VERATRUM IRRIGATION

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Abstract

Corn lily (*Veratrum californicum)* is of interest because it has the potential to provide pharmaceutical precursors for use in the treatment of cancer. Corn lily grows naturally in the mountains of the Intermountain West and grows in the vicinity of Ontario, Oregon between 2,900 and 10,000 ft elevation in wet meadows or open forests that receive summer rain. Most of the natural stands of corn lily have low cyclopamine and cyclopasine, the precursors needed for pharmaceutical manufacture.

Establishing cultivation guidelines for corn lily is essential for field-grown corn lily-based pharmaceuticals. Development of irrigation criteria is important in achieving this goal. The hypothesis for this work is that corn lily is exceedingly sensitive to both water stress and waterlogging stress, so it occupies a very narrow ecological niche of wet soil characterized by little variation in soil water tension (SWT) in the wet range. A corollary of this hypothesis is that successful production will be possible by mimicking these SWT conditions with very carefully controlled drip irrigation. In 2009 and 2010 corn lily plots were established at Ontario, Oregon and McCall, Idaho. Plots were assigned to five irrigation treatments of SWT 5, 10, 15, 20, and 30 cb. Of these treatments, the 2009 transplants irrigated at 10 cb consistently had greater survival and plant stalk diameter. The 2010 transplants irrigated at 10 cb and 30 cb had greater stalk diameter and superior survival at the Ontario site.

Materials and Methods

Two sites were selected for corn lily irrigation trials, Ontario, Oregon, and McCall, Idaho. The Ontario site is below the natural elevation range of corn lily but in close proximity to the Malheur Experiment Station, facilitating daily observations. The general climate of each site is summarized in Table 1 below. The trials were started in the fall of 2009 and the procedures and results for the 2009-2010 season have been reported previously (Shock et al. 2011a). Each plot was planted half full, using corn lily transplants from Fairfield, ID, and Manti-La Sal, UT planted in 2009.

Table 1. Summary of two trial sites. Annual precipitation data are a 10-year average for Ontario and an 80-year average for McCall. Temperature information is an average for October, 2010 through September, 2011. The corn lily growing seasons were based on observations in the field.

Site	Location	Elevation (ft)	Average annual precip. (inches)	Average annual daily maximum temp. (°F)	Average annual daily minimum temp. (°F)	Corn lily growing season
Ontario, OR	N 43.98 W 117.02	2,154	9.75	62	39	Mid March-July
McCall, ID	N 44.83 W 116.16	4,896	26.8	51	28	Late April or early May-Aug

Plant Collection and Transplanting, Fall 2010

Corn lily rhizomes for these trials were collected from the wild and transplanted into plots at the two sites described above. In early October, 2010, rhizomes were collected from Manti-La Sal National Forest in Utah (N 39.62, W 111.28) and stored in a cooler kept at 34°F and over 80 percent humidity. Rhizomes were not thoroughly cleaned in order to avoid harming the delicate root systems. On October 21, rhizomes were subjectively sorted into two size classes (medium and large). Each plot received transplants with approximately the same rhizome mass. The largest rhizomes were planted on the inner rows and the medium rhizomes were planted on the edge rows. The edge rows were not used in statistical analysis due to edge effects. Fourteen rhizomes per plot were weighed, dipped in rooting hormone (indole-3-butyric acid), and dusted in gypsum. Unlike the plantings in the fall of 2009, no Captan (fungicide) was used in 2010 because results of two transplant studies showed that Captan failed to improve survival or growth (Shock et al. 2011b). Rhizomes were planted only in split plots 11-20, and 31-40 (Fig. 1b). The rhizomes were planted 19 inches (0.5 m) apart on 30-inch (0.76 m) beds immediately after treatment on October 21 at Ontario and October 22 at McCall. The rhizomes were planted with their growth buds oriented up and the base of the bud 4 inches (10 cm) below the soil surface. Each rhizome received another 1.7 oz (50 grams) of gypsum in the planting hole to combat calcium deficiency.

Experimental Design

Figures 1a and 1b depict the layout of the irrigation trial plots. Trial layouts were identical at both Ontario and McCall except for compass orientation. Each trial consisted of 20 irrigation plots (Fig. 1a). Rhizomes were chosen so that there were no significant differences between plots in terms of total weight of rhizomes planted. There were 4 rows of plants in each plot, with 7 to 14 plants in each row (7 from 2009 and none or 7 from 2010). The main irrigation plots were subdivided into split plots for planting (Fig. 1b). Each split plot consisted of two rows of plants: an inner and an outer row. For this study, the plants in the inner rows of the treatment were the only plants measured for height and diameter. The experimental designs were randomized complete blocks with the five irrigation treatments (5, 10, 15, 20, and 30 cb) replicated four times, shown in Figure 3. Drip tape (T-tape 515-16-340) was installed after planting in each bed at 1-inch depth offset 7 inches from the bed center.

