IRRIGATION MANAGEMENT FOR HYBRID POPLAR PRODUCTION, 1997-1999

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Summary

Hybrid poplar (cultivar OP-367) was planted for saw log production 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 rate. The irrigation system consisted of microsprinklers installed along the tree row. The annual increment in wood volume showed a positive response to applied water (including precipitation) up to the highest water application of 27 acre-in in 1997, 45 acre-in in 1998, and 51 acre-in in 1999. Diameter at breast height and wood volume on September 30, 1999 were highest for the two wettest treatments. Each year, the annual increment in wood volume was also the highest for the two wettest treatments. The results suggest that, at minimum, poplar trees should be irrigated at -50 kPa with 1.56 inches of water applied at each irrigation during the first 2 years; and 2 inches applied at each irrigation in the third year. This treatment resulted, on average, in 23, 32, and 41 acre-in/acre of applied water and rainfall in 1997, 1998, and 1999, respectively.

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 2 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 irrigation rates and frequencies on poplar growth to determine optimum irrigation management practices for saw log production.

Materials and Methods

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 and is underlain by a calcium carbonate, cemented caliche hardpan. The field was planted to wheat for the 2 years before poplars, and before that to alfalfa. Treflan at 1 lb 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 was 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 0.14 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, which became 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 six irrigation treatments were replicated four times and consisted of three SWP thresholds (treatments 1,3, and 4) and four irrigation rates (treatments 2, 3, 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 30 each year.

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 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 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 and 1999. Because of a severe hail storm on July 4, 1998, an additional measurement of tree height was taken on July 14, 1998. 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).

Poplar evapotranspiration (Et_c) was estimated with a modified Penman equation (Wright, 1982) using data collected at the Malheur Experiment Station by an AgriMet weather station in 1998 and 1999. Poplar evapotranspiration was estimated from May 1 to September 30.

1997 Cultural Operations. 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.

On June 27, 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. The fertilizer was applied on the soil surface as a ring around each tree, 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. Leaf tissue samples were taken in 1997 on July 24, August 11, and September 2, then analyzed for nutrients. Based on the leaf analyses, trees were sprayed on July 30 with Fe at 0.2 lb/acre and K at 2 lb/acre; and on August 14 with Fe at 0.2 lb/acre, Mg at 2 lb/acre, and B at 0.1 lb/acre. Magnesium at 10 lb/acre as $MgSO_4$ was applied to the ground around each tree on September 15, 1997. Boron at 0.2 lb/acre was injected into the sprinkler system on September 10, 1997.

1998 Cultural Operations. The ground between tree rows was disked on April 1, and on April 2 Goal herbicide was broadcast at 2 lb ai/acre between the tree rows. Goal also was applied at 2 lb ai/acre 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 of Roundup using a backpack sprayer, and two hand weedings. Leaf tissue samples were taken on June 23, August 4, and August 20. Based on the leaf analyses, trees were fertilized with magnesium sulfate at 10 lb Mg/acre on July 2. On September 16, 1998 another 10 lb Mg/acre as magnesium sulfate was injected through the sprinkler system.

1999 Cultural Operations. The branches on the bottom third of the tree trunk were pruned in February. The ground between tree rows was disked on April 20, and on April 26 Scepter herbicide at 1 oz ai/acre was broadcast with 0.6 in of water applied for incorporation. Three hand weedings were necessary to keep the ground weed free during the season. Sprouts emerging at the pruning cuts were pulled off by hand three times during the season. On May 19, the trees received 50 lb N/acre as Uran injected through the sprinkler system. On May 28, the trees were fertilized with magnesium sulfate at 10 lb Mg/acre. On September 4, the field was sprayed aerially with Diazinon AG500 at 0.48 qt ai/acre for leafhopper control.

Results and Discussion

The annual increment in wood volume (the increase in a parameter from one year to the next) showed a positive response to applied water (including precipitation) up to the highest water application of 27 acre-in in 1997, 45 acre-in in 1998, and 51 acre-in in 1999 (Figure 1).

The analysis of the irrigation treatments shows that DBH and wood volume on September 30, 1999 were highest for the two wettest treatments (Treatments 1 and 2, Tables 1 and 2). Tree height on September 30, 1999 was less sensitive to irrigation and was reduced only by the driest treatment. Each year, the annual increment in wood volume was also the highest for the two wettest treatments (Table 3). Each year, the annual increment in wood volume was reduced significantly when irrigating at -50 kPa with an irrigation rate of 1.56 inches per irrigation (Treatment 3) compared to the wettest treatment. Treatment 2, which was irrigated when treatment 3 was irrigated and applying 2 inches at each irrigation was as productive as treatment 1 which was irrigated at -25 kPa; the annual growth in wood volume was comparable each year. The annual tree height increment became less sensitive to irrigation treatment as the trees aged. In 1997, tree height was highest for the two wettest treatments. In 1998, tree height increment was reduced by irrigating at -75 kPa. In 1999 tree height increment was not sensitive to irrigation treatment. In 1997 and 1998, DBH increment was the highest for the two wettest treatments. In 1999, DBH increment was highest for the three wettest treatments.

