Figure 1. Overhead irrigation of koa and other species at the Hawai'i Division of Forestry and Wildlife Kamuela (Waimea) State Tree Nursery.

Early field performance of *Acacia koa* seedlings grown under subirrigation and overhead irrigation

Anthony S Davis, Jeremiah R Pinto, and Douglass F Jacobs

ABSTRACT

Koa (*Acacia koa* A. Gray [Fabaceae]) seedlings were grown with subirrigation and overhead irrigation systems in an effort to characterize post-nursery field performance. One year following outplanting, we found no differences in seedling height or survival, but root-collar diameter was significantly larger for subirrigated seedlings. This indicates that koa seedlings, with equal or better morphological quality compared with overhead irrigated seedlings, can be effectively produced using subirrigation systems, thus allowing for potential reductions in water use and wastewater during nursery culture.

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KEY WORDS
Hawai'i, seedling quality, water management, Fabaceae

NOMENCLATURE
USDA NRCS (2011)

Photos by Anthony S Davis

Koa (*Acacia koa* A. Gray [Fabaceae]) is an ecologically and economically important endemic species in Hawai'i, and significant efforts are being devoted toward restoration of degraded koa forestland (Whitesell 1990; Scowcroft and Jeffrey 1999). Advances in outplanting techniques have helped to improve koa seedling establishment (Scowcroft and Jeffrey 1999); nonetheless, the first step in successful field establishment begins with nursery cultural practices used to raise seedlings. Irrigation in native plant nurseries is a critical component of nursery culture. Effective water management can have a major influence on plant quality, operating costs, and environmental impact (Dumroese and others 1995). Seedlings produced in native plant nurseries are typically overhead irrigated (Figure 1), resulting in considerable loss of water and nutrient leaching; however, new irrigation systems, such as subirrigation, may produce quality seedlings while reducing environmental and financial costs through resource conservation.

Recently, several studies have compared the effects of subirrigation and overhead irrigation practices on native plant development. Using koa seedlings, Dumroese and others (2011) found no differences in morphology and photosynthetic rate between subirrigated and overhead irrigated seedlings, but they did detect higher foliar nitrogen concentration in subirrigated seedlings. Similarly, in 2 separate studies using pale purple coneflower (*Echinacea pallida* (Nutt.) Nutt. [Asteraceae]) and northern red oak (*Quercus rubra* L. [Fagaceae]), subirrigated seedlings had improved nitrogen use efficiency compared with overhead irrigated controls (Bumgarner and others 2008; Pinto and others 2008). Because subirrigation may notably reduce water use for crop irrigation (Dumroese and others 2006), decrease nutrient leaching (Bumgarner and others 2008; Dumroese and others 2011), and produce seedlings of similar or greater size for a number of species (Bumgarner and others 2008; Davis and others 2008; Pinto and others 2008; Dumroese and others 2011), continued exploration of the impacts of subirrigation on post-nursery seedling performance is necessary.

Our study objective was to evaluate the effect of nursery irrigation technique (overhead versus subirrigation) on koa outplanting success. Given the importance of water conservation in Hawai'i, subirrigation could prove to be highly beneficial to nursery producers if seedling quality can be maintained during nursery culture and following outplanting. We hypothesized that growth and survival would not be influenced by nursery irrigation practices.

MATERIALS AND METHODS

We produced subirrigated (Figure 2) and overhead irrigated seedlings at the Hawai'i Division of Forestry and Wildlife Kamuela (Waimea) State Tree Nursery, on the Island of Hawai'i (lat 20°00′24″N, long 155°40′38″W). Using a Mauna Kea seed source, seedlings were grown in D-16 containers (Stuewe and Sons Inc, Tangent, Oregon), which provided a cavity volume of 262 ml (16 in^3) at a growing density of 269 cavities per m^2 (25 per ft^2). Seeds were sown in January 2009 and grown for 16 wk using the current nursery cultural practices described in Dumroese and others (2011). Seedlings were outplanted on 8 May 2009 at approximately 1980 m (6500 ft) elevation on the windward side of Mauna Kea within the Kanakalea Nui Bird Corridor. Three replicates were established containing 15 seedlings each of subirrigated and overhead irrigated seedlings. On 5 May 2010, seedling height and root-collar diameter (RCD) were measured and survival tallied. We conducted an analysis of variance on our data using the PROC MIXED function in SAS (SAS Institute Inc, version 9.2, Cary, North Carolina). Survival data were transformed using arcsine to meet the assumptions of the ANOVA. Differences were considered significant when $P < 0.05$.

