Propagation and Production of *Zamioculcas zamiifolia*

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**Keywords:** daily light integral, light quantity, temperature

**Abstract**  
*Zamioculcas zamiifolia* (Lodd.) Engl. is a tropical ornamental perennial native to Eastern Africa that produces succulent rhizomes at the base of its attractive dark green and glossy foliage. We performed experiments to determine if plants could be asexually propagated by single leaflets, apical leaflet sections, basal leaflet sections, or rachis cuttings. The effects of photoperiod and photosynthetic daily light integral (DLI) on rhizome development were also quantified. Cuttings were rooted in a greenhouse with overhead mist and maintained at 24 to 25°C and a vapor-pressure deficit of 0.3 kPa. A 9- or 16-h photoperiod was delivered using a 9-h natural day extended with light from soft-white fluorescent lamps. DLI environments were created using 0, 30, 50 and 70% woven shade cloth. Apical and entire leaflet cuttings developed 250% and 142% more rhizomes, respectively, than basal leaflet cuttings propagated under a 16-h photoperiod. In another experiment, apical leaflet cuttings produced fewer rhizomes under a 9-h photoperiod than under 16h. After 6 weeks, regardless of DLI, apical cuttings produced a mean of 4.3 rhizomes compared to 1.4 for basal cuttings. Rooted cuttings were then transplanted into 10-cm pots and grown at a constant 20, 23, 26, 29 and 32°C to determine the effects of temperature on plant development. Marketable plants were achieved after 6 to 8 months at temperatures of 29 to 32°C; temperatures below 26°C delayed leaf development. Commercial propagation and production time of *Zamioculcas* can be reduced by propagating apical leaflet cuttings under a 16-h photoperiod and a DLI as low as 0.6 mol·m⁻²·d⁻¹ and by subsequently growing plants at 29 to 32°C.

**INTRODUCTION**  
Tropical foliage plants are typically grown as indoor house plants or for interiorscapes because of their attractive foliage and ability to grow under low light conditions. Over the past 60 years, the foliage plant industry in the United States has been dominated by approximately 17 genera ranging from aglaonema (*Aglaonema* Schott) to weeping fig (*Ficus benjamina* L.) (Chen et al., 2002). From 1995 to 2005, the reported wholesale value of foliage plants increased by 45% in the United States and in 2005 over USD 720 million of potted foliage plants and hanging baskets were sold (USDA, 2006). New foliage crop introductions that have consumer appeal and can be readily propagated and finished are desirable for the continued success of the industry.  

*Zamioculcas zamiifolia*, known by several common names including African cootie, aroid palm, arum fern, cardboard palm, emerald frond, and ZZ plant, is a stemless tropical herbaceous perennial native to submontane and lowlands forests of eastern Africa (Chen and Henny, 2003; Doggart et al., 1999). *Zamioculcas* has thick, fleshy petioles supporting attractive dark green and glossy alternate pinnate leaflets. Petioles arise from succulent rhizomes that can range from 0.4 to 10 cm in diameter. Mature plants can form a short yellow-brown flowering spadix at the base of the plant, but inflorescences do not have ornamental value. The potential for *Zamioculcas* to become a popular foliage plant exists because it has naturally dark green glossy foliage, limited disease and insect pests, and it performs well in low light and dry conditions (Chen and Henny, 2003; Blanchard and Lopez, 2007). Chen and Henny (2003) also report that plants can grow in light levels as low as 4 µmol·m⁻²·s⁻¹ without detrimental effects on plant quality. In 2002, the Florida
Nurserymen and Growers Association named *Zamioculcas* a “Florida Plant of the Year” to promote its use as a foliage plant.

The commercial propagation and production of *Zamioculcas* can be challenging for greenhouses in temperate climates because of the long propagation and production time and warm temperatures that are required to produce a marketable plant. Plants can be propagated by rhizome division or by cuttings under air and bench temperatures of 24 to 32°C and relative humidity of 60% to 90% (Blanchard and Lopez, 2007; Chen and Henny, 2003). The objectives of work reported here are to identify a commercially viable method for asexual propagation using cuttings and to determine the effects of cutting type, photoperiod, and daily light integral (DLI) during propagation on rhizome and leaf development.