These results suggest that irrigating when the soil water potential in the top foot of soil reaches -25 kPa instead of -50 kPa did not result in a significant wood volume increase. When irrigating at -50 kPa, approximately 1.56 inches of water should be applied at each irrigation during the first 2 years, increasing to about 2 in of water applied at each irrigation in the third year (Treatment 2). This treatment resulted, on average, in 23, 32, and 41 acre-in/acre of applied water and rainfall in 1997, 1998, and 1999, respectively (Table 1). Because the plots were irrigated carefully to avoid leaching of water below the tree root zone, and minimizing runoff, the applied water may be approximately equivalent to evapotranspiration. Treatment 2 required an average irrigation frequency of once a week with a total of 20 irrigations each year. Irrigating at -25 kPa (Treatment 1) required an average irrigation frequency of every 4 to 5 days and a total of 34 irrigations each year.

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 (Figure 2). In 1998 and 1999, SWP at 32-in depth remained drier than or close to -50 kPa during most of the season for all except the wettest treatment (Figures 3 and 4). 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. Each year, the soil water potential at 20-in depth remained the same or slightly drier than at 8-in depth for all but the two driest treatments.

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 (Figures 5, 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 the wettest treatment (Treatment 1), the soil water potential in the second foot remained drier than in the first foot each year. 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.

Conclusions

Growth of poplar height and diameter was closely associated with ample irrigation. From the treatments tested here, a practical and productive treatment used soil water potential at -50 kPa as an irrigation criteria, with approximately 1.56 inches of water applied at each irrigation during the first 2 years, and 2 in of water applied at each irrigation in the third year.

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Table 1. Irrigation rates and amounts for hybrid poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999.

Treatment	Irrigated when soil water potential[a] reached	Irrigation rate			Total water applied			Total number of irrigations[e]		
		1997	1998	1999	1997[b]	1998[c]	1999[d]			
		in per irrigation			acre-in/acre			1997	1998	1999
1	-25 kPa	0.80	1.20	1.54	27.2	45.0	51.0	30	33	38
2	when trt 3 is irrigated	1.56	1.56	2.00	23.1	32.0	41.1	20	18	22
3	-50 kPa	1.20	1.20	1.54	18.6	28.8	34.6	18	21	26
4	-75 kPa	1.50	1.50	1.54	17.7	23.0	24.1	15	12	18
5	when trt 3 is irrigated	0.90	0.90	1.15	16.2	18.6	18.5	17	14	21
6	when trt 3 is irrigated	0.60	0.60	0.77	14.3	15.1	13.2	17	15	21
LSD (0.05)					2.3	4.6	4.1	3	3	2

[a]Soil water potential at 8-in depth

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

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

[d]From April 27 to September 30; included 1.41 inches precipitation from April 27 through September.

[e]Average of four replications; included nine 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 for hybrid poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999.

Treatment	Irrigated when soil water potential[a] reached	Tree height			DBH			Wood volume		
		1997	1998	1999	1997	1998	1999	1997	1998	1999
		----- ft -----			----- in -----			----- ft^3 /acre -----		
1	-25 kPa	9.9a	20.1a	26.2a	0.77a	3.1a	4.9a	2.82a	79.8a	255.6a
2	when trt 3 is irrigated	9.7a	20.3a	26.5a	0.74a	3.0a	4.8a	2.50a	74.4a	247.6a
3	-50 kPa	9.1b	19.4a	25.4a	0.63b	2.6b	4.3b	1.77b	57.8b	197.5b
4	-75 kPa	8.1c	16.8b	22.7a	0.51c	2.0c	3.5c	1.07c	31.4c	118.2c
5	when trt 3 is irrigated	8.5c	16.6b	22.9a	0.55b	2.0c	3.4c	1.15b	30.4c	120.3c
6	when trt 3 is irrigated	7.8d	14.5c	20.1b	0.46c	1.6d	2.8d	0.82c	17.4c	72.0d
LSD (0.05)		0.6	1.8	4.2	0.10	0.4	0.4	0.70	16.6	45.8

[a]Soil water potential at 8-inch depth

Numbers followed by different letters are significantly different at the 95 % level of confidence by the Duncan's multiple-range test.

Table 3. Annual growth increment for hybrid poplars submitted to six irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999.

