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FERTILIZATION OF GREENHOUSE POINSETTIA TO MINIMIZE NITROGEN RUNOFF

BY

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ABSTRACT

FERTILIZATION OF GREENHOUSE POINSETTIA
TO MINIMIZE NITROGEN RUNOFF

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Due to environmental concerns about nitrogen runoff from greenhouses more efficient methods of applying fertilizer are needed. Experiments were completed to determine the affects of the concentration and volume of fertilizer solution applied on media nutrient concentrations, the quantity of nitrogen leached and poinsettia growth. Different treatment combinations of fertilizer concentration and applied volume resulted in similar concentrations of N in the media with greatly different quantities of N leached. Media N concentrations could be maintained at acceptable levels using a fertilizer concentration at half commonly recommended concentrations with little detrimental effect on poinsettia growth. Poinsettia growth was also evaluated over a wide range of fertilizer concentrations under different photosynthetic photon flux and relative humidity conditions. Within accepted media nutrient concentrations no relationship was found between fertilizer concentration and the environmental conditions under which the plants were cultivated.

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Guidance Committee:

The paper format was adopted for this dissertation in accordance with departmental and university regulations. Section I is to be submitted to the Journal of the American Society of Horticultural Science, and section II and III are to be submitted to HortScience.

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INTRODUCTION

Fertilizer costs have been reported to range from 0.5 to 2% of the total cost of production of greenhouse flowering potted plants. This has given ornamental plant producers little incentive to use nutrients efficiently. With the drip irrigation systems currently used, high volumes of liquid fertilizer are often applied to uniformly moisten the media. These factors have lead to high leaching volumes and NO_3-N effluent from greenhouses. Environmental concerns about NO_3-N effluent from greenhouses will force growers to use environmentally sound and more efficient fertilization methods.

Current fertilizer recommendations commonly refer to the concentration of nitrogen to be applied at each irrigation. It is often recommended that 10% to 20% of the volume applied should be leached to prevent salts from accumulating in the pot, but larger volumes are often used. There have been few studies relating fertilizer concentration and leaching volume to media nutrient concentration or fertilizer efficiency. A better understanding of the relationship between fertilizer concentration and applied volume will help greenhouse growers become more efficient in fertilizing plants. Poinsettia was used as the model crop for this research because of the large number produced each year and because of it's reported high nutrient requirement. Both of these factors make poinsettia production susceptible to excess NO_3-N effluent production. The objective of this research was to better understand how fertilizer concentration and leaching volume influence the media nutrient concentration, quantity of nitrogen leached and poinsettia growth. A further objective was to better understand the influence of environment on the nutrient requirements of poinsettias.

Literature Review

Fertilization of Container Grown Poinsettia

Poinsettias have a long and colorful history. Native to the region around Taxco, Mexico, it was first cultivated by the Aztecs, then by Franciscan priests, and then commercially by American and Europeans. The poinsettia was first brought to the United States by Joel Robert Poinsett who propagated it and distributed it to friends (Ecke et al., 1990). Since Robert Buist first sold poinsettias commercially in the mid 1800's it has become the number one flowering pot crop sold in the United States (Anon., 1990).

Poinsettia fertilization research also has a long history with many different scientists working on various problems of poinsettia culture. The research on poinsettia nutrition can be broken down into several different categories: 1) nutrient deficiency symptoms, 2) optimal fertilizer rates and ratios, 3) post harvest quality, 4) salt tolerance, 5) tissue analysis standards, and 6) bract and leaf necrosis. This literature review will address these six topics and also evaluate the fertilization recommendations which are available to poinsettia growers in the forms of text books, extension bulletins and manuals.

Many different soil types, testing methods, fertilizer salts etc., were used in the paper reviewed. A standard fertilization rate (SFR) term was calculated for comparison proposes to provide consistency throughout. The units of SFR used in this paper is kilograms of nitrogen (N) per cubic meter of media per year (kg m^{3} y^{1}). SFR describes the total quantity of N applied in relation to the volume of growing media. The time term year was used even though poinsettias are typically produced in a 3 to 4 month period to make this an SI unit and to normalize the time period. For example a poinsettia cultured in a 1.8 liter pot and irrigated with 0.25 liters of 50 mmol $liter^{-1}$ N (700 mg $liter^{-1}$) once a week for 10 weeks would receive equivalent N to a plant irrigated with 0.25 liters of 25 mmol $liter^{-1}$ N (350 mg $liter^{-1}$) twice a week. Both plants would have had N applied at a rate of 50 kg m^{3} y^{1}. SFR only indicates what was applied and not what was available to the crop since in most cases leaching occurred.

The typical method of deriving SFR would be to take the concentration of fertilizer multiplied by the volume applied and number of applications divided by the volume of media used and duration of crop. SFR can be described by the formula,

$$\frac{FC*Vw*A}{Vm*D}$$

were FC is the fertilizer concentration (Kg $liter^{-1}$), Vw is the volume of water applied each irrigation (liter), A is equal to the number of applications, Vm is the volume of media (m^{-3}) and D is the duration (year). In several papers the volume applied was not reported, therefore an assumption was used based on the volume of solution that could be held in the space between the rim of the pot and surface of the media (Boodley et al., 1966 pp 36). A table is presented at the end of the review listing all the values used to calculate this SFR.

Nutrient Deficiency Symptoms

An important part of understanding how to fertilize a poinsettia is knowledge of nutrient deficiency symptoms. The effects of removal of a single element from a complete nutrient solution on poinsettia growth and development were investigated in several studies. While deficiency symptoms for many of the 16 essential elements have been reported for poinsettia, this review will focus on N.

Laurie and Wagner in 1937 investigated deficiency symptoms of N, P, K, Mg, Fe, Mn, S and B. Poinsettias were grown in either nutrient solution with NO_3-N at a concentration of 5.84 mmol liter^{-1} N (82 mg liter^{-1}) or in a nutrient solution minus N. Plants which received no N had chlorotic leaves which started first in the lower leaves and progressed towards the top. Widmer (1952) conducted an experiment to identify initial deficiency symptoms so that growers could correct deficiency problems early in their development. Poinsettias were grown in a sand culture with a concentration of 13.2 mmol liter^{-1} NO_3-N applied 1-2 times a day. Plants which received no N turned light green within a month and then uniformly chlorotic by two and half months. Plants receiving no N were reported to have reduced leaf and stem expansion with retarded flower development. Struckmeyer (1959) conducted a study similar to Widmer's but looked at leaf sections microscopically to observe anatomical changes caused by elemental deficiencies. Plants were grown in quartz sand and irrigated 3 times a week with a Hoagland's solution (15 mmol liter^{-1} NO_3-N) or Hoagland's minus-N. Nitrogen deficient plants were chlorotic and reported to be smaller in size. Within leaf tissue, phloem cells had collapsed and starch had accumulated in chloroplasts. Each of these studies were conducted to provide growers and researchers information to detect a nutritional deficiency once it has occurred. In each study, the symptoms were defined under conditions of zero N availability and the intent was not to determine the optimal N concentration for plant growth.

Optimal Concentrations

Another way researchers have provided growers with information is by determining the concentration of fertilizer needed for optimal growth. In the 1950's Shanks and Link conducted a series of experiments to determine the optimal concentration and ratio of N, phosphorous (P) and potassium (K). The first in this series of experiments sought to determine an optimal fertilizer concentration for cutting production from stock plants (Shanks and Link,1952). Plants received 946 ml of fertilizer solution, applied weekly for a total of 12 applications. The optimal concentration for maximum cutting production were 56-6.6-8.9 mmol liter^{-1} (784-203-277 mg liter^{-1}) of N, P and K. Nitrogen was applied at an SFR of approximately 2.48 kg m^{-3} y^{-1}. A similar experiment was conducted in 1956 by Link and Shanks (1956) in which they found weekly applications of 66.1-11.9-9.5 mmol liter^{-1} N-P-K (925-370-370 mg liter^{-1}) produced the highest number of cuttings. Nitrogen was applied at a higher SFR than in 1952, with plants receiving 3.79 kg m^{-3} y^{-1}.

