Whole-plant Response of Six Poinsettia Cultivars to Three Fertilizer and Two Irrigation Regimes

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Abstract. Six cultivars of poinsettia (*Euphorbia pulcherrima* Wind.), 'Angelika White', 'Celebrate 2', 'Freedom Red', 'Lilo Red', 'Red Sails', and 'Supjibi Red' were grown for 9 weeks during vegetative development under three constant-feed fertilizer treatments, 80, 160, or 240 mg N/liter and two irrigation regimes, well-watered (high irrigation) or water deficient (low irrigation). Plants fertilized with 80 or 240 mg N/liter were 10% to 18% shorter, while those fertilized with 160 mg N/liter were 25% shorter with low versus high irrigation. Leaf area and leaf dry weight increased linearly in response to increasing fertilizer concentrations. Low irrigation reduced leaf area, leaf, stem, and shoot dry weight 3670 to 41%. Cultivars responded similarly to irrigation and fertilizer treatments in all components of shoot biomass production and no interactions between the main effects and cultivars occurred. Stomatal conductance and transpiration decreased with increasing fertilizer rates or sometimes with low irrigation. Highest chlorophyll contents occurred in leaves of 'Lilo Red' and 'Freedom Red'. Leaves of plants fertilized with 80 mg N/liter were deficient in leaf N and had 40% to 49% lower leaf chlorophyll content compared to plants fertilized with 160 or 240 mg N/liter. Irrigation had no effect on leaf N or chlorophyll content. At the end of the experiment leaves of 'Supjibi Red' and 'Angelika White' contained higher concentrations of soluble proteins than the other four cultivars.

Fertilization and irrigation management are important components of producing a healthy crop. Applying liquid fertilizer at a constant rate with each irrigation has become a popular and economical practice for many poinsettia growers (Ecke et al., 1990). The advantage of such a program is ease of application, which supplies nutrients constantly at desired levels, while excess nutrients may be leached from the media. However, excess nutrients in the leachate are wasted.

About 250 mg N/liter are recommended for constant fertigation of poinsettias (Ecke et al., 1990). In recent years fertilizer recommendations have been reevaluated because nitrate leaching from intensive greenhouse production has become a major environmental concern (Biernbaum, 1992; Cabrera et al., 1993; Hershey and Paul, 1982). Poinsettias grown with a solution of 200 mg N/liter produced large plants with excessive foliar N levels (Tayama and Carver, 1992). Acceptable growth in poinsettias was achieved by lowering fertilizer applications via subirrigation to a constant rate of 125 mg N/liter (Rose and White, 1994), indicating that poinsettias can be grown successfully with 50% less fertilizer than is currently recommended.

Irrigation is a critical management tool when coupled with constant liquid fertilization to manipulate electrical conductivity (EC) levels of the growing medium. Poinsettias grown with constant application of 100, 200, or 400 mg N/liter and leaching fractions from 0 to 0.5 were of acceptable quality, but plant height and dry weight generally increased with decreasing root media EC (Yelanich and Biernbaum, 1993). Similar media EC, plant height, and fresh weight were produced with 100 mg N/liter and 0.2 to 0.3 leaching fraction, or with 200 or 400 mg N/liter, each with 0.4 to

0.6 leaching fraction. The 2- or 4-fold N application of the latter two treatments compared to the 100 mg N/liter treatment were wasted. Hershey and Paul (1982) reported that more N was lost through leaching at higher application rates of liquid fertilizer when the same leaching fraction was used. Poinsettias fertilized with 300 mg N/liter with leaching fractions ranging from 0 to 0.4 showed no differences in growth, but accumulated high EC levels in the media, particularly at low leaching fractions (Ku and Hershey, 1991).

Many floriculture crops, including poinsettias, are treated with growth retardants to achieve the desired shorter and compact canopy for container-grown plants (Larson, 1992). Water stress reduces plant growth and leaf area (Kramer, 1983) and may be used as a strategy to control stem elongation (Röber and Hafez, 1981). However, if water deficits are too severe, stomatal closure, reduced photosynthesis, or even permanent chloroplast damage can occur (Kramer, 1983).