Irrigation Procedures–2011

Ontario

The trial was installed in a field of Owyhee silt loam (30% sand, 52.5% silt, and 17.5% clay) at the Malheur Experiment Station, Ontario, Oregon. Late in the fall of 2010 the field received 5 tons/acre of elemental sulfur to intentionally acidify the soil and new soil analyses verified the modified soil chemistry. Analysis of the soil on October 21, 2011 showed a pH of 6.6, 1.64 percent organic matter, 30 ppm nitrate-N, 14 ppm ammonium-N, 29 ppm phosphorus (P), 461 ppm potassium (K), 103 ppm sulfate (SO_4), 2156 ppm calcium (Ca), 494 ppm magnesium (Mg), 141 ppm sodium (Na), 4.7 ppm zinc (Zn), 2.4 ppm copper (Cu), 49 ppm manganese (Mn), 39 ppm iron (Fe), and 1.0 ppm boron (B). Calcium nitrate was applied through the drip tape at 50 lb N/acre on April 13, 2011. Two gallons of iron chelate (0.16 oz /gal chelate at 10% iron) was sprayed on the plants of this trial on May 2. Liquid calcium fertilizer (5% Ca) (Inca, Plant Impact, Preston UK) was applied to the plants of this trial on May 10 and May 17. Each application was 2.7 gal of 7.5% Inca solution. Weeds were controlled by manual weeding.

Two Watermark soil moisture sensors (Model 200SS, Irrometer Co., Riverside, CA) were installed at 8-inch (20 cm) depth between 2 plants along the plant row in each of the inner 2 rows of each irrigation main plot (40 sensors total) during the 2010 growing season. All sensors had been connected to a CR1000 datalogger (Campbell Scientific, Logan, UT) via multiplexers in early June, 2010. The datalogger read the sensors every hour and made irrigation decisions every 12 hours. The irrigation decisions for each treatment were based on the average SWT of all the sensors in a treatment (8 sensors total per treatment) but the irrigation decisions of the 5 cb treatment were controlled by the readings of the tensiometers in those plots. The irrigations were controlled by the datalogger using a controller (SDM CD16AC controller, Campbell Scientific, Logan, UT) connected to solenoid valves in each plot. The automated irrigation system was started on April 30. Automated irrigations were terminated on August 2, the end of the growing season for corn lily.

Five SWT irrigation treatments were tested in this study: 5, 10, 15, 20, and 30 cb. The Watermark soil moisture sensors for the 5 cb treatment were replaced with tensiometers with pressure transducers due to superior performance in the 0- to 10-cb range. Tensiometers were installed by making a hole approximately 9.25 inches deep with a soil probe that had the same diameter as the tensiometer. The tensiometers were installed vertically so the ceramic cup was in direct contact with the soil. Tensiometers were connected via multiplexers to the same datalogger as the Watermarks.

The water for the drip treatments was supplied by a well that maintained a continuous and constant water pressure of 35 psi. The pressure in the drip lines was maintained at 10 psi by pressure regulators for each treatment. The amount of water applied to each treatment was recorded daily at 8:00 a.m. from a water meter installed between the solenoid valve and the drip tape.

McCall

The trial was installed in a field of loamy sand (85% sand, 5% silt, and 10% clay) at McCall, Idaho. Analysis of a soil sample taken in the fall of 2009 showed a pH of 6.3, 1.63 percent organic matter, 2 ppm nitrate-N, 3 ppm ammonium-N, 17 ppm P, 304 ppm K, 7 ppm SO_4, 846 ppm Ca, 102 ppm Mg, 21 ppm Na, 0.8 ppm Zn, 0.3 ppm Cu, 6 ppm Mn, 57 ppm Fe, and 0.2 ppm

B. The soil analyses showed that the soil was deficient in available N, and deficient in Ca, Mg, S, Zn, Cu, and B. On May 20, 2010 the field was fertilized with 200 lb/acre of prilled gypsum (23% Ca and 18.5% S), 100 lb N/acre as urea, 2.4 lb Zn/acre as zinc sulfate, 2.4 lb Cu/acre as copper sulfate, 1.2 lb B/acre as Granubor II, 20 lb Mg/acre, 40 lb K/acre as K-Mag, and 75 lb sulfate-S contained in the K-Mag and Zn and Cu sulfates. On June 21, 2011, 200 lb/acre of gypsum, 100 lb N/acre as urea, 40 lb K/acre as K-Mag, 2.4 lb of Zn/acre as zinc sulfate, 2.4 lb Cu/acre as copper sulfate, and 1.2 lb B/acre were broadcast. Weeds were controlled by manual weeding.

