Effect of Cyclic Irrigation on Growth of Magnolias Produced Using Five In-ground Systems[1]

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Abstract

Five in-ground systems were evaluated based on shoot growth and marketability for the production of 2.17 m (7 ft) tall and 5.08 cm (2 in) trunk diameter *Magnolia grandiflora* cv. 'Symmes Select'. Systems evaluated were Root Control Bags, Geo-Cell bags, and #25 containers in pot-in-pot in Experiment 1, and Agro-liners in socket pots and directly in-ground in Experiment 2. Each system was either cyclically irrigated or given a single irrigation event daily. In Experiment 1, cyclic irrigation increased the rate of height growth and trunk diameter compared to a single irrigation. Trees in Root Control Bags and pot-in-pot grew at a similar rate and faster than those in Geo-Cell bags. Faster growth rates with cyclic irrigation resulted in earlier marketability compared to single irrigation daily, except for pot-in-pot. In Experiment 2, cyclic irrigation increased the rate of trunk diameter growth, and Agro-liners in pots had greater height and trunk diameter growth rates than those directly in ground. Trees grown in the in-ground pot systems, whether in Agro-liners or black polyethylene containers, grew similarly to trees in Root Control Bags. Trees grown in Geo-cells or Agro-liners in-ground had significantly slower growth than the other treatments.

Index words: pot-in-pot, tree production, fabric containers, root control, inground production, root control bags, Agro-liners.

Species used in these study: *Magnolia grandiflora* L. 'Symmes Select'.

Significance to Nursery Industry

Magnolias grown in the pot-in-pot system, or modified by replacing the growing pot with a copper hydroxide impregnated spun polyester bag, grew as fast as trees in Root Control Bags in a sandy soil when irrigated with sufficient volumes. Cyclic irrigation increased height and trunk diameter growth compared to once daily irrigation, with larger effects occurring for trees in Root Control Bags than those in the #25 containers pot-in-pot system. In sandy soils, growers should consider cyclically irrigating trees in in-ground Root Control Bags to achieve faster marketable size. Growth benefits of cyclic irrigation have now been demonstrated for trees in container sizes ranging from #3 to #25. Similar benefits are likely to occur if cyclic irrigation is extended to larger container sizes.

Introduction

Based on nursery production, Southern magnolias, *Magnolia grandiflora*, have increased in popularity over the past decade, with production shifting to clonal cultivars. Over the same period, there has been increased interest in improving the quality of roots in a root ball and reducing labor requirements. This spurred interest in the use of pot-in-pot (PNP) production to eliminate root-killing heat loads on the container wall, reduce windfall of container-grown trees (13), and avoid the more labor intensive harvesting of field-grown trees. The desire for better quality root systems also spurred interest in using copper hydroxide (Spin Out®, Griffin Corp., Valdosta, GA) on the insides of containers to inhibit root circling (2).

While PNP production moderates root ball temperature and improves root ball quality (13), it retains the negative characteristic of container systems, limited soil volume. Most trees have unrestricted root spreads of about three times the canopy width (8), providing a large soil volume for extraction of nutrients and water. Most container systems restrict this soil volume to about 1% or less of that of a natural tree at marketable size (10). While supplemental fertilization can satisfy nutrient requirements, water availability is more critical, requiring daily or more frequent irrigation to sustain rapid growth (3, 6, 14). Previously, growth of trees in containers irrigated once daily was shown to be slower than that of comparable trees produced from in-ground production systems (10).

In-ground fabric bags (Root Control Bags, RCB, Root Control Inc, Stillwater, OK) have been in use in Florida since the early 1980s, and are favored by many tree farms over direct field growing for their ease of harvesting and root-pruning properties in coarse sand soils (16, 11). In the mid-1990s, many Florida tree farms, especially those in excessively-drained deep sand soils, began to evaluate PNP production, while still producing most of their larger magnolias in above ground containers or RCB. At the time, new products were being marketed to compete with the fabric bags and PNP. Earlier experimentation with cyclic irrigation of tree liners in #3 containers had found exceptional growth responses (3). Cyclic irrigation is the practice of applying a day's irrigation volume as two or more fractions throughout the day. Cyclic irrigation had not been evaluated over the several years period required to produce trees of 5.08 cm (2 in) stem diameters or larger.

