MICRO-IRRIGATION ALTERNATIVES FOR HYBRID POPLAR PRODUCTION, 2006 TRIAL

Clinton C. Shock, Erik B. G. Feibert, and Lamont D. Saunders
Malheur Experiment Station
Oregon State University
Ontario, OR

Summary

Hybrid poplar (cultivar OP-367) was planted for saw log production in April 1997 at the Malheur Experiment Station. Five irrigation treatments were established in 2000 and were continued through 2006. Irrigation treatments consisted of three water application rates using microsprinklers and two water application rates using drip tape. Irrigation scheduling was by soil water tension at 8-inch depth with a threshold for initiating irrigations of 50 kPa in 2000 through 2002 and 25 kPa in 2003 through 2006. Increasing the water application rate increased the annual growth in stem volume for the microsprinkler-irrigated treatments. There was no significant difference between the microsprinkler treatment irrigated at the highest rate and the drip-irrigated treatments in terms of height, DBH, or stem volume growth in 2000 and 2001. In 2002 and 2003, drip irrigation with two tapes per tree row resulted in greater tree growth than microsprinkler irrigation. In 2004, the microsprinkler and the drip-irrigated treatments irrigated at the highest rate had among the greatest stem volume growth. In 2005 and 2006, drip irrigation with two tapes per tree row resulted in the greatest stem volume growth.

Introduction

With timber supplies from Pacific Northwest public lands becoming less available, sawmills and timber product companies are searching for alternatives. Hybrid poplar wood has proven to have desirable characteristics for many nonstructural timber products. Growers in Malheur County, Oregon have made experimental plantings of hybrid poplars for saw logs and peeler logs. Clone trials in Malheur County during 1996 demonstrated that the clone OP-367 (hybrid of *Populus deltoides* x *P. nigra*) grew well on alkaline soils. Over the last 10 years OP-367 has continued to grow well on alkaline soils. Some other clones have higher productivity on soils with nearly neutral pH.

Hybrid poplars are known to have high growth rates (Larcher 1969) and water transpiration rates (Zelawski 1973), suggesting that irrigation management is a critical cultural practice. Research at the Malheur Experiment Station during 1997-1999 determined optimum microsprinkler irrigation criteria and water application rates for the first 3 years (Shock et al. 2002). These results showed that tree growth was maximized by irrigating at a soil water tension of 25 kPa, but 38 irrigations were required for 3-year-old trees, and more were anticipated for larger trees. Based on simplicity of operations, we decided to use an irrigation criterion of 50 kPa for the wettest treatments starting in 1998. In 2000 we noticed that the rate of increase in annual tree growth started to decline in the wettest treatment. One of the causes probably was the use of an irrigation criterion of 50 kPa. Starting in 2003 the irrigation criterion was changed to 25 kPa for the wettest treatment. The objectives of this study were to evaluate poplar water requirements and to compare microsprinkler irrigation to drip irrigation.

Materials and Methods

Establishment

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 8.1 and 0.8 percent organic matter. The field had been planted to wheat for the 2 years prior to poplar and to alfalfa before wheat. In the spring of 1997 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 inches on the first irrigation immediately after planting. Thereafter the field was irrigated twice weekly at 0.6 inches per irrigation until May 26. A total of 6.3 inches of water was applied in 9 irrigations from April 25 to May 26, 1997.

In late May 1997, 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 0.14 inches/hour at 25 psi with a radius of 14 ft. The poplar field was used for irrigation management research (Shock et al. 2002a) and groundcover research (Shock et al. 2002b) from 1997 through 1999.

Procedures common to all treatments

In March 2000 the field was divided into 20 plots, each of which was 6 tree rows wide and 7 trees long. The plots were allocated to one of five treatments arranged in a randomized complete block design and replicated four times. The microsprinkler-irrigation treatments used the existing irrigation system. For the drip-irrigation treatments, either one or two drip tapes were laid along the tree row in early May 2000 (Nelson Pathfinder, Nelson Irrigation, Walla Walla, WA). The plots with 2 drip tapes per tree row had the drip tapes spread 2 ft apart, centered on the tree row. The drip tape had emitters spaced 12 inches apart and a flow rate of 0.22 gal/min/100 ft at 8 psi. Each plot had a pressure regulator (set to 25 psi for the microsprinkler plots and 8 psi for the drip plots) and ball valve allowing independent irrigation. Water application amounts were recorded daily from the water meters in each plot.