The establishment of an irrigation system at McCall required an electrical transformer, a power line to the research site and to the pump site, electrical control for the pump from the research site, installation of a pump, water filtration at the pump site, and piping from the pump to the research plots. The pumping of water and opening of valves to specific treatments was controlled by a data logger. During the summer of 2010 soil moisture sensors were installed and connected to a datalogger as in Ontario. A controller was also installed and made irrigation decisions using the same criteria as in Ontario. Drip tape (Toro Aqua Traxx, EA 508 1222-750, 0.13 gal/hour with emitters spaced 12 inches apart) was installed as in Ontario in 2010.

The materials used and the set-up at McCall were identical to those used at Ontario. The same five irrigation treatments were tested at McCall, with tensiometers installed in the 5-cb plots. Irrigation began on May 25, and was terminated on August 26, at the end of the growing season. Water meters were read each time the field was visited.

The water at McCall was supplied by a well that maintained a water pressure of 35 psi. Occasional failure of the pump during the summer did occur but was fixed within a week. The pressure in the drip lines was 10 psi.

Irrigation plot numbers
Each irrigation plot = four 30-inch beds 26 ft long. (2 split plots)

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20

Irrigation plots - treatments

5	3	2	4	1	2	5	4	1	3
2	1	4	5	3	4	1	3	2	5

Figure 1a. The plot set-up for both McCall, Idaho and Ontario, Oregon. There were 20 plots in total (top) that were divided into 4 blocks and randomly assigned an irrigation treatment (1 = 10 cb, 2 = 15 cb, 3 = 20 cb, 4 = 30 cb, 5 = 5 cb) (bottom).

1	2	3	4	5	6	7	8	9	10
11	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
21	22	23	24	25	26	27	28	29	30
31	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**

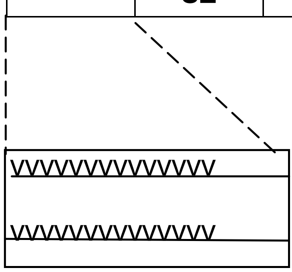

Figure 1b.The 20 irrigation plots were subdivided into 40 split plots. Each split plot contained 2 rows of 7 to 14 plants each (7 from 2009, 0-7 from 2010) represented here by v's. Idaho rhizomes in split plots 1-20 and 21-40. Utah rhizomes in split plots 11-20 and 31-40.

Data Collection

Soil water tension data were retrieved from the data loggers throughout the growing season. Cumulative water application data was tallied. Height and diameter of the plants on the inner rows were measured every month from both the 2009 and 2010 plantings. Survival was also noted, as some of the plants did not recover from transplanting. Mean diameter, height, and survival among the different irrigation treatments were compared using an ANOVA test.

Results

A statistical summary of the results can be found in Table 2 below. Results are separated based on year of transplant due to different transplanting methods in 2009 and 2010. Significant and insignificant relationships in 2011 are shown for 2009 and 2010 plantings. Soil water tension data for Ontario and McCall are presented graphically in Figures 2 and 3. Cumulative water input data are presented in Figures 4 and 5. Figures 6 and 7 show the regressions for irrigation criteria versus plant growth or survival at Ontario in 2011 from the 2009 and 2010 plantings, respectively.

Ontario

Unusually high amounts of spring rainfall in both 2010 and 2011 made it difficult to impose different irrigation treatments during the early part of plant growth. An unusually wet and cool spring kept soil moisture below 20 cb until mid-June 2011 (Fig. 2) at which point the plants had already been growing 80 to 90 days. The 30 cb treatment did not reach 30 cb until the end of July, when the plants were already dormant.

Averaged over plant sources for the 2010 planting, the 10- and 30-cb treatments resulted in plants significantly larger in diameter (Table 2). Plant survival at Ontario was significantly higher than that of McCall and did not vary with irrigation treatment. In addition, the height and diameter of the Utah selection for the 2010 planting were much larger than the Utah selection planted in 2009.

For the 2009 planting, the plants treated at 10 cb had significantly greater survival than all other treatments except for 5 cb for the Idaho selection. For the Utah selection, the 10-cb treatment produced greater survival than all other treatments. Irrigation at 5 cb resulted in very large water applications (Fig. 4).

The regression analysis for Ontario showed more significant relationships than the ANOVA test. Figure 6 summarizes the relationship between irrigation criterion and plant survival or growth for the 2009 planting. Results are separated by rhizome origin (either Fairfield or Manti-La Sal). The regression analyses showed that survival, height, and diameter were significantly related to the irrigation treatments for both the Fairfield and Manti-La Sal plant selections. The 2010 planting at Ontario showed a significant relationship between plant height and irrigation treatment (Fig. 7) but not for plant diameter or survival.

