Fertilizer, Irrigation and Root Ball Slicing Affects Burford Holly Growth after Planting[1]

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Abstract

Dwarf burford holly (*Ilex cornuta* 'Burfordii Nana') fertilized with 22.1 g N/container/yr of nitrogen during production in the nursery generated more new shoot weight but less root weight after transplanting to a landscape than those receiving 14.8 g N/container/yr. Slicing the root ball at planting, compared to not slicing, resulted in comparable regenerated root weight but reduced new shoot number, new shoot dry weight and new shoot:regenerated root dry weight ratio when irrigation was not applied daily after transplanting. Although irrigation frequency did not impact total weight of regenerated roots into landscape soil, more roots grew from the bottom half of the root ball when plants were irrigated periodically after planting than when plants received daily irrigation. Plants irrigated other than daily produced fewer shoots and less shoot weight than those receiving irrigation daily after transplanting. When plants were without irrigation for 4 or 6 days in the first week after transplanting, those planted without the nursery container on the root ball were more stressed (more negative xylem potential) than those planted with the container still on the root ball. However, two weeks later, plants without the nursery container were less stressed due to root growth into landscape soil.

Index words: landscape, transplanting, containers, root distribution, root regeneration, water stress, xylem potential.

Species used in this study: Dwarf Burford holly *Ilex cornuta* Lindl. & Paxt. 'Burfordii Nana'.

Significance to the Nursery Industry

Plants receiving a high fertilizer rate (22.1 g N/container/yr) during nursery production had greater shoot weight at transplanting but generated less root weight after transplanting than those receiving less fertilizer (14.8 g N/container/yr). This could make them more sensitive to dry soil conditions after planting. Without daily irrigation, root balls on plants from containers that were sliced to eliminate circling roots regenerated the same amount of roots after transplanting as those not sliced but less shoot weight than those not sliced. In addition to eliminating potentially girdling roots, slicing container root balls might increase survival on landscape sites with limited irrigation by reducing the shoot:root ratio in the months following transplanting. Irrigating regularly, but not daily, after transplanting generated a deeper root system than daily irrigation. This points to the potential for developing an undesirably shallow root system with extended daily irrigation after transplanting. Plants from containers require more frequent irrigation for a week or two after planting in the summer than before planting to maintain comparable water status in the plant.

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Introduction

Lack of water may be the most limiting factor in establishing container-grown trees and shrubs in the landscape

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(8). After removing the container from the root ball, up to 85% of the available water moves out of the root ball into the surrounding soil within a few hours of planting (14). To reduce the rapid depletion of water from the container medium after planting, Beeson (4) placed a concave plastic sheet beneath and extending several inches beyond the container root ball before backfilling. This treatment resulted in significantly more root growth on *Photinia frazeri* Dress. compared to a traditional planting without the plastic sheet.

However, there are few published studies evaluating the impact of irrigation frequency and/or soil moisture content on post-planting survival and growth. One study conducted in the coolest and wettest time of year in southern California showed little difference in growth and plant quality from irrigating once a day or once a week after planting with 60% historical reference evapotranspiration (16). Results may have been different if the study was conducted during the most stressful time of year, that is in the dry, hot summer.

Another factor besides water that can influence the long-term growth of transplanted plants is root circling. If circling roots are not cut, they could choke the plant by restricting subsequent trunk growth (15). Some horticulturists recommend that roots circling a container be cut before planting to help eliminate girdling and to stimulate root growth into the backfill soil. Although cutting roots can eliminate potential girdling, there is no evidence that slicing the root ball from top to bottom has any impact on root growth after planting (1, 19). Dana and Blessing (9) found that shoot growth reduction was negligible from root pruning container-grown shrubs at planting.

The shoot:root ratio of some herbaceous (7) and woody plants (21) grown in containers with high N rates increased with increasing rates of N due to greater shoot growth while root growth remained unaffected or even decreased. Thus low N levels in containers might be desirable for a period of time prior to transplanting since trees and some other woody plants allocate more biomass to roots than to shoots in low N environments (13, 20, 21).