Soil water tension (SWT) was measured in each plot by 6 granular matrix sensors (GMS; Watermark Soil Moisture Sensors model 200SS; Irrometer Co. Inc., Riverside, CA); 2 at 8-inch depth, 2 at 20-inch depth, and 2 at 32-inch 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) and were read at 8:00 a.m. daily starting on May 2 with a 30 KTCD-NL meter (Irrometer Co. Inc., Riverside, CA).

The daily GMS readings were averaged separately at each depth within each plot and over all plots in a treatment. Irrigation treatments were started on May 2.
The five irrigation treatments consisted of three water application rates for the microsprinkler-irrigated plots and two water application rates for the drip-irrigated plots. From 2000 through 2002, all plots in the 3 microsprinkler-irrigated treatments were irrigated whenever the SWT at 8-inch depth, averaged over all plots in treatment 1, reached 50 kPa. The plots in each drip-irrigated treatment were irrigated whenever the SWT at 8-inch depth, averaged over all plots in the respective treatment, reached 50 kPa. In 2003, the irrigation criterion was increased from 50 kPa to 25 kPa. Irrigation treatments were terminated on September 30 each year.

The heights and diameter at breast height (DBH, 4.5 ft from ground) of the central three trees in the two middle rows in each plot were measured monthly from May through September. Tree heights were measured with a clinometer (model PM-5, Suunto, Espoo, Finland) and DBH was measured with a diameter tape. Stem volumes (excluding bark and including stump and top) were calculated for each of the central six trees in each plot using an equation developed for poplars that uses tree height and DBH (Browne 1962). Growth increments for height, DBH, and stem volume were calculated as the difference in the respective parameter between October of the current year and October of the previous year. Curves of current annual increment (CAI) and mean annual increment (MAI) of stem volume over the 8 years for the treatment 1 microsprinkler-irrigated trees and for the 2 drip tape configurations were used to assess the growth stage of the plantation. The MAI is the CAI divided by the tree age.

2000 Procedures

The side branches on the bottom 6 ft of the tree trunk had been pruned from all trees in February 1999. In March of 2000, another 3 ft of trunk were pruned, resulting in 9 ft of pruned trunk. The pruned branches were flailed on the ground and the ground between the tree rows was lightly disked on April 12. On April 24, Prowl® at 3.3 lb ai/acre was broadcast for weed control. The microsprinkler-irrigated plots received 0.7 inch of water to incorporate the Prowl. To control the alfalfa and weeds remaining from the previous years' groundcover trial in the top half of the field, Stinger® at 0.19 lb ai/acre was broadcast between the tree rows on May 19, and Poast® at 0.23 lb ai/acre was broadcast between the tree rows on June 1. On June 14, Stinger at 0.19 lb ai/acre and Roundup® at 3 lb ai/acre were broadcast between the tree rows on the whole field.

On May 19 the trees received 50 lb nitrogen (N)/acre as urea-ammonium nitrate solution injected through the microsprinkler system. Due to deficient levels of leaf nutrients in early July, the field had the following nutrients in pounds per acre injected in the irrigation systems: 0.4 lb boron (B), 0.6 lb copper (Cu), 0.4 lb iron (Fe), 5 lb magnesium (Mg), 0.25 lb zinc (Zn), and 3 lb phosphorus (P). The field was sprayed aerially for leafhopper control with Diazinon AG500® at 1 lb ai/ac on May 27 and with Warrior® at 0.03 lb ai/acre on July 10.

2001 Procedures

In March of 2001, another 3 ft of trunk were pruned, resulting in 12 ft of pruned trunk. The pruned branches were flailed on the ground on April 2. On April 4, Roundup at 1 lb ai/acre was broadcast for weed control. On April 10, 200 lb N/acre, 140 lb P/acre, 490 lb Sulfur (S)/acre, and 14 lb Zn/acre (urea, monoammonium phosphate, zinc sulfate, and elemental S) were broadcast. The ground between the tree rows was lightly disked on April 12. On April 13, Prowl at 3.3 lb ai/acre was broadcast for weed control. The microsprinkler-irrigated plots received 0.8 inch of water to incorporate the Prowl.