In 1994, a project was initiated to compare the effects of cyclic and once daily irrigation on growth of trees grown in the RCB system, with trees grown in more restrictive substrate volume-limited systems. It was hypothesized that cyclic irrigation of substrate volume-limited production systems would compensate for a much larger soil volume exploited by trees grown in-ground RCB. Thus similar-sized trees would be produced over the same time period. A sec-

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ondary objective was a long term comparison of cyclic irrigation to once daily irrigation for production of large landscape trees within each system.

Materials and Methods

Five in-ground production systems were acquired and installed in an excessively drained, deep sand soil (Astatula sand, dark surface, [15]) . This soil type is characterized as having very low fertility and a water holding capacity of 0.02 to 0.05 in/in (15). At transplanting, the pH was 7.1. The systems were 45 cm (18 in) Root Control Bags (RCB), 45 cm (18 in) Geo-Cells (EaCon Industries, Sarasota, FL), 95 liter (#25) container pot-in-pot (PNP; Lerio Corp., Kissimmee, FL), 45 cm (18 in) Agro-liner (Tex-R Agroliner, Texel USA Inc., Quebec, Canada) in a socket pot (AiP) and 45 cm (18 in) Agro-liner planted directly in the ground (AiG). Filled volumes of each system differed by less than 10%. The RCB had plastic-lined bottoms and were installed with 2.5 cm (1 in) of the bag above ground. Geo-Cells were similar to RCB in size and design, except the side walls were made from Biobarrier (Reemay Inc., Old Hickory, TN). Trifluralin nodules incorporated into the spun fabric of Biobarrier were promoted to prevent root growth through the side walls. The AiG system consisted of an Agro-liner (spun polyethylene fabric incorporated with Spin Out) placed in the ground. A flat-bottom wire basket (Braun Basket, Cady Industries, Inc, Tampa, FL) was placed inside both Agro-liner systems prior to filling. RCB, Geo-Cells and AiG were filled with the excavated Astatula sand soil. PNP consisted of a 114 liter (#30) socket pot (Model PNP15, Lerio Corp.) installed inground to the rim of the container. The production container was a #25 black polyethylene container. These #25 containers were hand-painted with Spin Out (Griffin Corp., Valdosta, GA) prior to use. The AiP system consisted an of Agro-liner placed inside the same socket pot as the PNP. Both the PNP and AiP systems were filled with a container substrate consisting of pine bark fines:Florida sledge peat:coarse sand (3:2:2 by vol), amended with 1.8 kg (4 lb) dolomite and 0.7 kg (1.5 lb) micro-nutrients (Peter's Fritted Trace Minerals, Grace-Serra Chemical Co. Milpitas, CA) per cu m (cu yd).

In November 1994, 54 *Magnolia grandiflora* 'Symmes Select' were obtained from a local tree farm in 7.6 liter (#2) containers and transplanted into the RCB, Geo-Cells and PNP systems, constituting Experiment 1 (Expt. 1). In March 1995, thirty-six additional 'Symmes Select' trees were obtained from the same group and transplanted into the AiP and AiG systems (Experiment 2, Expt. 2).

In Expt. 1, nine trees were planted within each of six rows. Three rows each were randomly assigned to be irrigated with a cyclic or once daily regime. The three production systems were randomized within each row, with three adjacent trees replicates for each system. Trees transplanted for Expt. 2 were placed at the end of each row, with the Agro-liner systems randomized within each row, with three similar tree replicates for each system.

