Interaction of Light Intensity and Controlled-release Fertilization Rate on Growth and Flowering of Two New Guinea Impatiens Cultivars

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SUMMARY. New guinea impatiens (*Impatiens hawkeri*) (NGI) 'Pure Beauty Rose' (PBR) and 'Paradise Orchid' (PO) were grown in full sun, 55% shade, or 73% shade and fertilized with a controlled-release fertilizer (CRF) [Nutricote Total 13-13-13 (13N-5.7P-10.8K), type 100] incorporated at rates of 2, 4, 6, 8, 12, 16, 20, 24, 28 and 32 lb/yard³ of growing media (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³). Plant quality rating, shoot dry weight, and flower number were measured at harvest and substrate samples were collected to analyze final substrate pH and electrical conductivity (EC). For both cultivars, light intensity and fertilization rate interactions were different for shoot dry weight and flower number, but there was no difference in plant quality rating between the light levels. Quality ratings of both PBR and PO plants increased as CRF rate increased to 12 to 16 lb/yard³ above these levels quality was not improved. Shoot dry weight of PBR plants grown in full

sun increased as CRF rate increased to 28 lb/yard³ and then decreased, while shoot dry weight of plants grown with 55% and 73% shade increased as CRF rate increased to 20 and 16 lb/yard³, respectively, with no further increases. Shoot dry weight of PO plants grown in full sun and 55% shade increased as CRF rate increased to 28 and 24 lb/yard³, respectively, with no further increases, while shoot dry weight of plants grown with 73% shade increased as CRF rate increased to 24 lb/yard³ and then decreased. Flower number of PBR plants grown in full sun, 55% shade, and 73% shade increased as CRF rate increased to 24 lb/yard³ and then decreased. Flower number of PO plants grown in full sun increased as CRF rate increased to 28 lb/yard³ and then decreased, while flower number of plants grown in 55% and 73% shade increased as CRF rate increased to 24 lb/yard³ and then decreased.

Flowering in NGI is affected by several factors, including cultivar, fertilization program, light intensity, temperature, and number of cuttings per pot (Banner and Klopmeier, 1995). Flower development in NGI is encouraged by higher light intensities [4000 fc (43,055.6 lx)] while light intensities below 3000 fc (32,291.7 lx) encourage stem elongation and reduced flowering (Banner and Klopmeier, 1995). Growers are advised to reduce light intensities with shading if they want to keep NGI stock plants vegetative (Banner and Klopmeier, 1995).

However, plant nutritional requirements are believed to be higher under higher light intensities than under lower light levels (Joiner et al., 1981; Nelson, 1996). For example, Conover and Poole (1990) suggest that fertilizer rates for foliage plants grown in full sun be increased by 50% over those being grown under 50% shade. However, NGI plants are extremely sensitive to high soluble salt levels in the growing substrate, and high fertilization levels result in poor growth (Banner and Klopmeier, 1995). It is important during low light periods not to overfertilize NGI. The general recommendation is to fertilize NGI plants with a constant liquid fertilizer application of 100 to 200 ppm (mg·L⁻¹) nitrogen (N) and increasing rates to 200 to 250 ppm of N as plants mature (Banner and Klopmeier, 1995). Using

CRF is not recommended because they may raise substrate soluble salt concentrations to undesirable levels (Banner and Klopmeier, 1995). There is limited published data on optimal CRF rates of NGI plants. The purpose of this study was to determine the relationship between light intensity and CRF fertilization rate on growth and flowering of two cultivars of NGI plants.

Material and methods

Rooted cuttings of PBR (a tall cultivar) and PO (a compact cultivar) (Paul Ecke Ranch, Encinitas, Calif.) were transplanted into 6-inch-diameter (15.2 cm) azalea pots [55.1 fl oz (1.63 L)] filled with a commercial substrate (Pro-mix BX; Premier Horticulture Ltd., Red Hill, Pa.). Two experiments were performed consisting of three light levels and ten fertilization levels. The first experiment was initiated in Feb. 2000, and the second in Dec. 2000. For all experiments, a CRF [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100 (Florikan, Sarasota, Fla); 6.5% ammonium-nitrogen (NH₄-N) and 6.5% nitrate-nitrogen (NO₃-N)] was incorporated into the growing substrate prior to transplanting. The rates of CRF used for both experiments were 2, 4, 6, 8, 12, 16, 20, 24, 28 and 32 lb/yard³. Florikan Inc. recommends using a rate of 3.5 lb/yard³ (2.08 kg·m⁻³) for sensitive crops and a rate of 7.5 lb/yard³ (4.45 kg·m⁻³) for medium feeding crops.