The primary objective of this study was to evaluate six poinsettia cultivars for their vegetative growth and physiological characteristics in response to three fertilizer concentrations and two irrigation regimes. Additionally, as the impact of water stress and nitrogen fertilization on populations of phytophagous insects can be quite profound (Mattson and Haack, 1987a, 1987b; White, 1976, 1984), we also examined the impact of these factors on the potential suitability of poinsettia as an insect host plant. Host plant suitability to insects was estimated by the quantity of foliar soluble protein. Previous studies suggested higher concentrations of foliar protein to be associated with increased preference of such plants to phytophagous insects (Bentz et al., 1995; White, 1984).

Materials and Methods

Rooted poinsettia cuttings were transplanted individually in pots (1360 ml) with UC #3 mix (Matkin and Chandler, 1957) on 14 May 1994. The six cultivars used in this study were 'Angelika White', 'Celebrate 2', 'Freedom Red', 'Lilo Red', 'Red Sails', and 'Supjibi Red'. Plants were grown in a double-poly greenhouse

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Table 1. Analysis of variance for plant height measured 3, 5, 6, 7, and 9 weeks after three fertilizer and two irrigation treatments were imposed on six poinsettia cultivars.

	Weeks after treatments started				
	3	5	6	7	9
Fertilizer (F)	NS	***	***	***	***
Irrigation (I)	***	***	***	***	***
F × I	**	***	**	***	**
Cultivar (C)	***	***	***	***	***
F × C	NS	NS	NS	NS	NS
I × C	NS	NS	NS	NS	NS
F × I × C	NS	NS	NS	NS	NS
Single degree of freedom contrasts					
F linear	NS	***	***	***	**
F quadratic	NS	NS	NS	NS	NS
I × F linear	NS	NS	NS	NS	NS
I × F quadratic	**	***	***	***	**

located at the University of California at Riverside. The range of average day/night temperatures was between 27 to 32C and 19 to 24C, with average daily relative humidity between 44% and 85%. Poinsettias were grown as single stem plants and were provided only with natural daylight.

For the first 6 weeks plants were irrigated with a 150mgN/liter solution (Miracle Grow; Sterns Miracle Gro Products, Port Washington, N.Y.). Individual heavy weight emitters were placed on the media in each pot and water was delivered with a drip system. Distribution uniformity of the irrigation system was between 0.93 and 0.96 at the beginning of the experiment.

Six treatments (three concentrations of N fertilizer by two levels of irrigation) were started on 2 July and continued until final harvest on 1 Sept. Plantex 17-5-19 Poinsettia Fertilizer (Plantco Inc., Brampton, Ont., Canada) was injected continuously (model D 1-16; Dosatron Intl., France) into the irrigation water at 80, 160, or 240 mg N/liter. Actual nitrate and ammonia concentrations of the irrigation water were monitored weekly with a nitrate electrode (model 93-07) (Orion, Boston) and an ammonia electrode (model 95-12), respectively.

Irrigation treatments consisted of 24- or 48-sec applications (120 or 240 ml water per pot) every other day. To minimize run-off, half of the irrigation water was applied at 0800 HR, and the second half at 1000 HR. Plants receiving 240 ml (high irrigation) were well-watered and never displayed any signs of wilting; plants receiving the deficit irrigation of 120 ml (low irrigation) usually started to wilt between irrigation cycles.

Fig. 1. Plant height of poinsettia grown for 9 weeks under three fertilizer by two irrigation regimes (bars indicate ± 1 standard error). Means are averages of six cultivars.

Fig. 2. Plant height of six poinsettia cultivars grown for 9 weeks under three fertilizer by two irrigation regimes, averaged over fertilizer and irrigation regimes (bars indicate ± 1 standard error).

to 30 h after the most recent irrigation. Relative chlorophyll content of the most recently fully expanded leaves also was measured at these dates with an in situ SPAD-502 chlorophyll meter (Minolta, Japan). Actual chlorophyll content of leaf disks with a known SPAD reading was determined according to the method of Bruinsma (1963). Standard regression curves for chlorophyll content as a function of SPAD readings were calculated for each poinsettia cultivar.