Irrigation volumes were based on applying 3.7 liter/cm (2.5 gal/in) trunk diameter measured 15 cm (6 in) above the soil level. Total volume was supplied at 0800 h if applied as a single volume, or as two (0700 and 1430 h during mid-Nov. to mid-March) or three (0700, 1330 and 1700 h the rest of year) sub-volumes. Irrigation volumes were adjusted each time growth was recorded. Average stem diameter for trees in the fastest growing production system of Expt. 1 within each irrigation regime was used to adjust irrigation volumes. At each measurement period, irrigation application rate was randomly checked on 10 trees per irrigation regime. This application rate was used in adjusting irrigation volumes. Irrigation was applied using two Maxijet micro-spray heads (Maxijet, Dundee, FL) per tree. Each micro-spray head was installed so that all of the water applied fell within the confines of the production system. Twenty psi pressure (13.3 KPa) regulators (Model FJ-10, Bowsmith, Orlando, FL) were installed between the supply line and the microtubing leading to the micro-spray heads to minimize variations in the application rate.

Trees were fertilized with a controlled release fertilizer (18–6–12; Osmocote, Scotts Co., Marysville, OH) in April and July and with 14–14–14 Osmocote in December each year. Fertilizer application was based on trunk diameter and applied at a rate of 5.5 g N/cm (0.5 oz N/in) trunk diameter within the confines of the production system. Plants were pruned as needed to maintain commercial quality.

Growth measurements were recorded three time each year, during winter quiescence (usually January) and between growth flushes in June and early September. Tree growth was measured as maximum trunk diameter measured 15 cm (6 in) above the soil with a caliper. Tree height was measured using a 6 m graduated pole. Percent marketability was calculated for each production system within an irrigation regime by comparing tree trunk diameter and height to that required for the highest grade (Fancy) for trees in #25 container/18 in fabric containers based on the draft version of the Florida Grades and Standards for Nursery Stock (1). For these trees, minimum values were 2.16 m (7 ft) in height and 5.08 cm (2 in) in trunk diameter.

Tree height, stem diameter and percent marketability were analyzed as a split plot design with repeated measurements on individual tree replicates. Irrigation regime constituted whole plot treatments in a complete randomized design with rows as whole plots. Production systems constituted subplots and were completely randomized within each whole plot row. Effects of repeated measures were analyzed using time as the sub-subplot. Regression analysis was applied as appropriate. Where trends with time were linear, single-degree-of-freedom contrast were used to compare among regression line slopes (12). When trend with time was quadratic or the three way interaction was significant, the variable was analyzed for each month using GLM . Fisher's Protected LSD was then used for mean separation where appropriate (12). Expt. 1 and 2 were analyzed separately. All statistical analysis was conducted using SAS (SAS Ver. 8.1, SAS Institute, Cary, NC).

Results and Discussion

Experiment 1. For both tree height and trunk diameter, interactions of irrigation with time and production system with time were significant ($P < 0.001$). The three way interaction of irrigation, production system and time was not significant ($P > 0.05$) for either variable. Height growth was minimum for the first 15 months after transplanting, and essentially non-existent between September and January measurements (Fig. 1A). Yet, the trend with irrigation was linear ($P < 0.0001$) and not quadratic ($P > 0.59$). Trees which were cyclically irrigated grew taller at a significantly ($P < 0.01$) faster rate over the 34 month period than those irrigated once daily. The interaction of production system with time for