For both experiments, three light levels were used: full sun, 55% shade, or 73% shade. These light levels are representative of what is used by the Florida industry. Within each light treatment, light intensity (fc) and cumulative total radiation (W·m⁻²) were measured every half hour over a 24-h period using a data logger (LI-1000; Li-Cor, Lincoln, Nebr.) (Table 1). Three Li-Cor quantum light sensors were placed on a stand set at canopy level in each light level examined. Similarly, substrate and air temperature were measured every hour over a 24-h period using a Digi-Sense scanning thermometer (Cole Parmer, Vernon Hills, Ill.) (Table 1). Temperature sensors were placed into the growing substrate as well as placed at canopy level to measure substrate and air temperatures, respectively. Both light and temperature data were downloaded weekly. Total monthly rainfall data (in inches) also was collected (Table 2).

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Table 1. Average maximum light intensity, cumulative total radiation, and maximum, minimum, and mean soil and air temperature for 'Pure Beauty Rose' and 'Paradise Orchid' new guinea impatiens grown in full sun, 55% shade, or 73% shade. Expt. 1 was conducted from Feb. to May 2000, while Expt. 2 was conducted from Dec. 2000 to Mar. 2001. Values are averaged for both cultivars.

Light treatment	Avg max light intensity (fc) ^y	Cumulative total radiation (W·m ⁻²) ^x	Temp (°F) ^z					
			Soil			Air		
			Max	Min	Mean	Max	Min	Mean
<i>Expt. 1</i>								
Full sun	6145	191,867	100.4	50.0	69.8	82.4	51.8	68.0
55% shade	2765	86,340	86.0	50.0	66.2	78.8	51.8	64.4
73% shade	1660	51,804	82.4	50.0	66.2	80.6	50.0	64.4
<i>Expt. 2</i>								
Full sun	8880	286,833	102.2	60.8	75.2	89.6	57.2	71.6
55% shade	3995	129,075	93.2	55.4	71.6	86.0	57.2	69.8
73% shade	2395	77,445	86.0	57.2	71.6	87.8	57.2	71.6

^z5/9(°F - 32) = °C.

^y1 fc = 10.76 lx

^xCumulative total radiation was measured every half-hour over a 24-h period.

Table 2. Total monthly rainfall during the study period for 'Pure Beauty Rose' and 'Paradise Orchid' new guinea impatiens grown in full sun, 55% shade, or 73% shade. Expt. 1 was conducted from Feb. to May 2000, while Expt. 2 was conducted from Dec. 2000 to Mar. 2001.

Month	Total rainfall (inches) ^z
Feb. 2000	1.06
Mar. 2000	5.42
Apr. 2000	5.48
May 2000	5.54
Total Expt. 1	17.5
Dec. 2000	3.11
Jan. 2001	0.70
Feb. 2001	0.31
Mar. 2001	7.92
Total Expt. 2	12.04

^z1 inch = 25.4 mm.

Ten replicate pots per cultivar, CRF, and light treatment combination were arranged in a split plot design with light level as the main plot and CRF rate as the sub-plot. For each cultivar, pots were completely randomized for the CRF treatments within each light level. Full-sun plants were grown on a bench set outside on black ground cloth, which covered an asphalt runway, while 55% and 73% shade plants were grown on benches in an open-sided shade house. In addition to rainfall, plants were watered daily with Roberts No. 435 sprinkler head overhead irrigation (Hummert International, Earth City, Mo.) for 20 min, delivering approximately 0.4 to 0.8 inches (10.2 to 20.3 mm) of water to establish a 20% leaching fraction. The irrigation water used throughout the experiment

Table 3. Analysis of variance of 'Pure Beauty Rose' and 'Paradise Orchid' new guinea impatiens plant quality rating, shoot dry weight, and flower number. Plants were grown in substrates with 2, 4, 6, 8, 12, 16, 20, 24, 28, or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K type 100)] and grown in full sun, 55% shade, or 73% shade. Expt. 1 was conducted from Feb. to May 2000, while Expt. 2 was conducted from Dec. 2000 to Mar. 2001.

