IOWA STATE UNIVERSITY
Department of Horticulture

Angela R. Beaman and Richard J. Gladon

Sweet Basil Requires 500 µmol/m²/s PPF for Greatest Biomass Production

Introduction & Rationale

Energy conservation in controlled environments is a major concern for both commercial and research facilities, as well as for extraterrestrial controlled environment food production. Using the least amount of energy possible and still being able to produce the needed edible biomass in a controlled environment would help commercial industry and researchers control costs and be more efficient with energy and finances.

Objective

Our objective was to determine the optimal irradiance level for the greatest biomass production of three cultivars of sweet basil in a controlled environment. A secondary objective was to determine whether there are interaction effects between the irradiance levels and the cultivars of basil.

Materials & Methods

In 2007, three replications grew in growth chambers set to a constant 25°C and four irradiance levels set to a 16-hour photoperiod for 29 days. Replication occurred over time. Three cultivars of basil were used: 'Genovese', 'Italian Large Leaf', and 'Nufar'. The four irradiance levels were 300, 400, 500, and 600 µmol/m²/s. Seeds were germinated in Oasis LC-1 Horticubes® for 10 to12 days in a growth chamber set to a constant 25°C, with a 16-hour photoperiod. The seeds imbibed deionized water the first day, and then they were fertigated with full-strength Hoagland's Nutrient Solution No. 1 every 12 hours until transplanting occurred. Standard pots (12.5 cm) were filled with greenhouse potting mix substrate (Sunshine® LC-1). One plant per pot was transplanted into the LC-1 mix when the first true leaves were ≥ 0.5 cm long. Twenty-four plants of each cultivar were placed into each of the four chambers in a completely randomized design. (Each chamber contained 72 plants.) Plants were fertigated as needed with Hoagland's Nutrient Solution No.1. Plant height, plant diameter, leaf number ≥ 0.5 cm, plant fresh weight, and leaf fresh weight were recorded on day 29. Plants then were placed into a 67°C dryer for seven days, and the dry weights were recorded. Statistical analyses of the factorial design were done using proc glm for ANOVA in SAS.

Results

There was no interaction between cultivar and irradiance level (data not presented). However, there were main effects of irradiance (Table 1) and cultivar (Table 2). Plant height and plant diameter were lowest at 300 and 400 µmol/m²/s, and greatest at 500 and 600 µmol/m²/s. Leaf number greater than 0.5 cm was lowest at 300 and 400 µmol/m²/s, and greatest at 500 and 600 µmol/m²/s. Plant fresh weight, leaf fresh weight, and total dry weight was lowest at 300 and 400 µmol/m²/s, and greatest at 500 and 600 µmol/m²/s. The greatest biomass was produced at 500 and 600 µmol/m²/s, and the lowest biomass was produced at 300 and 400 µmol/m²/s. There were cultivar main effects for plant height, plant diameter, plant fresh weight, leaf fresh weight, and dry weight (Table 2). 'Italian Large Leaf' and 'Nufar' produced shorter plants with a greater diameter (Table 2). When compared to 'Genovese', 'Italian Large Leaf' produced the greatest biomass as measured by plant fresh weight, leaf fresh weight, and total dry weight, and 'Nufar' yielded an intermediate amount of biomass (Table 2).

Table 1. Means of three replications over time of plant height, plant diameter, leaf number (≥ 0.5 cm), plant fresh weight, leaf fresh weight, and total dry weight of three cultivars of basil ('Genovese', 'Italian Large Leaf', and 'Nufar') subjected to four irradiance levels. Plants were in growth chambers for 29 days, with a 16-hour photoperiod and a constant temperature of 25°C and irrigated with full-strength Hoagland's Nutrient Solution No. 1. Data are averaged over all three cultivars.

PPF (µmol/m²/s)	Plant Height (cm)	Plant Diameter (cm)	Leaf # (≥ 0.5 cm)	Plant FW (g)	Leaf FW (g)	Total Dry Weight (g)
300	14.2 b[x]	15.2 b	30 c	7.794 c	5.863 c	0.608 c
400	15.2 b	14.8 b	39 b	8.896 bc	6.822 bc	0.712 bc
500	19.3 a	16.5 a	49 a	11.856 a	8.359 a	0.949 a
600	18.6 a	16.8 a	44 ab	10.548 ab	7.740 ab	0.844 ab

[x]Means within each column followed by an identical letter are not different at $P \leq 0.05$ according to Fisher's least significant difference test. α = 0.05.

Table 2. Cultivar differences of three replications over time for plant height, plant diameter, leaf number (≥ 0.5 cm), plant fresh weight, leaf fresh weight, and total dry weight of three cultivars of basil, ('Genovese', 'Italian Large Leaf', and 'Nufar') subjected to four irradiance levels. Plants were in growth chambers for 29 days with a 16-hour photoperiod and a D/N temperature of 25°C and irrigated with full-strength Hoagland's Nutrient Solution No. 1. Data are averaged over all four irradiance levels.

Cultivar	Plant Height (cm)	Plant Diameter (cm)	Leaf # (≥ 0.5 cm)	Plant FW (g)	Leaf FW (g)	Total Dry Weight (g)
'Genovese'	19.7 a[x]	13.9 b	41 a	8.804 b	6.262 b	0.705 b
'Italian Large Leaf'	16.9 b	16.8 a	43 a	10.657 a	7.893 a	0.841 a
'Nufar'	13.9 c	16.8 a	37 a	9.859 ab	7.433 a	0.789 ab
	LSD = 1.514	*LSD = 1.006*	*LSD = 5.526*	*LSD = 1.5111*	*LSD = 1.063*	*LSD = 0.122*

[x]Means within each column followed by an identical letter are not different at $P \leq 0.05$ according to Fisher's least significant difference test. α = 0.05.

Conclusions & Recommendations

Photosynthetic irradiance was saturated at 500 µmol/m²/s because little if any additional growth occurred at 600 µmol/m²/s. In most cases, statistical differences were found between 500 and 600 µmol/m²/s for all parameters measured, indicating the irradiance was becoming toxic to the plants. We recommend lighting that does not exceed 500 µmol/m²/s to conserve energy while enabling the greatest biomass production of sweet basil in a controlled environment such as a growth chamber or extraterrestrial food production facility.

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