A leafhopper, the willow sharpshooter (*Graphocephala confluens,* Uhler), was monitored by three yellow sticky traps attached to the lower trunk of selected trees. Traps were checked weekly. From mid-April to early June only adults were observed in the traps. A willow sharpshooter hatch was observed on June 6, as many nymphs were noted in the traps and on the lower trunk sprouts. The field was sprayed aerially with Warrior at 0.03 lb ai/acre on June 11 for leafhopper control.

2002 Procedures

In March of 2002, another 3 ft of trunk were pruned, resulting in 15 ft of pruned trunk. The pruned branches were flailed on the ground on April 12. On April 23, 80 lb N/acre, 40 lb potassium (K)/acre, 150 lb S/acre, 20 lb Mg/acre, 6 lb Zn/acre, 1 lb Cu/acre, and 1 lb B/acre (urea, potassium/magnesium sulfate, elemental S, zinc sulfate, copper sulfate, and boric acid) were broadcast and the field was disked. On April 24, Prowl at 3.3 lb ai/acre was broadcast for weed control. The microsprinkler-irrigated plots received 0.7 inch of water to incorporate the Prowl.

The willow sharpshooter was monitored by three yellow sticky traps attached to the lower trunk of selected trees. Traps were checked weekly. The field was sprayed aerially with Warrior at 0.03 lb ai/acre on June 10 for leafhopper control.

2003 Procedures

In March of 2003, another 3 ft of trunk were pruned, resulting in 18 ft of pruned trunk. The pruned branches were flailed on the ground on March 31. On April 23, 80 lb N/acre as urea and 167 lb S/acre as elemental S were broadcast and the field was disked. On April 16, Prowl at 3.3 lb ai/acre was broadcast for weed control. The microsprinkler-irrigated plots received 0.4 inch of water to incorporate the Prowl.

Starting in 2003 the irrigation criterion was changed to 25 kPa and the water applied at each irrigation was reduced accordingly. All plots in the three microsprinkler-irrigated treatments were irrigated whenever the SWT at 8-inch depth, averaged over all plots in treatment 1, reached 25 kPa. The plots in each drip-irrigated treatment were irrigated whenever the SWT at 8-inch depth, averaged over all plots in the respective treatment, reached 25 kPa. Irrigation treatments were terminated on September 30.

The drip tape needed to be replaced because iron sulfide plugged the emitters. The drip tape was replaced with another brand (T-tape, T-systems International, San Diego, CA) in mid-April because Nelson Irrigation discontinued production of drip tape. The drip tape specifications were the same.

The willow sharpshooter was monitored by three yellow sticky traps attached to the lower trunk of selected trees. Traps were checked weekly. The field was sprayed aerially with Warrior at 0.03 lb ai/acre on June 5 for leafhopper control.

2004 Procedures
On March 31, 2004, N at 80 lb/acre, S at 250 lb/acre, P at 50 lb/acre, K at 50 lb/acre, Cu at 1 lb/acre, Zn at 4 lb/acre, and B at 1 lb/acre were broadcast. The field was lightly disked on April 1. On April 13, Prowl at 3.3 lb ai/acre was broadcast for weed control. The microsprinkler-irrigated plots received 0.4 inch of water to incorporate the Prowl. On June 12 the field was sprayed with Warrior at 0.03 lb ai/acre for leafhopper control. A leaf tissue sample taken on July 7 showed a P deficiency. On July 9, P at 10 lb/acre as phosphoric acid was injected through the sprinkler and drip systems.

2005 Procedures
A soil sample taken on April 4, 2005 showed the need for N at 50 lb/acre, and S at 400 lb/acre, which were broadcast on April 7. On April 8, Prowl at 3.3 lb ai/acre was broadcast for weed control. On June 22, the field was fertilized with N at 50 lb/acre as urea ammonium nitrate solution injected through the drip and sprinkler systems. On June 24 the field was sprayed with Warrior at 0.03 lb ai/acre for leafhopper control.