Source	df	<i>P</i> > <i>F</i> ^z		
		Quality ^y	Shoot dry wt	Flower no.
<i>Pure Beauty Rose</i>				
Expt.	1	0.8480	0.4459	0.4099
Replicate	9	0.4860	0.6100	0.1585
Light treatment (L)	2	0.2132	0.0001	0.0001
Fertilizer rate (F)	9	0.0001	0.0001	0.0001
L × F	18	0.0983	0.0001	0.0002
<i>Paradise Orchid</i>				
Expt.	1	0.2620	0.3374	0.6053
Replicate	9	0.5425	0.2958	0.2721
Light treatment (L)	2	0.0924	0.0001	0.0001
Fertilizer rate (F)	9	0.0001	0.0001	0.0001
L × F	18	0.2579	0.0001	0.0001

^zAccepted probability level of 5%.

^yPlant quality was based on a scale of 1 to 5, with 5 = excellent and 1 = poor.

had 252 ppm (0.36 dS·m⁻¹) EC and 94 ppm calcium carbonate (CaCO₃) total alkalinity.

Seventy days after transplanting, plant quality rating of each plant was measured in May 2000 for Expt. 1 and in Mar. 2001 for Expt. 2. Plant quality was subjectively rated based on overall appearance and uniformity of flowering using a scale of 1 to 5, where 5 = excellent; 3 = average; and 1 = poor. Any plant rated 3 or better was considered salable. Flower number also was determined at this time by counting the number of fully open flowers showing color on each plant. For both experiments, shoots were cut

at the surface of the growing substrate and dried at 140 °F (60.0 °C) for shoot dry weight determination. Substrate samples also were collected after harvesting the shoots to determine final pH and EC. Immediately after collecting the samples, the substrates were extracted with distilled water using the saturated media extraction method (Warncke, 1986). Final pH and EC were determined on the extracted solution using a pH/conductivity meter (Acumet model 20; Fisher Scientific, Pittsburgh).

Data were analyzed using analysis of variance and regression analysis (SAS Systems, SAS Institute, Cary, N.C.).

Regression analysis was performed within each light level to determine the relationship between the plant growth parameters measured (plant quality, shoot dry weight, and flower number) and fertilization rate for each cultivar. Results from the two experiments were combined because there was no difference between the experiments (Table 3).

Results and discussion

For both cultivars, light treatment and CRF rate interactions were different for shoot dry weight and flower number (Table 3). However, for both cultivars there was no difference in plant quality rating among the light levels (Table 3). Quality ratings of PBR and PO plants increased as CRF rate increased to approximately 16 lb/yard³ with no further increases (Fig. 1, Table 4). A minimum CRF rate of 4 to 6 lb/yard³ produced salable quality plants (rated a 3 or better) for both cultivars (Fig. 1).

Shoot dry weight of PBR plants grown in full sun increased as CRF rate increased to 28 lb/yard³ and then decreased, while shoot dry weight of plants grown with 55% and 73% shade increased as CRF rate increased to approximately 20 lb/yard³, with no further increases with increasing CRF rates (Fig. 2, Table 4). Shoot dry weight of PO plants grown in full sun and 55% shade increased as CRF rate increased to 28 and 24 lb/yard³, respectively, with no further increases, while shoot dry weight of plants grown with 73% shade increased as CRF rate increased to 24 lb/yard³ and then decreased (Fig. 3, Table 4).

