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Growth of Ten Species of Ornamental Tree Seedlings Exposed to Different Photoperiods

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Abstract. **Ten species of tropical to temperate ornamental tree seedlings. [*Bauhinia variegata* L., *Tabebuia heterophylla* (DC.) Britton, *T. caraiba* (Mart.) Bur., *Delonix regia* (Bojer) Raf., *Bursera simaruba* (L.) Sarg., *Pongamia pinnata* (L.) Pierre, *Jacaranda mimosifolia* D. Don, *Tamarindus indica* L., *Acer rubrum* L., and *Quercus virginiana* Mill.] were grown outdoors under natural photoperiods or long day (LD) photoperiods during the autumn, winter, and early spring months. Growth response to photoperiod and temperature varied widely among both tropical and temperate species. *Jacaranda mimosifolia, B. variegata*, and *T. indica* were classified as quantitative LD plants since growth was enhanced by LD, but not prevented by short days. However, temperature appeared to be an overriding factor in the growth of *T. indica. Delonix regia* and *A. rubrum* grew continuously under LD, but ceased all growth when natural daylength (ND) became shorter than 10.8 h. *Quercus virginiana, P. pinnata, B. simaruba*, and *T. heterophylla* showed virtually no response to photoperiod, but temperatures below 15°C prevented growth in *Q. virginiana*. LD increased growth rate in *T. caraiba* during the autumn months, but low temperature prevented growth in either LD or ND in the winter. ND plants of this species grew more rapidly in the spring than those maintained under LD. This negative influence of LD on growth during the spring months also was noted in other species in this study.**

Southern Florida provides a subtropical climate that supports a high diversity of ornamental trees. Although this area has a long and generally frostfree growing season, most tree species still have a definite quiescent period during the winter months.

External environmental factors such as temperature, water availability, and photoperiod are known to regulate the growth of plants (6). Many temperate woody species use photoperiod as an environmental cue signalling the onset of winter (14). Along with cessation of growth, these plants often undergo the Stage 1 hardening described by Van Huystee (19) and Weiser (20). Within a species there is often considerable variation in response to photoperiod, depending on the latitude and environmental factors at the specific location where the population evolved (3, 14, 18).

Seasonal changes in daylength are reduced as the equator is approached. For this reason, photoperiod has often been assumed to play a minor role in regulating the growth of woody tropical plants (13, 18). It appears that this assumption may be due to a paucity of information on tropical species (9). Photoperiod has been shown to affect the growth of *Plumeria rubra* L. (7), *Hildegardia barteri* (M.T. Mast.) Kosterm. (12), *Swietenia mahagoni* (L.) Jacq. (1), *Coffea arabica* L. (15), *Theobroma cacao* L. (16), *Hymenaea courbaril* L. (17), and other species (9, 10).

Cessation of growth is a prerequisite for cold acclimation in temperate woody plants (8, 20). However, in tropical and subtropical regions where an environment conducive to plant growth may be provided throughout the year and cold hardiness is of less concern, it may be possible to reduce plant production time by photoperiod manipulation. The purpose of this study was to determine how several species of tropical and temperate trees grown as ornamentals in southern Florida respond to photoperiod.

Materials and Methods

Ten species of temperate to tropical ornamental trees (*Bauhinia variegata, Quercus virginiana, Tabebuia caraiba, T. heterophylla, Acer rubrum, Delonix regia, Bursera simaruba, Pongamia pinnata, Jacaranda mimosifolia*, and *Tamarindus indica*) were evaluated for their growth responses to LD photoperiods during the winter months in southern Florida. Sixty uniform seedlings of each species were planted in 3-liter plastic containers on August 3, 1981. The *B. variegata* were transplanted into 6-liter containers on October 15, 1981. The trees were grown in a medium consisting of sphagnum peatmoss, perlite, sand, and cypress shavings (8:5:2:5 by volume) amended with 880 $g \cdot m^{-3}$ Micromax (a micronutrient fertilizer manufactured by Sierra Chemical Co., Milpitas, Calif.) and 4.9 $kg \cdot m^{-3}$ dolomitic limestone. Plants were fertilized at 32g/container with Osmocote 18N–3P–10K (Sierra Chemical Co.) at planting time and every 4 months thereafter. They were grown outdoors under 63% shadecloth (max. 480 $\mu mol\ sec^{-1}\ m^{-2}$) throughout the experiment. Plants received about 2 cm of water daily from overhead irrigation.

