid poplar wood has proven to have desirable characteristics for many timber products. Growers in Malheur County have shown interest in growing hybrid poplars for saw logs by making experimental plantings. Clone trials in Malheur County have demonstrated that the clone OP-367 (hybrid of *Populus deltoides x Populus nigra*) performs well on alkaline soils for at least two years of growth.

Hybrid poplars are known to have growth rates (Larcher, 1969) and transpiration rates (Zelawski, 1973) that are among the highest of temperate deciduous trees, suggesting that irrigation management is a critical cultural practice. Little research on irrigation management of poplars for saw logs has been done. The objective of this study was to test the effect of different irrigation rates and frequencies on poplar growth to determine optimum irrigation management practices for saw log production.

Materials and Methods

1997. The trial was conducted on a Nyssa-Malheur silt loam (bench soil) with 6 percent slope at the Malheur Experiment Station. The soil had a pH of 8.2 and 0.8 percent organic matter. The field was planted to wheat for the previous two years and before that to alfalfa. Treflan at 1lb ai/acre was broadcast and incorporated on April 22. The field was marked using a tractor, and a solid-set sprinkler system was installed prior to planting. Hybrid poplar sticks, cultivar OP-367, were planted on April 25, 1997 on a 14-ft by 14-ft spacing. The sprinkler system applied 1.4 in on the first irrigation immediately after planting. Thereafter the field was irrigated twice weekly at 0.6 in per irrigation until May 26. A total of 6.3 in of water was applied in nine irrigations from April 25 to May 26.

On May 27 the solid-set sprinkler system was removed and the field divided into 24 plots consisting of five trees surrounded by a single row of buffer trees (total plot area: three rows wide and seven trees long). A microsprinkler system (R-5, Nelson Irrigation, Walla Walla, WA) was installed with the risers placed between trees along the tree row at 14-ft spacing. The sprinklers delivered water at the rate of 0.12 in per hour at 25 psi and a radius of 14 ft. Each plot had a pressure regulator (25 psi) and ball valve allowing independent irrigation. Water application amounts were monitored daily by water meters in each plot.

Soil water potential (SWP) was measured in each plot by two granular matrix sensors (GMS; Watermark Soil Moisture Sensors model 200SS; Irrometer Co., Riverside, CA) at 8-in depth, two GMS at 20-in depth, and two at 32-in depth. The GMS were installed along the middle row in each plot and between the riser and the third tree. The GMS were previously calibrated (Shock et al., 1998). The GMS were read at 8:00 a.m. daily starting on June 13, becoming the starting date for the irrigation treatments. The daily GMS readings were averaged for each plot and over all plots in a treatment for each depth separately.

The 6 irrigation treatments were replicated four times and consisted of three SWP thresholds (treatments 1,3, and 4) and three irrigation rates (treatments 2,5, and 6; Table 1). All plots in a treatment were irrigated when the treatment average SWP at 8-in depth reached the threshold. Plots were irrigated separately as needed to maintain the plot average SWP at 8-in depth below the threshold. Irrigation treatments were terminated on September 29.

Soil water content in the wettest and the two driest treatments (treatments 1, 5, and 6, respectively) was measured with a neutron probe. Two access tubes were installed in each plot along the middle tree row on each side of the fourth tree between the sprinklers and the tree. Soil water content readings were made twice weekly at the same depths as the GMS. The neutron probe was calibrated by taking soil samples and probe readings at 8-in, 20-in, and 32-in depth during installation of the access tubes. The soil water content was determined gravimetrically from the soil samples and regressed against the neutron probe readings, separately for each soil depth. The regression equation was then used to transform the neutron probe readings during the season into inches of water per foot of soil. Coefficients of determination (R^2) for the regression equations were 0.89, 0.88, and 0.81 at $P = 0.001$ for the 8-in, 20-in, and 32-in depths, respectively.

The field was kept weed-free by rototilling between the tree rows and by hand weeding along the tree rows. The field was rototilled twice and hand weeded five times during the season.

The trees were fertilized with 100 lb N/acre, 44 lb P/acre (100 lb P_2O_5/acre), and 10 lb Zn/acre as a mixture of urea, monoammonium phosphate, and zinc sulfate on June 27. The fertilizer was applied on the soil surface as a ring around each tree and 2.5 ft away from the trunk. Leaf tissue analyses during the season, consisting of a composite sample of the first fully developed leaf from each of the five middle trees in the middle row of all plots in the wettest treatment were used to monitor and correct nutrient deficiencies. Trees in the wettest treatment might have the most vigorous growth and the greatest nutrient leaching so they would be expected to have the highest nutrient demand.

1998. The ground between tree rows was disked on April 1, and on April 2 Goal herbicide at 2 lb ai/acre was broadcast between the tree rows. Goal at 2 lb ai/acre was also applied with a backpack sprayer to the ground along the tree rows on April 10. Weed control during the season was achieved with one spot spray with Roundup using a backpack sprayer and two hand weedings.