Shanks and Link (1956) in another series of experiments investigated fertilization of flowering poinsettias. The concentrations of N applied was either 9.4, 28.3, or 84.9 mmol liter^{-1} N (132, 396 or 1188 mg liter^{-1} N). These treatments supplied N at an SFR of 0.27, 0.81 and 2.44 kg m^{-3} y^{-1}. The treatments receiving the highest concentration of N, 84.9 mmol liter^{-1}, preformed the best and supplied N at a rate similar to their stock plant study. Tissue analysis values for total N decreased with decreasing concentration of N applied. Leaves from the 84.9 mmol liter^{-1} N treatment contained 4.51% N while those from the 9.4 mmol liter^{-1} N treatment contained 2.5% N (dry mass basis). The second portion of the experiment was designed to investigate the timing of the application of fertilizer. Plants were fertilized with 53 mmol liter^{-1} (740 mg liter^{-1}) at potting (Sept 1), or at panning (Sept 15), and/or at Oct 15 or not till after Nov 1. Plants which didn't received any fertilizer till after Nov. 1 had similar stem and bract lengths but received 33% less N (6.10 vs 4.07 kg m^{-3} y^{-1} N). However these plants were unacceptable since they flowered 5 days after December 25, the traditional end marketing date.

In 1963 Kofranek, Byrne, Sciaroni and Lunt compared poinsettias grown with a 20-10-20 (N-P-K) media incorporated resin coated fertilizer (RCF), a liquid fertilizer (36 mmol liter^{-1} N) applied at every irrigation and a combination of both. They concluded that poinsettias could be produced with either 36 mmol liter^{-1} N supplied with liquid fertilization plus RCF or a split application of RCF (3 grams per pot initially and 3 grams per pot 8 weeks later) based on leaf color, visual rating, height and bract diameter. Assuming no leaching, the combined (liquid plus RCF) treatments received N at an estimated SFR of 17.5 and 19.35 kg m^{-3} y^{-1} N (3 and 6 grams per pot RCF respectively). The split RCF treatment received N at a rate of 3.67 kg m^{-3} y^{-1}. The split RCF treatment received 74% less N than the liquid plus RCF, but produced comparable plants. It is possible that leaching was occurring in all treatments which removed a portion of the N from the media. When all the RCF was incorporated initially (6 grams per pot) there wasn't enough fertilizer to support the plant but when a split application was made there was adequate fertilizer for plant growth. It is also possible that excessive amounts of N were being applied with the liquid+RCF treatments. The 6 gram per pot application of RCF was comparable to the amounts of N applied by Link and Shanks so it is possible that the results of Kofranek's experiment are due to excessive leaching and over application of fertilizer.

Meyer and Boodley (1963) experimented with fertilizing poinsettias by foliar applications of liquid fertilizer compared to plants grown in nutrient solutions. Foliar fertilization was shown not to be as effective as root fertilization for application of N,P or K. In this experiment control plants were grown in nutrient solutions of 15-1-6 mmol $liter^{-1}$ N-P-K (210-31-235 mg $liter^{-1}$).

In 1970 Boodley cultured poinsettias using two concentrations of N, 28.6 or 57.2 mmol $liter^{-1}$ (400 and 800 mg N $liter^{-1}$) applied weekly from 3 different salts. These treatments consisted of N SFR of 4.18 and 8.36 kg m^{-3} y^{-1}. Boodley recommended that a N concentration of 28.6 mmol $liter^{-1}$ be applied on a weekly basis from $Ca(NO_3)_2$. Boodley's experiment resulted in N application rates 14% higher than Kofranek's (3.67 kg m^{-3} y^{-1} N) and 10% higher than Link and Shanks' (3.79 kg m^{-3} y^{-1} N).

Post Production Performance

While most of the research on fertilization of poinsettia has been aimed at improving nutrition in the production phase there has been several studies designed to investigate fertilization effects in the consumer phase. Staby and Kofranek (1979) grew poinsettias fertilized at every irrigation with 21.4-1.3-3.6 mmol $liter^{-1}$ N-P-K (300-40-140 mg $liter^{-1}$) up until 0, 1, 2 or 4 weeks before shipping at which time they only received water. The plants were then put into a simulated post production environments for 31 days. Terminating fertilization prior to shipping had little effect on post harvest life, leaf drop, leaf color, bract quality, and cyathia abscission. One explanation for this result was that even after 4 weeks with no fertilizer, adequate levels of nutrients (N > than 3 mmol $liter^{-1}$, P > than 0.09 mmol $liter^{-1}$ and K > than 1.5 mmol $liter^{-1}$) still remained in the soil.

Plants shipped on December 15 which received no fertilizer for 4 weeks had medium concentrations of 13.9 mmol liter^{-1} NO_3-N (194 mg liter^{-1}). This was 27% lower than plants which received fertilizer up to shipping that had media concentrations of 19.1 mmol liter^{-1} NO_3-N (268 mg liter^{-1}). Higher rates of nitrogen were applied in this experiment compared to other experiments reviewed, approximately 8.92 kg m^{-3} y^{-1}. This rate was similar to Boodley's high SFR in 1970 (8.36 kg m^{-3} y^{-1}), in which he noted detrimental effects due to excess salts.

Prince and Cunningham (1988) grew poinsettias using 17.9 mmol liter^{-1} N (250 mg liter^{-1}) constant liquid fertilization (CLF). They used similar treatments as Staby and Kofranek with the plants receiving only water 0,1,2,3 or 4 weeks before harvest. The plants were sleeved for three days and then put into a simulated home environment for 27 days. Decreased leaf abscission was found in plants which had fertilizer terminated at 3 or 4 weeks before shipping. Prince attributed differences in results between these two experiments to the method of irrigation in the post production environment. In Staby's experiment plants were kept constantly moist which supposedly prevented any effects of high salts from occurring. Prince's plants were irrigated as needed. These two experiments were similar in that after four weeks with no fertilizer there was apparently adequate nutrients in the media. In Prince's experiment there were a greater differences in media nutrient concentrations between the 0 and 4 week plants. Plants which received no fertilizer four weeks prior to shipping had medium electrical conductivity (EC) of 1.25 mS cm^{-1} compared to 2.38 mS cm^{-1} in plants fertilized up to shipping, a 53% decrease.

Salt Tolerance

Another area of study in poinsettia nutrition has been aimed at determining the salt tolerance of the poinsettia. Kofranek et al. (1955) grew poinsettias in silicon sand irrigated with a 8-1-2 mmol $liter^{-1}$ N-P-K (112-31-78.2 mg $liter^{-1}$) solution. To the basic solution NaCl and $CaCl_2$ were added to provide approximately 15, 75, 135, and 195 meq $liter^{-1}$ of cations. Height and bract diameter decreased and leaf abscission increased as NaCl and $CaCl_2$ concentration increased. These solutions should give electrical conductivities of 1.5, 7.5, 13.5 and 19.5 mS cm^{-1} based on Richard's (1954) regression line which had a slope of 0.1 mS cm^{-1} meq^{-1}. The poinsettia was rated as moderately sensitive to salt concentrations especially as concentrations exceed 7.5 mS cm^{-1}. This agrees with work done by Richard's in 1954 in which an EC greater than 4.0 mS was shown to restrict yields in many crops. Kofranek's experiment has a very wide range of electrical conductivities between the control and the first treatment making it difficult to make a specific recommendation.

McCall et al. (1959) fertilized poinsettias growing in a loam:peat:sand medium with increasing amounts of a media incorporated 15-10-5 (N-P-K) fertilizer. Reduced growth occurred when the EC of a 2:1 (water:media) sample exceeded 0.55 mS cm^{-1} and plants died when the EC was 1.5 mS cm^{-1}.

