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Influence of Photoperiod, Photosynthetic Photon Flux, and Temperature on Growth of Canary Island Ivy

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***Abstract.* The effects of selected environmental factors [temperature, photosynthetic photon flux (*PPF*), and photoperiod] that contribute to optimal vegetative growth of Canary Island ivy (*Hedera canariensis* Willd.) were investigated. Experiments were conducted in growth chambers at constant day/night temperatures of 16 and 26 °C . The greatest number of leaves (6.1) and plant height (38.0 cm) were achieved with *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ and an 8-hour photoperiod at 16 °C. The greatest branch number (3.9), leaf area (41.4 cm^2) and leaf chlorophyll content (1.02 $mg \cdot cm^{-2}$) were achieved with a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ with a 12-hour photoperiod at 16 °C. Under normal greenhouse or field conditions, Canary Island ivy rarely branches; however, a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ also induced branching.**

Canary Island ivy displays a strong apical dominance and does not readily branch when pruned. About 6 months are required to produce a salable hanging basket from stem cuttings. Production methods that increase branching would reduce the time required to produce a marketable crop (Al-Juboory and Williams, 1991a, 1991b). Considerable research has been conducted on the use of controlled environments to accelerate the growth of selected woody plants such as birch seedlings (Krizek and Zimmerman, 1973). The major factor affecting the stimulation of lateral branching of birch seedlings in the growth chamber was photosynthetic photon flux (*PPF*) (Krizek and Zimmerman, 1973). This is similar to the response of herbaceous plants (Krizek et al., 1968, 1970) when high *PPF* was used in combination with low temperature. English ivy (*Hedera helix* L.) plants grown under high *PPF* produced significantly more branches than did plants grown under low *PPF* (Healy et al., 1980). Furthermore, high *PPF*, use of red light, and a long photoperiod stimulate lateral branching in many plant species, including English ivy (Healy et al., 1980), chrysanthemum (*Dendranthema* ×*grandiflorum* Kitam.) (Heins and Wilkins, 1979), and tomato (*Lycopersicon esculentum* Mill.) (Tucker, 1977), whereas far-red *PPF* inhibits it (Tucker, 1975). The growth of Canary Island ivy was accelerated when grown under a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at 16 or 26 °C and treated with benzylamino purine (BA) (Al-Juboory and Williams, 1991b).

The objective of this study was to compare the effects of selected environmental factors (temperature, *PPF*, and photoperiod) on increased lateral branching and vegetative growth of Canary Island ivy in a growth chamber.

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Materials and Methods

Plant material. Single-node leaf cuttings were rooted in a 1 peat : 1 perlite (by volume) rooting medium under intermittent mist in the greenhouse for 4 weeks. The plants were then potted in 10-cm-diameter pots (one plant per pot) in a 1 peat : 1 perlite : 1 soil (by volume) medium. Plants were spaced 20 cm on center to prevent leaf overlap and shading. The plants were fertilized biweekly with nutrient solution composed of 20N–8.6P–16.6K water-soluble fertilizer containing N at 200 $mg \cdot L^{-1}$.

Experimental design and analysis. This growth chamber study was conducted as three experiments with six growth chambers in each experiment. In each experiment the experimental design was a complete factorial in a split-split plot. Whole plots were growth chambers randomly assigned a temperature of either 16 or 26 °C, while split plots were *PPF* [70, 140, or 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ provided by cool-white fluorescent lamps and 60 W (120 V) incandescent lamps] and split-split plots were photoperiods (8, 12, 16, or 20 h). The relative humidity was maintained at 60% while the CO_2 concentration in the growth chamber was computer controlled and maintained at an ambient level of 350 + 10 ppm. The *PPF* levels were controlled by a LI-COR 1770 (LI-COR, Lincoln, Nebr.) solar monitor using a quantum sensor. Temperature and relative humidity also were computer controlled.

Ten plants with four nodes were selected 3 weeks after potting and placed in each split-split plot. These 10 plants were considered as subsamples and all analyses were based upon the means of the 10 plant subsamples. Data were analyzed via analysis of variance and regression analysis (SAS, 1989).