2006 Procedures
A soil sample taken on October 21, 2005 showed the need for P at 50 lb/acre, S at 400 lb/acre, and Cu at 1 lb/acre, which were broadcast on October 25, 2005. On April 14, 2006, Prowl at 3.3 lb ai/acre was broadcast for weed control. Due to bird damage the drip tape was replaced with drip tubing in May. The drip tubing (Triton X, Netafim, Fresno, CA) had emitters spaced 2 feet apart with 0.2 gal/hour flow rate. On June 12 the field was sprayed with Warrior at 0.03 lb ai/acre for leafhopper control. On June 16, Fe at 1 lb/acre was broadcast aerially. Leaf analyses on July 26 showed the need for N and P in trees in the drip plots. A total of 50 lb N/acre, 20 lb P/acre, and 8.7 lb of Fe were applied to the drip plots in 2006 (Table 1). A total of 50 lb N/acre, 10 lb P/acre, and 5.2 lb Fe/acre were applied to the microsprinkler plots in 2006.

Results and Discussion

The increase in irrigation intensity in 2006 for the microsprinkler-irrigated plots resulted in an increase in the total amount of water applied compared to previous years. For the microsprinkler-irrigated treatment receiving 2 inches of water/irrigation and for the 2 drip tubing treatments the total amount of water applied was higher than estimated evapotraspiration (ET_c) (49.3 inches) for the season (Table 2). In 2006, the two drip tube treatments had the highest stem volume growth increment followed by the one drip tube treatment and the microsprinkler treatment irrigated with 2 inches of water per irrigation (Table 3). The highest 2000-2006 stem volume growth increment was achieved with the two drip tubing treatment. In the fall of 2006 (tenth year), the highest wood volume per acre was for the 2 drip tubing treatment, with the 2-inch microsprinkler treatment and the 1 drip tubing treatment having among the highest wood volume of the other treatments. In the fall of 2006, the 2 drip tubing and 2-inch microsprinkler treatments had among the highest DBH.

Although tree growth increased with increasing applied water up to the highest amount tested, tree growth may not have been maximized in this study (Fig. 1). There were similar linear relationships, with similar slopes, between total water applied and stem volume growth from 2000 to 2006 for the drip and microsprinkler systems (Fig. 1). The greater stem volume growth for the drip system reflected the higher water use efficiency of the drip system.

The soil water tension at 8-inch depth was maintained below the criterion of 25 kPa, except for brief periods during the season for microsprinkler irrigation with 2 inches of water applied and for drip irrigation (Fig. 2). The soil water tension at 8-inch depth was increased, as expected, with the reductions in the water application rate in the sprinkler treatments (Fig. 2, Table 4).

The rate of increase in annual stem volume growth increased (growth approximately doubled every year) up to 2001, when the stem volume growth for the microsprinkler-irrigated trees started to decline (Table 5, Fig. 3). In 2002 the stem volume growth for the drip-irrigated trees started to decline. The decline in annual growth was not expected until later, when the trees approach harvest size. The reduction of the soil water tension for irrigation scheduling from 25 to 50 kPa in 2000 might be associated with the decline in annual stem volume growth. Tree growth was substantially greater in 2003 and was approximately double the growth in 2002; this could have been due to the change to a wetter irrigation threshold from 50 to 25 kPa.

Starting in 2004, and through 2006, the trees in the microsprinkler-irrigated plots started exhibiting leaf chlorosis around the middle of July, whereas the trees in the drip-irrigated plots did not exhibit leaf chlorosis. Foliar analysis has not revealed a clear cause-and-effect relationship.

The soil Na concentration increased over the years through the fall of 2005 and decreased in the spring of 2006, but remained above the recommended maximum level in the microsprinkler and drip plots (Table 6). The increase in Na concentration over the years could be due to the high Na in the well water used for irrigation (200 ppm). The recommended maximum Na level in irrigation water is 69 ppm.

In 2005, leaf analyses showed that the microsprinkler trees had excesses of S, Ca, Mg, and B. In 2005, leaf analyses showed that the drip trees had excesses of S, Ca, Mg, Fe, and B. In 2006, the leaf analyses showed that the microsprinkler trees had excesses of N, P, K, S, Ca, Mg, Zn, Mn, Cu, and Fe. In 2006, leaf analyses showed that the drip trees had excesses of S, Ca, Mg, Mn, Cu, Fe, and B. Both Na and B in excess in the soil or irrigation water can cause leaf chlorosis. The normal leaf B concentrations in the microsprinkler trees and the excessive leaf B concentrations in the drip trees in 2006 suggest that the leaf chlorosis in the microsprinkler poplar is not related to B.