**MATERIALS AND METHODS**

**Stock Plant Management**

*Zamioculcas zamiifolia* stock plants were grown in glass greenhouses in East Lansing, MI (43°N lat.) at 23 ± 2°C under a constant 16-h photoperiod (6am to 10pm) with a maximum photosynthetic photon flux (PPF) of ≈450 µmol·m⁻²·s⁻¹. The photoperiod consisted of natural daylengths with day-extension lighting from high-pressure sodium lamps that delivered a supplemental PPF of ≈50 µmol·m⁻²·s⁻¹ at plant height when the outdoor PPF was <140 µmol·m⁻²·s⁻¹.

Air temperature at plant height was measured by a thermocouple in an aspirated chamber every 10 seconds, and hourly averages were recorded by a CR-10 data logger (Campbell Scientific, Logan, Utah). Stock plants were grown in 13-cm (1.1-L) square plastic containers filled with a medium containing 70% peat moss, 21% perlite, and 9% vermiculite by volume. Plants were irrigated as necessary with reverse osmosis water supplemented with a water-soluble fertilizer to provide the following (mg/L): 125 N, 12 P, 100 K, 1.0 Fe and Cu, 0.5 Mn and Zn, 0.3 B, and 0.1 Mo.

**Propagation Environment**

For each experiment, cuttings were harvested from stock plants between 1pm and 3pm and dipped into 1,000 mg/L indole-3-butyric acid and 500 mg/L naphthalene acetic acid rooting hormone (Dip ’N Grow, Clackamas, Oregon) and propagated in 72-cell (28-mL) plug trays in a medium containing 50% of a peat-based mix (Sure-Mix) and 50% screened coarse perlite. All cuttings were rooted in a greenhouse with medium and air temperatures of 25 ± 1°C. Medium temperature was measured using 40-gauge type E thermocouple. A vapor-pressure deficit of 0.3 kPa was maintained by the injection of steam or fine mist. Overhead misting was controlled by an environmental computer as a function of time and accumulated PPF. The overhead mist contained reverse osmosis water and water-soluble fertilizer to provide the following (mg/L): 50 N, 8 P, 42 K, 22 Ca, 1.0 Fe and Cu, 0.5 Mn and Zn, 0.3 B, and 0.1 Mo.

**Cutting Types and Temperature (Expt. 1)**

Entire leaflets (=9 cm in length), apical leaflet sections, basal leaflet sections, or rachis cuttings (=3 cm in length) were harvested from stock plants in February and November 2004 and propagated as described above under a 16-h photoperiod. Apical and basal leaflet sections (=4 cm in length) were produced by horizontally cutting (perpendicular to the midrib) a leaflet across the middle with a knife. Polarity of each cutting type was maintained and propagules were inserted approximately 1.5 cm into the medium. After 30 days of propagation, 10 rooted cuttings of each cutting type were transplanted into 10-cm containers containing a peat-based media. The plants were subsequently grown in greenhouse compartments with constant air temperature setpoints of 20, 23, 26, 29, and 32°C under a 16-h photoperiod (as described previously).
Photoperiod During Propagation (Expt. 2)

Entire leaflets, apical leaflet sections, and basal leaflet sections were harvested in August and October 2005 and propagated under 9- and 16-h photoperiods for 42 days. Photoperiods were created by pulling opaque blackout cloth over individual propagation compartments between 5pm and 8am. The 16-h photoperiod was created using the 9-h truncated natural day that was extended with light from soft-white fluorescent lamps (≈3 \( \mu \text{mol} \cdot \text{m}^{-2} \cdot \text{s}^{-1} \) at canopy level).