Growth and chlorophyll measurements. Branch number, leaf number, leaf area, growth rate, plant height, and chlorophyll content were recorded 5 weeks after the plants were placed in the growth chamber. Leaf area was determined with an electronic area meter LI-COR model LI-3100 (LI-COR). Chlorophyll

Table 1. Abbreviated analysis of variance for the main effects and interactions of temperature, photosynthetic photon flux (*PPF*), and photoperiod on the growth of Canary Island ivy.

		Significance of F value				
Source	df	Branch number	Leaf number	Leaf area	Plant height	Chlorophyll content
Experiment (E)	2	NS	NS	NS	NS	NS
Temperature (T)	1	**	**	**	**	**
Error a	12					
Light (L)	2	**	**	**	**	**
E*L	4	NS	NS	NS	NS	NS
T*L	2	**	**	**	**	**
E*T*L	4	NS	NS	NS	NS	NS
Error b	24					
PPF (P)	3	**	**	**	**	**
E*P	6	NS	NS	NS	NS	NS
T*P	3	**	**	**	**	NS
E*T*P	6	NS	NS	NS	NS	NS
L*P	6	**	**	**	**	**
E*L*P	12	NS	NS	NS	NS	NS
T*L*P	6	**	**	**	**	**
E*T*L*P	12	NS	NS	NS	NS	NS

NS, *, **Indicates nonsignificance or significance at alpha = 0.05 and 0.01, respectively.

was determined by the fluorescence spectra recorded on a photon-counting spectrofluorometer model SLM 8000 C, interfaced with an IBM PC model XT (Beckman Instruments, Fullerton, Calif.). Pigment solutions were measured at room temperature in cylindrical microcells 3 mm in diameter. An aliquot of the hexane extract was dried under a stream of N, and the pigment was redissolved in 80% acetone at room temperature. Total chlorophyll content (mg·cm^{-2}) was determined spectrofluorometrically (Ioannides, 1989).

Results

Analysis of variance indicated that for each observation the three-way interaction of temperature × *PPF* × photoperiod was significant (Table 1). No interaction involving experiments was noted and thus data were pooled over experiments. Since the treatments were quantitative in nature, regression analysis was conducted via the Proc Reg procedure of SAS utilizing the STEPWISE selection option. All main effects and two and three factor interactions were selected for inclusion in the model. The surface models were graphed (Figs. 1–5) via the Proc G3D procedure of SAS. Coefficients of determination (r^2) were >0.99 for each measure.

Branch number. After 5 weeks of treatment, plants exposed to a *PPF* of 210 µmol·m^{-2}·s^{-1} for 8 or 12 h at 16 °C exhibited multiple branching, while those exposed to a *PPF* of 140 or 70 µmol·m^{-2}·s^{-1} for the same photoperiod and temperatures had only one branch (Fig. 1). Extending the photoperiod to 16 or 20 h completely inhibited axillary bud break at the highest *PPF*. There were significant interactions among photoperiod, *PPF*, and temperature. In general, axillary bud break increased when plants were grown at a *PPF* of 210 µmol·m^{-2}·s^{-1} at 16 °C, confirming the findings of Al-Juboory and Williams (1991b), Carpenter and Carlson, (1974) and Erickson et al. (1980). No branching occurred at 26 °C, which is consistent with results obtained by Carpenter (1974) for *Petunia*.

Leaf number. The greatest number of leaves (6.1) was achieved on plants exposed to a *PPF* of 210 µmol·m^{-2}·s^{-1} for an 8-h photoperiod at 16 °C (Fig. 2). During the 5-week period in the growth chamber, these plants produced a weekly average of 1.22, 1.14, and 1.14 leaves at photoperiods of 8, 12, and 16 h, respectively. The interactions among photoperiod, *PPF*, and temperature for number of leaves produced were significant, but leaf number generally declined as temperature increased and rose with *PPF*.

Leaf area. After 5 weeks of treatment, leaf area was greater at 16 °C than at 26 °C regardless of photoperiod (Fig. 3). Leaf area increased linearly with increasing *PPF* levels at both temperatures. The greatest leaf area (41.4 cm^2) was obtained at 16 °C with the highest *PPF* and a 12-h photoperiod.