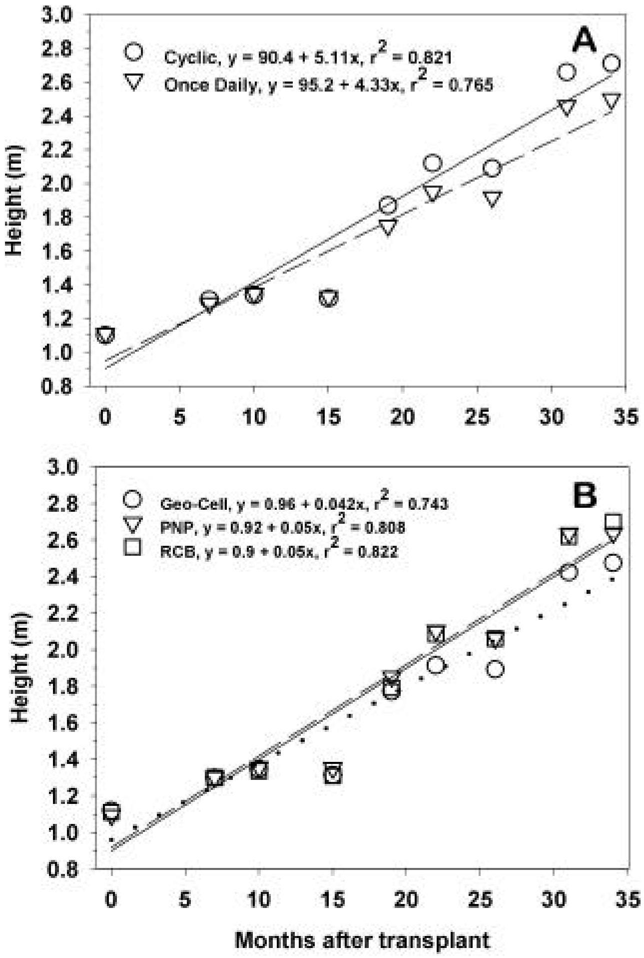

Fig. 1. Interaction of time after transplanting with irrigation regime (A) and production system (B) for height growth of magnolias in Experiment 1. Solid and dashed lines (A) represent cyclic and once daily regression equations, respectively, with each mean representing 27 single tree replicates. For production systems (B), Geo-Cell, PNP and RCB regression equations are represented by dot, dashed and solid lines, respectively, with each mean representing 18 tree replicates.