On September 2, 1981, 30 plants of each species were placed under a LD photoperiod provided by illuminating the plants nightly from 10:00 PM to 2:00 AM with 100W incandescent bulbs (2). The bulbs, which were placed at a height of 2 m and were spaced 1.4 m apart, provided a minimum of 1.5 $\mu mol\ sec^{-1}\ m^{-2}$ at a height of 1 m. The remaining 30 plants of each species were maintained under ND photoperiods throughout the experiment and were isolated from the LD plants by a 20 m wide × 2 m high barrier with no contaminating light sources in the experimental area. Daylength (sunrise to sunset) at 26° N decreases from 12 hr 32 min on September 2 to 10 hr 22 min on December 21 and then increases to 12 hr 15 min on March 31. A split-plot experimental design with 3 replicate blocks of 10 trees each was used for this experiment. Individual plant heights were measured biweekly for each species and initial plant heights

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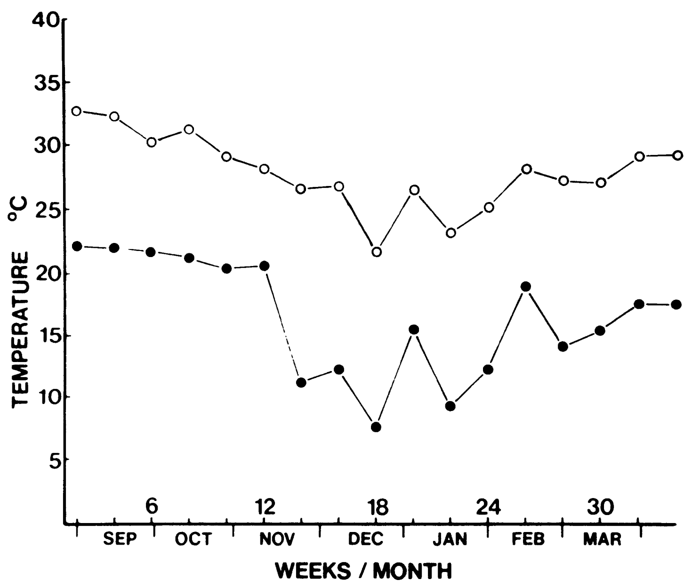

Fig. 1. Mean biweekly maximum (open circles) and minimum (closed circles) temperatures during the experiment.

were subtracted from all subsequent measurements to eliminate any differences in initial plant height. Analysis of variance was performed on the cumulative and incremental growth data. Maximum and minimum ambient temperatures were recorded daily and biweekly averages are shown in Fig. 1. The experiment was terminated on March 1, 1982 for *B. variegata* and on March 31, 1982 for all other species.

Results

B. variegata grown under LD were significantly (0.05 level can be assumed throughout this paper) taller than ND plants after 6 weeks and remained taller throughout the experiment (Fig. 2). Biweekly incremental growth was greater in LD plants from week 4 (September 14) through week 18 (December 21), but did not differ from ND plants after that time. A maximum height difference of 41 cm between LD and ND plants occurred on December 21, with the difference between treatments gradually decreasing to 33 cm at the end of the study (March 1).

There was no growth response to LD photoperiods in *Q. virginiana* at any time during the study (Fig. 2). Growth of both LD and ND plants ceased in mid-November and did not resume until late February, with ND plants seeming to grow at a more rapid rate in March than LD plants.

In *T. caraiba*, LD plants were significantly taller than ND plants after 6 weeks of artificial illumination (late September) and continued to grow at a greater rate until early December (Fig. 2). There was essentially no growth in either treatment from December 1 through January 31. Both groups of trees resumed growth in early February, but ND plants grew at a more rapid rate than LD plants, resulting in nonsignificant final height differences between the 2 treatments.

Differences in cumulative growth of *T. heterophylla* were nonsignificant throughout the study period (Fig. 2). Growth rate increased faster in February and March for ND plants than for LD plants, but there was considerable variability in growth rate of plants of both treatments.

A. rubrum grown under LD grew continuously and at a rather constant rate throughout the experiment (Fig. 2). ND plants essentially ceased growing in early November and resumed rapid growth in early March. Growth rates were similar for LD and ND plants until November, but not thereafter. Average final height of LD plants was more than twice that of ND plants (108 vs. 42 cm).

In *D. regia*, LD plants were significantly taller than ND plants 6 weeks after artificial illumination was begun and were 52 cm taller when the experiment was terminated at the end of March (Fig. 2). Plants grown under ND grew very slowly from November through January, but resumed rapid growth in mid-February. LD plants initially grew at a rapid rate, but during the cooler months of November through January, growth rate was slightly lower than during the warmer months.