Plant height. Temperature, *PPF*, and photoperiod all had a significant effect on plant height. Plants grown under an 8-h photoperiod were consistently taller than those grown un-

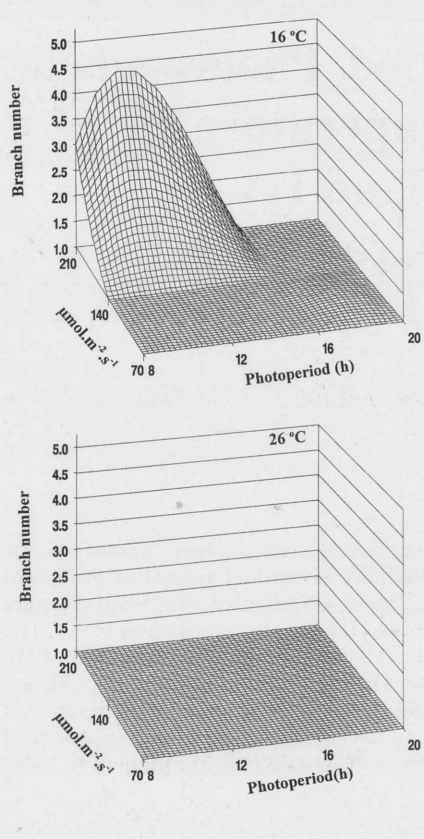

Fig. 1. Effects of temperature, *PPF*, and photoperiod on branch number of Canary Island ivy.

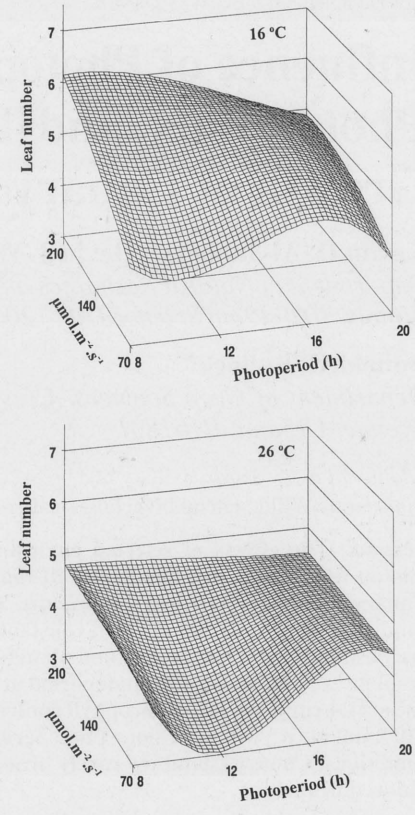

Fig. 2. Effects of temperature, *PPF*, and photoperiod on leaf number of Canary Island ivy.

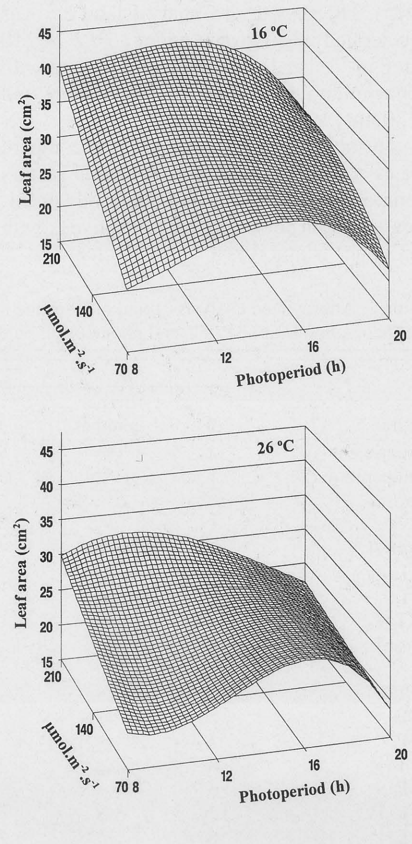

Fig. 3. Effects of temperature, *PPF*, and photoperiod leaf area of Canary Island ivy.

