

Tree Production in Desert Regions Using Effluent and Water Harvesting

Martin M. Karpiscak¹ and Gerald J. Gottfried²

Abstract.—Treated municipal effluent combined with water harvesting can be used for land restoration and enhancing the growth of important riparian tree species. Paired studies in Arizona are assessing the potential of growing trees using mixtures of effluent and potable water. Trees are grown in the field and in containers. Initial results from the field show high survival for four of the six species; cottonwood and willow had rapid growth.

Introduction

In the Southwestern United States, Israel, and many other arid areas of the world, the prudent use of limited water supplies is critical for improving the management of desert environments. Growing competition for water has heightened interest in a variety of approaches for increasing available water. As the major metropolitan regions in arid areas continue to grow, the availability and volume of treated effluent have increased. This treated wastewater combined with harvested rainfall can be used for the restoration of degraded lands, and the growth of vegetation having commercial and environmental value may be possible.

It is believed that arboreal species take up large amounts of water and minerals, serving as effective biological sieves that inhibit recharge of the wastewater to the underground aquifer and reduce accumulation of minerals in the soil and the underground aquifer (Nelson 1995). The use of sewage water for irrigation has been shown to increase tree growth (Attiwill and Cromer 1982; Bialkirwicz 1978; Cromer et al. 1983; Dighton and Jones 1991; Stewart and Flinn 1984) and to increase the amount of minerals in the foliage of the plants (Brister and Schultz 1981, Neilsen et al. 1989). Results from Australia, however, (Hopmans et al. 1990) indicate that tree species differ greatly in their ability to absorb minerals when irrigated with municipal effluent.

The reuse of treated water as a source of supplemental water for constructed wetlands and maintaining riparian

areas in Arizona is an important management alternative (Karpiscak et al. 1996). Water harvesting techniques and appropriate use of treated effluent may provide opportunities for the rehabilitation and preservation of important riparian communities where irrigation and water diversion have lowered local water tables.

Studies established in the 1990s in the U.S. and Israel are evaluating the potential of growing trees using combinations of potable and effluent water supplemented by harvested rainwater for irrigation. The studies are part of a collaborative research program among The University of Arizona, the Volcani Center at Bet-Dagan, Israel, and the USDA Forest Service.

The major hypothesis of this research effort is that the use of reclaimed municipal effluent for irrigation of arboreal species will increase the growth rate of these plants in arid areas compared to irrigation with fresh water. A second hypothesis is that environmentally, there is no critical uptake of harmful constituents from the effluent by the plants or any adverse impacts to the soil irrigated with effluent.

Specific objectives of the research study both at The University of Arizona and in Israel are: (1) to study the effects of effluent irrigation on tree growth and production, (2) to determine the benefits of water harvesting techniques used in conjunction with wastewater irrigation on trees, and (3) to evaluate the ability of the selected tree species to absorb minerals and pollutants found in effluent.

This paper describes initial observations from the Arizona study and focuses on the tree survival rates and growth under different irrigation regimes. Detailed findings on water harvesting and soil and plant tissue analyses will be presented in subsequent reports. Project results from the Israeli study will be published in separate papers. No statistical analyses will be presented in this preliminary report; however, the 5% level will be used in the future to determine significance in growth among treatments.

Methods

The 1.3 ha field plot is located at a University of Arizona research farm. The plot consists of 13 rows with 5 m wide

¹ Research Scientist, The University of Arizona, Tucson, AZ

² Research Forester, USDA Forest Service, Flagstaff, AZ

water harvesting catchments graded perpendicular to the slope of the field. Separate drip lines along each row allow irrigation with a combination of reclaimed and potable water. Both lines are equipped with timers to ensure that proper amounts of irrigation water are provided to the individual plants if harvested rainfall is not available. Irrigation treatments reflecting five mixtures of water are applied. The five mixtures, expressed as % fresh water:% reclaimed municipal effluent are: 100:0, 75:25, 50:50, 25:75 and 0:100. Total water applied by the irrigation system is adjusted based on seasonal evapotranspirational losses. Plots are periodically treated by application of herbicides or by cultivation to control weeds.