We conducted the following experiment to investigate the influence of production fertility rate, root slicing and post-transplant irrigation on establishment and growth of *Ilex cornuta* 'Burfordii Nana'. A second experiment was designed to determine if removing a container from the root ball and planting in landscape soil changed the irrigation requirements compared to leaving the root ball in the container.

Materials and Methods

Experiment 1: Two-hundred multiple branched liners of *Ilex cornuta* 'Burfordii Nana' were potted in March 1989 in 2.8 liter (trade 1 gal) containers using a native peat:pine bark:cypress mulch:sand (47:27:17:5 by vol) growth medium amended with dolomitic limestone at 4.2 kg/m^3 (7 lb/yd^3), urea-formaldehyde at 0.54 kg/m^3 (0.9 lb N/yd^3), and Rally micronutrients at 1.8 kg/m^3 (3 lb/yd^3, Growers Fertilizer Cooperative, Lake Alfred, FL). Plants were grown on polypropylene ground cover at Greenbriar Nurseries, Inc., Dunnellon, FL, in a randomized complete block design with 10 replicate plants for each fertilizer treatment in each of 10 blocks. Marico 18N–1.7P–8.3K–2MG (18–4–10-2, Seminole Stores, Inc., Ocala, FL) granular fertilizer containing urea-formaldehyde N was surface-applied at two rates, 5.8 g N and 8.6 g N/container/yr. The lower rate is considered standard by growers producing plants of this size. Fertilizer was divided into 5 equal applications made April 5, May 10, July 14, August 29 and October 31, 1989. Plants received 0.76 cm (0.33 in) of water by overhead irrigation as needed (nearly daily in summer).

Plants were repotted January 1990 using a native peat:pine bark:cypress sawdust:sand (54:27:9.5:9.5 by vol) growth medium in 10 liter (3 gal) containers. Growth medium amendments, cultural protocols and experimental design were the same as in 1989. Marico 18–4–10–2 application rates were 14.8 g N/container/yr (applied to plants that previously received 5.8 g N/container/yr) and 22.1 g N/container/yr (applied to plants that previously received 8.6 g N/container/yr). The lower rate was considered the standard for producing a plant of this size. Fertilizer was divided into 5 equal applications made April 16, June 15, July 25, September 6 and October 30, 1990. On November 26, 1990, plant height was measured on 3 plants in each block for both fertilizer rates (30 plants per rate).

In late January 1991, 6 plants were choosen at random from both treatments and plants were severed at the soil line. Dry weight was determined on leaves and stems. Total N in leaf tissue was determined for each plant. Five equally spaced, 2.5 cm (1 in) deep slices were made on each of 12 root balls (6 from both fertilizer treatments) from top to bottom and along the undersides. Roots cut from the ball were separated from those that remained intact with the plant by washing the growth medium from the roots. Roots in each group were placed into diameter classes of 0–1 mm, >1–2mm, >2–5 mm, and >5 mm and dry weight determined.

February 20, 1991, 24 plants were randomly selected from both fertilizer treatments and planted into a simulated landscape (48 plants total) at Gainesville, FL (USDA hardiness zone 8). Before planting, root balls were sliced as described above on half the shrubs (12 plants) in each treatment. Plants were installed under a rainout shelter into Astatula fine sand in 113 liter (30 gal), 56 cm (22 in) diameter × 46 cm (18 in) deep cylindrical metal containers open at the bottom to the same soil type. This prevented formation of a perched water table. The plastic-covered rainout shelter excluded 38% of full sun light and all rain and surface drainage water from the study area. Day time high temperatures averaged 3C (5F) higher under the shelter than outside.

