# The Effects of Year-Round Irrigation on Landscape Plant Quality and Health in Ohio

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**Abstract. Deep (over 165 cm), permeable, unsaturated soil is needed to treat and dispose of wastewater through septic systems. In Ohio, only 6.4% of the state's land area is suited for septic systems for wastewater treatment. Soils with shallow depth to a limiting condition, between 30 and 60 cm, represent 49% of Ohio's land area. In these areas onsite wastewater treatment systems could be followed by irrigation on the lot to disperse the treated wastewater. Several months each year in Ohio reach subfreezing temperatures, making year-round irrigation a challenge. The objective of this research was to examine the feasibility of year-round onsite irrigation and its impacts on landscape plant quality. Three 210 m$^2$ plots were established on a site with unsaturated soils of at least 30 cm deep to a limiting condition of dense glacial till. Three irrigation regimes were applied in each area, no irrigation, irrigation from April through October, and year-round irrigation. No significant differences were shown in plant growth between the two irrigated plots. The non-irrigated plot was different from the two irrigated plots. Thirty-three percent of the plants in the non-irrigated plot died compared to no plant death in the two irrigated plots. The winterized irrigation system operated in sub-zero temperatures without freezing and caused no significant harm to the landscape plants.**

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## INTRODUCTION

The human desire for a well-groomed landscape is as old as civilization. Humans have also been concerned with proper sanitation since first organizing into tribes (Burks and Minnis, 1994). Throughout history, the design of wastewater sanitation facilities has focused on minimizing health risks. In developed countries, the aesthetic value placed on residential gardens and lawns has been largely separated from the design and function of on-site wastewater treatment systems.

The U. S. Congress amended the Federal Water Pollution Control Act in 1972 setting the goal of eliminating the discharge of pollutants into the nation's waters. The enactment of this law set the groundwork for steady progress toward eliminating the discharge of water pollutants by establishing the National Pollutant Discharge Elimination System (NPDES). Wastewater collection and treatment before reuse through land application meets the national goal. Small systems that treat and dispose of wastewater on-site, meet the national goal and eliminate the need for a sewer system (Mancl, 2002).

Deep (over 165 cm), permeable, unsaturated soil is needed to treat and dispose of wastewater through septic systems. In Ohio, only 6.4% of the state's land area is suited for septic systems for wastewater treatment (Mancl and Slater, 2001). Soils with shallow depth to a limiting condition, between 30 and 60 cm, represent 49% of Ohio's land area. In these areas onsite wastewater treatment systems could be followed by irrigation on the lot to disperse the treated wastewater (Mancl and Slater, 2002). Wastewater treatment to reduce biochemical oxygen demand ($BOD_5$) for odor reduction and pathogen control through disinfection are required to safely reuse wastewater.

A range of systems provide wastewater treatment. Wastewater stabilization ponds (also known as facultative lagoons), in combination with effluent filters and septic tanks, are one system option. Sand or fixed-media bioreactors also treat wastewater onsite before reuse through irrigation (Crites and Tchobanoglous, 1998).

Irrigation is used to protect plants from cold weather. Sprinkler irrigation was used successfully for frost protection of strawberries and citrus (Gerber and Martsolf, 1979). Wilcox and Davies (1981) found that leaf temperatures in the lower canopy of irrigated trees were as much as 7.3°C greater than those of non-irrigated trees during freezing weather. Buchanan et al. (1982) found increases in leaf temperature of 1.5 to 3°C and 3.8°C for sprinkler irrigated trees with high-volume and low-volume rates respectively. Leaf temperature for sprinkler-irrigated trees averaged 1.1°C to 2.2°C higher than for non-irrigated trees. High-volume sprinklers provided a 0.5°C to 1.1°C increase in leaf temperature even during a severe advective freeze (Davies, 1980).