McCall

Soil water tension for the McCall plots remained below 20 cb until mid-July due to unusually heavy snow pack and above-normal spring precipitation, making it difficult to impose different treatments (Fig. 3). Both the 20- and 30-cb treatments did not reach their prescribed maximum

SWT. By mid-August the plants were dormant. Irrigation at 5 cb appeared to be wasteful of water and energy (Fig. 5).

For the 2010 planting, McCall plants were smaller in diameter than their counterparts at Ontario. Of the different treatments, the 30-cb treatment produced plants largest in diameter. Overall survival at McCall was not as high as that at Ontario, probably due to harsh weather. However, survival rate from the 2010 planting was much higher than that of the 2009 planting.

For the 2009 planting, the Idaho selection had significantly better survival than the Utah selection. Survival was not affected by irrigation treatment at McCall. However, the plants in the 15-cb treatment for the Utah selection were significantly taller than in any other treatment group.

Discussion

The previous season of data showed that the plants have greater survival and growth at 10-cb SWT (Shock et al. 2011a). The data from the 2011 season are mixed: the 10-cb treatment did result in greater survival and growth in some cases; however the plants in the 30 and the 5-cb treatments survived just as well or better than those in the 10-cb treatment. This variation was not what was expected given last year's data. We attribute these results to the unusually heavy snow pack and substantial late spring rainfall, which made it impossible to impose the drier irrigation treatments. As mentioned earlier, the soils at both Ontario and McCall remained wet until late July and August, respectively. By these times, corn lily growth had already ceased and the plants had begun to die back. This is the second year in a row that late rainfall was an interfering factor in the irrigation trials.

References

Shock, C.C., E.B.G. Feibert, C.A. Parris, and L.D. Saunders. 2011a. Irrigation criteria for corn lily (*Veratrum californicum*) Production. Oregon State University Agricultural Experiment Station, Malheur Experiment Station Annual Report 2010, Department of Crop and Soil Science Ext/CrS 132:216-221.

Shock, C.C., E.B.G. Feibert, C.A. Parris, and L.D. Saunders. 2011b. Techniques to transplant corn lily (*Veratrum californicum*). Oregon State University Agricultural Experiment Station, Malheur Experiment Station Annual Report 2010, Department of Crop and Soil Science Ext/CrS 132:216-221.

Table 2. Veratrum plant height (2.54 cm = 1 in), diameter, and survival based on treatment, planting site, and collection site for 2009 and 2010 plantings at Ontario, OR and McCall, ID.

Veratrum irrigation trial								
			2009 planting			2010 planting		
Site	Irrigation criterion	Selection	Height cm	Diameter mm	Survival %	Height cm	Diameter mm	Survival %
Ontario	5	Idaho	28.6	12.9	64.3			
	10		33.2	13.3	75.0			
	15		25.6	12.3	57.1			
	20		27.0	11.9	42.9			
	30		22.9	9.9	17.9			
	average		27.4	12.0	51.4			
	5	Utah	27.7	14.5	60.7	43.1	18.2	100.0
	10		28.7	16.9	85.7	34.7	19.7	100.0
	15		19.5	13.5	50.0	35.1	17.8	96.4
	20		22.1	12.3	57.1	34.2	17.2	89.3
	30		17.9	9.3	21.4	32.0	19.9	100.0
	average		23.2	13.3	55.0	35.8	18.5	97.1
	5	average	28.2	13.7	62.5			
	10		30.9	15.1	80.4			
	15		22.6	12.9	53.6			
	20		24.5	12.1	50.0			
	30		20.4	9.6	19.6			
McCall	5	Idaho	33.7	10.8	82.1			
	10		37.2	11.7	82.1			
	15		37.1	11.0	71.4			
	20		37.8	11.7	82.1			
	30		36.9	10.8	67.9			
	average		36.6	11.2	77.1			
	5	Utah	34.7	9.8	32.1	36.6	15.7	96.4
	10		33.8	13.0	25.0	37.9	15.6	89.3
	15		44.9	13.5	39.3	34.6	15.7	78.6
	20		37.1	13.5	39.3	34.3	15.2	75.0
	30		34.6	12.4	28.6	39.9	17.2	78.6
	average		37.0	12.4	32.9	36.7	15.9	83.6
	5	average	34.2	10.3	57.1			
	10		35.5	12.3	53.6			
	15		41.0	12.3	55.4			
	20		37.5	12.6	60.7			
	30		35.8	11.6	48.2			
Overall average	5		31.2	12.0b*	59.8a	39.8	16.9b	98.2
	10		33.2	13.7a	67.0a	36.3	17.6ab	94.6
	15		31.8	12.6ab	54.5b	34.8	16.8b	87.5
	20		31.0	12.3ab	55.4b	34.2	16.2b	82.1
	30		28.1	10.6b	33.9c	36.0	18.5a	89.3
LSD (0.05)								
Treatment			NS	1.6	11.6	NS	1.4**	NS
Site			4.5	NS	NS	NS	1.0**	10.9
Selection			NS	NS	8.9	NS	NS	NS
Trt X site			NS	NS	NS	NS	NS	NS
Site X sel.			NS	NS	12.5	NS	NS	NS

*Numbers followed by different letters are significantly different.