Plant height was measured from the media surface to the shoot apex on the dates above and at final harvest. On 1 Sept., plants were harvested and leaves were

Actual volumes of irrigation solution applied were measured once a week for 6 weeks.

Stomatal conductance and transpiration were measured with a steady-state porometer (LI-1600; LI-COR, Lincoln, Neb.) on 23 July and on 4, 12, and 18 Aug. Measurements were taken about 26

counted, leaf area was measured with a LI-3100 leaf area meter, and leaf and stem dry weight were determined. Leaf N concentration of the most recently fully expanded leaves was determined with the Kjeldahl method. Soluble proteins of these same leaves were determined according to the procedure of Jones et al. (1988).

Table 2. Number of leaves, leaf area, and leaf, stem, and shoot dry weight of six poinsettia cultivars grown at three fertilizer and two irrigation treatments from 2 July until 1 Sept.

	No. of leaves	Leaf area (cm ²)	Dry wt (g)		
			Leaf	Stem	Shoot
Fertilizer (mg N/liter)					
80	102	2708	12.0	8.2	20.2
160	108	3394	13.6	5.7	19.4
240	118	3947	15.1	6.8	22.0
Irrigation (ml/pot)					
120	91	2592	10.5	5.1	15.6
240	127	4107	16.8	8.7	25.5
Cultivar					
Angelika White	157 a ^z	4477 a	15.2 a	8.3 a	23.5 a
Celebrate 2	92 c	2991 bc	12.0 c	6.6 b	18.5 b
Freedom Red	84 c	2765 c	12.6 bc	5.9 b	18.5 b
Lilo Red	129 b	3518 b	15.0 a	7.3 ab	22.3 a
Red Sails	102 c	3435 b	14.6 ab	7.1 ab	21.7 b
Supjibi Red	92 c	2912 bc	12.3 bc	6.2 b	18.5 b
Significance of F test					
Fertilizer (F)	NS	*	NS	NS	NS
Irrigation (I)	***	***	***	***	***
F × I	NS	NS	NS	NS	NS
Cultivar (C)	***	***	**	*	**
F × C	NS	NS	NS	NS	NS
I × C	NS	NS	NS	NS	NS
F × I × C	NS	NS	NS	NS	NS
Single degree of freedom contrasts					
F linear	NS	**	*	NS	NS
F quadratic	NS	NS	NS	NS	NS
I × F linear	NS	NS	NS	NS	NS
I × F quadratic	NS	NS	NS	NS	NS

^zMeans within a column followed by different letters are significantly different at $P < 0.05$, Duncan's multiple range test.

NS, *, **, *** Nonsignificant or significant at $P < 0.05, 0.01$, or 0.001 , respectively.

Table 3. Stomatal conductance and transpiration of six poinsettia cultivars grown at three fertilizer and two irrigation treatments from 2 July until 1 Sept.

	Stomatal conductance (cm·s ⁻¹)				Transpiration rate (g·cm ⁻² ·s ⁻¹)			
	Weeks after treatments begun				Weeks after treatments begun			
	3	5	6	7	3	5	6	7
80	0.34	0.53	0.67	1.13	5.25	3.98	5.18	6.04
160	0.11	0.58	0.32	0.37	2.10	4.49	2.70	3.35
240	0.05	0.41	0.24	0.29	1.01	3.26	1.97	2.00
Irrigation (ml/pot)								
120	0.12	0.53	0.36	0.57	2.07	4.05	2.75	3.60
240	0.22	0.48	0.47	0.66	3.51	3.77	3.84	4.06
Cultivar								
Angelika White	0.10 a'	0.52 b	0.41 b	0.60	1.74 a'	3.95 b	3.14 b	3.75
Celebrate 2	0.17 ab	0.35 a	0.35 ab	0.80	2.88 ab	2.81 a	3.20 b	4.60
Freedom Red	0.26 b	0.58 b	0.56 c	0.73	4.09 b	4.41 b	4.43 c	4.65
Lilo Red	0.10 a	0.52 b	0.30 a	0.54	1.57 a	4.06 b	2.50 ab	3.30
Red Sails	0.14 ab	0.43 ab	0.28 a	0.53	2.35 ab	3.40 ab	2.34 a	3.32
Supjibi Red	0.25 b	0.65 b	0.57 c	0.45	4.09 b	4.87 b	4.19 c	3.28
Significance of F test								
Fertilizer (F)	***	**	***	**	***	*	***	**
Irrigation (I)	***	NS	**	NS	***	NS	**	NS
F × I	**	NS	NS	NS	*	NS	NS	NS
Cultivar (C)	***	**	***	NS	***	**	**	NS
F × C	**	NS	NS	NS	**	NS	NS	NS
I × C	NS	NS	NS	NS	NS	NS	NS	NS
F × I × C	NS	NS	NS	**	NS	NS	**	
Single degree of freedom contrasts								
F linear	***	NS	***	**	***	*	***	**
F quadratic	NS	**	NS	NS	NS	**	NS	NS
I × F linear	*	NS	NS	NS	*	NS	NS	NS
I × F quadratic	NS	NS	NS	NS	NS	NS	NS	NS