Cumulative growth curves for *B. simaruba* grown under LD and ND were comparable until March, when ND plants began to grow faster (Fig. 3). ND plants were significantly taller than those grown under LD conditions at the termination of the experiment.

With *P. pinnata*, LD plants had greater biweekly growth rates and total heights than ND plants in October, but growth in the 2 groups was virtually identical during the remainder of the experiment (Fig. 3).

Both LD and ND *J. mimosifolia* grew continuously throughout the study period, with ND plants initially growing at a slower rate, but after March 1, growing at a faster rate than the LD plants (Fig. 3). The maximum height difference of 63 cm between the 2 treatments occurred on February 15, but this difference was reduced to 42 cm 6 weeks later, at the end of the experiment.

Cumulative growth curves for ND and LD *T. indica* were similar throughout the experiment (Fig. 3). LD plants were significantly taller than ND plants from mid-October through early December and again at the termination of the experiment on March 31. Neither group of trees grew much during the cooler months of December through February. Incremental growth rates of LD plants during March were greater than those of ND plants.

Discussion

Growth response to photoperiod varied considerably, not only among tropical species, but also between the 2 temperate species tested. Nitsch (11) categorized over 100 species of predominantly temperate woody plants into 4 response types: 1) Class A—LD cause continuous growth while short days (SD) cause dormancy; 2) Class B—LD cause periodic growth while SD cause dormancy; 3) Class C—LD prevent dormancy but SD do not cause dormancy; and 4) Class D—LD do not prevent the onset of dormancy.

Among widespread temperate species, ecotypes from low latitudes are known to be less responsive to photoperiod than higher latitude populations of the same species (21). In some species such as *Cercis canadensis* L., high latitude plants cease growth in late summer in response to photoperiod while low latitude populations are insensitive to daylength and cease growth in response to the dry winter season (3). *A. rubrum* is a wide ranging species in North America, but our plants, representing the southernmost population of this species, responded similarly to those from higher latitudes (2, 4, 5) in that growth was continuous under LD, but completely stopped under ND in early November.

Among the 7 species of *Quercus* discussed by Nitsch (11), 3 were tentatively assigned to Class D, while the remaining 4 were categorized as Class B. *Q. virginiana* grew as a Class D plant in our study, with neither LD nor ND plants growing from November through February. A minimum night temperature of