Daily Light Integral During Propagation (Expt. 3)

Apical and basal leaflet sections were harvested and propagated under a 12-h photoperiod as described above. DLI environments were created using no shade or permanent woven shade cloth that reduced light transmission by ≈30, 55, and 70% (OLS 30, 50 and 70; Ludvig Svensson, Charlotte, North Carolina) over individual propagation compartments. Line quantum sensors were placed directly above the cuttings under each of the four lighting compartments to measure the PPF. The mean DLI under each environment during 42 days of propagation was 0.6, 0.9, 1.3, and 2.2 \( \text{mol} \cdot \text{m}^{-2} \cdot \text{d}^{-1} \), respectively. After propagation, all rhizomes were planted and grown at 29°C under a 16-h photoperiod as described previously.

Data Collection and Analysis

Ten plants or cutting types were randomly assigned to each treatment. The number of rhizomes formed was recorded for Expt. 1, 2, and 3. For Expt. 3, time to first visible leaf was recorded and the number of leaves (>2 cm in length) was recorded after 56 and 98 days. A complete randomized design was used and data were analyzed using SAS (SAS Institute, Cary, North Carolina) mixed model procedure (PROC MIXED).

RESULTS

Cutting Types (Expt. 1)

After 30 days of propagation, rachis cuttings did not form any rhizomes or roots, while 100% of the other cutting types produced rhizomes and roots. Entire leaflet, apical leaflet, and basal leaflet cuttings produced a mean of 2.9, 4.2, and 1.2 rhizomes, respectively (Fig. 1). Few additional leaves developed when rooted cuttings were grown at 20 to 23°C for 112 days (data not recorded). Leaf emergence and development of apical and basal leaflet cuttings was accelerated as production temperature increased from 26 to 32°C (data not recorded).

Photoperiod Treatments (Expt. 2)

Apical leaflet sections formed 31% more rhizomes under a 16-h photoperiod than under a 9-h photoperiod (Fig. 2). For basal leaflet sections, propagation photoperiod did not significantly influence the number of rhizomes formed.

Daily Light Integral Treatments (Expt. 3)

There were no apparent trends on the effect of DLI on rhizome number (Table 1). Regardless of propagation DLI, apical leaflet sections produced 210% more rhizomes than basal leaflet sections. Time to first leaf emergence and the number of leaves formed after 56 and 98 days were not influenced by propagation DLI. Leaf emergence from apical leaflet cuttings occurred 5 days earlier than basal leaflet cuttings. In addition, apical leaflet cuttings formed 0.3 and 1.7 more leaves, respectively, after 56 and 98 days of forcing at 29°C.

DISCUSSION

The three experiments collectively demonstrate that apical leaflet cuttings produce significantly more rhizomes compared to basal or entire leaflet cuttings. Chen and Henny (2003) reported that the number and size of rhizomes at initial planting determines the
time required to produce a marketable plant. For example, to produce a finished Zamioculcas grown in 10- or 15-cm pots in 8 to 12 months, 2 to 3 rhizomes or 4 to 5 rhizomes, respectively, are required. Therefore, growers who propagate using apical leaflet section cuttings will likely have a marketable crop earlier than if plants are propagated by basal leaflet section cuttings.

Rhizome development of Zamioculcas was also influenced by the photoperiod delivered during the 43 days of propagation. Apical leaflet cuttings propagated under a 16-h photoperiod produced approximately 1 more rhizome than those propagated under a 9-h photoperiod. It is well documented that photoperiod can influence bud dormancy, formation of storage organs, asexual reproduction, and leaf development (Thomas, and Vince-Prue, 1984). For example, tuber development and flowering of dahlia (Dahlia Cav.) is promoted by short photoperiods (≤12h) and inhibited by long photoperiods (≥14h) (Runkle, 2003). It is unclear why the 16-h propagation photoperiod promoted rhizome development in apical leaflet section cuttings, but not in basal leaflet section cuttings.

Rooting of cuttings is accelerated in some species when the DLI provided during propagation increases. For example, as propagation DLI increased from 1.2 to 3.9 mol·m⁻²·d⁻¹, root number, root length, and root and shoot dry mass increased, while shoot length decreased in petunia (Petunia × hybrida) (Lopez and Runkle, 2006). Interestingly, DLI during propagation did not clearly influence rhizome development of Zamioculcas. However, we did observe that root initiation and development increased as propagation DLI increased (data not recorded). This suggests that shade-tolerant plants such as Zamioculcas can be successfully propagated under very low light levels, in contrast to shade-avoiding plants. The mean DLI provided during propagation had no residual effect on leaf development when plants were subsequently grown at 29°C.