**LSD (0.10)

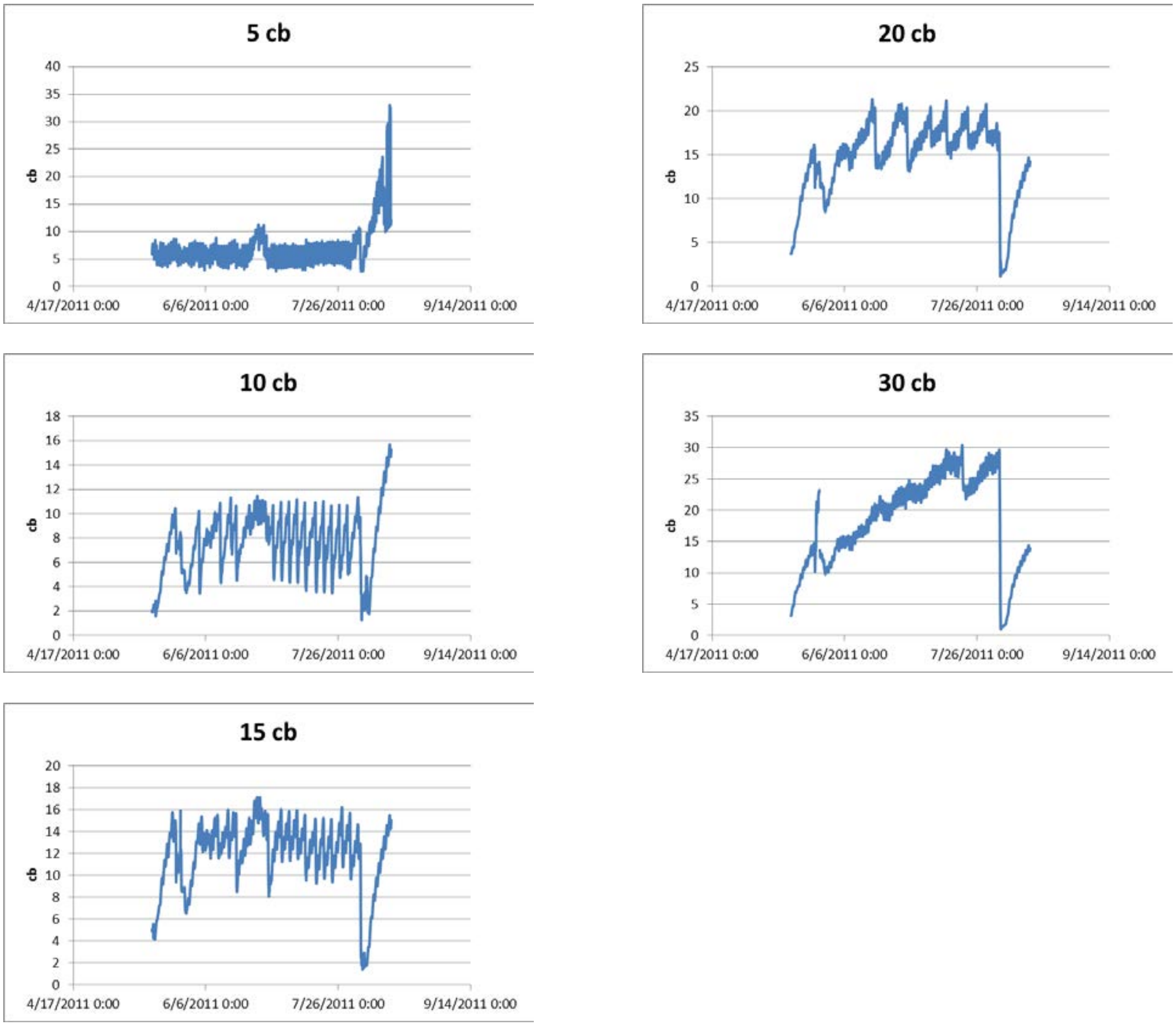

Figure 2. The soil water tension over time for the five Veratrum californicum *irrigation treatments at Ontario, OR, 2011.*