The first week after planting, 7.5 cm (3 in) water was applied daily to all 48 plants. The volume was changed to 4 cm (1.6 in) for all subsequent irrigations until the experiment terminated on June 13, 1991. After the first week, half the plants (24) of each treatment were irrigated daily (daily irrigated) and the other half were irrigated only when predawn xylem potential (measured daily) of 5 cm (2 in) long shoots reached –0.4 MPa (mean = –0.54 MPa) on at least two of the 24 plants (periodic irrigation). This predawn xylem potential was chosen because it typically indicated that mid-day xylem potential would reach approximately –1.8 MPa. At –1.8 MPa, diffusive resistance increased dramatically on burford holly (Fig. 1). This strategy stressed the plants before there were rewatered. Mid-day measurements were not used to determine when plants were irrigated because xylem potential reacted to the weather conditions during the day. To determine the frequency of irrigation that would result in increased diffusive resistance induced by water stress, we stopped irrigating 5 additional plants in late May, 1992. Every two days, diffusive resistance (LI-

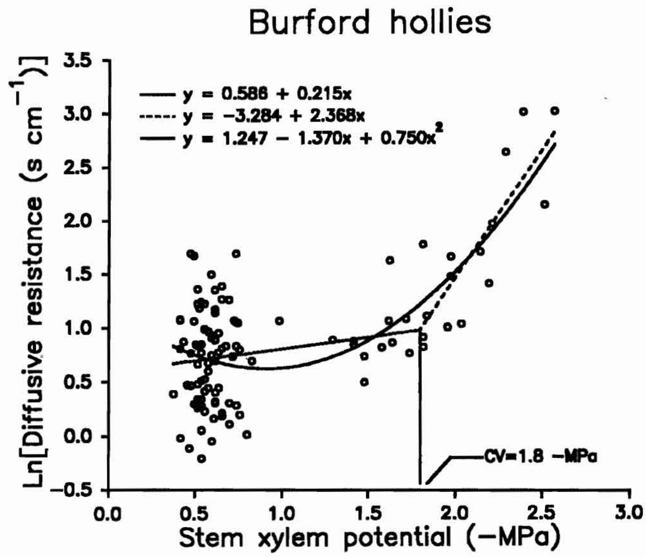

Fig 1. Relationship between *Ilex cornuta* 'Burfordii Nana' diffusive resistance and xylem potential during 8 days without irrigation.

1600 Steady State Porometer, Li-Cor, Inc., Lincoln, NE) and xylem potential were recorded simultaneously at 900, 1100, 1300 and 1500 HR. The relationship between these two is shown in Fig. 1. The point on the curve which indicated an increase in diffusive resistance was identified with the nonlinear regression (NLIN) procedure of SAS (17). The 5 plants used to determine this relationship were excluded from further use.

Average time between irrigations was 7 days (range 6 to 9). Diurnal xylem potentials measured with a pressure chamber (Model 3001, SoilMoisture Corp., Santa Barbara, CA) were recorded on February 21, March 7, March 14, April 15 and June 12, 1991. Measurements were taken predawn, 0900, 1100, 1300, 1500 and 1700 HR. Cumulated water stress was determined for each diurnal xylem potential curve by calculating the area over the diurnal curve to 0 MPa and presenting it as MPa-hr ($S\Psi$) (5). This permitted us to quantify the water status of each plant and make comparisons among treatments. Lower $S\Psi$ values indicated lower water stress. Both levels of all three treatments (fertilizer rate, root ball slicing, irrigation after planting—8 treatment combinations total) were included in each of 6 blocks in a 2 × 2 × 2 factorial in a randomized complete block design with single plant replicates in each block.

Plants were harvested at the conclusion of the experiment. New shoot numbers, new shoot dry weights, and dry weight of roots growing into the backfill soil were recorded for each plant. Roots originating from the top half of the root ball were dried separately from those growing from the bottom half.