Means within a column followed by different letters are significantly different at $P < 0.05$, Duncan's multiple range test.

NS, *, **, *** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

The experimental design was a split plot in a randomized split block with four blocks. The treatment design was a $3 \times 2 \times 6$ factorial with three N fertilizer concentrations by two irrigation treatments by six cultivars. Fertilizer and irrigation were the two main plot factors and cultivar was the subplot factor. Data were analyzed with analysis of variance and single degree of freedom contrasts where appropriate. Mean separation of cultivars was calculated with Duncan's multiple range test if F test for cultivars was significant. Stepwise regression was used to correlate chlorophyll content to SPAD readings (SAS Inst., Cary, N.C.).

Results

Plant height was significantly influenced by a fertilizer-irrigation interaction and by cultivar main effects (Table 1, Figs. 1 and 2). Low irrigation and the 160 mg N/liter resulted in the shortest plants, while well-watered plants were the tallest. Plants fertilized with 80 or 240 mg N/liter were 10% to 18% taller when watered with high versus low irrigation throughout the experiment. Cultivar specific differences were found for plant height throughout the experiment with 'Freedom Red' as the shortest cultivar, around 8 cm shorter than the other cultivars (Fig. 2). 'Angelika White' was the tallest cultivar during the second half of the experiment.

Treatment effects from irrigation dominated all components of shoot biomass production. Low versus high irrigation significantly reduced leaf area, leaf, stem and shoot dry weight 36% to 41%,

while leaf number was reduced by 28% (Table 2). A positive linear fertilizer effect on leaf area and leaf dry weight was detected with single degree of freedom contrasts. Cultivars responded similarly to irrigation and fertilizer treatments in all components of shoot biomass production as no interactions between treatments and cultivars were found (Table 2). 'Angelika White' and 'Lilo Red' produced plants with the largest shoot biomass while 'Celebrate 2', 'Freedom Red', and 'Supjibi Red' produced less biomass. 'Red Sails' ranked between those two groups.

Stomatal conductance and transpiration decreased with increasing fertilizer rates (Table 3). Low irrigation was associated with lower conductance and transpiration 3 and 6 weeks after water treatments began (Table 3). Highest stomatal conductance and transpiration were measured on leaves from cultivars 'Freedom Red' and 'Supjibi Red'. We also observed that the natural diheliotropism of leaves was altered when plants under deficit irrigation developed epinasty as the experiment progressed.

Chlorophyll content measured by extraction from leaf disks corresponded closely to that determined by the in situ chlorophyll meter (Fig. 3). Chlorophyll content measurements for each cultivar were taken from foliage ranging from chlorotic to dark green. The relationship between destructive and in situ chlorophyll content measurements for cultivars 'Freedom Red' and 'Red Sails' were similar and best described with a quadratic regression. Similar relationships with a linear and quadratic component were determined for 'Celebrate 2' and 'Lilo Red', while a linear regres-

sion produced the best fit for 'Angelika White' and 'Supjibi Red'.