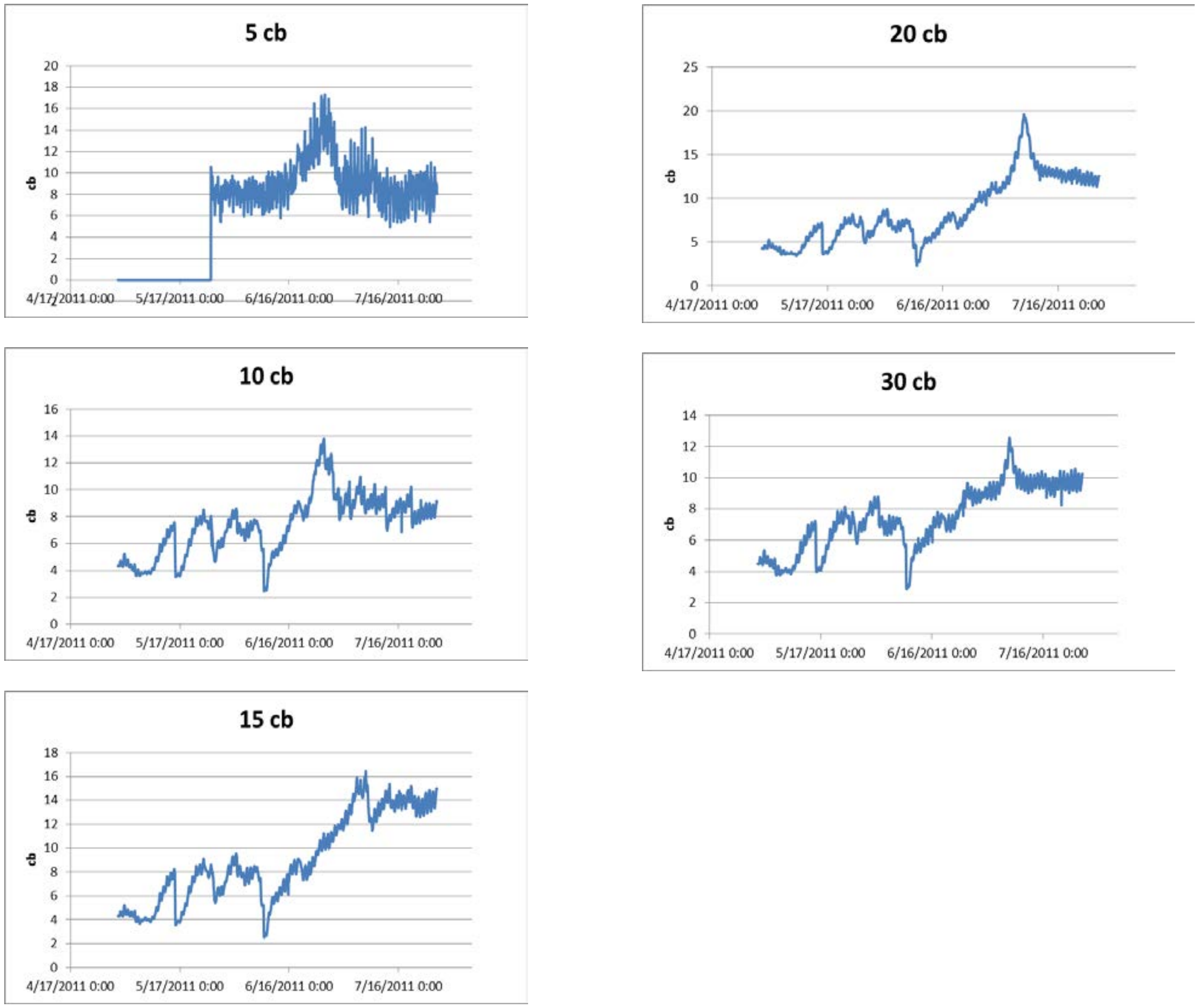

Figure 3. The soil water tension over time for the five Veratrum californicum *irrigation treatments at McCall, ID, 2011.*