Warncke et al. (1985) and by Nelson (1985) proposed for a 2:1 dilution that reduced growth would occur at EC's greater than 1.75 mS cm^{-1}, well above McCall's range. McCall's optimal range worked out to be 0.10 to 0.25 kg m^{-3} N applied as a one time application. In Boodley and Sheldrake's (1977) bulletin they recommended that 0.51 to 1.25 kg m^{-3} N be incorporated to soilless mixes prior to planting. These differences could be due to the media type or could indicate that some other toxicity may have been occurring in McCall's experiment to give reduced growth at such low levels of fertilizer.

Tissue Analysis

An important part of a fertilization program would be how well the plant is utilizing the fertilizer. One way of evaluating uptake efficiency is by tissue analysis. Boodley (1974) investigated how the concentration of the macro elements varied in the media and in plant tissue over time using a conventional fertilization program. He grew plants in a peat:vermiculite medium and fertilized the plants weekly with 28.6-0-10.2 mmol $liter^{-1}$ N-P-K (400-0-400 mg $liter^{-1}$). Assuming no leaching (not indicated) and 200 ml applied at each irrigation, N was applied at an SFR of 4.18 kg m^{-3} y^{-1}. Leaf concentrations of N remained fairly constant at 4% (2.86 mol kg^{-1} N) up to week 9, declining to 3% (2.14 mol kg^{-1}) by the end of the experiment (week 13). The concentration of NO_3-N in the media was highly variable with a high of 7.8 mmol $liter^{-1}$ (109 mg $liter^{-1}$) at week 3 which gradually dropped to 0.3 mmol $liter^{-1}$ (4 mg $liter^{-1}$) by week 13.

Cox and Seeley (1983) conducted a similar experiment but looked at 2 concentrations of N (21.4 and 2.1 mmol liter^{-1}) and 2 concentrations of K (7.7 and 0.77 mmol liter^{-1}) and investigated their effect on N,P,K,Ca, and Mg concentration in the leaves. They had similar results as Boodley with N concentration remaining fairly constant in the tissue but declining slightly near the end of the experiment. Nitrogen concentration applied did have a significant effect on the N concentration in the tissue. At 21.4 mmol liter^{-1} N the tissue concentration of N was around 4.5% (3.21 mol kg^{-1} N) where at 2.1 mmol liter^{-1} it was between 3.0 to 3.5% (2.14 to 2.5 mol kg^{-1} N). Nitrogen deficiency symptoms were evident at the low concentration. Assuming two irrigations per week and application volume of 0.25 liters, N was applied at rate of 4.70 kg m^{-3} y^{-1} similar to the other experiments reviewed.

Dole and Wilkins (1991) investigated what effect plant age and nodal position of leaf had on leaf tissue concentrations of B, Ca, Cu, Fe, Mg, Mn, N, P, K, and Zn. Plants in this experiment were grown in 10 cm pots (450 ml) in a peat, perlite, soil mixture (3:1:1). Plants were fertilized with 14-1.4-4.2 mmol liter^{-1} (200-44-166 mg liter^{-1}) applied during week days and only water on the weekends. No mention was made about application volume or frequency or media nutrient concentration. Nitrogen concentration in the upper leaves (younger) was greater than in the lower leaves (older). Plants sampled 19 days since planting had lower N concentration in the leaf tissue than plants sample 67 days since planting.

While there hasn't been a conclusive study looking at tissue concentrations of elements in poinsettias the recommendation that is currently given to growers is that N concentration in the tissue should range from 4% to 6% (2.86 to 4.29 mol kg^{-1} N) and deficiency symptoms could occur if concentration decrease below 3.5% (25 mol kg^{-1}) (Ecke et al., 1990).

Bract and Leaf Necrosis

One specific disorder which has plagued growers in the late 70's and 80's has been bract necrosis. Nell and Barrett (1985) found that plants fertilized with only ammonium fertilizer had an increase in the incidence of bract necrosis, which was reduced when NO_3-N fertilizer was applied alone or in addition to NH_4-N. Nell and Barrett (1986) also found that there was an increase in necrotic spots on bracts from well watered plants grown with 28.6 mmol $liter^{-1}$ N (400 mg $liter^{-1}$) up to anthesis. They attributed the necrosis mainly due to salts being transported to the tips of leaves. By fertilizing using 7 mmol $liter^{-1}$ and terminating fertilization at bract color, bract necrosis was greatly reduced.

Woltz and Harbaugh (1986) found that plants which were Ca deficient had an increase in bract necrosis, and that the necrosis could be prevented with foliar applied Ca. In a further study, Harbaugh and Woltz, (1989) found that NO_3-N and supplemental Ca in the liquid fertilizer program also helped in reducing necrosis. Foliar applied Ca (10.8 mmol $liter^{-1}$ applied once a week using $Ca(NO_3)_2$ was found to prevent bract necrosis better than soil applied Ca.

Bierman, Rosen and Wilkins (1990) investigated the causes of leaf edge burn on vegetative poinsettias. Plants were grown in 1 liter pots using a peat, perlite and sand (2:1:1) medium and fertilized with 18-2.5-9 mmol $liter^{-1}$ N-P-K (252-77-352 mg $liter^{-1}$) using 3 different ratios of NH_4-N to NO_3-N. They also investigated Ca sprays and medium applied Ca and Mo as ways of reducing leaf edge burn. Their final conclusions were that leaf edge burn could be minimized by using foliar Ca sprays and using NO_3 source of N. The plants in this experiment were fertilized with N at a rate of 9.73 kg m^{-3} y^{-1}, 2 times the amount applied in other experiments in this review. It was indicated that weekly leaching with tap water were necessary to prevent excess salt accumulation so it is likely excess fertilizer was being applied.

Grower Literature

The information on fertilization that is made available to poinsettia growers comes from four basic sources: university or extension publications; textbooks; poinsettia producers; and fertilizer manufacturers.

There is a wealth of information available to growers from universities and extension services. Commercial Poinsettia Production (Larson et al. 1978) from the North Carolina Extension Services give fertilization recommendations based on work by Boodley (1970, 1971), Shanks (1956) and information given by Ecke (Ecke et al. 1976). Their basic recommendation is 14.2 mmol $liter^{-1}$ (200 mg $liter^{-1}$) N (mainly NO_3-N) and 5.1 mmol $liter^{-1}$ (200 mg $liter^{-1}$) K applied at every irrigation. More recent information for growers in this region was provided by Nelson (1989) who claims that the poinsettia "..has one of the highest demands for nutrition of any greenhouse crop" and recommends weekly applications of 43 to 51 mmol $liter^{-1}$ N (600 to 720 mg $liter^{-1}$) or 17 to 26 mmol $liter^{-1}$ N (240 to 360 mg $liter^{-1}$) be applied with every irrigation.

In an extension publication from the of University of Connecticut, Koths et al. (1980) claims that poinsettias "require heavy fertilization" and that it is a "heavy feeder". They recommended 14.2 mmol $liter^{-1}$ (200 mg $liter^{-1}$) NO_3-N at every irrigation or 32.14 mmol $liter^{-1}$ (450 mg $liter^{-1}$) NO_3-N once a week.

Cornell University (Bing et al.,1981) recommendations are that poinsettias be fertilized with 21.4 mmol $liter^{-1}$ (300 mg $liter^{-1}$) N, mainly NO_3-N, and 6.4 mmol $liter^{-1}$ (250 mg $liter^{-1}$) K at every irrigation. The current Ohio State University guidelines (Tayama and Roll, 1990) suggest that from 14.3-25.0 mmol $liter^{-1}$ (200-350 mg $liter^{-1}$) N be applied at every irrigation or 35.71 mmol $liter^{-1}$ (500 mg $liter^{-1}$) N be applied once a week.