Highest chlorophyll content was observed in 'Lilo Red' followed by 'Freedom Red' for all four sampling times (Table 4). The other cultivars were not consistent in their relative ranking based on chlorophyll content. Linear and quadratic increases in chlorophyll content were observed with increasing fertilization. At week 5, chlorophyll content was 40% and 49% higher for plants at the medium and high fertilization level, respectively, compared to plants at the low level (Table 4). A cultivar-fertilizer interaction was found at week 7 when chlorophyll content of 'Supjibi Red' increased linearly over the fertilizer treatments while chlorophyll content of the other cultivars increased from 80 to 160 mg N/liter and then remained stable or decreased at 240 mg N/liter (Fig. 4). Irrigation had little influence on leaf chlorophyll content (Table 4).

Leaf N concentration responded linearly and quadratically to increasing fertilizer, with overall means of 3.66%, 4.40%, and 4.59%, for the low, medium, and high fertilizer treatments, respectively. Leaf N concentration also showed an interaction between fertilizer treatments and cultivar at the end of the experiment, while irrigation had no effect throughout the experiment. With increasing N in the fertilizer solution, leaf N increased linearly for 'Celebrate 2', 'Lilo Red', and 'Angelika White' (Fig. 5). Leaf N in 'Supjibi Red' and 'Red Sails' increased when fertilizer was increased from 80 to 160 mg N/liter and then remained constant when N was increased to 240 mg/liter. 'Freedom Red' showed the strongest response to an increase in fertilizer from 80 to 160 mg N/liter with a 38% increase in leaf N to 4.8%, the highest leaf N at this fertilizer treatment. At 240 mg N/liter, leaf N of 'Freedom Red' dropped to 4.6%.

Soluble proteins in poinsettia leaves differed between cultivars. Leaves of 'Supjibi Red' and 'Angelika White' contained 0.26 and 0.24 mg·g⁻¹ dry weight, respectively, while leaves of the other four cultivars contained less soluble proteins, ranging from 0.21 to 0.19 mg·g⁻¹ dry weight. Nine weeks of different fertilizer and irrigation regimes had no effect on the amount of soluble proteins in leaves.

Discussion

Growth of all cultivars was similarly affected by fertilizer and irrigation treatments. The lowest fertilizer treatment (80 mg N/liter) produced commercially unacceptable plants with smaller leaf area, proportionally bigger stems, and chlorotic foliage. Doubling the fertilizer concentration to 160 mg N/liter eliminated the chlorosis and resulted in an attractive green foliage,

the intensity of which characteristically varies by cultivar. Our results are in agreement with previous studies indicating that acceptable poinsettias can be grown with up to 5070 less fertilizer than the recommended 250 mg N/liter (Rose and White, 1994; Yelanich and Biernbaum, 1993, 1994).

Deficit irrigation reduced plant height with a similar reduction in the low and high fertilization treatments, but a disproportionate decrease at the medium fertilizer treatment. Other negative side effects of low irrigation were the considerable reductions in leaf area and leaf and stem growth, resulting in a relatively sparse canopy. Lieth and Burger (1989), using a soil-moisture tension-based irrigation system with preset soil moisture levels, determined that chrysanthemums (*Chrysanthemum morifolium* Ramat.) experiencing low soil moisture levels between irrigations without leaching grew less leaf, stem, and shoot biomass compared to plants grown with daily irrigation and leaching. In the experiment described here, presumably by affecting carbohydrate allocation, low fertilizer rates resulted in proportionally larger stems and lower leaf biomass compared to the medium and high fertilizer treatments. Ratio of leaf to stem dry weight was 3/2 for the low and 7/3 for the medium and high fertilizer treatments.

Reduced shoot growth and reduction in stomatal conductance and transpiration at low irrigation were most likely due to the total amount of N applied and the leachate fraction. Only half the amount of total N was applied to the plants under the low deficit

Fig. 3. Relationship between chlorophyll content of six poinsettia cultivars as determined by extraction or nondestructively with a SPAD-502 chlorophyll meter. Best fit regressions were Angelika White— $y = 11.298 \text{ SPAD}$, $R^2 = 0.98$; Supjibi Red— $y = 9.831 \text{ SPAD}$, $R^2 = 0.98$; Celebrate 2— $y = 5.735 \text{ SPAD} + 0.107 \text{ SPAD}^2$, $R^2 = 0.98$; Lilo Red— $y = 4.911 \text{ SPAD} + 0.169 \text{ SPAD}^2$, $R^2 = 0.98$; Freedom Red— $y = 0.313 \text{ SPAD}^3$, $R^2 = 0.96$; Red Sails: $y = 0.330 \text{ SPAD}^3$, $R^2 = 0.96$.