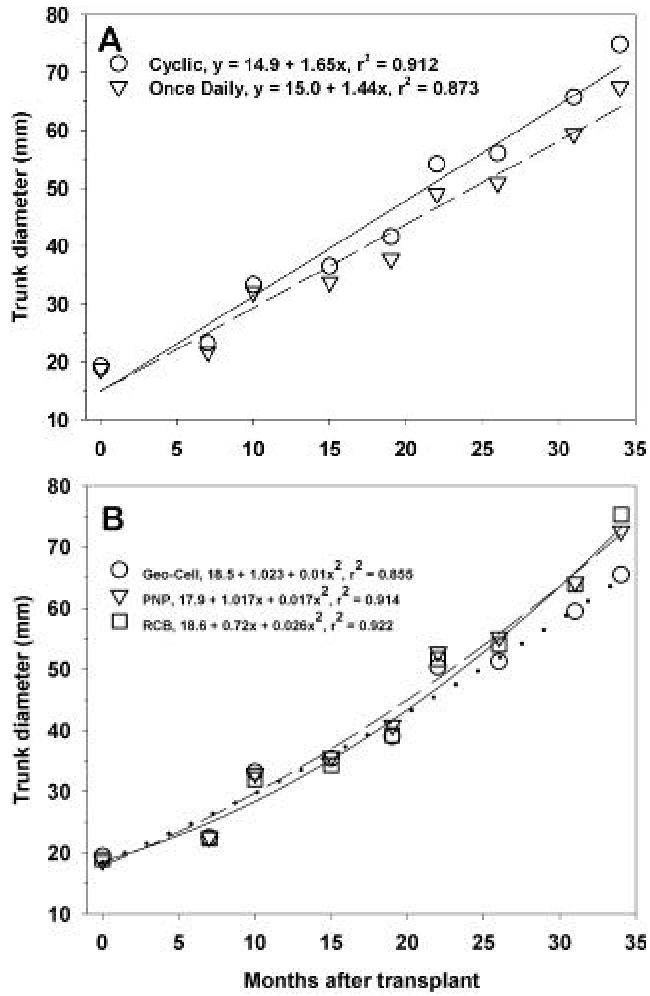

Fig. 2. Interaction of time after transplanting with irrigation regime (A) and production system (B) for trunk diameter growth of magnolias in Experiment 1. Solid and dashed lines (A) represent cyclic and once daily regression equations, respectively, with each mean representing 27 single tree replicates. For production systems (B), Geo-Cell, PNP and RCB regression equations are represented by dot, dashed and solid lines, respectively, with each mean representing 18 tree replicates.

height growth was also linear ($P < 0.0001$) and not quadratic ($P > 0.39$; Fig. 1B). Trees grown in the PNP and RCB systems had similar height growth rates (Fig. 1B). Trees grown in the Geo-Cell system increased in height at a slower rate ($P < 0.01$) than those in the other two systems.

Like height, increase in trunk diameter as a function of irrigation regime with time was linear ($P < 0.001$), and not quadratic ($P > 0.66$). Trees cyclically irrigated increased in trunk diameter at a faster rate than those irrigated once daily (Fig. 2A). Unlike height, trunk diameter increased at each measurement, with substantial increases the first 12 months, compared to limited increases in height. Trunk diameter growth, as functions of production systems, were quadratic ($P < 0.01$) with time. Comparisons among production systems at each measurement date found no significant differences ($P > 0.05$) the first 15 months (Fig 2B). Thereafter, trees grown in the PNP or RCB systems had larger trunk diameters than those grown in the Geo-Cells when measured 19, 26 and 34 weeks after transplanting. After 34 months, stem diameters of trees in the Geo-Cell system averaged about 3 months behind those in the other two systems (Fig. 2B).

Marketability was calculated to examine the effects of differential growth rates on a level more relevant to the nursery industry, i.e. which treatments produced market size trees the fastest. For marketability, the three-way interaction of irrigation regime, production system and time was significant ($P < 0.01$). Twenty-two months were required for the first trees to obtain marketable size after transplanting (Fig. 3). At this point, there were no significant differences ($P > 0.05$) in the percent of marketable trees among irrigation and production system combinations. Differences ($P < 0.05$) among treatments only occurred at month 26, where the percentage of cyclic irrigated RCB trees of marketable size was greater than once daily irrigated trees in RCB and Geo-Cell systems (Fig. 3). By 31 months after transplanting, eight or nine of the nine trees within each irrigation and production system combination had obtained market size, except for once daily irrigated trees in Geo-Cells (Fig. 3). The best combination for quickest production of market size trees was cyclic irrigated RCB, followed by once daily irrigated PNP trees. The slowest combination was once daily irrigated Geo-Cells.

Experiment 2. The three-way interaction of irrigation, production system and time were not significant ($P > 0.96$) for the variables analyzed, nor was irrigation a factor in magnolia height growth for trees in the Agro-Liner systems. However the interaction of production system and time was significant ($P < 0.05$) for height. The trend was linear ($P < 0.05$), with trees in the AiP system growing taller at a faster rate than those grown in-ground (AiG, Fig. 4A).

Trunk diameters increased with time both as functions of irrigation regime ($P < 0.05$) and production systems ($P < 0.01$). For both interactions, the trend was linear ($P < 0.05$) and not quadratic ($P > 0.41$). Trunk diameter growth was greater with cyclic irrigation than with once daily irrigation (Fig. 4B). Between production systems, trunk diameter increased faster for trees in AiP than those in the AiG system (Fig. 4C).