Higher light levels usually result in higher photosynthesis rates and greater dry weight accumulation (Faust and Logan, 1998). Larouche et al. (1989) reported that at lower photosynthetic photon flux, the vegetative growth of tomato (*Lycopersicon esculentum*) plants was limited and that plants did not respond to increasing nitrogen levels in the nutrient solution. Broschat (2002) also reported that higher fertilization rates were required in full sun to achieve optimum artillery fern (*Pilea serpyllacea*) quality compared to plants grown in shade.

PBR plants grown in 55% shade and full sun had, on average, more flowers than plants grown in 73% shade (Fig. 2, Table 4). Flower number of PBR plants grown in full sun increased

Fig. 1. Quality rating (based on a scale of 1 to 5 with 5 = excellent) of 'Pure Beauty Rose' (A) and 'Paradise Orchid' (B) new guinea impatiens plants grown in substrates with 2, 4, 6, 8, 12, 16, 20, 24, 28 or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100]. Values were averaged over the three light levels. (SE for 'Pure Beauty Rose' = 0.05; SE for 'Paradise Orchid' = 0.03)

Table 4. Regression equations for quality rating (based on a scale of 1 to 5 with 5 = excellent and 1 = poor), final shoot dry weight, and final flower numbers of 'Pure Beauty Rose' and 'Paradise Orchid' new guinea impatiens plants grown in substrates with 2, 4, 6, 8, 12, 16, 20, 24, 28 or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100] and grown in full sun, 55% shade, or 73% shade.

Parameter measured	Regression equation
Pure Beauty Rose	
Quality	
Averaged for light level	$y = -3.13 \times 10^{-3}x^2 + 0.15x + 2.71, r^2 = 0.90$
Shoot dry wt	
Full sun	$y = -3.59 \times 10^{-2}x^2 + 2.12x + 0.183, r^2 = 0.98$
55% shade	$y = -3.32 \times 10^{-2}x^2 + 1.70x + 5.59, r^2 = 0.97$
73% shade	$y = -3.59 \times 10^{-2}x^2 + 1.70x + 3.80, r^2 = 0.96$
Flower no.	
Full sun	$y = -4.98 \times 10^{-2}x^2 + 2.13x + 0.77, r^2 = 0.94$
55% shade	$y = -3.82 \times 10^{-2}x^2 + 1.64x + 7.17, r^2 = 0.95$
73% shade	$y = -2.81 \times 10^{-2}x^2 + 1.26x + 3.89, r^2 = 0.94$
Paradise Orchid	
Quality	
Averaged for light level	$y = -3.17 \times 10^{-3}x^2 + 0.15x + 2.38, r^2 = 0.95$
Shoot dry wt	
Full sun	$y = -1.17 \times 10^{-2}x^2 + 0.71x + 1.15, r^2 = 0.98$
55% shade	$y = -1.53 \times 10^{-2}x^2 + 0.78x + 2.49, r^2 = 0.97$
73% shade	$y = -2.13 \times 10^{-2}x^2 + 0.98x + 0.94, r^2 = 0.97$
Flower no.	
Full sun	$y = -8.41 \times 10^{-3}x^2 + 0.45x - 1.23, r^2 = 0.92$
55% shade	$y = -1.20 \times 10^{-2}x^2 + 0.54x - 0.46, r^2 = 0.94$
73% shade	$y = -5.73 \times 10^{-3}x^2 + 0.28x - 0.35, r^2 = 0.97$

Fig. 2. Final shoot dry weight and final flower numbers of 'Pure Beauty Rose' new guinea impatiens plants grown in substrates with 2, 4, 6, 8, 12, 16, 20, 24, 28 or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100] and grown in full sun (□), 55% shade (○), or 73% shade (△). (SE for shoot dry weight = 2.9; SE for flower number = 2.0) (28.4 g = 1 oz)

as CRF rate increased to 28 lb/yard³ and then decreased while flower number of plants grown in 55% shade and 73% shade increased as CRF increased to 24 lb/yard³ and then decreased (Fig 2, Table 4). PO plants grown in 55% shade, on average, had more flowers than plants grown in full sun or 73% shade (Fig 3, Table 4). Flower number of PO plants grown in full sun and 55% shade increased as CRF rate increased to 24 lb/yard³ and then decreased while flower number of plants grown in 73% shade increased as CRF rate increased to 28 lb/yard³ and then decreased (Fig 3, Table 4).