Recommendations from Michigan State University (Berghage et al. 1987) are that poinsettias have a high N requirement and that 25-29 mmol $liter^{-1}$ (350-400 mg $liter^{-1}$) N (no greater than 30% of which should be NH_4-N) should be applied at every irrigation.

Text books are a very accessible source of information on how to grow plants. Nelsons (1985) advises that poinsettias are heavy feeders and that 18.1 mmol liter^{-1} N (254 mg liter^{-1}) should be applied at every irrigation or 51.4 mmol liter^{-1} N (719 mg liter^{-1}) once a week. Mastarlerz (1977) suggests that poinsettias can be grown successfully when 10.7 to 14.3 mmol liter^{-1} (150 to 200 mg liter^{-1}) of N and 3.8 to 5.1 mmol liter^{-1} (150 to 200 mg liter^{-1}) K are applied at every irrigation.

Shanks (1980) in the textbook Introduction to Floriculture recommends that weekly applications of 54 mmol liter^{-1} N (750 mg liter^{-1}) be made. He recommends that poinsettias require high levels of nitrogen but are intolerant of excess soluble salts.

The Ball Redbook (Ball, 1985) is a readily available source of information to growers on a wide variety of crops and is frequently updated. Recommendations in the Redbook (Ecke, 1985) are that poinsettias have a "substantial" N requirement and "moderate" K and P requirement. Concentrations of 17.9 to 18.9 mmol liter^{-1} (250 to 263 mg liter^{-1}) N and 2.2 to 4.04 mmol liter^{-1} (85 to 158 mg liter^{-1}) K applied at every irrigation or 35.7 to 37.6 mmol liter^{-1} (500 to 526 mg liter^{-1}) N and 4.4 to 8.1 (170-316 mg liter^{-1}) applied once a week are recommended. Of historical significance is the textbook by Laurie, Kiplinger and Nelson (1969) which was first published in 1934. They have no specific recommendation for the poinsettia but suggest 14.3 mmol liter^{-1} (200 mg liter^{-1}) of N and 5.1 mmol liter^{-1} (200 mg liter^{-1}) K be applied at every irrigation as a general fertilization program for any crop.

Ecke's (Ecke et al., 1976, Ecke et al., 1990) Poinsettia Manual is probably one of the most up to date sources of information available to growers on poinsettias culture. The most recent edition has recommendations that 18.4 mmol liter^{-1} (258 mg liter^{-1}) of N and 7.1 mmol liter^{-1} (278 mg liter^{-1}) of K be applied at every irrigation or 37 mmol liter^{-1} (518 mg liter^{-1}) of N and 14.2 mmol liter^{-1} (555 mg liter^{-1}) of K be applied every second or third irrigation. Their recommendation has not changed greatly in the 20 years since the first edition of The Poinsettia Manual (Ecke and Matkin, 1971). In the first edition it was recommended that 17.9 mol liter^{-1} of N (250 mg liter^{-1}) and 4.5 mmol liter^{-1} of K (175 mg liter^{-1}) be applied at every irrigation.

The Paul Ecke Poinsettia Ranch also puts out a series of publications on growing poinsettias. One publication was devoted to poinsettia nutrition. In this publication Williams (1990) suggested 21.4 to 28.6 mmol liter^{-1} (300 to 400 mg liter^{-1}) N CLF (constant liquid fertilization) from planting to October 15, after which reducing to 17.9 (250 mg liter^{-1}) N. He also suggests terminating fertilization 1-2 weeks before the crop is ready to sell.

One final source of information for growers on fertilization of poinsettias is the fertilizer manufacturers. One manufacturer, W.R. Grace & Co., has developed a poinsettia fertilizer, (Poinsettia Peat-lite Special 15-5-25) and has provided growers with technical information (Peters, 1987, Grace, 1987) on its use. They recommend applying this material at every irrigation 28.6 mmol liter^{-1} (400 mg liter^{-1}) N for the first three weeks and then reducing to 21.4 mmol liter^{-1} (300 mg liter^{-1}) N until two weeks before sale. They then recommend applying only water from this point until sale.

In order to compare these recommendations it was calculated how much nitrogen would be applied in a typical production scheme. For example, rooted cuttings would be planted in 0.0014 m^{-3} pots on August 19 and shipped on December 12 (16 week production period). Incorporated into the media would be 1.8 kg m^{-3} of KNO_3. Plants would be irrigated twice a week with 0.5 liters of water which would give a 0.10 leaching fraction. The data from these calculation is presented in Table 2. The average rate of N applied was 10.1 kg m^{-3} y^{-1}, with a high of 15.6 and a low of 5.4 kg m^{-3} y^{-1} N. The average from the experimental data reviewed was 6.8 kg m^{-3} y^{-1} (Table 1) which is 32% less N.

Summary

Poinsettia fertilization research over a span of more than 50 years has been presented. In experiments (Table 1) reviewed there is a six fold range in N application rates. Within the 2 to 15 kg m^{-3} y^{-1} range of nitrogen application rates, all produced "acceptable" poinsettias. With estimates from the grower literature (Table 2) a 3 fold range would have been applied. All of the grower fertilizer recommendations give some optimal concentration of fertilizer to apply. In looking at the experimental results it can be seen that applying a certain concentration would not always give the same rate of N application. For example Boodley (1970,1974) applied 400 mg $liter^{-1}$ N at a rate of 4.18 kg m^{-3} y^{-1}. Nell and Barrett (1986) applied the same concentration but were estimated to have applied N at a rate of 10.15 kg m^{-3} y^{-1}. Cox and Seeley (1983) applying 300 mg $liter^{-1}$ N were estimated to have applied N at a similar rate as Boodley (4.7 kg m^{-3} y^{-1}).

It was also interesting that similar rates of N application would give different results. For example Boodley's high concentration (800 mg $liter^{-1}$) treatment in 1970 gave N rates of 8.36 kg m^{-3} y^{-1} which were reported to have reduce growth due to high nitrate levels. Staby and Kofranek, based on a conservative estimate, applied N at a similar rate (8.92 kg m^{-3} y^{-1}) but produced acceptable plants.

Conclusion

Many different studies have been conducted to determine the best method of fertilizing poinsettia. Common recommendations for concentration of N to apply are 200 to 400 mg $liter^{-1}$ for a CLF program and 350-750 mg $liter^{-1}$ N for a weekly program. In the experiments reviewed the concentration of N applied ranged from 200 to 500 mg $liter^{-1}$ for CLF programs and 300-1188 mg $liter^{-1}$ N for weekly programs. It can be concluded that many different strategies can be used to produce poinsettias but that there is no clear understanding of why different strategies work. As environmental concerns become more prevalent, growers may be required to use production strategies which minimize N runoff out of the greenhouse (Biernbaum, et al., 1989; Jones, 1983; Drushal, 1990). Further research is needed to understand the variables influencing fertilization and to determine what impact poinsettia production may have on the environment. With this information it will be possible to develop fertilization strategies which are environmentally sound but still feasible for growers to use.

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Table 1. Summary of data from selected experiments reviewed and assumptions used to calculate the rate of N applied.