Leaf tissue analyses during the season, consisting of a composite sample of the first fully developed leaf from each of the five middle trees in the middle row of all plots in the wettest treatment were used to monitor and correct nutrient deficiencies.

The heights of the central five trees in the middle row in each plot were measured at the end of June, August and September in 1997. Diameter at breast height (DBH, 4.5 ft from ground) was measured at the end of August and September in 1997. Tree heights and DBH were measured at the end of May, June, July, August, and September in 1998. Because of a severe hail storm on July 4, an additional measurement of tree height was taken on July 14. Wood volumes were calculated for each of the central five trees in the middle row in each plot using an equation developed for poplars that uses tree height and DBH (Browne, 1962).

The irrigation treatment procedures were the same as in 1997. Poplar evapotranspiration (Et_c) was calculated with a modified Penman equation (Wright, 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station. Poplar evapotranspiration was calculated from May 1 to September 30.

Results and Discussion

Tree height, DBH, and wood volume on September 30, 1997 were highest for the two wettest treatments (Treatments 1 and 2, Table 1, Fig. 1). Wood volume and DBH on September 30, 1998 were highest for the two wettest treatments, but tree height was highest for the three wettest treatments. Wood volume and DBH increment in 1998 were also highest for the two wettest treatments. Tree height increment in 1998 was highest for the two wettest treatments.

Since the plots in each treatment were irrigated individually as necessary, based on SWP readings, the total water applied to each plot within a treatment was slightly different. Regression analysis gives a perspective of the response of wood volume to water applied. Wood volume at the end of September both in 1997 and 1998 showed a positive response to applied water (Fig. 2). The highest water application plus rainfall for any plot was 30 and 48 acre-inches/acre of water by the end of September in 1997 and 1998, respectively.

These results suggest that at minimum poplar trees should be irrigated at -50 kPa with 1.56 in of water applied at each irrigation (Treatment 2). This treatment resulted, on average, in 23 and 32 acre-in/acre of applied water and rainfall in 1997 and 1998, respectively. Because the plots were carefully irrigated to avoid leaching of water below the tree root zone, the applied water may be approximately equivalent to evapotranspiration.

In 1997 the SWP at 32-in depth was little influenced by irrigation management and remained relatively constant and drier than the SWP at 8-in depth (Fig. 4). In 1998 SWP at 32-in depth remained drier than or close to -50 kPa during most of the season for all except the wettest treatment (Fig. 5). For the -25 kPa treatment the soil water potential at 32-in depth remained drier than -25 kPa during the season. The soil water potential at 8-in depth oscillated at a substantially higher frequency in 1998 than in 1997, reflecting the higher rate of water use by the trees in 1998. Since treatment 2 was only irrigated whenever treatment 3 was irrigated, the SWP at 8-in depth in treatment 2 was not always maintained wetter than -50 kPa and became often drier in 1998. However, when treatment 2 was irrigated the SWP at 8-in depth became wetter than in treatment 3. This suggests that an irrigation threshold for poplars on this site of -50 kPa might be reasonable as long as about 1.56 in of water are applied.

The soil water content was higher in the third foot than in the second foot in the plots measured by neutron probe in 1997 and 1998 (Fig. 6 and 7). The soil water content in the second and third foot remained relatively constant compared to the first foot. The soil water content in the first foot was lower than in the second foot in treatments 5 and 6. In treatment 1 the soil water content was similar in the first and third foot in 1997. In 1998 the soil water content in the first foot was higher than in the third foot for treatment 1. The soil water content did not increase over time at any depth for any of the three treatments measured. These results indicated a low leaching potential for the wettest treatment, suggesting that the applied water was not much in excess of usage in the wettest treatment.

On average, 91 percent and 88 percent of tree height growth occurred by August 31 in 1997 and 1998, respectively (Figure 1). However, only 46 percent and 67 percent of the growth in wood volume occurred by August 31 in 1997 and 1998, respectively, suggesting the importance of irrigation during the month of September. The hail storm on July 4, 1998 resulted in approximately 60 percent leaf loss and reduced tree height, possibly causing a larger proportion of tree growth to occur in September. Terminal budset occurred in approximately mid to late September each year. Leaf abscission started by mid-to-late October with trees becoming completely leafless in early to mid-November.

1997 Nutrient Management. In early June, leaves showed general chlorosis symptoms typical of N deficiency, indicating the need for fertilization. A N deficiency would be expected since the field previously had two years of unfertilized wheat. The soil sample taken on April 11 showed only 45 lb/acre of available N in the top foot of soil. After the June 27 fertilization, the leaf N content was in the excessive range on July 24 and September 2 and within the sufficiency range on August 12 (Table 3). Phosphorus and zinc were in the excessive range on all sampling dates. Potassium was deficient on July 24 and then became excessive and sufficient on August 12 and September 2, respectively, suggesting the effectiveness of the July 30 foliar application of potassium carbonate (Double OK, Na-Churs Plant Food Co., Marion, OH). Iron was deficient on July 24, and August 12, but sufficient on September 2, suggesting that the July 30 foliar application of iron chelate (Sprint 330, Ciba-Geigy, Greensboro, NC) did not completely correct the deficiency and that the August 14 foliar application of iron sulfate was effective in raising leaf-iron levels. Magnesium levels fell below the sufficient range on August 12, and did not respond to the August 14 foliar application of magnesium sulfate. Boron was deficient on all sampling dates, suggesting that the August 14 foliar application of boric acid (Borosol 10, Platte Chem. Co., Fremont, NE) did not completely correct the deficiency.