Marketability increased quadratically ($P < 0.0001$) with time after transplanting (Fig. 5). Neither irrigation regime nor production system ($P > 0.30$) impacted marketability, nor were interactions significant ($P > 0.15$). Trees first obtained marketable size 18 months after transplanting, four months earlier after transplanting than trees in Expt. 1 (Fig. 3). By the end of the experiment, 30 months after transplanting, the percentage of market size trees was comparable to the best treatment and irrigation regimes in Expt. 1.

Height and trunk diameter growth of trees in the AiP system mirrored that of trees in RCB and PNP systems. Similar growth rates are the reason for the shorter period between transplanting and market size trees for the AiP system. In terms of shoot growth, the additional four months of root growth afforded the RCB and PNP trees was not advantageous. In Central Florida, where the soil surface rarely freezes, root growth of evergreen species can occur year round (9). Thus for these magnolias, the irrigation scheme (3.7 liter/cm [2.5 gal diameter/in]) utilized compensated for the smaller root volumes of AiP trees the first year or two after transplanting.

Both the Geo-Cell and AiG systems were designed to ease tree harvest by preventing root growth outside the container. While neither system was completely successful, visually there were substantially less roots through these containers than through the RCB. All three systems were backfilled with the same native soil. Limited root growth exterior to Geo-Cell and AiG containers restricted root volumes relative to the RCB system. More restricted root volumes and therefore limited water resources are evident in the significantly ($P < 0.05$) smaller trees from Geo-Cells compared to those in RCB.

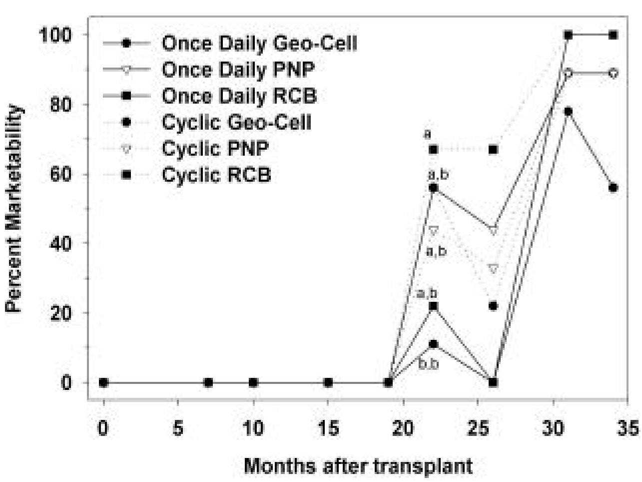

Fig. 3. Three-way interaction of irrigation regime and production systems with time after transplanting for percent marketability of magnolias grown in Experiment 1. Each mean represents 9 tree replicates. Means with the same letter are not significantly different based on Fisher's Protected LSD " = 0.05.