Species planted include velvet ash (*Fraxinus velutina*), black willow (*Salix nigra*), Fremont cottonwood (*Populus fremontii*), Arizona sycamore (*Platanus wrightii*), eucalyptus (*Eucalyptus camaldulensis*) and Mondell pine (*Pinus eldarica*). Fifty individuals of each of the tree species were placed in a randomized complete block design along the rows. The first four species were selected because they are important riparian species in the Southwest. They were grown from pole cuttings. Mondell pine and eucalyptus are popular ornamental species in major urban areas of Arizona and were planted as transplants from plastic sleeves and 10 cm pots, respectively. The same species of eucalyptus is used in the experiments in Israel.

Planting of all species in the field was completed in December 1996. Ash and sycamore were replanted because of poor survival after the initial planting. The trees initially were fenced to protect them from rabbits and rodents until they had achieved adequate growth and size to survive browsing. Height measurements of pine and eucalyptus were begun in December 1996 and, of the other four species, in May 1997. Tree diameter at breast height measurements began in September 1997.

Soil samples were collected prior to planting in 1996 and again in December 1997. The first tissue samples will be collected from the field plants in late 1999 after they have achieved sufficient size to sustain the harvesting of 100 to 125 grams of leaf and stem tissue. The tissues will be analyzed for selected parameters such as sodium, chloride, phosphate, nitrate and copper.

A concurrent study was performed in containers to avoid the influence of differences in field soils. Experiments began in April 1997 at the Constructed Ecosystems Research Facility (CERF), about 0.8 km from the field plot when 120 plastic 120-liter containers were filled with clean mortar sand (<1 mm grain size). Ten replicates of each of the same six tree species as in the field plot were planted randomly in the containers. Pine and eucalyptus were planted as seedlings in May 1997; cottonwood, black willow, ash and sycamore were planted as poles, the first two species in June 1997, and the second in August 1997. Because of poor survival, cottonwood was replanted in November 1997.

Drip lines were installed to each of the containers, one to deliver fresh or potable water and one to deliver treated effluent. Emitters are placed randomly and each container is supplied with either 100% fresh water or 100% effluent water. The lines were equipped with timers so that each tree received an equal amount of effluent or fresh water as designated. No water mixtures were tested due to the logistics of installing more irrigation lines and maintaining large numbers of trees in containers.

Results and Discussion

Survival

Tree survival at the field site in December 1998 is shown in figure 1. Nearly 100% survival was achieved for pine, cottonwood and willow, regardless of the water mix. Ash had about an 80% survival rate overall while sycamore had about 60%. These rates for ash and sycamore are higher than the 30% and 50% survival rates observed in August 1997. It appears that pole plants of these two species are slower to take root and show less growth than willow and cottonwood. Eucalyptus had the lowest overall survival rate with mortality increasing between August 1997 and December 1998.

There appears to be little correlation between a species' survival rate and irrigation treatment in the field. All

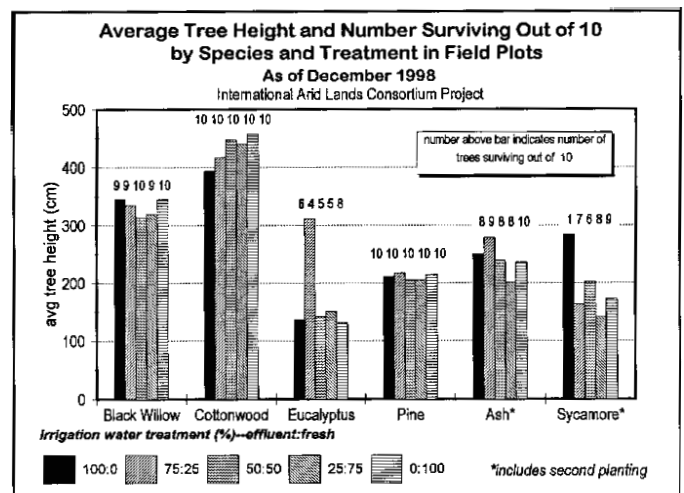


Figure 1. Average Tree Height and Number Surviving Out of 10 by Species and Treatment in Field Plots as of December 1998.

cottonwood and pine and most willows and ash survived regardless of irrigation scheme. For sycamore, however, the survival rate was only 10% when irrigated solely with effluent, but 90% when irrigated with 100% fresh water. Eucalyptus transplants had inconsistent survival responses to effluent irrigation, varying from 40% when treated with 75% effluent to 80% when supplied with only fresh water. However, in all instances in which there were differences in survival, plants supplied solely with fresh water appeared to have a slightly higher survival rate.