1998 Nutrient Management. Leaf tissue samples taken on June 23, August 4, and August 20 showed Mg deficiency. Magnesium at 10 lb/acre was applied as magnesium sulfate on the surface of the ground around each tree on July 2. On September 16 another 10 lb Mg/acre as magnesium sulfate was injected through the sprinkler system.

References

Browne, J.E. 1962. Standard cubic-foot volume tables for the commercial tree species of British Columbia. British Columbia Forest Service, Forest Surveys and Inventory Division, Victoria, B.C.

Larcher, W. 1969. The effect of environmental and physiological variables on the carbon dioxide exchange of trees. Photosynthetica 3:167-198.

Zelawski, W. 1973. Gas exchange and water relations. p. 149-165 In S. Bialobok, (ed.) The poplars-*Populus* L. Vol. 12. U.S. Dept. of Comm., Nat. Techn. Info. Serv., Springfield, VA.

Shock, C.C., J.M. Barnum, and M. Seddigh. 1998. Calibration of Watermark Soil Moisture Sensors for irrigation management. p. 139-146. Proceedings of the International Irrigation Show, Irrigation Association, San Diego, CA.

Wright, J.L. 1982. New evapotranspiration crop coefficients. J. Irrig. Drain. Div., ASCE 108:57-74.

Table 1. Irrigation rates and amounts for hybrid poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.

Treatment	Irrigated when soil water potential[a] reached	Irrigation rate		Total water applied		Total number of irrigations[d]	
		1997	1998	1997[b]	1998[c]		
		in per irrigation		acre-in/acre		1997	1998
1	-25 kPa	0.80	1.20	27.2	45.0	30.0	33
2	when trt 3 is irrigated	1.56	1.56	23.1	32.0	20.0	18
3	-50 kPa	1.20	1.20	18.6	28.8	18.0	21
4	-75 kPa	1.50	1.50	17.7	23.0	15.0	12
5	when trt 3 is irrigated	0.90	0.90	16.2	18.6	17.0	14
6	when trt 3 is irrigated	0.60	0.60	14.3	15.1	17.0	15
	LSD (0.05)			2.3	4.6	3.0	3

[a]at 8-in depth

[b]from June 20 to Sept. 22; included 6.3 in applied in 9 irrigations during tree establishment and 3.61 in precipitation from May through September.

[c]from May 1 to Sept. 30; included 6.97 in precipitation from May through September.

[d]average of 4 replications; included 9 irrigations applied during tree establishment in 1997.

Table 2. Average tree height, diameter at breast height (DBH), and wood volume on September 30, each year, and current annual increment in 1998, for hybrid poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.

Treatment	Irrigated when soil water potential[a] reached	Tree height		DBH		Wood volume		1998 annual increment[b]		
		1997	1998	1997	1998	1997	1998	Height	DBH	Volume
		---- ft ----		-- in --		--- ft³ /acre ---		ft	in	ft³ /acre
1	-25 kPa	9.9	20.1	0.77	3.1	2.82	79.8	10.1	2.30	77.0
2	when trt 3 is irrigated	9.7	20.3	0.74	3.0	2.50	74.4	10.6	2.20	71.9
3	-50 kPa	9.1	19.4	0.63	2.6	1.77	57.8	10.3	2.00	56.1
4	-75 kPa	8.1	16.8	0.51	2.0	1.07	31.4	8.6	1.50	30.3
5	when trt 3 is irrigated	8.5	16.6	0.55	2.0	1.15	30.4	8.1	1.50	29.1
6	when trt 3 is irrigated	7.8	14.5	0.46	1.6	0.82	17.4	6.7	1.20	16.6
	LSD (0.05)	0.6	1.8	0.10	0.4	0.70	16.6	1.4	0.29	15.9

[a]at 0.2 m depth

[b]September 30, 1997, to September 30, 1998.

Table 3. Hybrid poplar leaf tissue analyses and nutrients applied in 1997. (Leaf tissue was a composite of the first fully developed leaf from each of 5 middle trees from all plots in the wettest treatment.) Malheur Experiment Station, Oregon State University, Ontario, OR.