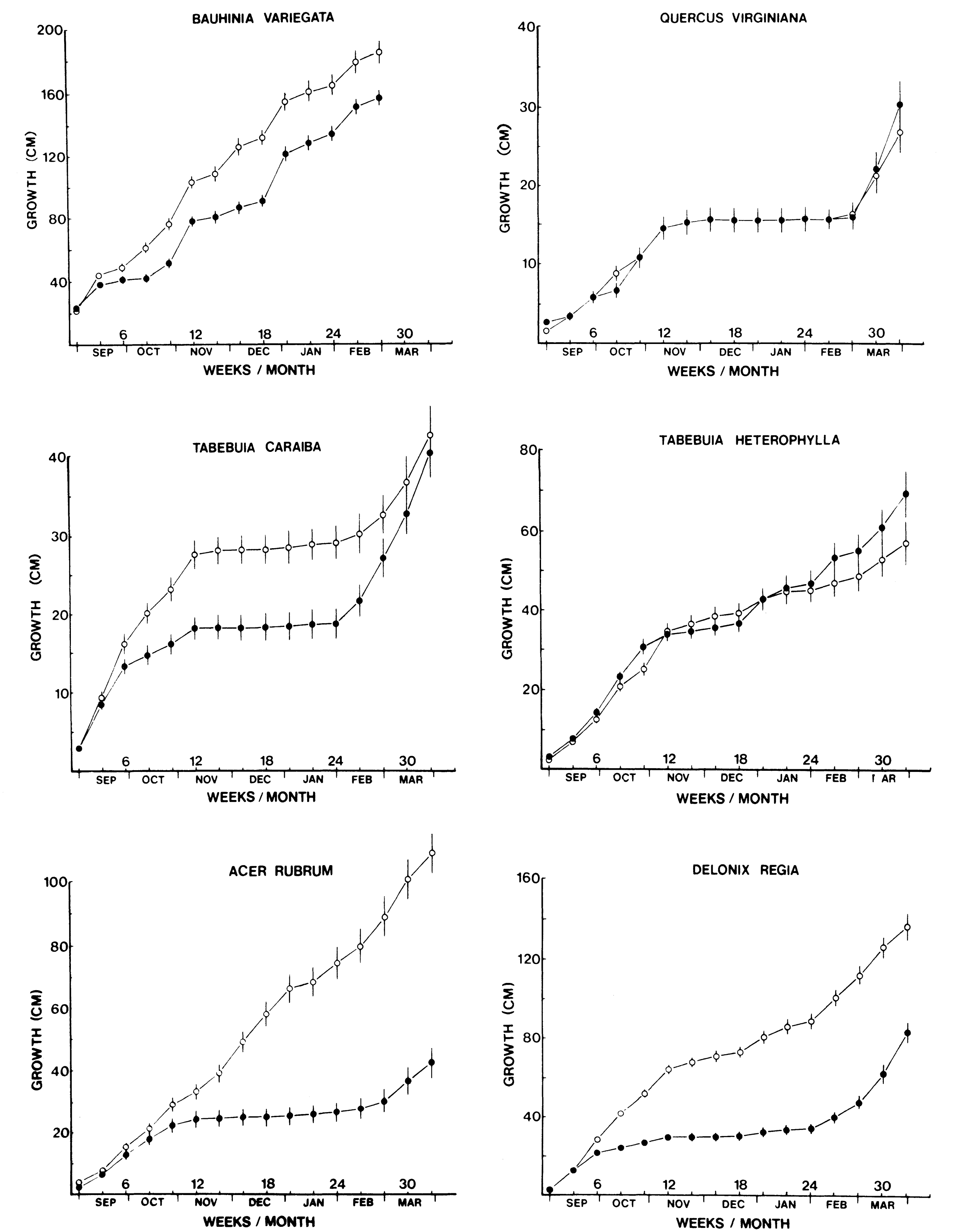

Fig. 2. Cumulative height growth of *Bauhinia variegata*, *Quercus virginiana*, *Tabebuia caraiba*, *T. heterophylla*, *Acer rubrum*, and *Delonix regia* grown under LD (open circles) and ND (closed circles) photoperiods. Individual points represent biweekly means ± SE (vertical bars).