Source	kg m^{-3} y^{-1} N	mg $liter^{-1}$N	Applic. #	Duration (Weeks)	Volume (liters)	Initial N (Kg)	Pot size (m^3)
Shanks and Link,1952	2.48	784	12	24.6	0.95	0	0.0076
Link and Shanks,1956	3.79	925	12	19.0	0.95	0	0.0076
Shanks and Link,1956	2.44	1188	5	14.4	0.24	0	0.0022
Shanks and Link,1956	6.10	740	6	14.9	0.55	0	0.0014
Shanks and Link,1956	4.07	740	4	14.9	0.55	0	0.0014
Kofranek et al.,1963	15.68	500	51	17.0	0.20	0	0.0010
Kofranek et al.,1963	3.67	0	51	17.0	0.20	0.0012	0.0010
Boodley,1970	8.36	800	12	12.3	0.20	0	0.0010
Boodley,1970	4.18	400	12	12.3	0.20	0	0.0010
Boodley,1974	4.18	400	10	9.9	0.20	0	0.0010
Staby and Kofranek,1979	8.92	300	26	13.0	0.25	0.0012	0.0014
Cox and Seeley,1983	4.70	300	33	16.7	0.20	0.0001	0.0014
Nell and Barrett,1985	11.65	263	33	9.4	0.40	0	0.0016
Nell and Barrett (a),1986	10.15	400	26	12.9	0.40	0	0.0016
Nell and Barrett (b),1986	3.90	300	25	12.6	0.20	0	0.0016
Prince and Cunningham,1988	11.27	400	26	12.9	0.20	0.0025	0.0016
Harbaugh and Woltz,1989	7.28	1120	13	13.0	0.20	0	0.0016
Bierman et al.,1990	9.73	252	68	22.9	0.25	0	0.0010
Average	6.81						
Max	15.68						
Min	2.44						

Table 2. Assumptions used in calculating rate of nitrogen applied from various fertilization recommendations.

Source		kg $m^{-3} w^{-1}$	kg $m^{-3} y^{-1}$	N mg liter^{-1}	# of applic.	applic.per week
Kiplinger and Nelson	1969	0.157	8.17	200	33	2
Mastarlerz	1977	0.157	8.17	200	33	2
Larson et al.	1978	0.157	8.17	200	33	2
Nelson	1980	0.105	5.46	254	16	1
Koths et al.	1980	0.175	9.10	450	16	1
Shanks	1980	0.282	14.67	750	16	1
Bing et al.	1981	0.121	6.31	300	16	1
Ecke	1985	0.202	10.51	526	16	1
Peters	1987	0.139	7.24	350	16	1
Berghage et al.	1987	0.300	15.60	400	33	2
Nelson	1989	0.271	14.11	720	16	1
Tayama and Roll	1990	0.139	7.24	350	16	1
Ecke et al.	1990	0.203	10.55	528	16	1
Williams	1990	0.300	15.60	400	33	2
Average		0.194	10.065			
Max		0.300	15.599			
Min		0.105	5.459			

Plants were planted on 19 August and shipped on 12 December (16 weeks). Plants were placed in 0.0014 m^3 pots which had 300 mg pot^{-1} N initially incorporated.

SECTION I

FERTILIZER CONCENTRATION AND LEACHING FRACTION DETERMINE MEDIA NUTRIENT CONCENTRATION AND GROWTH OF POINSETTIA 'V-14 GLORY'.

Subject Category: Soils, Nutrition and Fertilizers

Fertilizer Concentration and Leaching Fraction Determine Media Nutrient Concentration and Growth of Poinsettia 'V-14 Glory'.

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__Abstract.__ Poinsettia (__Euphorbia pulcherrima__ Willd. 'V-14 Glory') were cultured using different combinations of fertilizer concentration and leaching fraction to evaluate what influence these factors have on media nutrient concentration and plant growth. Poinsettias were grown with three concentrations of fertilizer (7/3,14/6 and 28/12 mol m^{-3} N/K) applied at every irrigation, and four leaching fractions (0, 0.1-0.2, 0.3-0.4, and 0.5-0.6) or with subirrigation. The amount of N applied ranged from 0.62 g to 6.5 g pot^{-1} applied over 12 to 25 irrigations. Over the developmental cycle of the crop, media NO_3-N, K and EC was greatest at the highest fertilizer concentration and lowest leaching fraction. Phosphorous concentration declined until week 12 when phosphoric acid was added for pH adjustment. Subsequently P concentration was greatest in treatments with the highest leaching volume. Final shoot height, plant dry mass, leaf area decreased at higher fertilizer concentration. Total fresh mass, bract area and shoot to root ratio were greater at 14 and 28 mol m^{-3} N as higher leaching fraction were used, or when 7 mol m^{-3} N was applied with 0.15 leaching fraction. Tissue N was lower and tissue Ca was higher as lower leaching fraction was used. Tissue P and Mg were lower as higher leaching fraction was used. Tissue K was not influenced by the treatments.

There have been several studies to determine the optimal concentration of fertilizer required for poinsettia growth and development. Shanks and Link (1956) recommended that a concentration of 66-12-9 mol m^{-3} N-P-K be applied once a week. Boodley (1970) reported that poinsettias fertilized weekly with 28.6 mol m^{-3} N had larger bract area than plants fertilized weekly with 57.2 mol m^{-3} N. Current commercial poinsettia fertilizer recommendations were reviewed (Yelanich, 1991) and range from 14.3 mol m^{-3} to 28.6 mol m^{-3} N to be applied at every irrigation.

Leaching is commonly used during the application of liquid fertilizers to greenhouse crops to prevent soluble salts from accumulating in the media. The volume of solution leached from the media be expressed as a fraction of the total applied solution, which is termed the leaching fraction (LF = volume leached/volume applied) (Hershey and Paul, 1982). The recommended LF is 0.10 (Mastalerz, 1977; Nelson, 1985) but it is not uncommon for growers using drip irrigation to have LF in excess of 0.4 to 0.5 (George, 1989).

Leaching has been shown to influence the concentration of nutrients in the media and in the leachate. Hershey and Paul (1982) reported that the concentration of nitrogen leached from chrysanthemum root medium was affected by the fertilizer concentration (FC) applied and the time from planting. Hershey and Paul also found that at low FC the leachate N concentration was lower than the applied, but at higher FC the leachate N was higher than the applied and continued to increase over time. Kerr and Hanan (1985) found that most of the soluble salts initially in the media were removed when a volume of 1 to 1.5 container capacities had been leached. They also determined that the concentration of salts in the applied solution had no effect on the amount of salt removal from the pot but would have an effect on the concentration of salt remaining in the pot.

The volume of leachate and the concentration of fertilizer applied determine the amount of nutrient that is made available to the plant (Nelson, 1986). However, this fact is usually not considered in most nutrient studies and there are few reports of what affect LF and FC have on media nutrient concentration in a container crop. An understanding of the relationship between LF and FC is needed to fertilize container grown plants more efficiently with less fertilizer leaving the pot. This relationship is also an important aspect of determining fertilization rates for flood subirrigation methods where leaching of salts from the pot does not occur.

The objectives of this experiment were to investigate how LF and FC influence media nutrient concentration and growth of poinsettia and to compare flood subirrigation to traditional top watering methods.

Material and Methods

The treatments were arranged as a split plot, using the 3 fertilizer treatments as the main plots, which were split by the five LF treatments. FC and LF treatments were placed in three blocks, blocked by location in the green house. At the start of the experiment there were 18 plants per treatment in each block. One plant was randomly selected from each block at each sampling date, giving three replicates per sampling date. To meet the assumption of homogeneity of variances the weekly media concentration data were transformed by the addition of 1 to each value and then taking the logarithm.

The three fertilizer solutions (Table 1) were initially made from calcium nitrate and potassium nitrate but were changed on 22 October (Week 9) to ammonium nitrate and potassium nitrate in order to lower the media pH. The water used to make the fertilizer solutions had an EC of 0.6 to 0.7 mS cm^{-1} and an alkalinity of 3.0 to 3.2 mol m^{-3} $CaCO_3$. The nutrient solutions were applied when the pot, media and plant weighed 700 to 750 g. Phosphoric acid (3.9 mol m^{-3}) was added to the stock solution on 20 November (Week 13) to further lower the pH. After 12 December plants received only tap water which was applied as needed by subirrigated.

The four LF treatments were determined by adding known volumes of solution to established plants and measuring the volume of leachate. It was determined that 500, 750 and 1250 ml of solution were necessary to achieve the 0.1 to 0.2 (0.15), 0.3 to 0.4 (0.35), and 0.5 to 0.6 (0.55) target leaching fractions. The 0 LF and subirrigation treatments received 300 ml of solution at each irrigation, which was based on the amount of solution the media could absorb by subirrigation. The nutrient solution was applied to the subirrigation treatments by adding 300 ml of solution to a 18 cm diameter tray, which was placed under each container.