Experiment 2: Seventy-two burford holly grown in 2.8 liter (1 gal) containers as described above with the lower rate of N were repotted into 10 liter (3 gal) containers in late fall 1991. On June 22, 1992, 48 were planted in soil under the rainout shelter in the same bottomless containers that simulated a landscape described for Experiment 1. Containers on 24 of these were removed before planting (NC); containers were not removed on the other 24 (YC) in order to compare water usage between YC and NC plants. YC containers were rotated in the planting hole about every 2 weeks to prevent roots from growing into the soil. A third set of 24 plants was placed under the rainout shelter but were left above ground in the original 10 liter containers (AC). All plants received 9.8 liter (2.6 gal) each time they were irrigated.

One set of 6 plants from each of the 3 planting treatments was watered daily, one set of 6 was watered every other day, one set was watered every fourth day, and a fourth set was watered 2 and 8 days after planting then every 14 or 16 days. Treatments were arranged in a 4 × 3 factorial in a randomized complete block design with single plant replicates in each block.

Diurnal xylem potential was measured periodically after planting. Cumulated water stress ($S\Psi$) was calculated for each diurnal xylem potential curve by calculating the area over the curve as described for Experiment 1. New shoot number, new shoot dry weight and dry weight of roots growing into backfill soil were measured at the end of the experiment September 18, 1992. Roots growing from the top half of the root ball were separated from those growing from the bottom half.

Data were analysed with analysis of variance and regression using SAS GLM and NLIN procedures (17).

Results and Discussion

Experiment 1: At the end of the production period (November 1990), heights of holly were not significantly different for plants that received a total of 14.8 or 22.1 g N from 5 applications of Marico 18–4–10–2. As Gilliam et al. (11) and Yeager et al. (20) found, leaf N content was greater ($P < 0.05$) for plants grown with the higher fertilizer rate (1.97%) than the lower rate (1.71%). Shoot dry weight (150.0 g) and shoot:root dry weight ratio (1.9) on plants grown in containers receiving the high rate of fertilizer were greater ($P < 0.05$) than on those receiving the lower rate (133.8 g and 1.7, respectively). Yeager and Wright (21) had similar results with *Ilex crenata* Thunb. 'Helleri'. There were no other differences between fertilizer treatments at the end of the nursery production portion of Experiment 1.

Neither fertilization rate during production nor root ball slicing at planting (in agreement with 9) had an effect on diurnal xylem potential after transplanting in the simulated landscape. However, plants receiving daily irrigation were less ($P < 0.05$) water stressed than those irrigated less frequently. Interactions were not significant for water potentials.

Plants receiving the higher fertilizer rate during production generated more ($P < 0.05$) new shoot weight (68.7 vs. 59.5 g) but less new root weight (32.1 vs. 39.2 g) after transplanting than those receiving the lower fertilizer rate (Table 1). This coincided with *Ilex crenata* 'Helleri' grown in containers (21). Consequently, after transplanting into the simulated landscape new shoot weight:new root weight ratio was greater for plants grown in the nursery with the higher fertilizer rate than for those grown with the lower rate.

Root ball slicing removed 6.4% of the root weight from the root ball; whereas, Arnold and Struve (2, 3) found that from 0 to 50%, depending on species, was removed when root balls were vertically sliced in four places 2.5 cm (1 in) deep. Slicing at transplanting resulted in reduced new shoot

Table 1. Analysis of variance for Burford Holly response to fertilization, irrigation, and root slicing.

Source of variation	New shoot dry weight	New shoot number	New shoot:new root dry weight ratio	Regenerated root dry weight	Regenerated roots from top half of ball:regenerated roots from bottom half of ball dry weight ratio
Fertilizer	**[z]	NS	**	*	NS
Slicing root ball	NS	NS	NS	NS	NS
Fertilizer x slicing	NS	NS	NS	NS	NS
Irrigation	***	***	***	NS	***
Fertilizer x irrigation	NS	NS	NS	NS	NS
Slicing x irrigation	*	*	**	NS	NS
Fertilizer x slicing x irrigation	NS	NS	NS	NS	NS