Survival data for the container trees are shown in figure 2. Willow, cottonwood and eucalyptus survival rates were similar but not identical, whether irrigated with fresh or effluent water. There was a slightly reduced survival for willow and cottonwood when irrigated with effluent. All eucalyptus seedlings survived, whether irrigated with fresh or effluent water. Pine appeared to have higher survival (100%) when irrigated with fresh water while ash did better (60%) with effluent water. No sycamore plants appeared to be alive in the containers in December 1998 (fig. 2).

One of the most interesting observations was the failure of the cottonwood pole plants (some 60 cuttings) to become established in the containers during the initial planting, in contrast to the nearly 100% survival obtained in the field. This finding also is in contrast to the survival of similar transplants in the gravel-filled subsurface constructed wetland cells at CERF. The survival rate for fresh water-irrigated container-grown vs. field-grown pine trees is 20% compared to 100%, a large difference. Sycamore also shows a large difference in survival: no container-

grown trees survived in December 1998 vs. about 60% of field-grown trees (figs. 1 and 2).

Growth

Cottonwood and black willow grew rapidly in the field plots. Many of the cottonwood trees were over 400 cm in height by December 1998 (fig. 1). Except for eucalyptus and sycamore, tree heights were more or less the same for a single species independent of the irrigation regime (fig. 1). Eucalyptus irrigated with 75% effluent:25% fresh water were almost twice as high (300 cm vs. 130 cm) as eucalyptus irrigated with the other treatments and sycamore grew to almost 300 cm when irrigated with 100% effluent.

As of December 1998, all species except eucalyptus showed more growth in the field than in the containers. This is due in part to the 6-month difference in planting time, but also perhaps to the difference in growing media. All container-grown species irrigated with effluent grew taller than those irrigated with fresh water (fig. 3). Eucalyptus seems to grow better in the sand in the containers than in the field (fig. 3). However, some individual eucalyptus trees in the field plots showed rapid growth. This finding supports results found by the Israeli team members. Pine initially responded well both in the field and in containers, but many of the container-grown trees have shown stress. Because of the need to keep the sand moist to establish other plants, the pines may have been over watered.

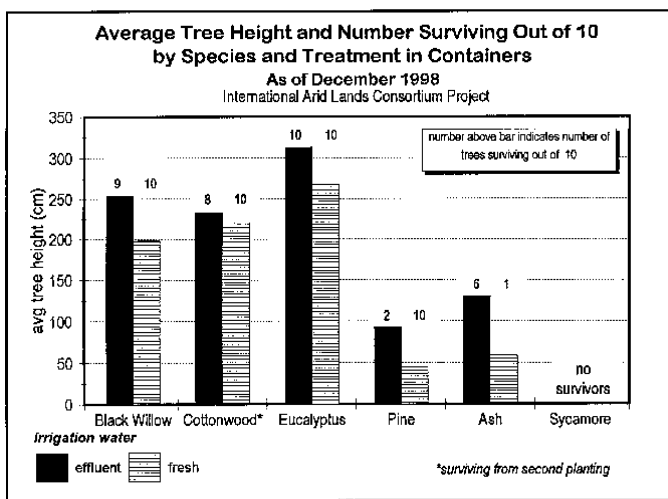


Figure 2. Average Tree Height and Number Surviving Out of 10 by Species and Treatment in Containers as of December 1998.

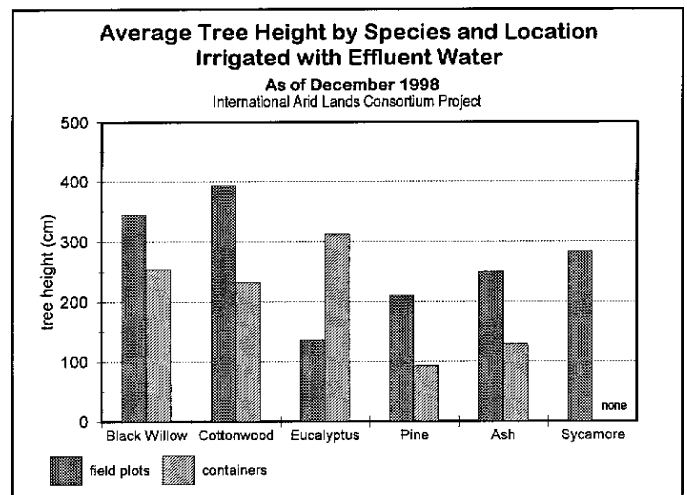


Figure 3. Average Tree Height by Species and Location Irrigated with Effluent Water as of December 1998.