Irrigation of plants has been found to cool plants during unseasonably warm weather, delaying blooming. The phenological development of flower buds on fruit trees is correlated to the number of degree-hours above 4. 5°C accumulated after the plants' chilling requirement is completed (Rieger, 1989). Ballard and Proebsting (1978) found that the cold hardiness of flower buds decreased by 10°C or more as bud development proceeds from the dormant to full bloom condition. Initial experiments in Utah (Alfaro et al., 1974; Anderson et al., 1975) tested procedures used to delay fruit bud development by using evaporative cooling to decrease the energy available for plant growth. The sprinkler irrigation system was designed to automatically activate when air temperature reached 7.2°C (45°F). Sprinkling continued as long as the air temperature remained above 6.1°C (43°F), and was terminated when the air temperature reached this value. Bud growth was delayed in apple and cherry by 17 and 15 days, respectively.

The objective of this research was to examine the feasibility for reusing reclaimed wastewater through year-round onsite irrigation and its impacts on landscape plant quality. No previous research has been published on the effects of winter irrigation on woody ornamental plants. The focus was on the residential scale, for which the wastewater effluent volume and irrigation system outputs were optimally balanced.

## MATERIALS AND METHODS

The experiment was conducted at Molly Caren Agricultural Center, London, OH beginning January 2002. A three-bedroom house at the site was surrounded by extensive lawn area. The

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section used for onsite irrigation was a fallow portion of the house lawn and allowed to grow with no herbicide treatment, fertilizer addition or mowing. Soil excavations revealed silty clay loam soil with compacted glacial till at a depth of 60 to 85 cm, making the site unsuited for a septic system leach field. Soil test analysis for the silty clay loam in the three test plots is presented in Table 1. Soil tests revealed the fertility of each plot was similar but the non-irrigated plot showed the highest levels of phosphorus and potassium.

Three 210 $m^2$ (2260 $ft^2$) plots were outlined in the unsaturated silty clay loam soil. A different irrigation regime was applied in each plot. One plot received no irrigation and served as the control to determine possible mortality due to preexisting plant disease, animal damage or mismanagement during the planting phase. A second plot received irrigation throughout the entire year, and the third plot was irrigated April through October.

Planted Dec. 10, 2001 was a select grouping of typical ornamental trees and shrubs (Table 2). Native species were selected, having potential for better survival and performance in moist conditions. These species could withstand 3.6 cm (1.4 inches) of irrigation per week in addition to the approximately 96.5 cm (38 inches) of rainfall received per year (Estadt et al., 1995). Each of the plots contained 15 species with two specimens each per plot. Each plant specimen was placed at a different distance to irrigation sprinklers. Tall plants were situated at adequate distance from overhead power lines. Under-story plants were placed where they would receive direct sunlight and not subjected to shade from taller plants.

The irrigation equipment was installed in November 2001, prior to planting. Daily year-round irrigation began January 19, 2002 and was implemented with over-wintering equipment protection to decrease the likelihood of pipes freezing. Heat tape, reflective adhesive and foam insulation was fitted on the entire pipe length, running from the pumping tank to the opposite end of the freeze-protected plot. Each sprinkler head sat on a riser at a height of approximately one meter to maintain the ability to disperse the water even with significant snowfall.

The remaining two plots were constructed in the same manner, using the same risers and spray heads but without over-winter protection. Pipe and sprinklers were installed in the non-irrigated plot so that the area experienced the same soil disturbance as the treatment plots. Summer-only irrigation began on April 1 and continued through October 24, 2002.

Combinations of 5.7 L (1.5 gallons) and 11.4 L (3 gallons) per-minute heads were grouped into irrigation zones that discharged a maximum of 28.4 LPM (7. 5 GPM). Each plot contained two separate irrigation zones, when combined, discharged at a rate of 56.8 LPM (15 GPM). The maximum target irrigation rate was 0.51 cm (0.2 inches) per day. Incorporating the plot area and the irrigation application rate, the duration of application fell just under 20 minutes per zone.

Plant mortality, growth and vigor of like species in each plot were observed and measured. Growth was recorded by apical measurements taken in late March and early October. Vertical growth was taken on all species by comparing the differences in height of living stems to the nearest 2.5 cm (1 inch). Horizontal growth was recorded in the same manner for a low-growing species, *Rhus aromatica*. Plants could experience negative growth if the tips of stems died or were grazed by animals.