Nutrient	Sufficiency range	Leaf nutrient concentrations			Nutrients applied*			
					Soil		Foliar	
		July 24	Aug. 12	Sept. 2	June 27[a]	Sept. 15[d]	July 30[b]	Aug. 14[c]
	-------------- % --------------				--------- lb/ac ----------			
N-nitrogen	2.0-3.2	5.72	2.25	3.39	100			
P-phosphorus	0.22-0.45	0.61	0.67	0.55	44			
K-potassium	1.7-3.0	1.46	4.05	2.76			2	
S-sulfur	0.22-0.40	0.22	0.4	0.72				
Ca-calcium	0.60-2.40	0.92	0.92	0.97				
Mg-magnesium	0.40-0.80	0.45	0.39	0.34		10		2
Na-sodium	0.01-0.02	0.02	0.02	0.02				
	---------- ppm ----------							
Zn-zinc	25-55	69	109	81	10			
Mn-manganese	60-175	106	76	137				
Cu-copper	6-30	5	13	9				
Fe-iron	125-350	93	116	284			0.2	0.2
B-boron	30-65	27	23	19		0.2		0.1

[a]June 27: urea, $NH_4H_2PO_4$, and $ZnSO_4$ applied to ground around tree, 2.5 ft from trunk.

[b]July 30: K_2CO_3, and Fe chelate* foliar sprayed at 30 gal/ac.

[c]August 14: $MgSO_4$, $FeSO_4$, and boric acid* foliar sprayed at 30 gal/ac.

[d]Sept. 15: $MgSO_4$ applied to ground around tree, 2.5 ft from trunk. Boric acid injected in sprinkler syst.

*see appendix and text for trade names

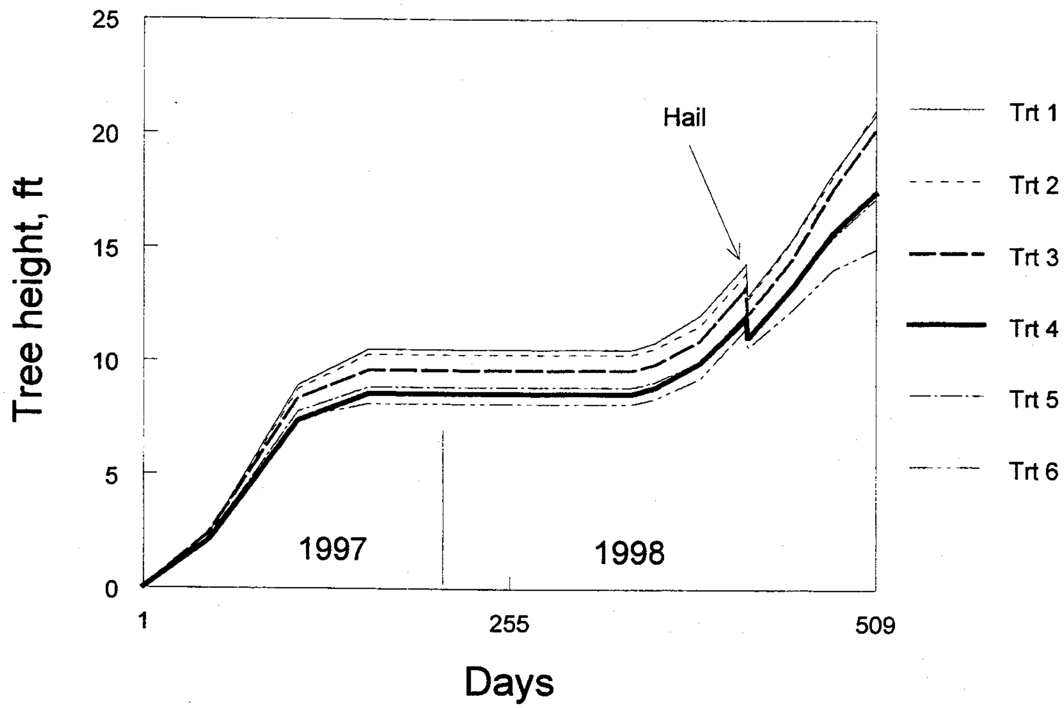

Figure 1. Tree height over time for poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR, 1997-1998.