Conclusions

Field tree survival rates in Arizona were 80% to 100% for most species. Initial survival rates for container-grown trees varied from those grown in the field. Sycamore pole-plants appear to have a higher rate of survival in field plots when supplied with fresh water, while ash in the containers appears to be the only species to have a higher survival rate when irrigated with effluent. Overall average growth appears best in cottonwood and willow grown in the field. The use of effluent may reduce survival rates slightly, but it also may stimulate the growth of some species once established because of nutrients found in the wastewater. However, this preliminary observation still needs to be statistically evaluated.

The use of supplemental irrigation water for trees in arid environments can achieve rapid establishment and growth of some trees such as cottonwood, willow and some eucalyptus. Initial results have shown that some species, especially cottonwood and willow in the field, grew to heights of 230 to 300 cm within 12 months of planting. In Arizona, all species except eucalyptus grew more in the field plots compared to growth in the containers when irrigated with effluent (fig. 3). These results indicate the potential for use of effluent for growing selected tree crops for wood production, aesthetics and environmental benefits.

Acknowledgments

The authors would like to acknowledge Drs Kenneth E. Foster and Leonard F. DeBano, University of Arizona, for their thoughtful and very helpful comments and suggestions. This research and development was supported in part by funds provided to the International Arid Lands Consortium (IALC), by the USDA Forest Service, Rocky Mountain Research Station, and by the USDA Cooperative State Research, Education, and Extension Service. The IALC was established in 1990 as a means to promote research, demonstrations, and training applied to development, management, restoration, and reclamation of arid and semiarid lands in North America, the Middle East, and elsewhere in the world. The facilities of CERF

were made available by the generosity of Pima County Wastewater Management Department.

Literature Cited

- Attiwill, P.M.C.; Cromer, R.N. 1982. Photosynthesis and transpiration of *Pinus radiata* D. under plantation conditions in southern Australia in response to irrigation with waste water. *Australian Journal of Plant Physiology*. 9: 749-760.
- Bialkiewicz, F. 1978. Some aspects of the purification and utilization of municipal sewage in forest plantation. *Sylvan*. 122: 7-17.
- Brister, G.H.; Schultz, R.V. 1981. The response of a southern Appalachian forest to waste water irrigation. *Journal of Environmental Quality*. 10: 148-153.
- Cromer, R.N.; Tompkins, D.; Barr, N.J. 1983. Irrigation of *Pinus radiata* with waste water, tree growth in response to treatment. *Australian Forest Research*. 13: 57-85.
- Dighton, J.; Jones, H.E. 1991. The use of roots to test N, P, and K deficiencies in Eucalyptus nutrition. IUFRO Symposium on Intensive Forestry: The Role of Eucalyptus. Durban, South Africa. Pp. 635-643.
- Hopmans, P.J.; Stewart, T.L.; Flinn, D.W.; T.J. Hillman, T.J. 1990. Growth, biomass production and nutrient accumulation by seven tree species irrigated with municipal effluent at Wodonga, Australia. *Forest Ecology and Management*. 30: 203-211.
- Karpiscak, M.M.; Gerba, C.P.; Watt, P.M.; Foster, K.E.; Falabi, J.A. 1996. Multi-species plant systems for wastewater quality improvement and habitat enhancement. *International Association on Water Quality. Water Science and Technology*. 33:231-236.
- Nelson, M. 1995. Conceptual design of zero discharge and safe discharge biological wastewater treatment systems using fast-growing wetland trees. M.S. Thesis, School of Renewable Natural Resources, The University of Arizona, Tucson, Arizona.
- Neilsen, G.H.; Stevenson, D.S.; Fitzpatrick, J.J.; Brownlee, C.H. 1989. Nutrition and yield of young apple trees irrigated with municipal waste water. *Journal of the American Society of Horticultural Science*. 114: 377-383.
- Stewart, J.T.L.; Flinn, D.W. 1984. Establishment and early growth of trees irrigated with waste water at four sites in Victoria. *Forest Ecology and Management*. 8: 81-88.