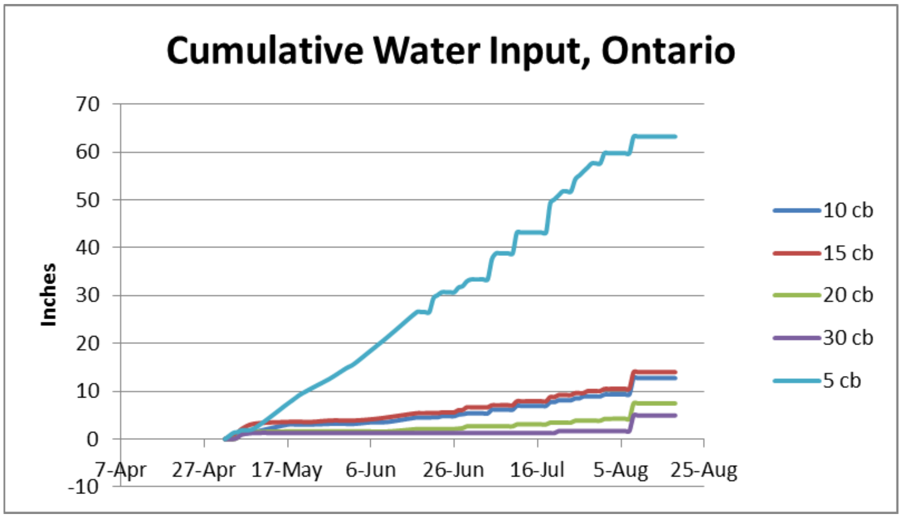

Figure 4. Cumulative water applied at Ontario, OR in 2011 for all five Veratrum californicum *irrigation treatments.*

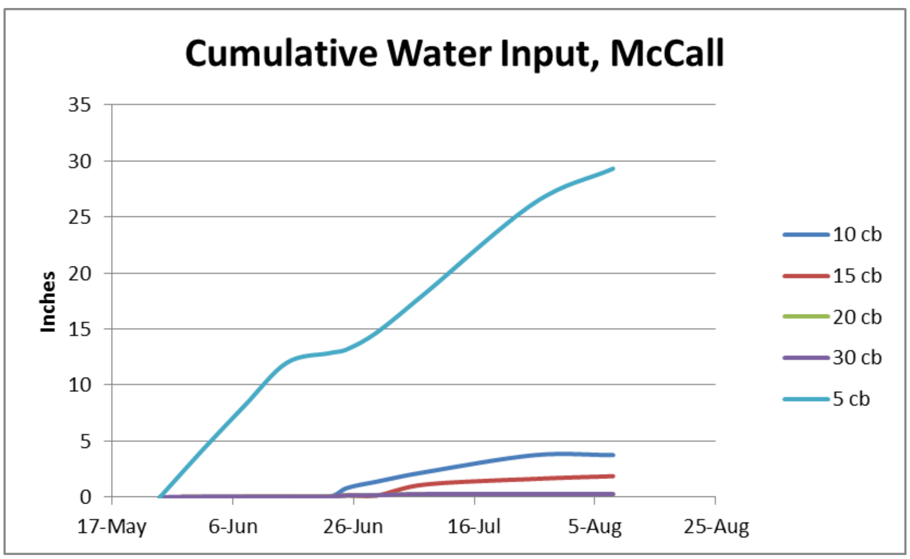

Figure 5. Cumulative water applied at McCall in 2011 for all five Veratrum californicum *irrigation treatments. The 20-cb treatment data is not visible because it lies directly under the 30-cb treatment.*