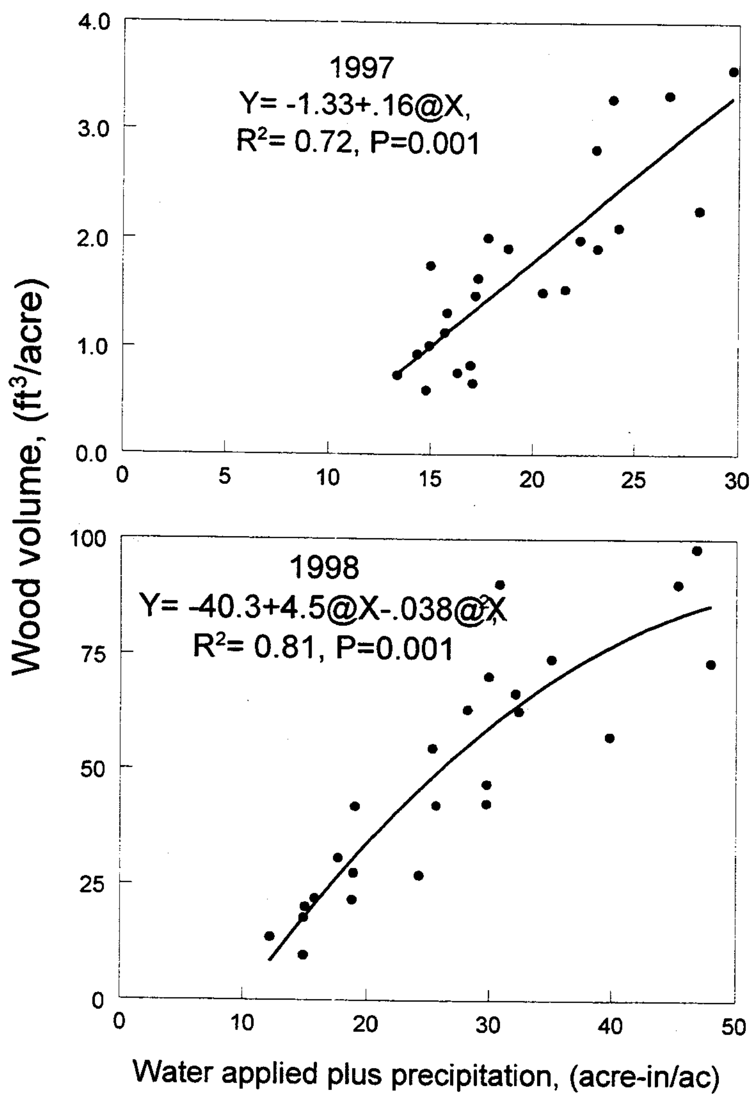

Figure 2. Poplar wood volume (measured on Sept. 30 each year) response to total water applied (includes precipitation). Malheur Experiment Station, Oregon State University, Ontario, OR, 1997. Each data point is the average of 5 trees.

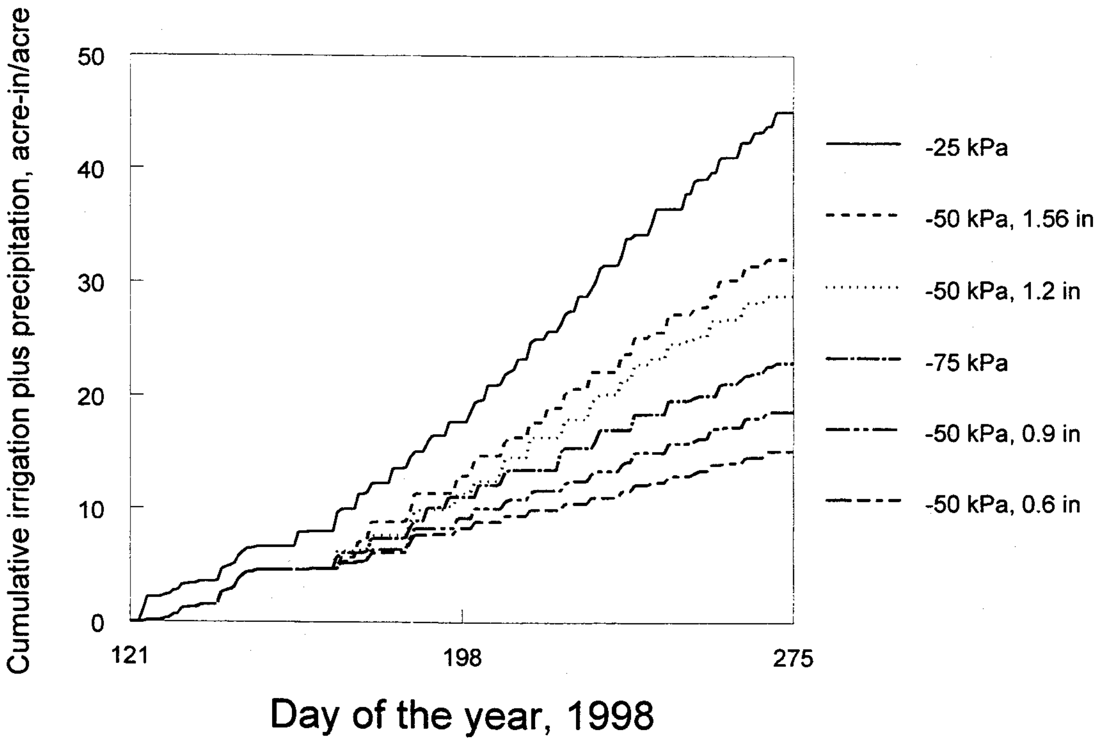

Figure 3. Cumulative water applied (including precipitation) for poplars submitted to six irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.