Observations of vigor, a subjective measurement, were made twice per month during this same time period. Changes in the quality of leaf health and color were noted through visual recordings and photographs. Plants were classified as good vigor if shrub and tree leaves were displaying appropriate seasonal color and healthy leaf density. Curling, browning of leaf edges, or yellowing of the leaves were indications of poor vigor. No seasonal leaves or mortality of a specimen was lack of vigor.

In addition to the irrigation system a 3785 liter (1000 gallon) holding tank and a 465 $m^2$ (5000 $ft^2$) treatment and storage pond were constructed. A 5678 liter (1500 gallon) septic tank already on the site was pumped out. Costs of system installation and management were documented for comparison.

Plant growth in the three irrigation plots were compared using ANOVA main-effect model with minitab.

## RESULTS

### Year-Round Irrigation

Sub-0°C temperatures were experienced 41 days from January through March of 2002. Irrigation during freezing temperatures resulted in ice coverage on the plants and surrounding grass. Ice development concentrated in patches near the sprinkler with thicker ice coverage on the sprinkler side of the plants. The ice coverage was more apparent on evergreen species (*Tsuga canadensis*, and *Thuja occidentalis*). Ice accumulation covering the grass was extremely dense; however, no standing water was present following any irrigation cycles on warm days.

Of the 30 plants in the winter-irrigated plot, *Thuja occidentalis, Magnolia virginiana, Clethra alnifolia* and *Itea virginiana* had an average decrease in total growth as a result of stem death or grazing by animals. Two species, *Clethra alnifolia* and *Itea virginiana*, showed evidence of animal grazing damage in both specimens.

Observations of vigor were made twice per month from March to October in 2002. The two evergreen species displayed poor vigor due to detrimental effects from ice coverage in the year-round

Table 1

*Soil analysis of test plots.*

| Plot | pH | Lime index | P(µg/g) | K (µg/g) | Ca (µg/g) | Mg (µg/g) | % organic matter |
|---|---|---|---|---|---|---|---|
| Year-round | 7.89 | 70 | 18 | 202 | 2846 | 466 | 4.72 |
| April-October | 7.78 | 70 | 42 | 295 | 2757 | 503 | 5.89 |
| Non-irrigated | 7.87 | 70 | 50 | 403 | 2879 | 432 | 4.57 |

Table 2

*Listing of plants tested for growth health and vigor with different irrigation treatments.*

| Botanical Name: | Common Name: |
|---|---|
| *Acer rubrum* | Red Maple |
| *Aronia arborea* 'brilliantissima' | Red Chokeberry |
| *Clethra alnifolia* | Summer Sweet |
| *Diervilla sessilifolia* | Summer Stars Honeysuckle |
| *Fraxinus pennsylvanica* | Patmore Ash |
| *Hammamelis virginiana* | Witchazel |
| *Ilex verticulata* | Winter Red Holly |
| *Itea virginiana* | Virginia Sweetspire |
| *Magnolia virginiana* | Sweetbay Magnolia |
| *Myrica pennsylvanica* | Northern Bayberry |
| *Rhus aromatica* | Fragrant Sumac |
| *Salix purpurea* | Arctic Willow |
| *Thuja occidentalis* | Emerald Arborvitae |
| *Tsuga canadensis* | Canadian Hemlock |
| *Viburnum dentatum* | Chicago Luster Viburnum |

plot. The *Tsuga canadensis* (Canadian Hemlock) displayed low leaf numbers and poor overall health. Yellowing of leaves adjacent to the irrigation riser on *Thuja occidentalis* (Emerald Arborvitae) was observed in early spring. All other species displayed healthy leaf color and good vigor. Of the 30 plants tested, none died.

**April Through October Irrigation**

Of the 30 specimens in the plot irrigated from April through October, *Ilex verticulata, Rhus aromatica, Viburnum dentatum, Clethra alnifolia, Hammamelis virginiana and Itea virginiana* showed a decrease in total growth compared with initial measurements. Of these six species, *Itea virginiana* exhibited animal grazing damage in both specimens and one specimen of *Viburnum dentatum*. All other species displayed an average growth of 2.5 cm (one inch).