For both cultivars, the lowest flower numbers were on plants grown

in 73% shade. This was expected because flowering in NGI is encouraged at light levels between 4000 and 6000 fc (43,055.6 and 64,583.4 lx) (Banner and Klopmeier, 1995). The average light intensity for the two experiments was 3380 and 7515 fc (36,382.0 and 80,890.7 lx), respectively, for 55% shade and full sun.

No differences were observed in final substrate pH or EC values between the two cultivars or between the two experiments; therefore, these data were combined. There also was no difference in substrate pH or EC due to light intensity. Final substrate EC values for each light level increased as CRF application rate increased (Table

Fig. 3. Final shoot dry weight and final flower numbers of 'Paradise Orchid' new guinea impatiens plants grown in substrates with 2, 4, 6, 8, 12, 16, 20, 24, 28 or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100] and grown in full sun (□), 55% shade (○), or 73% shade (△). (SE for shoot dry weight = 0.98; SE for flower number = 0.90) (28.4 g = 1 oz)

5). Judd and Cox (1992), using a 1 soil :2 water extraction method, reported that growth of NGI was not negatively affected as long as EC levels do not exceed 875 ppm (1.25 dS·m⁻¹). Similarly, Banner and Klopmeier (1995) recommend that EC values range from 1050 to 1575 ppm (1.5 to 2.25 dS·m⁻¹) using the saturated media extraction method. Our final substrate EC concentrations ranged from 91 to 693 ppm (0.13 to 0.99 dS·m⁻¹) (Table 5). Although our final substrate EC values are below recommended NGI soluble salt concentrations, we believe that nutrients were taken up by the plants as well as leached due to irrigation and rain events. When using CRF

Table 5. Final substrate pH and electrical conductivity (EC) of new guinea impatiens ‘Pure Beauty Rose’ and ‘Paradise Orchid’ plants fertilized with 2, 4, 6, 8, 12, 16, 20, 24, 28 or 32 lb/yard³ (1.2, 2.4, 3.6, 4.7, 7.1, 9.5, 11.9, 14.2, 16.6, and 19.0 kg·m⁻³) of a controlled-release fertilizer [Nutricote Total 13-13-13 (13N-5.7P-10.8K) type 100]. Because values were not different between cultivars or between the two experiments, these numbers were combined. (N = 12)

Light treatment	Fertilizer application rate (lb/yard ³)	pH ^z	Electrical conductivity (dS·m ⁻¹) ^y
Full sun	2	6.04	0.13
	4	6.02	0.16
	6	6.03	0.23
	8	6.08	0.27
	12	6.16	0.27
	16	5.94	0.44
	20	5.88	0.44
	24	5.82	0.47
	28	5.76	0.52
	32	6.06	0.89
55% shade	2	5.44	0.15
	4	5.99	0.25
	6	5.61	0.26
	8	5.81	0.28
	12	5.59	0.31
	16	5.43	0.44
	20	5.45	0.45
	24	5.54	0.60
	28	5.76	0.79
	32	5.56	0.99
73% shade	2	5.50	0.17
	4	5.68	0.18
	6	6.05	0.23
	8	6.04	0.30
	12	5.98	0.32
	16	5.44	0.38
	20	5.75	0.43
	24	5.40	0.49
	28	5.47	0.50
	32	6.00	0.66
Significance			
Light treatment (L)		NS	NS
Fertilizer rate (F)		NS	*
L × F		NS	NS

^zStandard error for pH means = 0.03.

^yStandard error for EC means = 0.08; 1 dS·m⁻¹ = 700 ppm.

^{ns} Nonsignificant or significant at *P* > 0.01, respectively.

products for NGI production, recommended substrate EC levels may not be as reliable.

PBR and PO NGI growing in full sun required slightly higher fertilization rates than those growing in shade. For both cultivars, there were differences among the light levels in plant response to CRF rate. Salable quality plants were produced at all three light levels. However, higher light levels produced plants with more flowers.

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