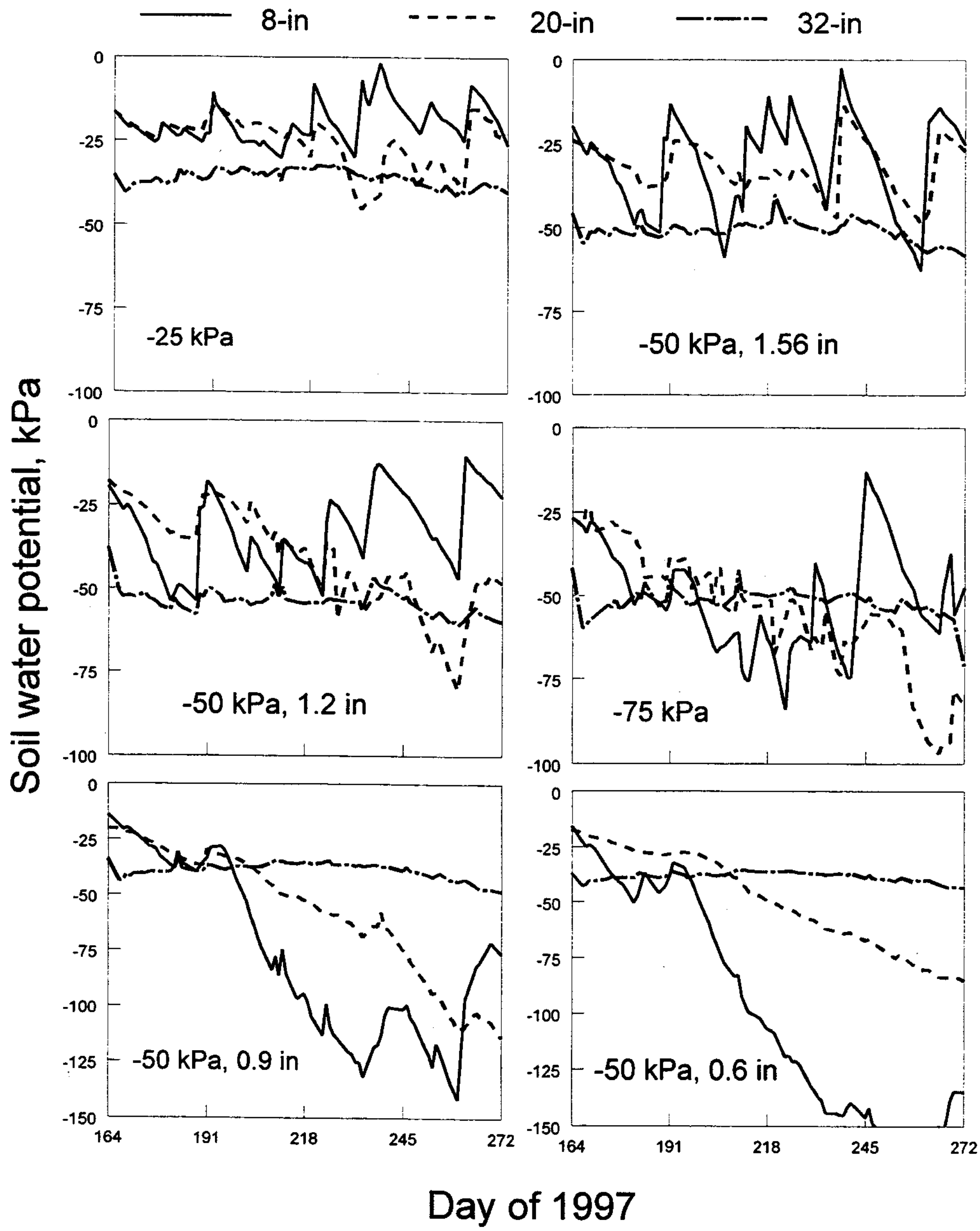

Figure 4. Soil water potential at 3 depths using granular matrix sensors in a poplar stand submitted to 6 irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 1997.