Eighteen of 20 shrub specimens displayed appropriate leaf color, size, and good vigor. Only one specimen of *Clethra alnifolia* ( Summer Sweet) and one of *Hammamelis virginiana* (Witchazel) displayed poor vigor with wilting, yellow, and low leaf density. All tree species and the remaining shrub species displayed good vigor with healthy leaf color and quality of growth. Of the 30 plants tested, none died.

**No Irrigation - Control**

Of the 29 specimens situated in the non-irrigated plot, four species *Clethra alnifolia, Hammamelis virginiana, Itea virginiana*, and *Mtrica pennsylvanica*, lacked vigor with deaths of both specimens. Two other species, *Diervilla sessilifolia* and *Salix purpurea* had deaths of one of two specimens. Out of the remaining 19 specimens, *Aronia arborea, Ibex verticulata, Rhus aromatica, Thuja occidentalis, Tsuga canadensis,* and *Viburnum dentatum* had an average decrease in size. Animal grazing damage was observed in both specimens of *Thuja occidentalis*, and *Viburnum dentatum* and one specimen of *Aronia arborea*. The remaining five species displayed an average growth of 2.5 cm (one inch). Two evergreen species (*Tsuga canadensis* and *Thuja occidentalis*) displayed poor leaf quality, health, and vigor. Ilex verticillata and *Rhus aromatica* were observed to have poor leaf quality, health, and vigor in a single specimen. Of the 29 specimens in the non-irrigated plot, eight were dead and eight others displayed poor vigor leading to imminent death.

**Plant Growth**

Death of plants in the non-irrigated plot shows a significant difference with the two irrigated plots. Only the non-irrigated plot showed plant death. Comparing the year-round irrigated plot with the summer-only irrigated plot, the large p-value (0.716) in the ANOVA main-effect model suggests that there is no significant difference in plant growth between the two plots.

Comparisons of the average growth rates and specimen survival rates between the three plots demonstrated the species' dependence on an adequate water supply. Over a three-month period, from the middle of June through the middle of September, natural rainfall was just over 15.2 cm (6 inches). Rainfall was 19.05 cm (7.5 inches) below the average for this period and was insufficient for sustaining most of the non-irrigated plants.

**Plant Vigor**

Observations for nearly all the plants showed good vigor in the year-round irrigated plot The only exceptions were the two evergreen species. The *Tsuga Canadensis* showed low leaf numbers and the *Thuja occidentalis* had yellow leaves. The evergreens in the summer irrigated plot showed good vigor. In the non-irrigated plot eight plants died and eight showed poor vigor. Observations were recorded with photographs such as those presented in Figs. 1, 2 and 3.

**System Costs**

Total system costs for the study are presented in Table 3 and show that the winterization of the irrigation system added $4,000 to the irrigation system, tripling the installation cost for a winterized system over a comparably sized summer-only irrigation system. As an alternative, a treatment and storage pond constructed at the site for a three-bedroom home cost $17,000. Holding tanks cost about $1,000 to purchase and install. If 7,570-liter (2000 gallons) tanks were used to store five months of wastewater (approximately 102,200 liters) the estimated costs would be $14,000. Pumping a holding tank at this site costs more than $100 per 3,875 liters (1,000 gallons), making the cost of pumping through the winter months more than $27,000 per year.

## DISCUSSION

In the year-round irrigated plot, the potential for frost protection was present during the irrigation cycles. During sub-0°C temperatures, the conversion of any irrigated water to ice would have provided the plant protection from frost present during the irrigation cycle. In decreasing frost exposure, plant recovery from temperature extremes hastens, adverse effects on plant structure are lessened, and plant vigor and health increases. Temperature is a key environmental parameter for synchronizing these species' capacity to withstand freezing temperatures. Species that depend on temperature for cold weather acclimation benefit from the dampening of temperature fluctuations through the effects of evaporative cooling. A pause in plant development, extends the dormancy period, and protects the plants from frost damage during any subsequent return of sub-0°C weather. Frost delay shelters winter irrigated plants from structural damage, increasing the likelihood of proper leaf development and vigor in the next growing season.