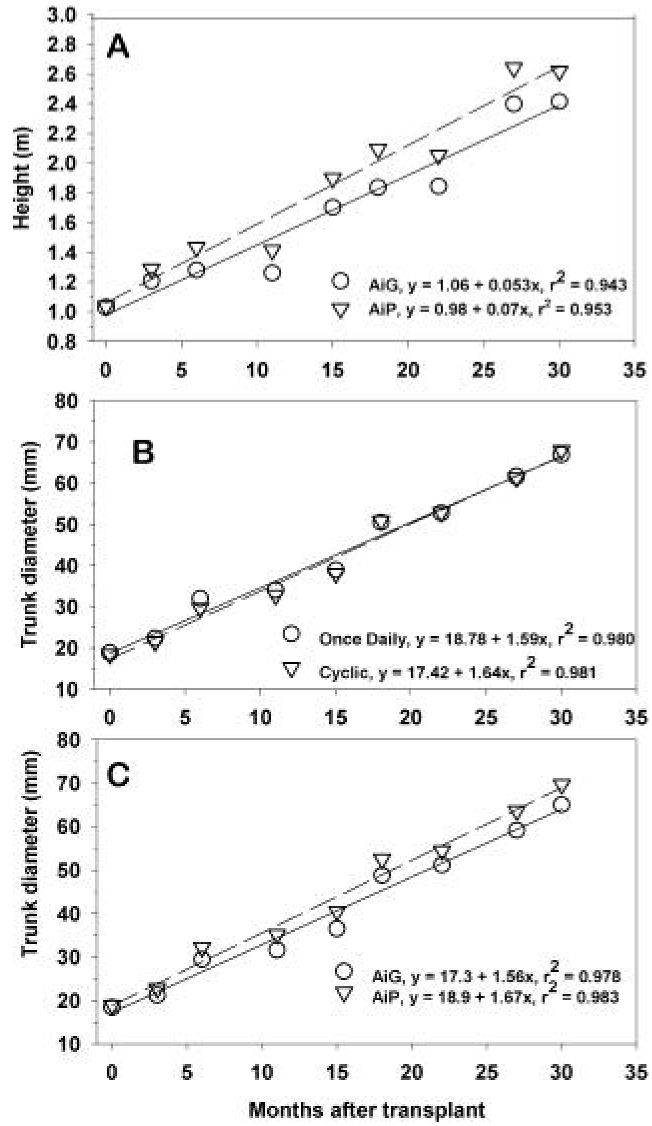

Fig 4. Interactions of time after transplanting with Agro-liner systems for height (A) and trunk diameter (C) growth, and irrigation regime (B) for trunk diameter growth, of magnolias in Experiment 2. Solid and dashed lines represent AiG and AiP (A,C), and once daily and cyclic (B) regression equations, respectively. Each mean represents 18 tree replicates.

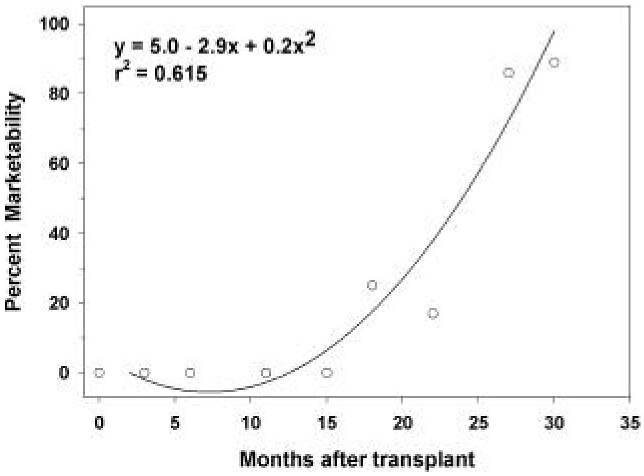

Fig. 5. Increase in the percentage of marketable trees after transplanting for trees produced in the Agroliner systems. Each mean represents 36 tree replicates.

Previous use of fabrics to improve root structure did not always improve shoot growth, and sometimes slowed it (5, 7). Growth of trees in Geo-Cell and AiG systems were comparable. From a production standpoint, both the Geo-Cell and AiG systems were inferior to the RCB system.

This project tested the hypothesis that cyclic irrigation of substrate volume-limited production systems would compensate for limited root volumes and produce trees with comparable growth rates to trees grown in less root restrictive RCB systems. In terms of height and trunk diameter growth rates, the hypothesis was validated. These results agree with previous research on trees in #3 (3), #7 (14), and #15 containers (6); and extends the positive response to cyclic irrigation to #25 containers. This suggest similar growth responses to cyclic irrigation may occur in even larger containers. Trees grown in in-ground pot-in-pot systems, and likely Agro-liner-in-pot systems, if provided with sufficient irrigation volumes, can be grown nearly as rapidly as trees in root-penetrating in ground fabric containers. It was unexpected that cyclic irrigation would produce strong significant responses from trees grown in the RCB system. While these fabric containers restrict root growth outside the container boundary, root growth through the fabric is expected and associated with faster tree growth (4). Apparently this root restriction limits tree growth in low water holding capacity soils.

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