CONCLUSIONS

Zamioculcas zamiifolia has great potential as a foliage crop for greenhouse growers because it is relatively easy to propagate and finish in 10-cm pots or larger. Propagation and production time can be reduced if apical leaflet cuttings are rooted under a 16-h photoperiod and a DLI as low as 0.6 mol·m⁻²·d⁻¹ is provided. This propagation strategy will decrease rooting time and produce the highest number of rhizomes and subsequent petioles with leaves during finished production.

ACKNOWLEDGEMENTS

We gratefully acknowledge Mike Olrich for greenhouse assistance, Michigan Grower Products and The Blackmore Company for their donations of media and fertilizer, and support from the Michigan Agricultural Experiment Station.

Literature Cited


Tables

Table 1. The effect of propagation daily light integral (DLI) and cutting type (apical or basal leaflet sections) on the number of rhizomes of *Zamioculcas zamiifolia* formed after 43 days of propagation at 25°C under a 12-h photoperiod. Plants were subsequently grown at 29°C and the effects of propagation DLI and cutting type were evaluated on the number of days to first leaf emergence from the start of propagation, and the number of leaves formed after 56 and 98 days.

<table>
<thead>
<tr>
<th>DLI (mol m⁻² d⁻¹)</th>
<th>Cutting type</th>
<th>Rhizome (no.)</th>
<th>Days to first leaf</th>
<th>Leaf number after 56 d</th>
<th>Leaf number after 98 d</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.6</td>
<td></td>
<td>2.1 b&lt;sup&gt;z&lt;/sup&gt;</td>
<td>57 a</td>
<td>1.9 a</td>
<td>3.5 a</td>
</tr>
<tr>
<td>0.9</td>
<td></td>
<td>3.3 a</td>
<td>56 a</td>
<td>1.8 a</td>
<td>3.5 a</td>
</tr>
<tr>
<td>1.3</td>
<td></td>
<td>2.8 ab</td>
<td>57 a</td>
<td>1.9 a</td>
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</tr>
<tr>
<td>2.2</td>
<td></td>
<td>3.2 ab</td>
<td>52 a</td>
<td>2.1 a</td>
<td>3.9 a</td>
</tr>
<tr>
<td></td>
<td>Apical</td>
<td>4.3 a</td>
<td>53 b</td>
<td>2.1 a</td>
<td>4.3 a</td>
</tr>
<tr>
<td></td>
<td>Basal</td>
<td>1.4 b</td>
<td>58 a</td>
<td>1.8 b</td>
<td>2.9 b</td>
</tr>
</tbody>
</table>

Significance

- **DLI**
  - *NS*
  - NS
  - NS
- **Cutting type**
  - ***
  - *
  - *
  - ***
- **DLI × Cutting type**
  - NS
  - NS
  - NS
  - NS
- **P<sub>Linear</sub>**
  - NS
  - *
  - NS
  - NS
- **P<sub>Quadratic</sub>**
  - NS
  - NS
  - NS
  - NS

<sup>z</sup> Within-column means for DLI and cutting type followed by different letters are significantly different by Tukey’s honestly significant difference (HSD) test at *P* ≤ 0.05.

NS, ***, *: Nonsignificant or significant at *P* ≤ 0.05 or 0.001.
Fig. 1. The effect of cutting type on rhizome development in *Zamioculcas zamiifolia* cuttings. Entire, apical, and basal leaflet sections and rachis sections were propagated at 25°C for 30 days under a 16-h photoperiod. Error bars represent standard errors of the mean.

Fig. 2. The effect of photoperiod and cutting type on rhizome development in *Zamioculcas zamiifolia* cuttings. Apical and basal leaflet cutting sections were propagated at 25°C for 42 days under a 9- or 16-h photoperiod. Error bars represent standard errors of the mean.