Treatment	Irrigated when soil water potential[a] reached	Annual increment[b]					
		1998			1999		
		Height	DBH	Volume	Height	DBH	Volume
1	-25 kPa	10.10a	2.3a	77.0a	6.1	1.79a	176.0a
2	when trt 3 is irrigated	10.60a	2.2a	71.9ab	6.5	1.84a	174.5ab
3	-50 kPa	10.30a	2.0b	56.1b	5.9	1.70a	139.3b
4	-75 kPa	8.60b	1.5c	30.3c	6.0	1.48b	87.4c
5	when trt 3 is irrigated	8.10b	1.5c	29.1c	6.1	1.38b	88.6c
6	when trt 3 is irrigated	6.70c	1.2d	16.6c	5.5	1.14c	54.2c
LSD (0.05)		1.40	0.3	15.9	NS	0.18	36.0

[a]Soil water potential at 8-inch depth

[b]From September 30 the previous year to September 30 the current year.

Numbers followed by different letters are significantly different at the 95 % level of confidence by the Duncan's multiple-range test.

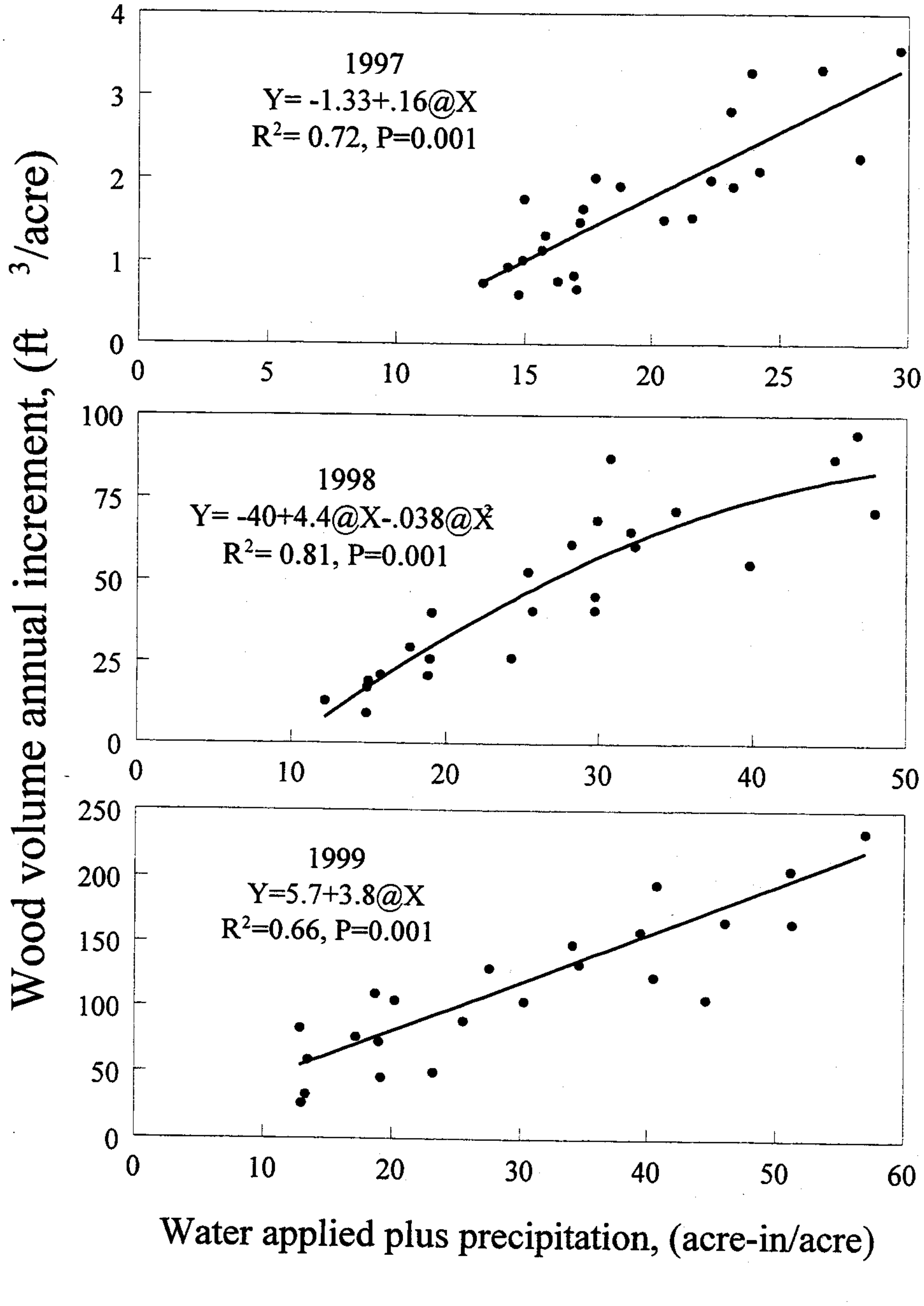

Figure 1. Poplar annual growth increment (measured from September 30 the previous year to September 30 the current year) response to total water applied (includes precipitation). Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999. Each data point is the average of 5 trees.