The experiment was conducted in a well ventilated glass greenhouse with constant air circulation and cement floors located in East Lansing, Michigan. Rooted cuttings of Euphorbia pulcherrima 'V-14 Glory' were planted on 19 August 1988, in plastic pots which were 15 cm wide at the top by 12 cm tall (pot volume=1580 cm^3). Plants were pinched on 6 September to six nodes. Cycocel was applied at 1500 mg $liter^{-1}$ on 26 September. On 12 December 1988 plants were sleeved for 24 hours and then placed in a simulated post production environment until to 3 January, 1989 when the experiment was terminated. The average greenhouse temperature measured over the duration of the experiment was 19.7°C (21.0°C average day and 18.7°C average night). The post production temperatures were maintained at 20° C with a photosynthetic photon flux density averaging 0.67 mol m^{-2} day^{-1} from cool white fluorescent bulbs.

A commercially available root media consisting of peat, coarse vermiculite and perlite (Baccto Professional Growers Mix, Houston TX) with the media physical and chemical properties described in Table 2 was used. Medium samples were collected every two weeks after planting for sixteen weeks. The media sample consisted of the entire pot of media, except for the subirrigated treatments which had the surface layer without roots scraped off and discarded. The top layer was removed from subirrigation treatments to approximate production practices and to allow better comparison of the 0 LF and subirrigation treatment. The nutrients in the media were sampled using the saturated media extraction (SME) method using distilled water as the extracting solution (Warncke, 1986). Nitrate-N was determined using an ion specific electrode. Potassium, Ca and P were determined by the Michigan State University soil testing lab. K was determined by emission, Ca was determined by atomic absorption and P was determined colorimetrically by the ascorbic acid method (Knudsen and Beegle, 1988).

Shoot height, fresh mass, leaf, root, stem and bract dry weight (dried in a forced draft oven at 60°C), leaf and bract area, and leaf number were measured at two week intervals. Mature fully expanded green leaves were collected after 16 weeks for elemental analysis. Yellow leaves and necrotic spots were counted on 3 January.

Results

Fertilizer applications. The amount of N applied ranged from 0.62 g to 6.5 g pot^{-1}. Number of irrigations ranged from 12 to 25 (Table 3). Subirrigated plants received approximately 5 more applications at all FC than 0 LF top watered plants.

Root media nutrient levels. Media NO_3-N, EC, K and Ca concentrations varied over the duration of the experiment. From time of planting until week 2, NO_3-N, EC, K and Ca concentrations in the media were greater at higher LF than at lower LF at each FC (Figure 2 A-C and 3 D). At the week 4 sample for NO_3-N and EC, and at the week 4 and 6 sample for K and Ca, media concentrations were higher at high FC than at lower FC but were not greatly influenced by LF. At the week 6 sample for NO_3-N and EC and the week 8 sample for K and Ca, concentrations in the media at each FC were lower at high LF than at lower LF. At the week 14 sample, there was an unexplained decrease in media K concentration in all treatments and in media Ca concentration at the high FC and 0.55 and 0.35 LF treatments. The 0.00 LF and 0.15 LF treatments at each FC were not significantly different for NO_3-N, EC, K and Ca throughout most of the experiment. Data from the week 16 harvest for NO_3-N, EC, K and EC is presented in Table 3.

Phosphorous was initially incorporated in the media and no new additions were made until week 12 when phosphoric acid was added to the nutrient solution for media pH control . From time of planting until week 8, media P concentration in decreased in all treatments, but was lower at higher LF than at lower LF (Figure 3E). From week 8 until week 12, there was little change in P concentration in the media. After week 12 with the addition of phosphoric acid the concentration of P in the media was greatest in the 14 and 28 mol m^{-3} treatments which had the most leaching and lowest in treatments which had no leaching. After week 12, media P concentrations in the 7 mol m^{-3} N treatments increased in the media but was not influenced by LF.

Similar media nutrient concentrations were obtained with different FC and LF combinations. For example, a 0.15 LF with a FC of 14 mol m^{-3} N gave a similar N concentration in the media as a FC of 28 mol m^{-3} N with a 0.55 LF throughout most of the experiment. The amount of nitrogen applied to each treatment was 1.4 g pot^{-1} and 6.5 g pot^{-1} respectively.

From planting until week 10 media pH gradually rose over time in all treatments and with the largest increase in pH occurring at the highest LF (Figure 3F). At week 10 with the switch from calcium to ammonium nitrate and the addition of phosphoric acid the pH began to drop at all FC. In the 14 and 28 mol m^{-3} N treatments the most rapid decline in pH occurred at higher LF, but with 7 mol m^{-3} N there was little effect of LF on pH. Media pH data from the final harvest are presented in Table 3.

<u>Plant growth and nutrient levels.</u> Final shoot height, total dry mass and leaf area were higher as lower FC was used (Table 4). Plant height, dry mass and leaf area were not significantly effected by the LF used. The shoot fresh mass and bract area of treatments receiving 14 or 28 mol m^{-3} N was greatest at higher LF, but when 7 mol m^{-3} N was applied shoot fresh mass and bract area was greatest when 0.15 LF was used. Bract area of subirrigated plants was greater than the non-leached top watered plants at 28 mol m^{-3} N but not at 7 or 14 mol m^{-3} N. Shoot to root ratio was greatest when 14 mol m^{-3} N was applied with a 0.35 LF and was lowest when 7 mol m^{-3} N was applied by subirrigation (Table 4). The percent dry mass and leaf number were not significantly affected by the treatments (Data not shown).

Nitrogen concentration in the leaf tissue at week 16 was not affected by FC applied but was generally lower at higher LF (Table 4). Phosphorous and Mg concentrations in the leaf tissue were generally lower at higher LF. Calcium concentration in the leaf tissue was generally greater at higher LF and higher FC. Tissue nutrient concentration for subirrigation treatments were lower than the 0 LF top watered plants and more like levels in the high LF plants. Leaf tissue K concentrations were not influenced by any of the treatments.

Post production. After the 3 weeks in the post production environment there were no differences between the treatments for the number of yellow leaves (average 2 per plant) or necrotic spots or margins on the bracts (average 5 per plant).

Discussion

There were no significant differences between 0 and the normally recommended 0.15 LF for NO_3-N, K, EC and Ca concentrations in the media at each of the sampling dates. Leaching fractions of 0.35 were needed to maintain EC in the accepted ranges when the commonly recommended FC of 14 mol m^{-3} N was applied. This could be one explanation why leaching fractions above 0.4 have been reported to be used with drip irrigations systems (George, 1989). The effect of leaching volume was similar for all 3 FC. This is illustrated by normalizing the week 16 EC data by dividing the mean data by the zero LF mean at each FC (Fig 1). This supports Kerr and Hanan's (1985) conclusions that the solution concentration applied did not influence salt removal.

Subirrigated plants preformed similarly or better than the top irrigated treatments with no leaching. One explanations for this response could be that the salts were accumulating in the top layer of the subirrigated media to a greater extent than the zero leaching plants (Biernbaum et al., 1991). Nutrient levels in the media sampled from subirrigated plants were similar to the levels reported in Figure 2 for the 0 and 0.15 LF (data not shown). This was not expected since the top layer of media which presumably contained accumulated fertilizer was removed. One possible explanation was that the subirrigated plants were fertilized 5 times more than the top watered treatments.

Adequate media fertility levels (Warncke et al, 1983) were maintained using 7 mol m^{-3} N, even at the highest LF, which is less than half the commonly recommended concentrations. It is possible that commonly recommended FC supply nutrients in excess of what the plant can use and require either leaching or periodic irrigation with plain water to reduce media FC. In two recently published papers (Dole and Wilkins, 1990; Bierman et al, 1991) in which FC in excess of 14 mol m^{-3} N were applied, weekly irrigations with plain water were used to maintain acceptable media concentrations.