The CAI decreased for both the drip and microsprinkler trees compared to 2005 (Fig. 3). The MAI continued to increase over time. Typically, both the CAI and MAI initially increase, reach a maximum, and then decline. The CAI peaks before the MAI. The intersection of the two curves is termed the economic rotation and is used in some poplar plantations to determine the harvest timing. The two curves intersected in 2006 for the microsprinkler trees, but not for the drip trees. The lower CAI for the microsprinkler trees could be related to undetermined nutritional problems discussed above.

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.

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

Shock, C.C., E.B.G. Feibert, M. Seddigh, and L.D. Saunders. 2002a. Water requirements and growth of irrigated hybrid poplar in a semi-arid environment in eastern Oregon. Western Journal of Applied Forestry 17:46-53.

Shock, C.C., E.B.G. Feibert, M. Seddigh, and L.D. Saunders. 2002b. Initial growth of irrigated hybrid poplar decreased by ground covers. Western Journal of Applied Forestry 17:61-65.

Zelawski, W. 1973. Gas exchange and water relations. Pages 149-165 *in* S. Bialobok (ed.) The poplars-*Populus* L. Vol. 12. U.S. Dept. of Commerce National Technical Information Service, Springfield, VA.

Table 1. Nutrients applied through the drip- and microsprinkler-irrigation systems in 2006. Malheur Experiment Station, Oregon State University, Ontario, OR.

Date	Nutrient	Quantity
Sprinkler		lb/acre
June 26	Fe	1.3
July 5	Fe	1.3
July 12	Fe	1.3
August 10	Fe	1.3
July 31	N	20
July 31	P	10
August 28	N	30
Drip		
June 28	Fe	2.9
July 5	Fe	2.9
July 12	Fe	2.9
July 31	N	20
July 31	P	10
August 16	N	30
August 22	P	10

Table 2. Irrigation rates, amounts, and water use efficiency for hybrid poplar submitted to five irrigation regimes in 2006, Malheur Experiment Station, Oregon State University, Ontario, OR.

Treatment	Irrigation threshold	Water application	Irrigation system	Total number of irrigations	Total water applied[a]	Water use efficiency
	kPa[b]	inch			acre-inch/ acre	ft^3 of wood/acre-inch of water
1	25	2	Microsprinkler	42	89.1	3.4
2	coincide with trt #1	1.54	Microsprinkler	42	45.0	5.1
3	coincide with trt #1	0.77	Microsprinkler	42	30.9	7.6
4	25	1	Drip, 2 tapes	38	74.3	8.4
5	25	0.5	Drip, 1 tape	40	55.7	8.5
LSD (0.05)				1	29.4	NS

[a]Includes 2.18 inches of precipitation from mid-April through September.

[b]Soil water tension at 8-inch depth.

Table 3. Height, diameter at breast height (DBH), and stem volume in early November 2006, and 2006 growth in height, DBH, and stem volume for hybrid poplar submitted to five irrigation treatments, Malheur Experiment Station, Oregon State University, Ontario, OR.

Treatment	November 2006 measurements			2006 growth increment			2000-2006 growth increment
	Height	DBH	Stem volume	Height	DBH	Stem volume	Stem volume
	ft	inch	ft³/acre	ft	inch	ft³/acre	ft³/acre
1	64.3	10.0	2,819	1.3	0.48	303.2	2,588
2	54.4	8.9	1,878	1.5	0.53	229.9	1,678
3	45.3	6.6	849	4.1	0.74	235.0	772
4	78.4	11.1	4,330	1.6	0.77	629.8	4,157
5	61.3	9.5	2,489	3.1	0.69	453.7	2,304
LSD (0.05)	NS	1.4	1,209	NS	NS	319.5[a]	1,241

[a]Significant at a 0.10 level of probability.

Table 4. Average soil water tension and volumetric soil water content for hybrid poplar submitted to five irrigation treatments in 2006, Malheur Experiment Station, Oregon State University, Ontario, OR.

Treatment	Average soil water tension		
	1st ft	2nd ft	3rd ft
	kPa		
1	26.8	25.2	24.7
2	55.4	36.1	31.2
3	62.5	46.2	43.9
4	26.5	24	26.4
5	23.7	19.5	22.3
LSD (0.05)	21.6	NS	NS

[a]Significant at P = 0.10.