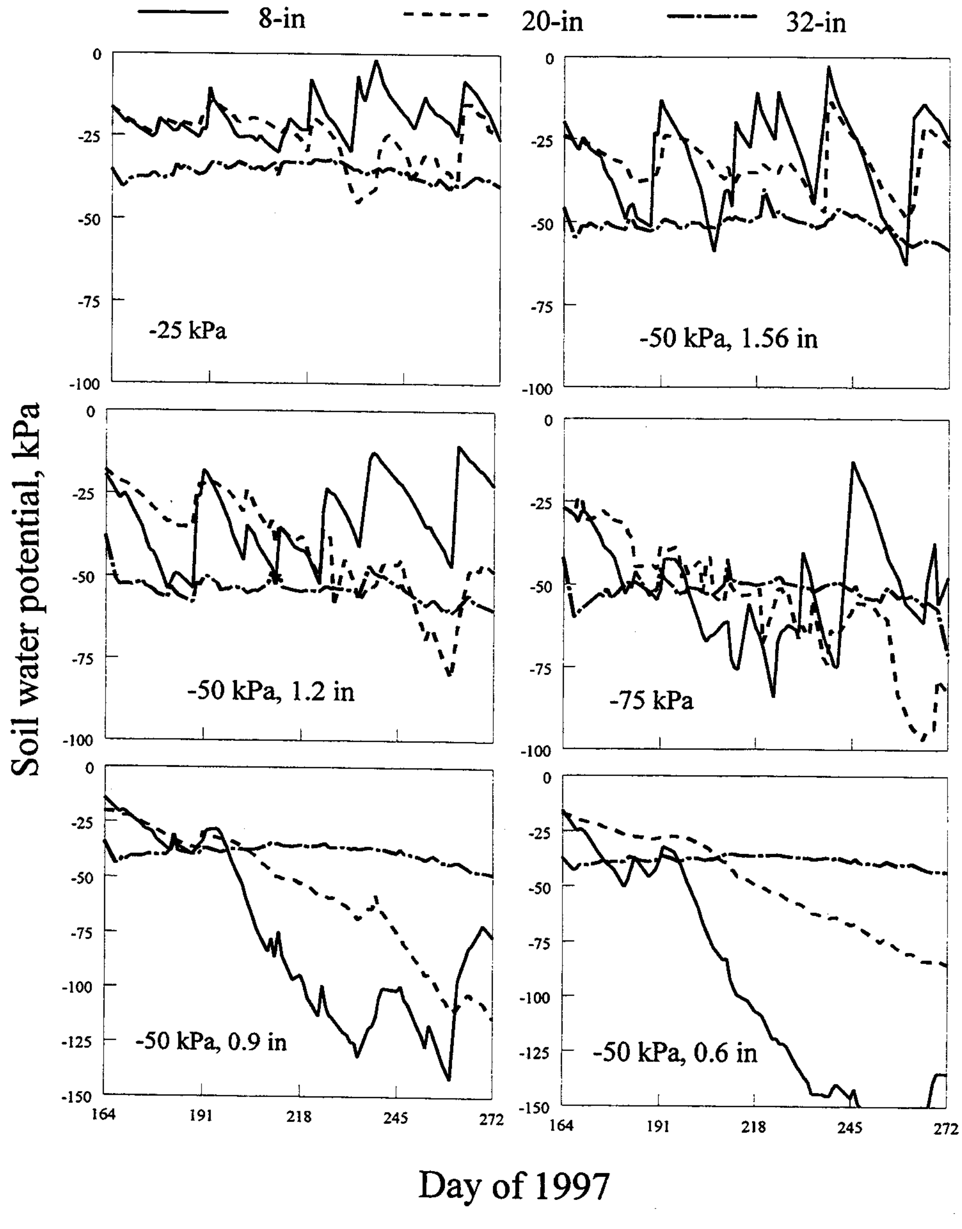

Figure 2. Soil water potential at three depths using granular matrix sensors in a poplar stand submitted to six irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1997.