The growth differences between the two irrigated plots and the non-irrigated plot may also be due to the evaporative cooling effects on the species that were irrigated. Protection from summer heat was provided through irrigation, which acted to decrease the plant temperature. Any heat required to evaporate water from the plant was heat to which the plant was not exposed. Through the combined effects of irrigation and evaporative cooling average species growth, in the irrigated plots, was enhanced (Fig. 4).

Figure 1. Example plants in year-round irrigated plot displaying mid-summer leaf color and vigor

Figure 2. Examples of plants in April through October irrigated plot displaying mid-summer leaf growth and vigor. Note the healthy hemlock evergreen tree.

Figure 3. Examples of plants in control plot (no irrigation) displaying extremely poor vigor and mortality.

**Plant Vigor**

Nearly all the plant showed good vigor in the year-round irrigated plot. The only exceptions were the two evergreen species. The *Tsuga Canadensis* showed low leaf numbers and the *Thuja occidentalis* had yellow leaves. This compared to the non-irrigated plot where eight plants died and eight showed poor vigor. The evergreens in the summer irrigated plot showed good vigor, suggesting that winter irrigation is detrimental to hemlock and arborvitae.

## CONCLUSIONS

Use of treated wastewater for irrigation has much potential for agricultural and horticultural plant development. Combining the functions of an onsite wastewater treatment system with an appropriate landscape setting allows for the possibility of the treatment and dispersal system to function as a landform design element. The purpose of this research was to measure and observe the impacts and effects of year-round irrigation, especially winter irrigation, on landscape plant quality. Application of water through irrigation throughout the year caused no harm to most landscape plants. However, two species of evergreen were damaged through winter irrigation. Caution should be taken when selecting plants for year-round irrigation plots. Avoid applying freezing water directly onto the leaves of evergreens.

Table 3

*Approximate costs of irrigation, pump, and winterizing equipment and installation as compared to a treatment and storage pond or a holding tank with regular pumping over the winter.*

| System Elements | Unit Price |
|---|---|
| Pump and controls | $ 980.00 |
| Irrigation system (for all 3 plots) | $ 3,014.80 |
| Winterizing system (for 1 plot) | $ 4,035.76 |
| Treatment and storage pond | $16,950.00 |
| Holding tank and installation | $ 1,041.00 |
| Tank pumping | $ 128.00/1,000 gallons |

The study also revealed the practicality of year-round irrigation. Winterization of the irrigation system with insulation and heat tape protected the system from freezing and allowed for irrigation during sub-zero temperatures.

Part of judging if a system is practical is its cost. The added cost of heat tape and the associated electrical expenses, the reflective adhesive, and the insulation wrap all increased the system costs. Total system costs for the winterization of the irrigation system added $4,000 to the irrigation system, tripling the installation cost for a winterized system over a comparably sized summer-only irrigation system. To determine if winter irrigation is practical, it should be compared to the cost of winter wastewater storage. A winter treatment and storage pond was $17,000. The installation of storage tanks for five months of wastewater (approximately 102,200 liters) would be about $14,000. Pumping a holding tank through the winter months would cost over $27,000 per year. Winterizing an irrigation system for year-round irrigation appears to be a viable option for areas with shallow soils unsuited for septic systems.

Irrigation of wastewater also supplemented the deficit in water supply seen in months having high evapotranspiration and low precipitation rates. Plant mortality of 33% in the non-irrigated plot was not experienced in the two irrigated plots. Irrigation during dry, summer months can balance the water deficit and directly influence the health and vitality of the surrounding landscape. Recycling wastewater can also decrease the costs associated with the irrigation of potable water.

The soil characteristics dictate the suitability of the site for wastewater reuse through irrigation needing at least 30.5 cm (12 inches) of permeable, unsaturated soil depth. Soils with appropriate depth are present over 49% of the land area of Ohio (Mancl and Slater, 2002) making reuse of reclaimed wastewater through irrigation an important option for onsite wastewater treatment. This study shows that the integration of an onsite wastewater treatment within a selected landscape design can compliment the functional aspects of both systems and is viable in Ohio and other areas with sub-zero winter temperatures.