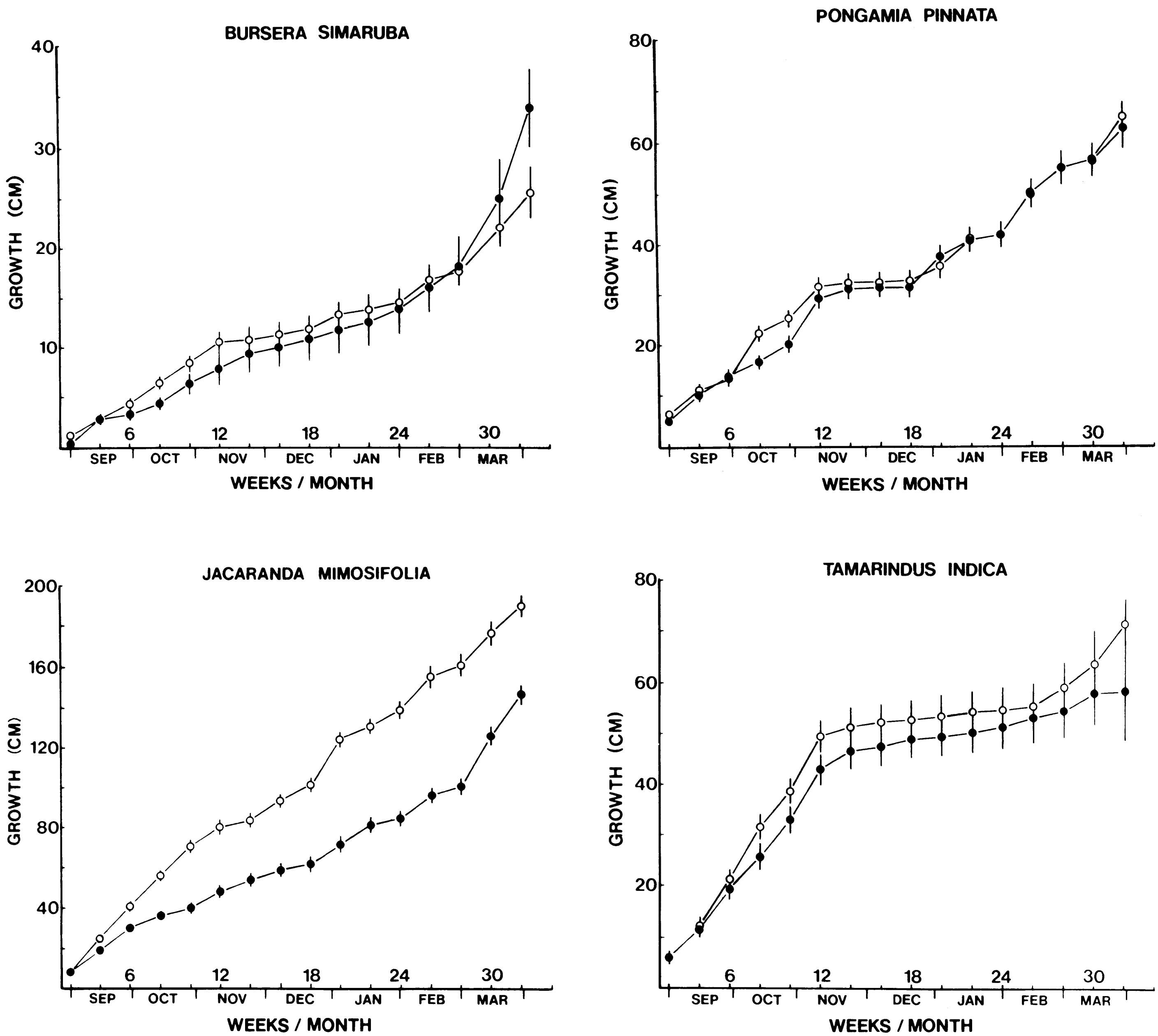

Fig. 3. Cumulative height growth of *Bursera simaruba, Pongamia pinnata, Jacaranda mimosifolia,* and *Tamarindus indica* grown under LD (open circles) and ND (closed circles) photoperiods. Individual points represent biweekly means ± SE (vertical bars).

15°C appears to be essential for growth in this population of *Q. virginiana*. The greater growth rate of ND plants in the spring was a phenonemon observed in several tropical species in this experiment and in previous studies (1).

P. pinnata grew at a rather constant rate throughout the experiment, regardless of photoperiod or temperature, and could be categorized as a Class C species in which SD do not cause cessation of growth. *B. simaruba* and *T. heterophylla* also grew more or less continuously throughout the year, but with a slight decrease in growth rate during the cooler months of November through January. There was no apparent response to photoperiod until March when ND plants began growing at a faster rate than those grown under LD.

T. indica, B. variegata, and *J. mimosifolia* may be described as quantitative LD plants. Growth among *B. variegata* and *J. mimosifolia* for both LD and ND plants was more or less continuous, although LD plants grew at a faster rate than ND plants. Growth in both LD and ND *T. indica* slowed considerably during the cooler months of November through February, but during months when average minimum temperatures exceed 15°C, LD plants grew at a slightly faster rate. Temperature appears to be the most important environmental factor influencing growth of this species.

D. regia responded like a typical Class A species in this experiment. Growth was continuous throughout the study period for LD plants, but under ND conditions, no growth was measured during the SD of November through January. Daylength during this period is less than 10.8 hr at 26° N latitude. Since minimum average temperatures were still quite warm in October, it is assumed that photoperiod, not temperature, is responsible for seasonal cessation of growth in this species. In this respect it is similar to *A. rubrum*, a temperate species.

LD in *T. caraiba* enhanced growth rate over that of ND plants in the warmer autumn months. In the winter months growth ceased for both groups, presumably in response to cool temperatures. During the warmer months of February and March, ND plants grew at a much more rapid rate than LD plants, negating the height advantage incurred by the LD plants in the autumn months. The growth response curve for this species is virtually identical to that of *Swietenia mahagoni* (1). The phenomenon of greater growth in the spring by ND plants has been noted in several tropical species here, as well as in *Q. virginiana*. Although LD conditions do not necessarily promote growth during the cooler winter months, they perhaps prevent natural changes in endogenous chemical growth substances from occurring, thus reducing growth rate in these species in the spring. The nature of such growth substances remains to be determined. Optimum growth might be achieved in species which exhibit this phenomenon, by providing artifical LD only as long as incremental growth rate of LD plants significantly exceeds that of ND plants. Artificial illumination could be discontinued at this time, allowing time for natural endogenous chemical changes to take place in the plants before spring and at the same time resulting in greater cost efficiency due to reduced energy consumption for illumination.

For Class A species such as *A. rubrum* and *D. regia*, providing LD throughout the autumn and winter months in southern Florida results in substantial increases in annual growth. Artificial photoperiod extension for quantitative LD plants such as *B. variegata* and *J. mimosifolia* is effective, but since final height differences were not great and both species grow rapidly anyway, this practice may not be cost-effective.

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