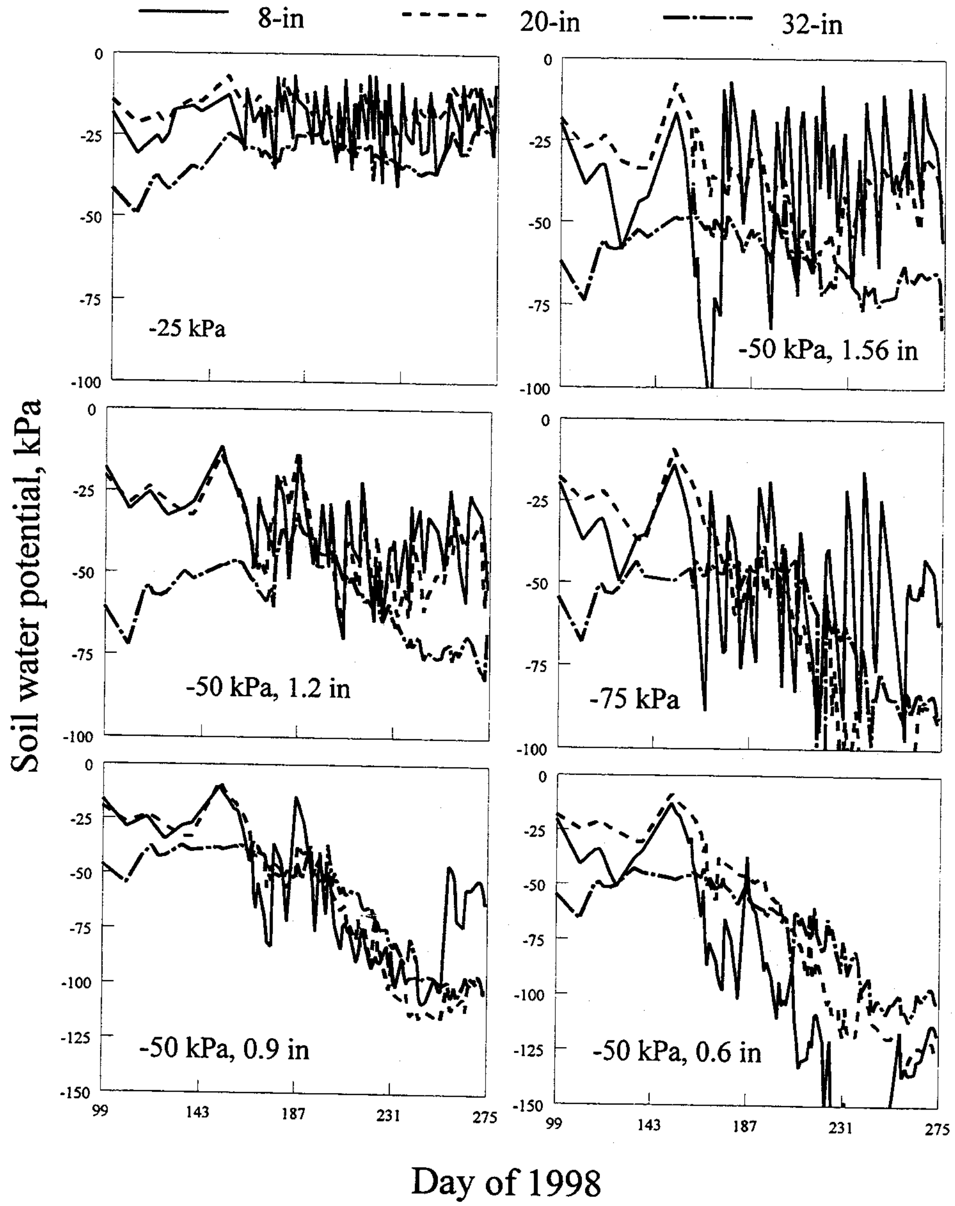

Figure 3. Soil water potential at three depths using granular matrix sensors in a poplar stand submitted to six irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1998.