Figure 2. Subirrigated koa seedlings.

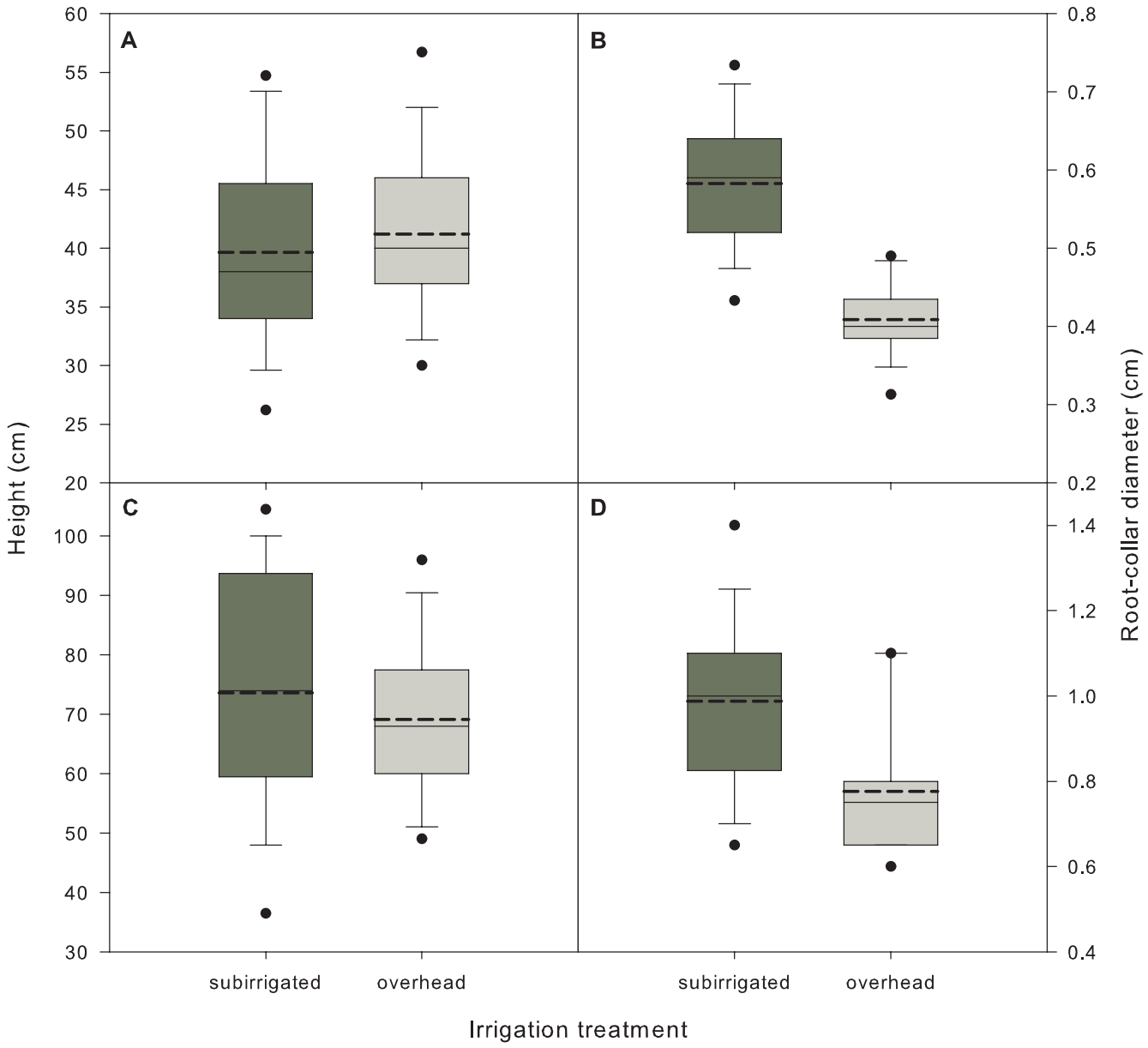

Figure 3. Initial (A and B) and 1-y (C and D) outplanting height and root-collar diameter of koa seedlings. Box plots show the distribution as follows: boxes represent the 25th to 75th percentiles, error bars represent the 10th and 90th percentiles, the solid line is the median, the dashed line is the mean, and the black dots are outlying points.