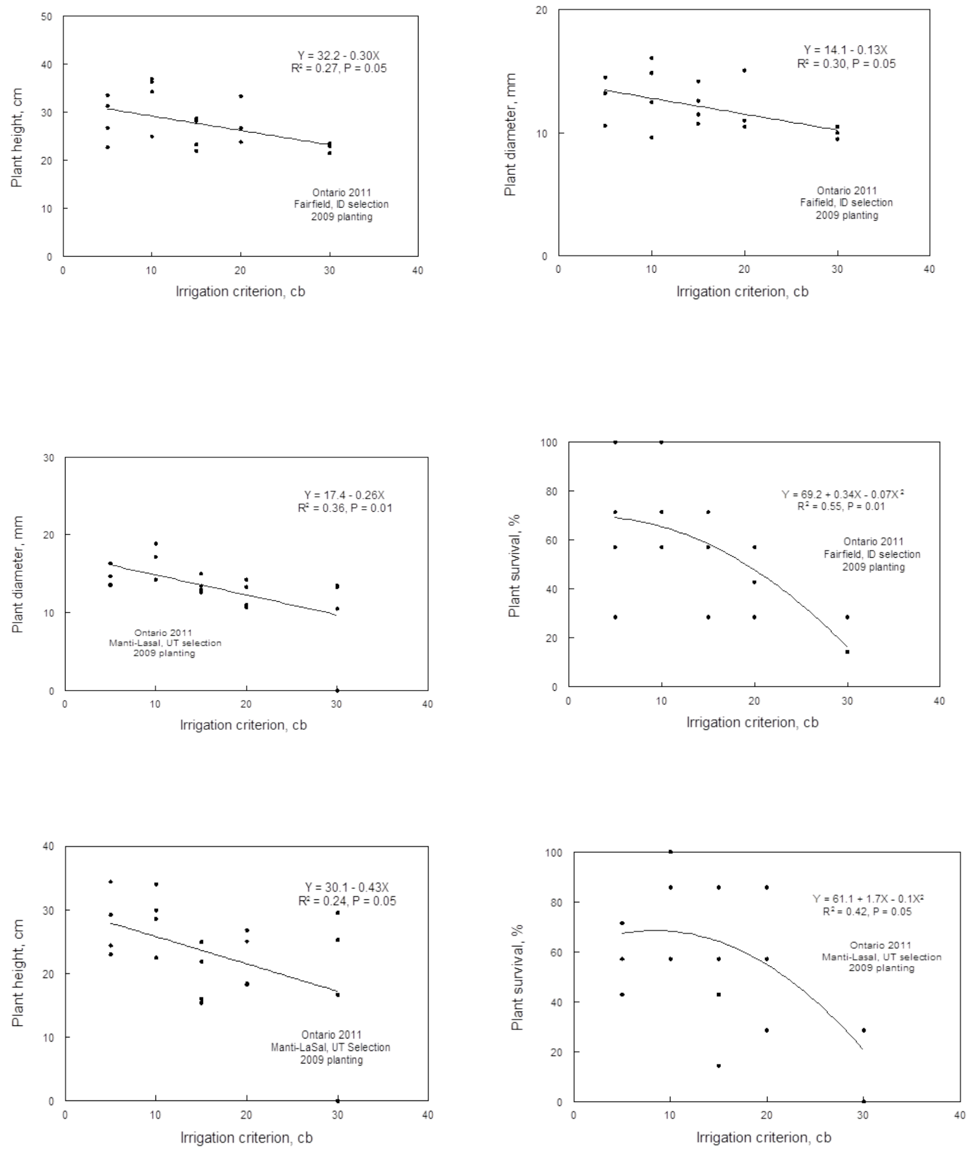

Figure 6. Plant heights, diameters, and survival in 2011 for the 2009 Veratrum californicum *planting at Ontario, OR. P-values of 0.05 or lower are indicative of a significant relationship.*

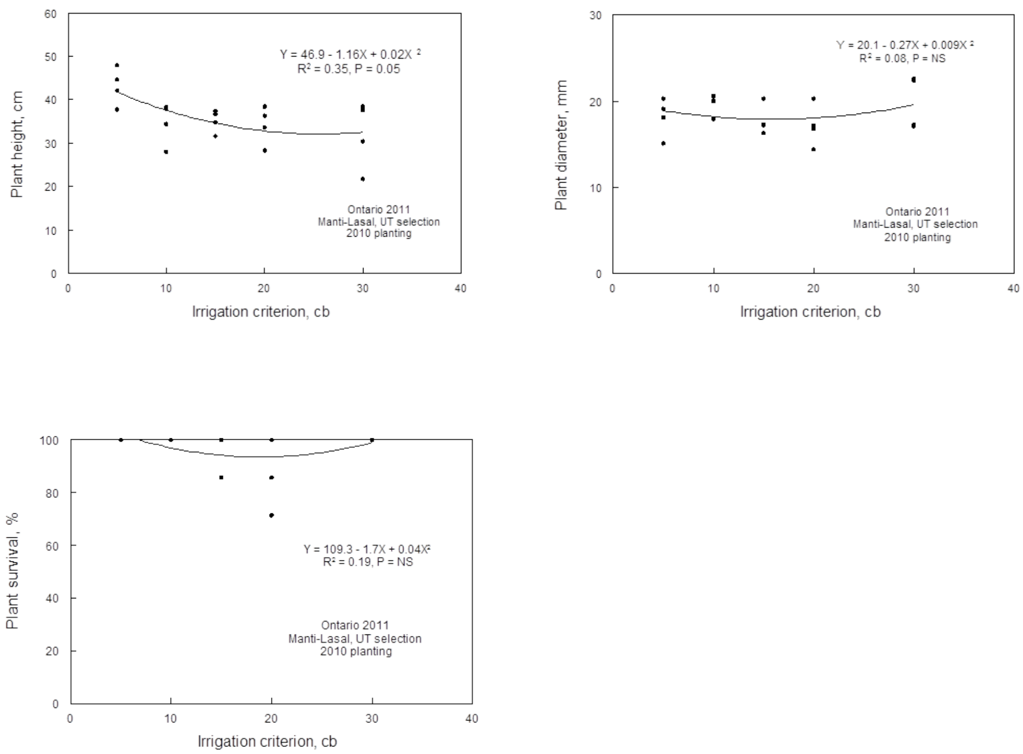

Figure 7. The relationship between irrigation treatment and Veratrum californicum *plant height in 2011 was significant for the 2010 planting in Ontario, OR.*