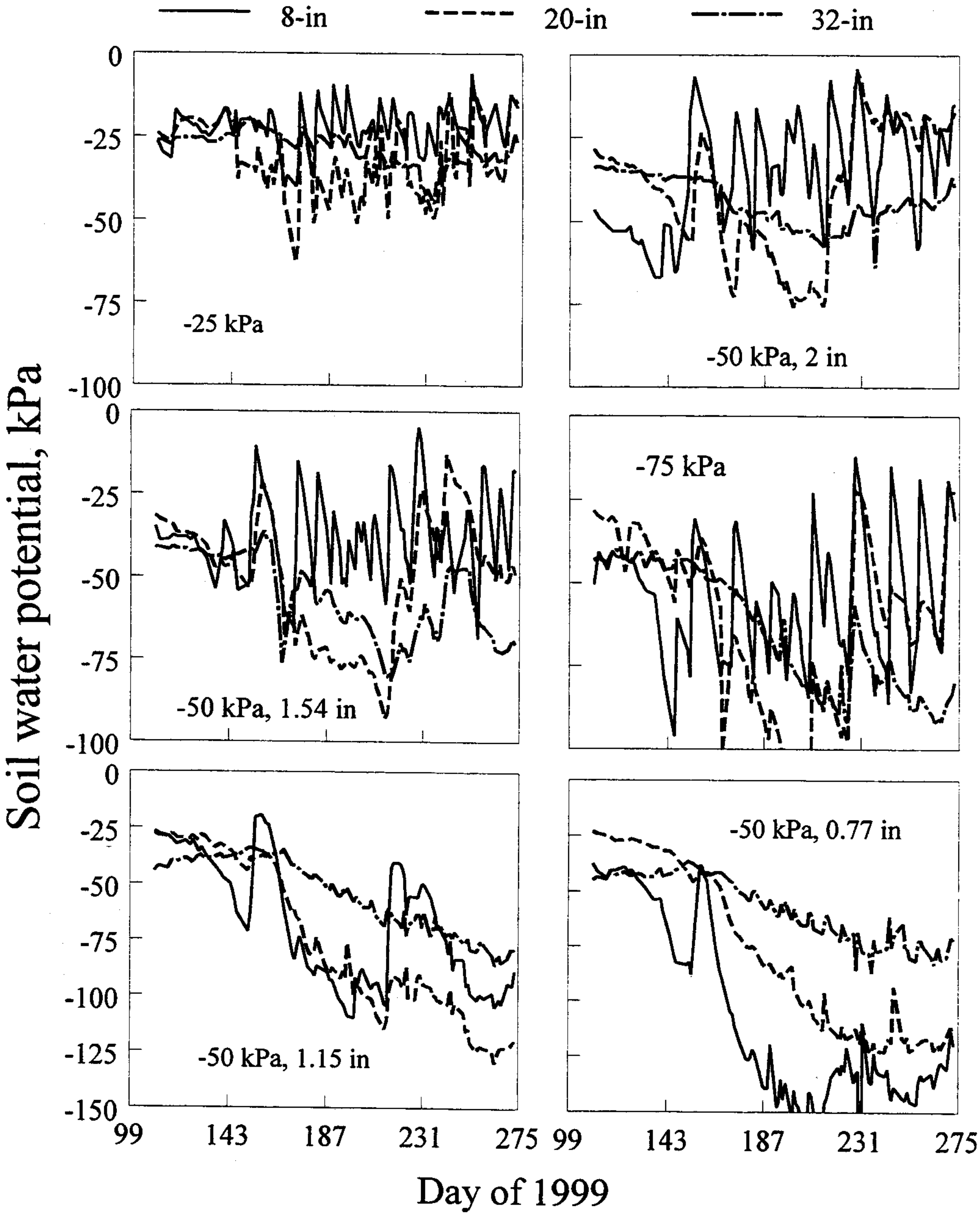

Figure 4. Soil water potential at three depths using granular matrix sensors in a poplar stand submitted to six irrigation treatments. Malheur Experiment Station, Oregon State University, Ontario, Oregon, 1999.