Table 5. Annual stem volume growth, seasonal average soil water tension at 8-inch depth, and growing degree days for the drip and microsprinkler treatments receiving the most water, Malheur Experiment Station, Oregon State University, Ontario, OR.

Year	Annual stem volume growth		Seasonal average soil water tension at 8-inch depth		Water applied plus precipitation		ET_c	April - Oct. Growing degree days (50 - 86°F)
	Drip	Microsprinkler	Drip	Microsprinkler	Drip	Microsprinkler		
	ft³/acre		kPa		inches			
1997		1.3		21.4		27.2		3,049
1998		78.5		20.0		45.0	37.1	2,968
1999		177.7		22.2		51.0	45.5	2,846
2000	387.9	401.5	24.2	37.9	35.2	42.1	47.1	3,067
2001	479.9	354.7	26.4	33.9	35.8	34.3	44.7	3,118
2002	440.1	256.8	31.3	35.8	30.6	38.1	44.4	3,023
2003	737.9	450.7	21.8	26.9	54.8	47.1	45.9	3,354
2004	679.4	512.3	20.2	22.2	56.3	51.7	44.1	3,106
2005	719.3	306.4	24.0	25.9	56.1	51.5	45.3	2,829
2006	629.8	303.2	26.5	26.8	74.3	89.1	49.3	3,022

Table 6. Soil pH, soluble salts, Na, and B for poplar microsprinkler and drip plots over time. Malheur Experiment Station, Oregon State University, Ontario, OR.

Year	pH	Soluble salts	Na (ppm)	B (ppm)
		Sprinkler		
April 1999	8.2	0.8	159	0.5
March 2001	8.3	0.84	132	0.9
March 2003	8.4	0.66	132	0.8
April 2005	8	0.57	265	2.7
October 2005	8.4	0.29	200	4
April 2006	8.2	0.24	139	1.7
		Drip		
October 2005	8.2	1.63	606	15.8
April 2006	8.5	0.26	291	2.3
Sufficiency range		<1.5	<225	0.7-1.5

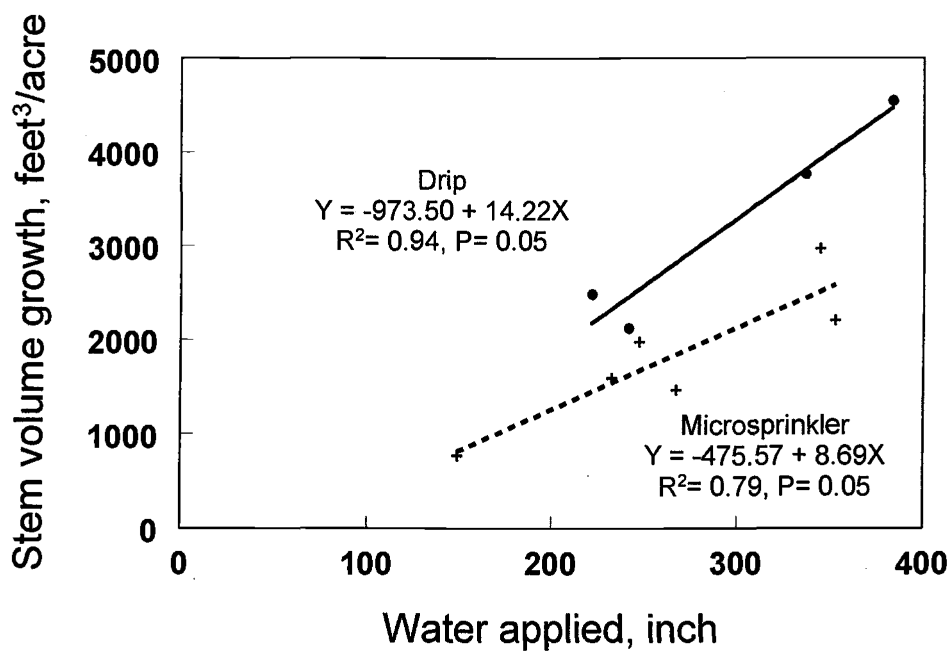

Figure 1. Response of stem volume growth to water applied from March 2000 through November 2006 for the drip and microsprinkler systems. Malheur Experiment Station, Oregon State University, Ontario, OR.