One concern regarding poinsettia fertilization that is often discussed is that of nutrient levels in the media immediately following planting (Sheldrake, 1987). Solution concentrations of 21 to 28 mol m^{-3} N are often recommended to raise nutrient levels quickly. In this experiment no detrimental effects on dry mass or leaf area were observed at early (data not shown) or late samples (Table 4) in the 7 mol m^{-3} N treatments. Root media N concentrations in the 7 mol m^{-3} did not reach the reported optimal range until the week 4 sample.

Plants cultured using a 0 LF with a FC of 7 mol m^{-3} N were similar or larger than plants grown at higher FC and LF. The amount of N applied to a greenhouse using such a system would be 404 kg Ha^{-1} a^{-1} (120 kg Ha^{-1} per crop) based a density of 200,000 plants per hectare. From an environmental perspective, if good quality water is available, excess effluent produced in poinsettia production can be controlled by limiting the LF and lowering FC.

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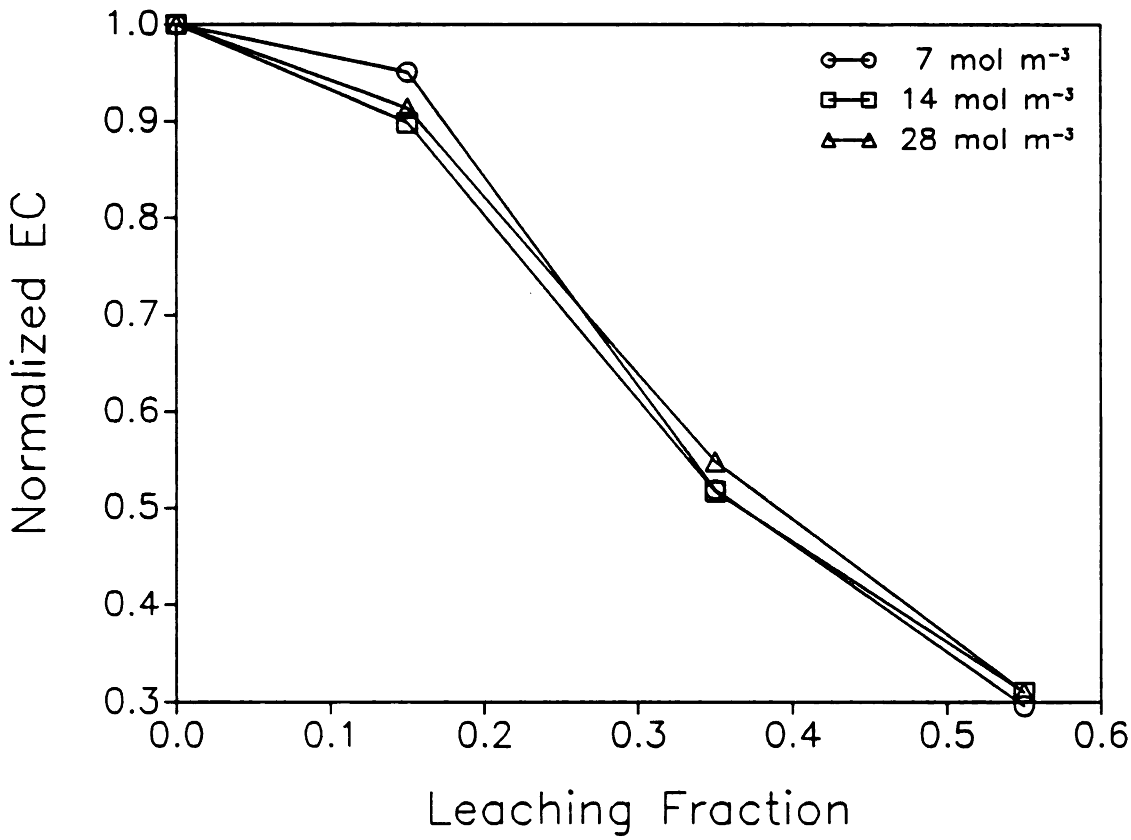

Figure 1. Normalized EC at week 16 harvest. The EC's at each of the three FC were divided by the maximum EC for that FC.

Figure 2. Effect of fertilizer concentration (FC) and leaching fraction (LF) on the media concentration of nitrate nitrogen (A), potassium (B), electrical conductivity (C), at two week intervals since planting. Dotted lines indicate the recommended range(s) for the SME (Warncke and Krauskopf, 1983).

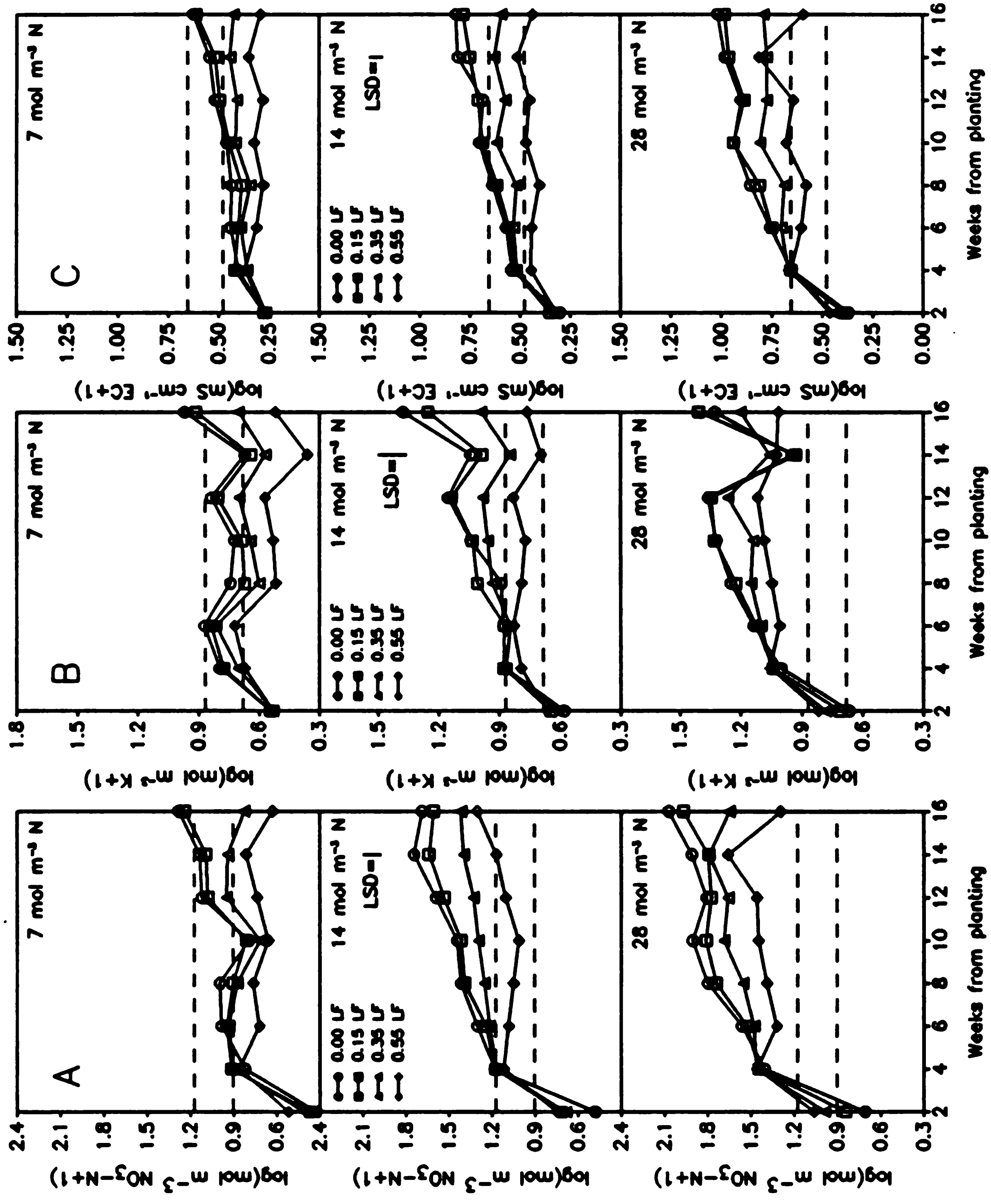
A
B
C
7 mol m⁻³ N
14 mol m⁻³ N
28 mol m⁻³ N
LSD=
0.00 LF
0.15 LF
0.35 LF
0.55 LF
log(mol m⁻³ NO₃-N+1)
log(mol m⁻³ K+1)
log(mS cm⁻¹ EC+1)
Weeks from planting
2
4
6
8
10
12
14
16
2.4
2.1
1.8
1.5
1.2
0.9
0.6
0.3
1.50
1.25
1.00
0.75
0.50
0.25
0.00