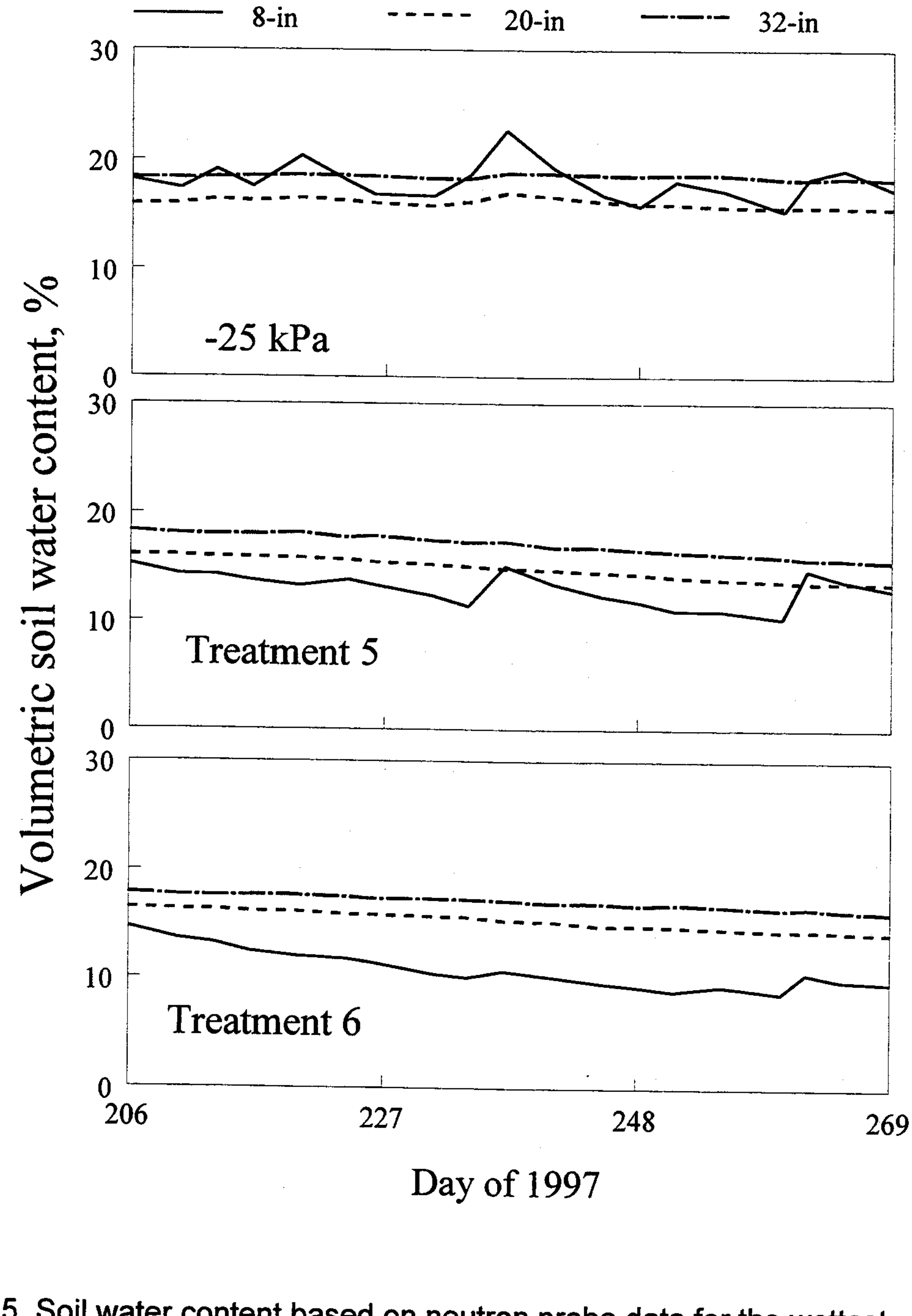

Figure 5. Soil water content based on neutron probe data for the wettest and two driest treatments in poplar irrigation trial in 1997. Malheur Experiment Station, Oregon State University, Ontario, Oregon.