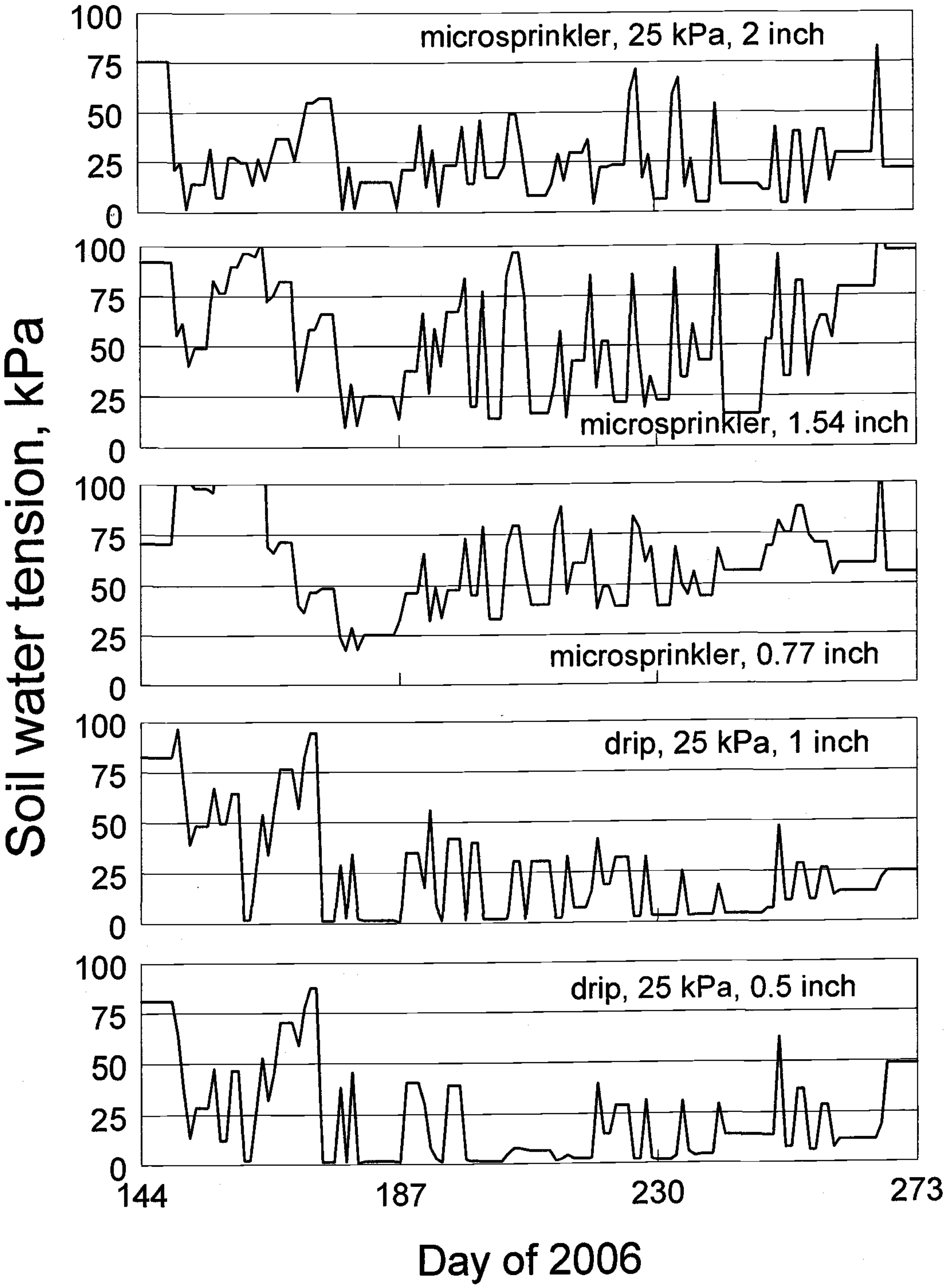

Figure 2. Soil water tension at 8-inch depth in a poplar stand submitted to five irrigation regimes, Malheur Experiment Station, Oregon State University, Ontario, OR.