Table 4. Chlorophyll SPAD measurements of six poinsettia cultivars grown at three fertilizer and two irrigation treatments from 2 July until 1 Sept.

	Chlorophyll SPAD			
	Weeks after treatments begun			
	3	5	6	7
Fertilizer (mg N/liter)				
80	25.7	25.8	26.5	29.2
160	34.2	36.2	37.8	36.9
240	37.0	38.4	38.4	37.9
Irrigation (ml/pot)				
120	32.9	34.6	34.9	35.1
240	31.8	32.2	33.6	34.1
Cultivar				
Angelika White	29.3 c'	33.5 bc	34.1 bc	33.5 bc
Celebrate 2	33.1 bc	31.1 c	32.0 c	32.4 c
Freedom Red	33.4 ab	33.8 b	35.0 b	35.1 b
Lilo Red	36.9 a	37.7 a	39.2 a	38.8 a
Red Sails	30.3 bc	31.1 c	31.9 c	33.7 bc
Supjibi Red	30.8 bc	33.5 bc	33.0 bc	34.4 bc
Significance of F test				
Fertilizer (F)	***	***	***	***
Irrigation (I)	NS	**	NS	NS
F × I	NS	NS	NS	NS
Cultivar (C)	***	***	***	***
F × C	NS	NS	NS	**
I × C	NS	NS	NS	NS
F × I × C	NS	NS	NS	NS
Single degree of freedom contrasts:				
F linear	***	***	***	***
F quadratic	*	***	***	**
I × F linear	NS	NS	NS	NS
I × F quadratic	NS	NS	NS	NS

*Means within a column followed by different letters are significantly different at $P < 0.05$, Duncan's multiple range test.

NS,*, **,*** Nonsignificant or significant at $P < 0.05$, 0.01, or 0.001, respectively.

irrigation compared to the plants under high irrigation at respective fertilizer treatments. Total N applied was 298,595, and 893 mg at low irrigation and 595, 1190, and 1786 mg at high irrigation for low, medium, and high fertilizer treatments, respectively. The leaching fraction was not measured in this experiment, but we observed runoff from both irrigation treatments and assume that plants under deficit irrigation also had lower leaching fractions. Previous studies reported no difference in shoot dry weight when poinsettias were fertilized with 300 mg N/liter and were grown without leaching, resulting in a medium with an EC as high as 8.9 dS·m⁻¹ compared to plants grown with leaching (Ku and Hershey, 1991). Yelanich and Biernbaum (1993) found highest medium EC with fertilization of 400 mg N/liter and no leaching, but obtained maximum shoot growth with fertilizer concentrations of 100 or 200 mg N/liter and leaching fractions of 0.55. These results indicate that even if EC increased, poinsettias are extremely tolerant to a high medium EC and with the fertilizer concentrations used in our study a growth inhibition is not expected. Rather it appears that the irrigation management and the fact that media was allowed to dry out until water became unavailable and wilting occurred was responsible for reduced shoot growth. We suggest that growth inhibition under low irrigation and 80 mg N/liter fertilization could be attributed to an insufficient supply of nutrients, which is corroborated by the smaller leaf area, chlorotic foliage, and deficient leaf N at both low and high irrigation. Although growth was inhibited considerably by the low irrigation

treatment, leaf chlorophyll content was rarely affected (Table 4), indicating that the water stress was mild enough to avoid damage to the chloroplasts (Kramer, 1983).

At medium and high fertilization, plants received adequate nutrients, which is evident from the leaf N concentration and biomass production of all shoot components in the high irrigation treatment. The frequent drought of plants receiving the low irrigation treatment probably prevented uptake of nutrients that were in solution and available to the plant only for a short time. Additionally, precipitation of salts during the drought period may have damaged uptake sites of the root system. We suggest that high EC in the media can be tolerated by plants as long as the salts are in solution, but that high or even moderate EC may damage root hairs once the moisture in the media falls below a certain threshold. Similar conclusions were suggested from a study where chrysanthemum growth declined with increasing soil moisture tensions (Kiehl et al., 1992).