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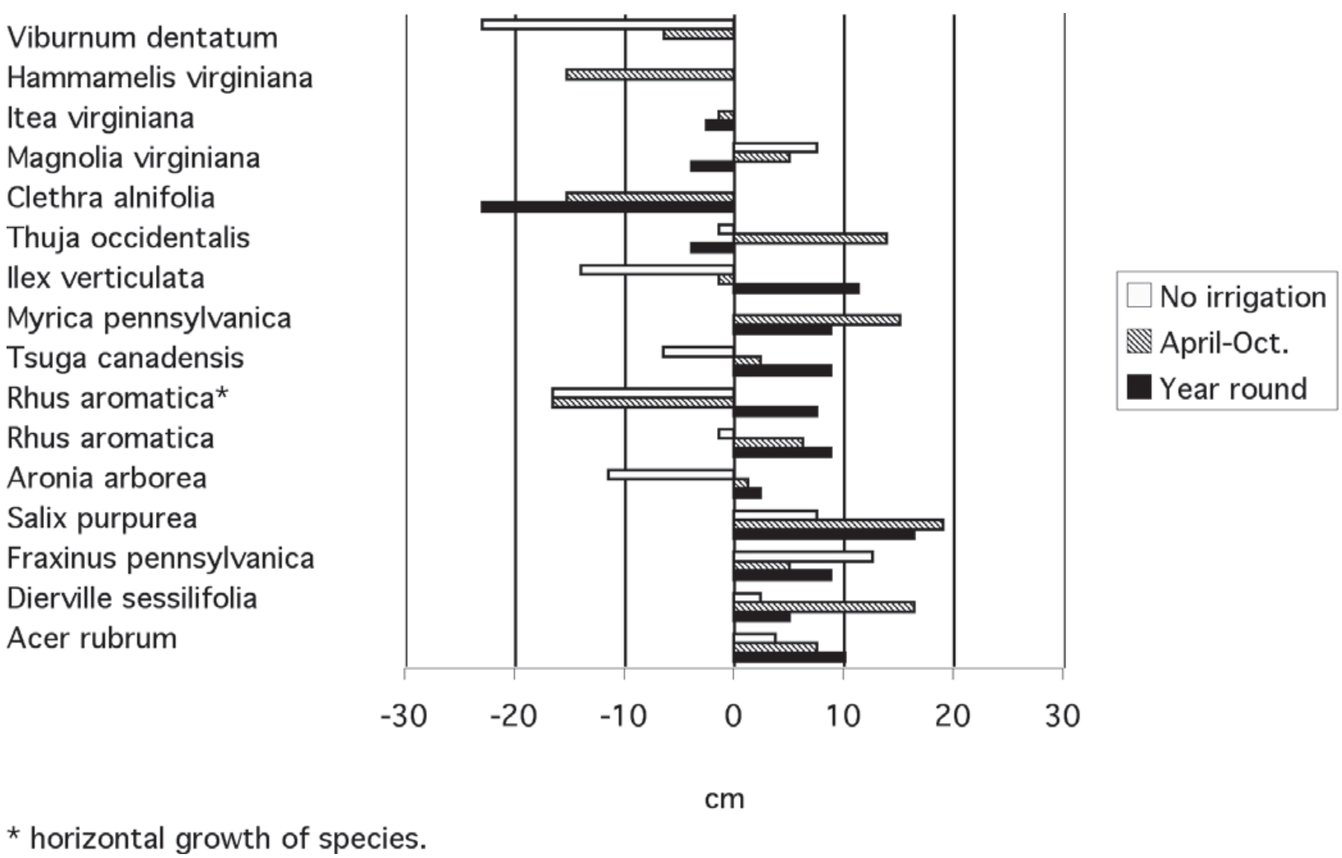


Figure 4. Comparative one-year vertical growth (cm) of ornamental and native plant species subject to three irrigation regimes. Negative growth the result of stem death or animal grazing. Values are the average growth of two plants of each species per irrigation treatment.

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