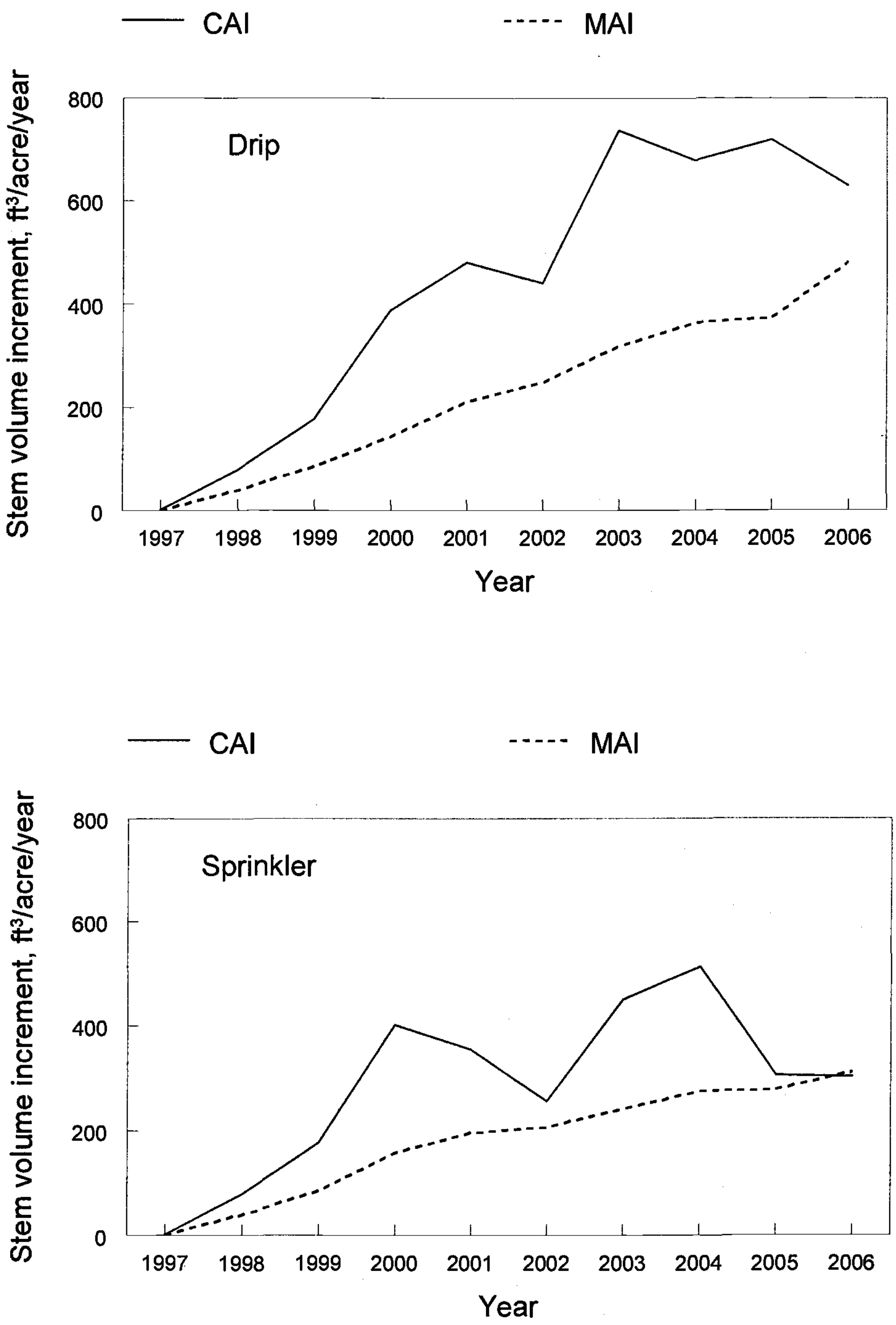

Figure 3. Current annual increment (CAI, annual stem volume growth) and mean annual increment (MAI, mean annual stem volume growth) starting at planting in 1997 through the tenth year for hybrid poplar irrigated with two drip tapes per tree row and with microsprinklers. Data are from plots receiving the highest irrigation rates, Malheur Experiment Station, Oregon State University, Ontario, OR.