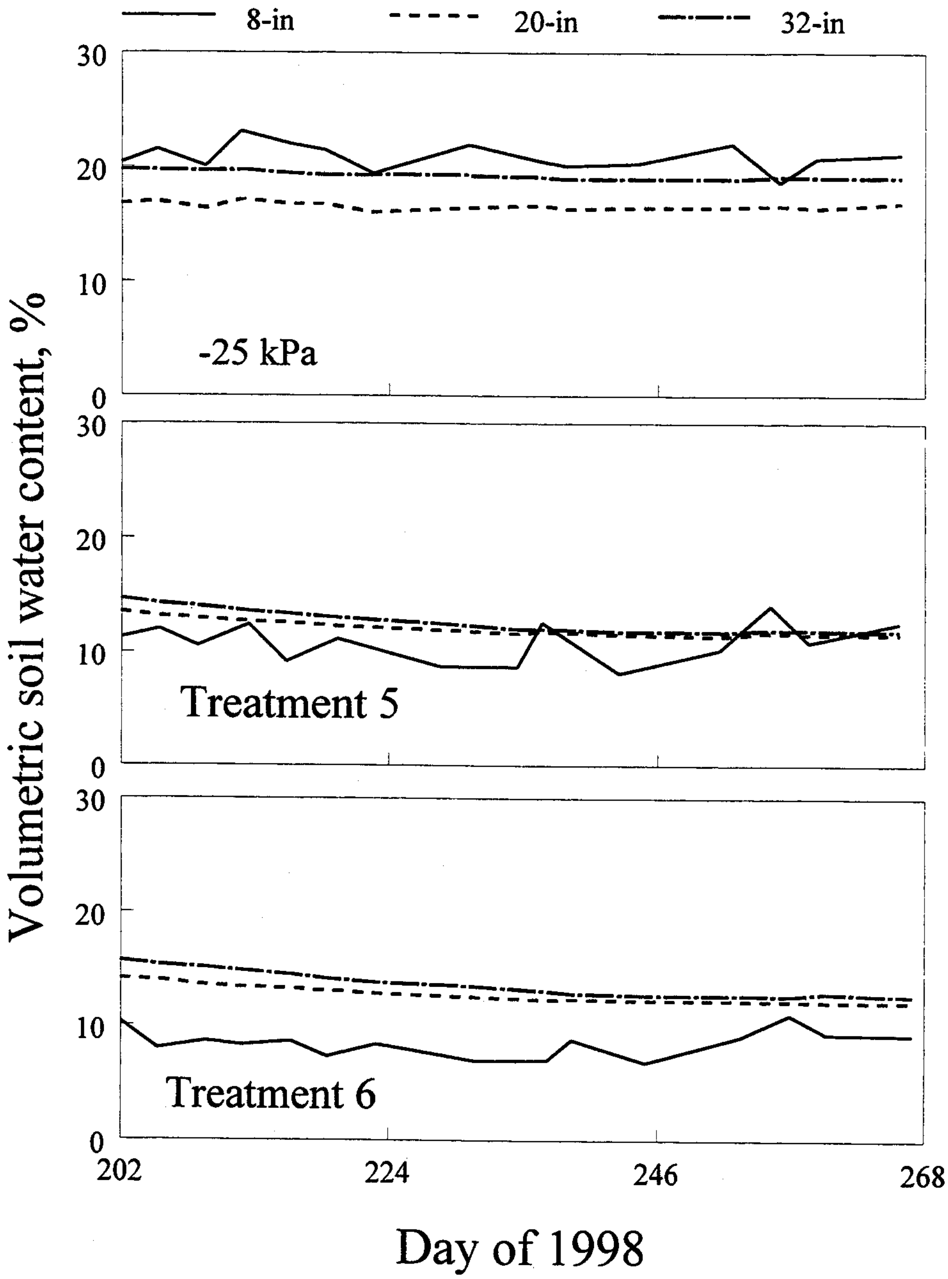

Figure 6. Soil water content based on neutron probe data for the wettest and two driest treatments in poplar irrigation trial in 1998. Malheur Experiment Station, Oregon State University, Ontario, Oregon.

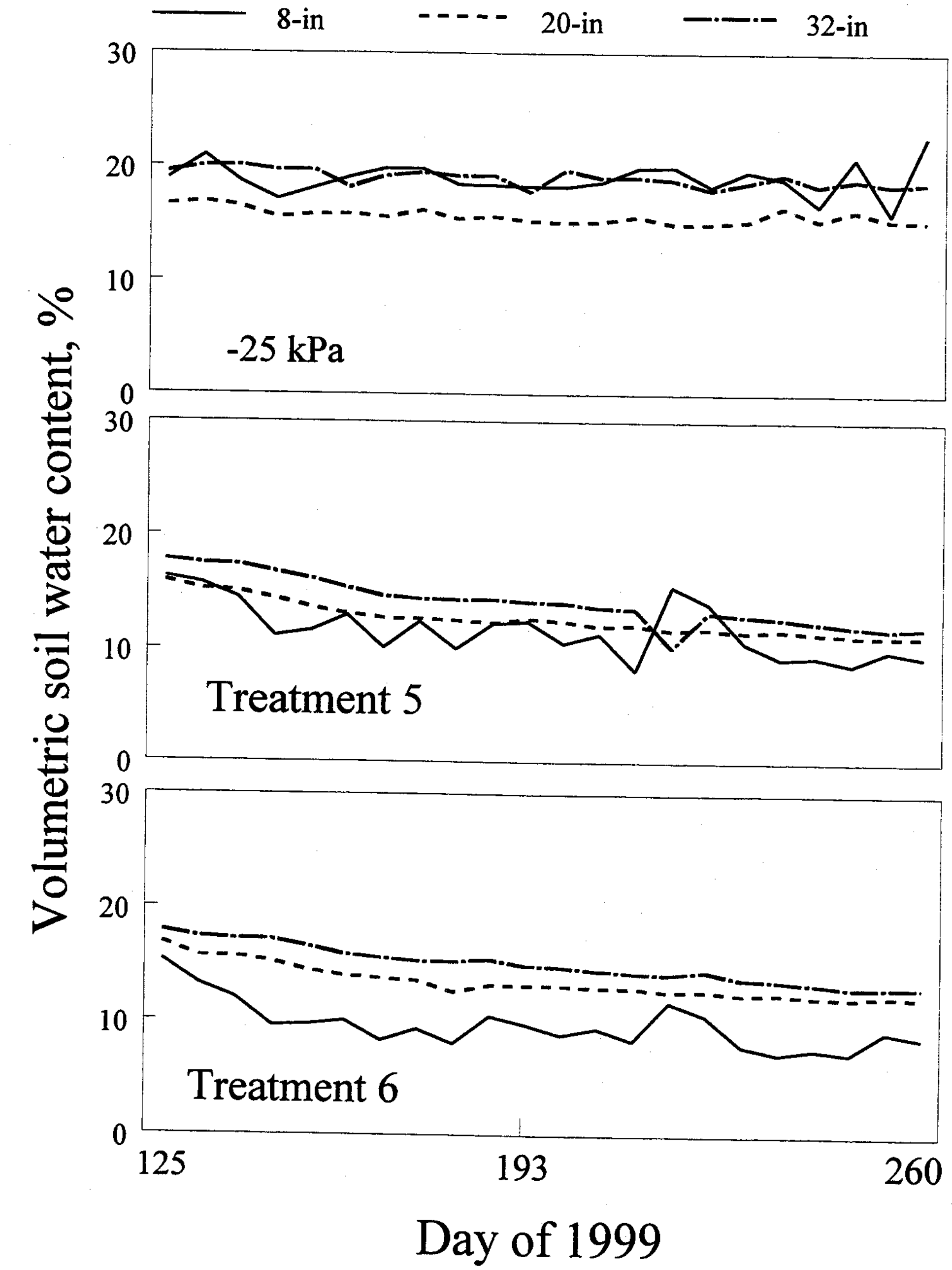

Figure 7. Soil water content based on neutron probe data for the wettest and two driest treatments in poplar irrigation trial in 1999. Malheur Experiment Station, Oregon State University, Ontario, Oregon.