[z]NS, *, **, ***: Not significant or significant at 5%, 1%, 0.1% respectively.

number (78.8 vs. 107.3), new shoot dry weight (20.2 vs. 32.5 g) and new shoot:regenerated root dry weight ratio (0.7 vs. 1) only when irrigation was not applied daily after transplanting. With daily irrigation, slicing had no impact on root or shoot growth in the 4 months after transplanting. However, most roots appeared to regenerate from along the sliced portion of the root ball, whereas roots were more or less randomly distributed in the non-sliced root balls. Struve (18) found no difference in shoot or trunk growth of 3 tree species in the first 3 years after planting due to root ball slicing.

Compared to fertilizer rate and root ball slicing, irrigation frequency after planting had the greatest impact on shoot growth (Table 1). New shoot dry weight and new shoot number were significantly greater for plants receiving daily irrigation after transplanting than those irrigated periodically. Although irrigation frequency had no impact on total weight of regenerated roots into landscape soil, frequency impacted distribution of regenerated roots. More roots grew from the bottom half of the root ball when plants were irrigated periodically after planting (88%) than when plants received daily irrigation (77%). In other words, irrigating infrequently after planting shifted roots from the top of the soil profile to the bottom. Shrubs with a deeper root system might be able to withstand longer periods of drought because the deeper soil layers dry slower than the top portion of the soil profile.

Experiment 2: Holly planted with the container on the root ball (YC) responded similarly in all respects to those in the container and not planted (AC). Therefore, data for the planting treatment AC will not be presented.

There were no significant differences in SΨ between holly planted with the container and those without the container if irrigated daily or every other day (Fig. 2). There was no difference in xylem potential between holly irrigated daily and those irrigated every two days. When plants were left without irrigation for 4 or 6 days in the first week after planting (July 1), holly without the container were more stressed (greater SΨ, $P < 0.01$) than those planted with the container. This accounted for the significant interaction ($P < 0.01$) between irrigation and planting treatment. Costello and Paul (8) also showed that root balls of *Liquidambar styraciflua* L. planted without the container lost water faster than trees with the container left on the root ball. Nelms and Spomer (14) also indicated that the root ball dries quicker when planted in the landscape than it did in the container due to water quickly draining from the root ball after planting. This makes container trees very susceptible to drought until roots grow into the landscape soil, and shows that plants from containers need more irrigation after planting than before. Other work shows that *Pinus elliottii* Engelm. planted from plastic containers establish in the landscape slower than B&B trees from a field nursery (6).

Seventeen days after planting (July 9, 1992), SΨ of plants irrigated 4 and 14 days earlier was greater ($P < 0.01$) than for the more frequently watered plants. There were no differences in SΨ between planting treatments except that holly planted with the container that had not received irrigation for 14 days had greater SΨ ($P < 0.01$) and lower predawn xylem potential than all other treatment combinations (Fig. 2). This accounted for the significant interaction between irrigation and planting treatment. Lower stress on plants without the container might indicate that roots were growing out of the root ball into the backfill soil. To check for this we removed two plants that were not included in the data analysis from the soil and saw many roots several cm long growing into the backfill soil. This was not surprising since Arnold and Struve (2) found that intact roots of container grown trees continue growing at a rate of 1 cm (0.4 in) per day after planting.

On July 25, xylem potential on plants in containers last irrigated 16 days earlier was lower ($P < 0.01$) than other irrigation treatments and well below −1.8 MPa (Fig. 2). Xylem potential below −1.8 MPA corresponds with a dramatic reduction in diffusive resistance (Fig. 1) Plants without the container receiving the same irrigation treatment were more stressed (greater SΨ) than those receiving more frequent irrigation ($P < 0.01$), but the xylem potential was above −1.8 MPa. Sixteen days later (August 10), all plants with the container receiving irrigation every 16 days were dead. Those irrigated every 16 days without the container had greater SΨ than holly receiving more frequent irrigation but all plants appeared healthy.