RESULTS AND DISCUSSION

At the time of outplanting, height of subirrigated (39.6 ±1.22 cm; mean ± standard error; [1 cm = 0.39 in]) and overhead irrigated (41.1 ±1.11 cm) seedlings were statistically similar ($P = 0.3502$) (Figure 3A). Irrigation method did affect ($P < 0.0001$) initial RCD, with subirrigated seedlings significantly larger (0.58 ±0.01 cm) than overhead irrigated seedlings (0.41 ±0.01 cm) (Figure 3B). While these results differ from those presented for koa by Dumroese and others (2011), they are not entirely unexpected given the increase in biomass in subirrigated pale purple coneflower (Pinto and others 2008) and northern red oak (Bumgarner and others 2008) seedlings.

One y after outplanting (Figure 4), seedling survival was statistically similar ($P = 0.1076$) for subirrigated and overhead irrigated seedlings (64.4 ±11.1 and 42.2 ±13.5%, respectively). Mean survival for both treatments was relatively high for this elevation given that frost protection devices were not used (Scowcroft and Jeffrey 1999). Height did not differ ($P = 0.3812$) between subirrigated (73.7 ±3.67 cm) and overhead irrigated (69.2 ±2.92 cm) seedlings (Figure 3C). Significant differences ($P = 0.0002$) in seedling RCD persisted at this time

Figure 4. Subirrigated koa seedling 1 y following outplanting at the Kanakalea Nui Bird Corridor on the Island of Hawai`i.

with subirrigated seedlings being larger than overhead irrigated seedlings (0.99 ±0.04 cm and 0.78 ±0.03 cm, respectively) (Figure 3D). While our study showed no growth differences ($P > 0.6919$) across irrigation regimes following outplanting, Bumgarner and others (2008) found increased RCD growth in subirrigated versus overhead irrigated northern red oak seedlings following outplanting. Subirrigation practices can lead to higher foliar nutrient concentrations for some native plants (Bumgarner and others 2008; Pinto and others 2008; Dumroese and others 2011), which may be of benefit to field establishment.

Because koa is extremely important in the restoration of degraded forests (Scowcroft and Jeffrey 1999), and because it has high timber value (Whitesell 1990), production of koa seedlings, and other endemic Hawaiian plants, will continue. Simultaneously, nursery cultural practices must constantly evolve, striving to improve seedling quality while decreasing environmental (that is, water and nutrient runoff) and financial (that is, fertilizer and water) costs wherever possible. Currently, options for implementing subirrigation systems in existing nurseries are wide ranging; it is possible for nurseries to find simple methods to convert to such a system, and reap the rewards, without undue cost (Schmal and others 2011).

CONCLUSION AND FUTURE DIRECTIONS

With relatively few studies examining the comparative field performance of subirrigated and overhead irrigated seedlings, this field trial makes an important contribution toward understanding subsequent field performance of subirrigated seedlings. These findings support our hypothesis that subirrigated seedlings perform on par with overhead irrigated seedlings. Furthermore, it is possible that continued tailoring of nursery practices (for example, irrigation and nutrient treatments) could further improve seedling quality (Pinto and others 2011), which should promote higher survival and growth following outplanting. With the known benefit of reduced nursery water use (Dumroese and others 2006), it is likely that broader adoption of this method of irrigation could improve water-use efficiency at Hawaiian native plant nurseries.

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AUTHOR INFORMATION

Anthony S Davis
Assistant Professor
Center for Forest Nursery and Seedling Research
College of Natural Resources
University of Idaho
Moscow, ID 83843
asdavis@uidaho.edu

Jeremiah R Pinto
Research Plant Physiologist
USDA Forest Service
Rocky Mountain Research Station
Grassland, Shrubland, and Desert Ecosystem Program
1221 S Main Street
Moscow, ID 83843
jpinto@uidaho.edu

Douglass F Jacobs
Professor
Hardwood Tree Improvement and Regeneration Center
Department of Forestry and Natural Resources
Purdue University
West Lafayette, IN 47907
dfjacobs@purdue.edu