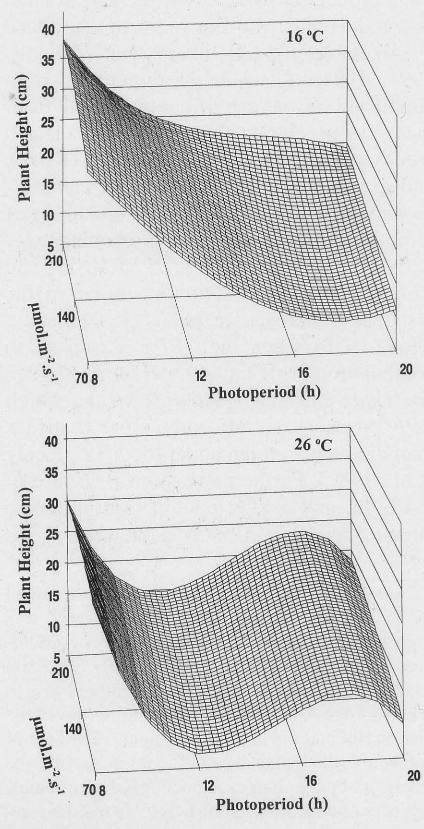

Fig. 4. Effects of temperature, *PPF*, and photoperiod plant height of Canary Island ivy.

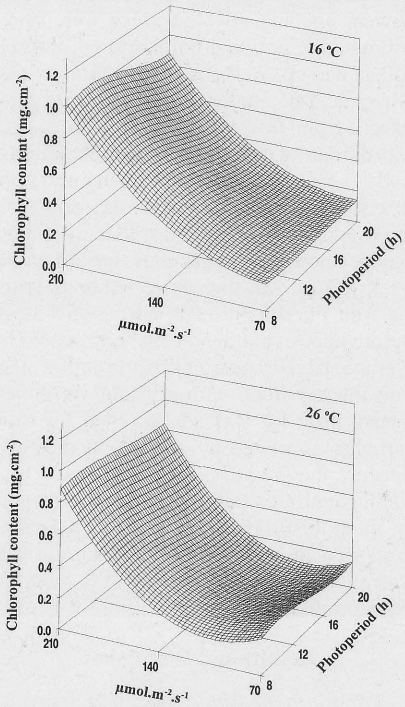

Fig. 5. Effects of temperature, *PPF*, and photoperiod chlorophyll content of Canary Island ivy.

der longer photoperiods (Fig. 4). The mean height of plants at 8 h was almost twice that attained by plants grown under the same conditions with a 20-h photoperiod. Height was linearly related to *PPF*. Plants grown at 16 °C were significantly taller than those grown at 26 °C, suggesting that net photosynthesis was the higher at the lower temperature. Height was consistently greatest under an a 8-h photoperiod, increasing as *PPF* increased and as temperature decreased.

Total chlorophyll content. The chlorophyll content of leaves was significantly higher under a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ than under lower levels of illumination regardless of temperature or photoperiod (Fig. 5). Neither temperature nor photoperiod had a marked effect upon chlorophyll content, regardless of *PPF*.

Discussion

Our results indicate that temperature, *PPF*, and photoperiod are important factors for vegetative growth of *H. canariensis* (Al-Juboory and Williams, 1991b). This conclusion agrees with the findings of earlier studies with both *H. canariensis* (Al-Juboory and Williams, 1991b) and chrysanthemum (Heins and Wilkins, 1979), which demonstrated the predominant influence of photoperiod on branching. In the present study, the major effect of a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at 16 °C was stimulation of lateral branching. This response was similar to that obtained by Krizek et al. (1968, 1970, 1973) for birch (*Betula* spp.) and crabapple (*Malus* spp.) seedlings at elevated temperature, and agrees with previous observations on stimulation of lateral branching as the most marked influence of *PPF* in the growth chamber (Al-Juboory and Williams, 1991b; Heins and Wilkins, 1979).

Hanging baskets of Canary Island ivy are in high demand for patio and interior decoration. Foliage density is the main factor contributing to their appearance and aesthetic quality and this determines marketability and price. Foliage density is a result of lateral branching and total leaf area. Therefore, increasing these positive attributes is a high priority. Weakening apical dominance is particularly desirable because it results in hanging baskets that are full and compact. Canary Island ivy plant grown in a growth chamber under *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at 16 °C and an 8- or 12-h photoperiod grew more rapidly than those under a *PPF* of 70 or 140 $\mu mol \cdot m^{-2} \cdot s^{-1}$ at both temperatures (16 or 26 °C). These findings provide evidence that temperature and *PPF* can be manipulated to optimize growth of *H. canariensis*. Our recommendation for the most efficient and commercially feasible production of Canary Island ivy hanging baskets would be l6 °C, a *PPF* of 210 $\mu mol \cdot m^{-2} \cdot s^{-1}$, and a photoperiod between 8 to 16 h in a growth chamber.

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