Holly planted without the container generated more ($P < 0.001$) new shoot weight (mean 12.5 g) and shoot number (mean 38.7) than those left in the container (mean 1.4 g and 5.3, respectively, Fig. 3). Since water stress with daily or every other day irrigation was similar for both planting methods (Fig. 2) some other factor such as mineral availability in the soil and medium may have impacted shoot growth. There was no significant ($P = 0.08$) effect of irrigation on shoot length and the interaction between planting treatment and irrigation was not significant.

With irrigation frequencies of daily, every 2 days or every 4 days, from 40% to 49% of roots (no significant difference) growing into the backfill soil originated from the top half of

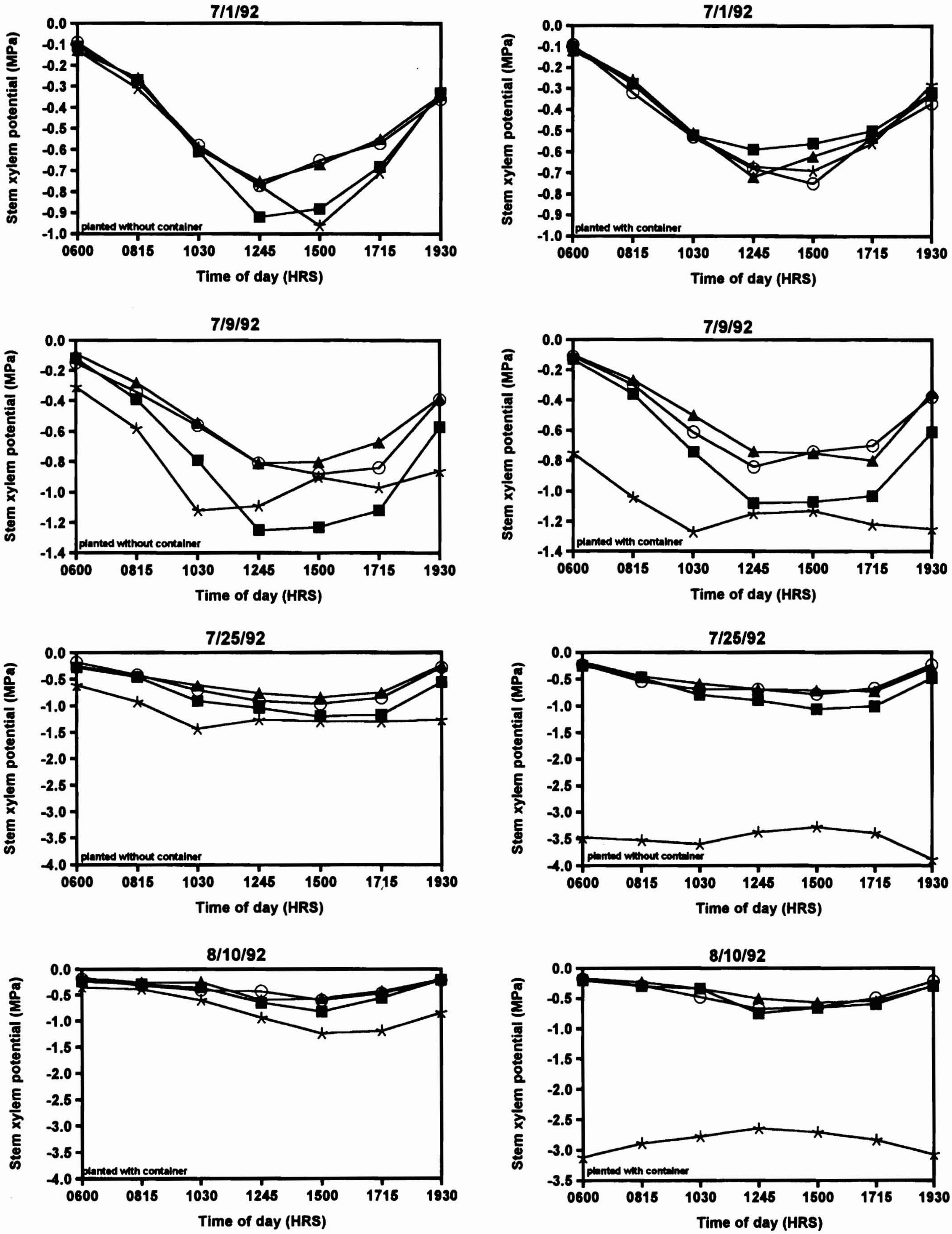

Fig 2. *Ilex cornuta* **'Burfordii Nana' Diurnal xylem potential in each irrigation treatment after transplanting to simulated landscape and with or without container removed from root ball. Plants were irrigated every day (triangle), every two days (circle), every four days (square) or every 14–16 days (star).**

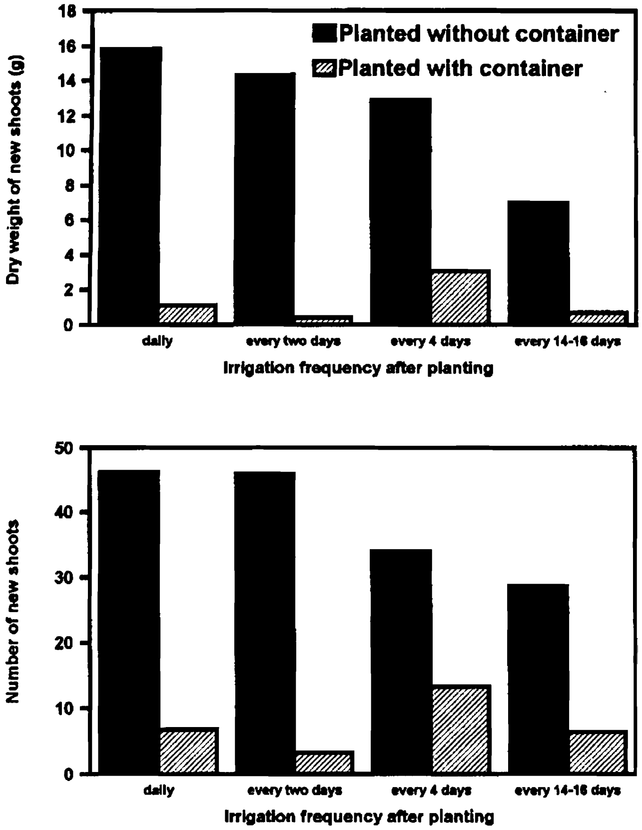

Fig 3. Shoot dry weight and shoot number for *Ilex cornuta* 'Burfordii Nana' planted with and without the nursery container into a simulated landscape under four irrigation treatments.

a root ball. Only 16% originated from the top half of a root ball on plants receiving irrigation every 14 to 16 days which supports the findings in the first experiment. This redistribution ($P < 0.05$) on infrequently irrigated plants is common on grasses (10) and may be due to dry soil at the top of the soil profile that is poorly suited for root growth. It could also be due to improved aeration near the bottom half of the root ball in the infrequently irrigated plants. Perhaps daily irrigation kept the soil too wet deeper in the soil profile for vigorous root growth.

The shoot:root dry weight ratio for plants without the container and irrigated every 14–16 days (1.7) was lower ($P < 0.1$) than for plants irrigated daily (5.5) as in the first experiment. This has been noted for other plants (7) and is recognized as a response to drought conditions. Dry matter diversion from the shoot into the root system in a drought environment has a survival value for plants. Moreover, since roots on water stressed plants often grow best in the deeper soil layers (12), plants have access to additional water reserves during periods of drought.

Literature Cited

1. Arnold, M.A. and D.K. Struve. 1989. Cupric carbonate controls green ash root morphology and root growth. HortScience 24:262–264.