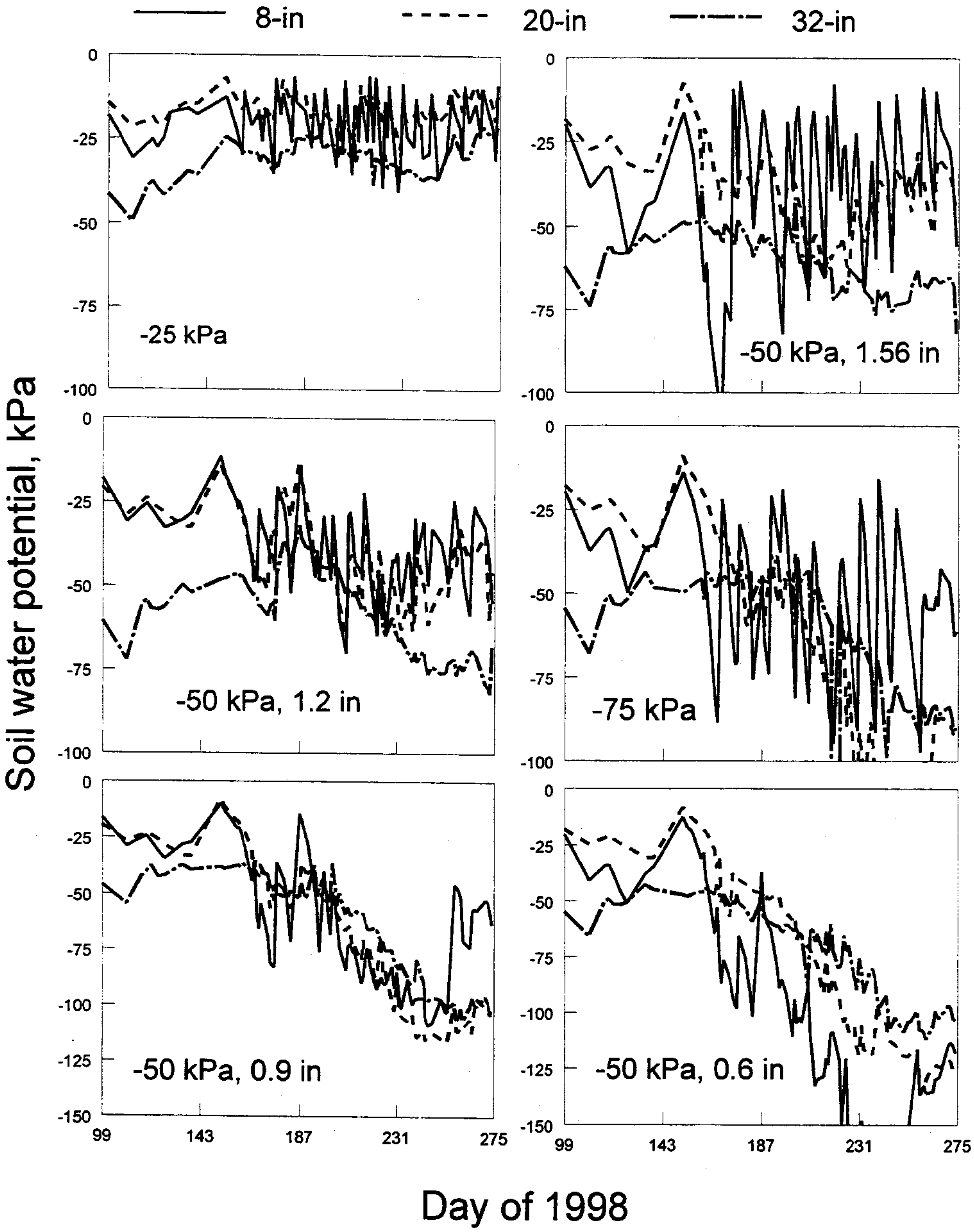

Figure 5. Soil water potential using granular matrix sensors at 3 depths in a poplar stand submitted to 6 irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.