Nondestructive chlorophyll measurements required a calibration curve with extracted chlorophyll content for each cultivar. Leaves of 'Freedom Red' and 'Red Sails' had a higher chlorophyll content with increasing SPAD readings compared to the other cultivars. For example, at a SPAD reading of 45, chlorophyll content of leaves from 'Red Sails' and 'Freedom Red' would be equivalent to 668 and 634 µg·g⁻¹ fresh weight (FW), those from 'Celebrate 2' and 'Supjibi Red' 474 and 563 µg·g⁻¹ FW, and those from 'Angelika White' and 'Lilo Red' would amount to 508 and

566 $\mu\text{g}\cdot\text{g}^{-1}\text{FW}$, respectively. Species differences in leaf greenness based on SPAD-501 measurements and chlorophyll content extraction had been determined previously (Marquard and Tipton, 1987; Yadava, 1986), but to our knowledge no calibration curves for cultivars have been established.

Leaf N of plants from all cultivars fertilized with 80 mg N/liter was below the minimum recommended normal range of 4.0% (Ecke et al., 1990) and visually appeared deficient. For plants receiving 160 or 240 mg N/liter, leaf N ranged from 4.1% to 4.9%. Increasing fertilization from 80 to 160 mg N/liter increased both leaf N and leaf chlorophyll content. Increasing N to 240 mg/liter resulted in cultivar specific responses. As the N rate increased, leaf

chlorophyll content of 'Supjibi Red' increased and leaf N concentration of 'Celebrate 2' and 'Angelika White' increased. Further research is needed to determine whether in situ chlorophyll content measurements can be useful to predict leaf N for possible adjustment of fertilizer applications during the production period.

Soluble foliar protein content was unaffected by irrigation and fertilizer treatments, but was cultivar specific. Although the cultural treatments did not alter soluble foliar protein content, they affected survivorship and development time of the silverleaf whitefly (*Bemisia argentifolii* Bellows & Perring). Low irrigation significantly reduced insect survivorship and low fertilizer treatment decreased insect development time (R.A. Redak, unpublished data).

Stomatal conductance responded consistently to fertilizer treatments, but was more variable in response to irrigation and cultivar. Higher transpiration and conductance of plants receiving the

lowest fertilizer treatment, especially at week 6 and 7 suggest that these plants suffered from a loss of stomatal control in response to the nutrient deficit. Contrasting evidence exists regarding the role of mineral deficiencies on stomatal behavior. Early studies found that nitrogen deficient plants reduced responsiveness of stomata to water stress (Kramer, 1983). Radin et al. (1991) reported that stomatal conductance and transpiration rates of mature cotton (*Gossypium hirsutum* L.) leaves were unaffected by N. Similarly, Bennett et al. (1986) found a treatment effect in well-watered corn (*Zea mays* L.) to N stress. Contrasting studies show that N deficiency caused early stomatal closure under water stress and is due to increased root resistance that lowers leaf water potential (Radin and Boyer, 1982).

Under the conditions of this study acceptable poinsettias could be grown with 160 mg N/liter continuous fertilizer application and irrigation volumes of 240 ml every other day. A further increase in fertilizer concentration is unwarranted because it showed no benefit for shoot biomass production or plant quality as expressed in foliage color. 'Supjibi Red' was the only cultivar where leaf chlorophyll content increased in response to increasing fertilizer from 160 to 240 mg N/liter. If a darker foliage color were desired for this cultivar, nitrogen-use efficiency could be increased by decreasing the leaching fraction or by applying nutrients based on plant uptake (Rose et al., 1994; Yelanich and Biernbaum, 1993).

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Fig. 4. SPAD chlorophyll in leaf tissue of six poinsettia cultivars grown for 9 weeks under three fertilizer by two irrigation regimes, averaged over irrigation regimes (bars indicate ± 1 standard error).

Fig. 5. Nitrogen concentration in leaf tissue of six poinsettia cultivars grown for 9 weeks under three fertilizer by two irrigation regimes, averaged over irrigation regimes (bars indicate ± 1 standard error).

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