2. Arnold, M.A. and D.K. Struve. 1989. Growing green ash and red oak in $CuCO_3$-treated containers increases root regeneration and shoot growth following transplant. J. Amer. Soc. Hort, Sci. 114:402–406.

3. Arnold, M.A. and D.K. Struve. 1989. Green ash establishment following transplant. J. Amer. Soc. Hort. Sci. 114:591–595.

4. Beeson, Jr., R.C. 1994. Root growth and water status of container grown *Photinia frazeri* Dress. transplanted into a landscape. HortScience 29:1295–1297.

5. Beeson, Jr., R.C. 1992. Restricting overhead irrigation to dawn limits growth in container-grown woody ornamentals. HortScience 27:996–999.

6. Beeson, Jr., R.C. and E.F. Gilman. 1992. Diurnal water stress during landscape establishment of slash pine differs among three production methods. J. Arboriculture 18:281–287.

7. Boote, K.J. 1977. Root:shoot relationships. Soil and Crop Sci. Soc. Fla. Proc. 36:15–23.

8. Costello, L.R. and J.L. Paul. 1975. Moisture relations in transplanting container plants. HortScience 10:371–372.

9. Dana, M.N. and S.C. Blessing. 1994. Post-transplant root growth and water relations of *Thuja occidentalis* from field and containers. *In*: Watson, G.W. and D. Neely (eds.), Landscape below ground, International Soc. Arboriculture, Savoy, IL.

10. Doss, B.D., D.A. Ashley, and O.L. Bennett. 1962. Effect of soil moisture regime on root distribution on warm season forage grasses. Agron. J. 54:569–572.

11. Gilliam, C.H., S.M. Still, S. Moor, and M.E. Watson. 1980. Effects of three nitrogen levels on container-grown *Acer rubrum*. HortScience 15:641–642.

12. Huck, M.G., C.M. Peterson, G. Hoogenboom and C.D. Busch. 1986. Distribution of dry matter between shoots and roots of irrigated and non-irrigated determinate soybeans. Agron. J. 78:807–813.

13. Munson, A.D. and V.R. Timmer. 1990. Site-specific growth and nutrition of planted *Picea mariana* in the Ontario Clay Belt. III. Biomass and nutrient allocation. Can. J. For. Res. 20:1165–1171.

14. Nelms, L.R. and L.A. Spomer. 1983. Water retention of container soil transplanted into ground beds. HortScience 18:863–866.

15. Nichols, T.J. and A.A. Alm. 1983. Root development of container-reared, nursery-grown, and naturally regenerated pine seedlings. Can. J. For. Res. 13:239–245.

16. Paine, T.D., C.C. Hanlon, D.R. Pittenger, D.M. Ferrin, and M.K. Malinoski. 1992. Consequences of water and nitrogen management on growth and aesthetic quality of drought-tolerant woody landscape plants. J. Environ. Hort. 10:94–99.

17. SAS. 1992. SAS/STAT Users guide. SAS Institute, Inc., Cary, NC.

18. Struve, D.K. 1993. Effect of copper-treated containers on transplant survival and regrowth of four tree species. J. Environ. Hort. 11:196–199.

19. Wade, G.L. and G.E. Smith. 1985. Effect of root disturbance on establishment of container grown *Ilex crenata* 'Compacta' in the landscape. Proc. Southern Nurseryman Assoc. Res. Conf. 30:110–111.

20. Yeager, T.H., R.D. Wright, and M.M Alley. 1980. Response of *Ilex crenata* Thunb. cv. Helleri to timed fertilizer applications. J. Amer. Soc. Hort. Sci. 105:213–215.

21. Yeager, T.H. and R.D. Wright. 1981. Influence of nitrogen and phosphorus on shoot:root ratio of *Ilex crenata* Thunb. 'Helleri'. HortScience 16:564–565.