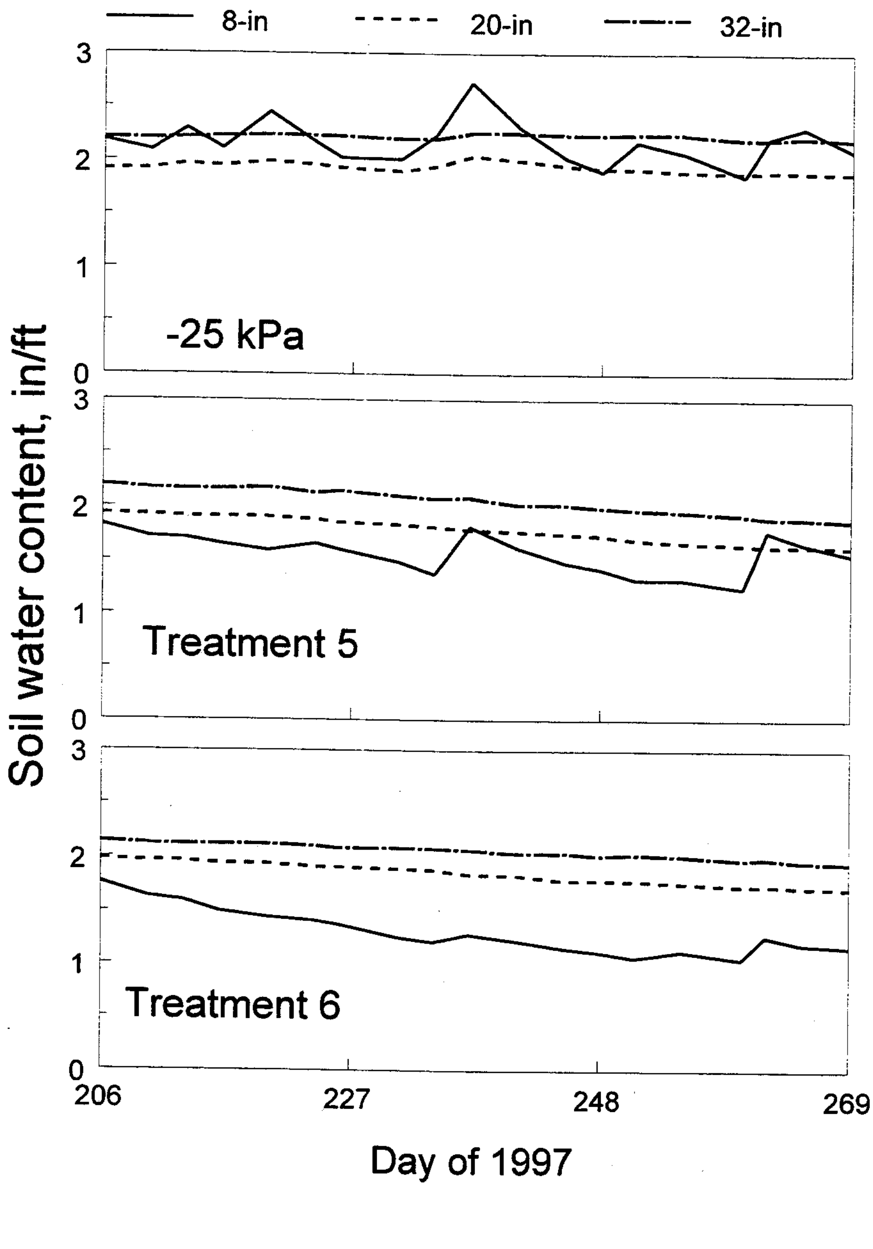

Figure 6. Soil water content based on neutron probe data for the wettest and two driest treatments in poplar irrigation trial in 1997. Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.

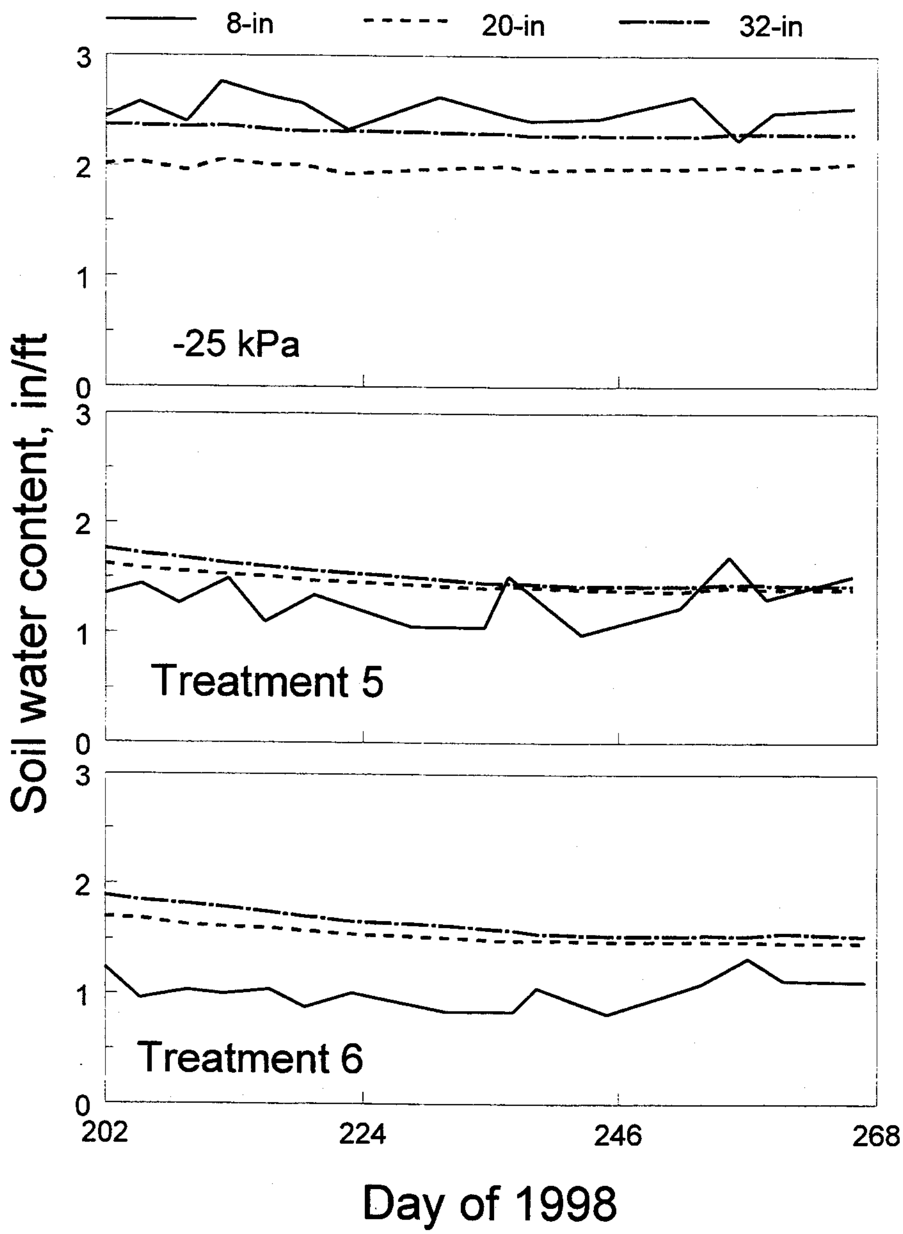

Figure 7. Soil water content based on neutron probe data for the wettest and two driest treatments in poplar irrigation trial in 1998. Malheur Experiment Station, Oregon State University, Ontario, OR, 1998.