Figure 3. Effect of fertilizer concentration (FC) and leaching fraction (LF) on the media concentration of calcium (D),phosphorous (E) and pH (F) at two week intervals since planting. Dotted lines indicate the recommended range(s) for the SME (Warncke and Krauskopf, 1983).

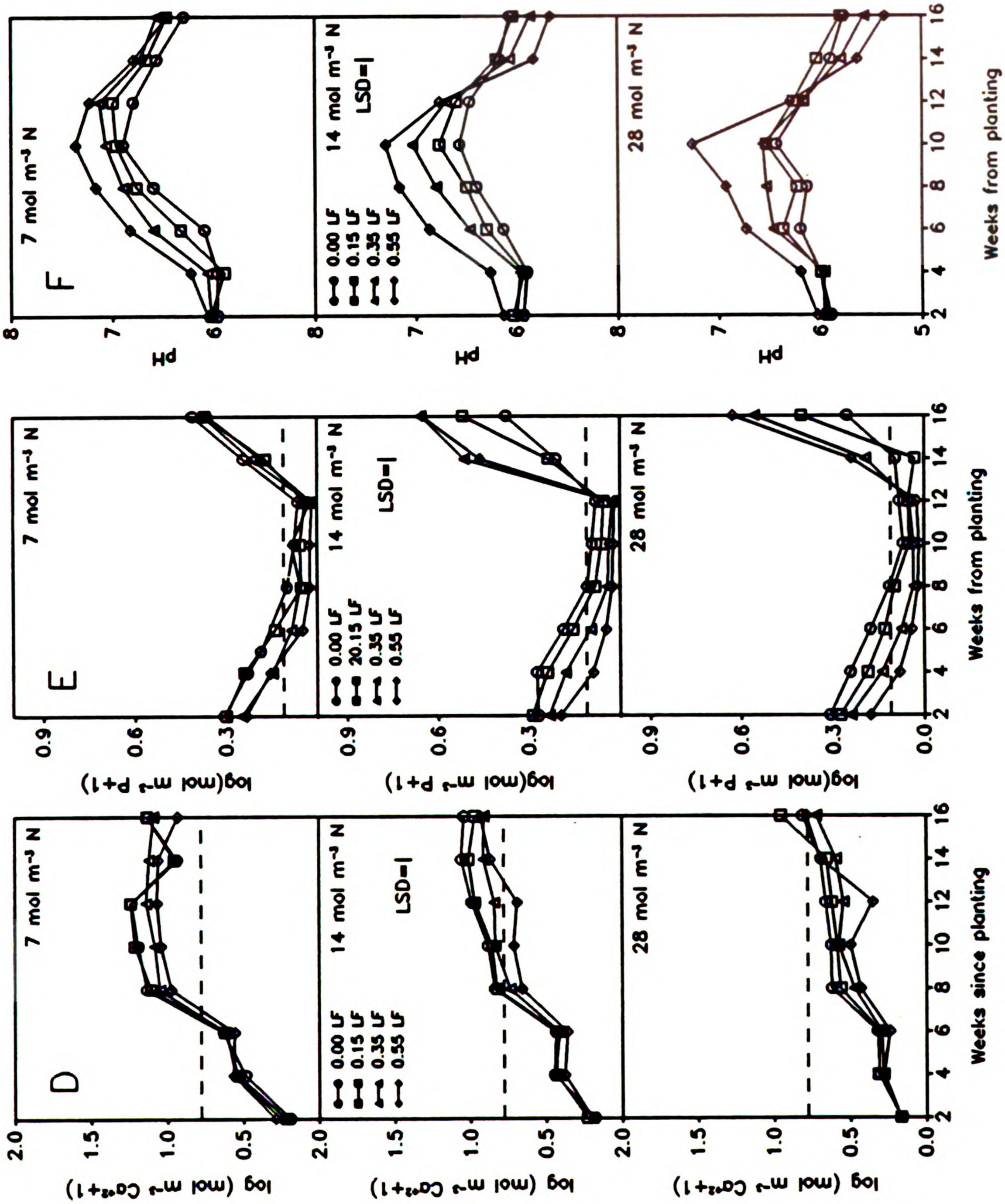
D
E
F
7 mol m-3 N
14 mol m-3 N
28 mol m-3 N
LSD=|
0.00 LF
0.15 LF
0.35 LF
0.55 LF
20.15 LF
log (mol m-3 Ca+2+1)
log(mol m-3 P+1)
pH
Weeks since planting
Weeks from planting

Table 1. Fertilizer concentrations (mol m^{-3}) applied. Initial (8/22 to 10/22) stock solution made from fertilizer grade calcium nitrate[z] and potassium nitrate. Final (10/22 to end) stock solution made from potassium nitrate and ammonium nitrate.

	8/22-10/22			10/22-12/12		
	FC 1	FC 2	FC 3	FC 1	FC 2	FC 3
Total N	7.2	14.4	28.9	7.3	14.7	29.3
NO_3-N	6.8	13.7	27.3	5.0	10.0	20.0
NH_4-N	0.4	0.8	1.5	2.3	4.7	9.3
K	2.7	5.3	10.7	2.7	5.3	10.7
Ca	1.9	3.8	7.6	0.00	0.00	0.00
EC	1.42	2.08	3.40	1.67	2.56	3.73

[z] Fertilizer grade- 5 $Ca(NO_3)_2$-NH_4NO_3-10 H_2O

Table 2. Root media physical and chemical properties.

Initial pH	5.6	
Initial EC (SME)	1.00	mS cm^{-1}
Bulk Density	0.20	g cm^{-3}
Container Capacity[z]	1010	cm^{-3}
Water Porosity	0.64	cm^3 cm^{-3}
Air Porosity	0.15	cm^3 cm^{-3}

[z] Total available and unavailable water volume at saturation.

Table 3 The effect of leaching fraction and fertilizer concentration on the quantity of N applied, the number of irrigations and media nutrient concentration 16 weeks since planting.

Treatments	Applied N g	Applic.	pH	EC mS	NO_3-N mol m^{-3}	P mol m^{-3}	K mol m^{-3}	Ca mol m^{-3}
					7 mol m^{-3} N			
Subirrigation	0.75	25	6.20	3.53	20.5	1.74	8.7	3.44
0.00 LF	0.62	20	6.30	3.24	18.1	1.58	8.4	3.36
0.15 LF	0.80	16	6.47	3.08	16.4	1.36	7.2	2.87
0.35 LF	1.13	16	6.57	1.68	5.6	1.39	4.0	2.52
0.55 LF	2.13	17	6.47	0.96	3.3	3.3	2.3	1.22
					14 mol m^{-3} N			
Subirrigation	1.44	24	6.03	6.59	59.4	1.42	24.7	3.69
0.00 LF	1.18	19	6.07	5.61	47.9	1.39	22.9	6.69
0.15 LF	1.40	15	6.03	5.04	39.5	1.29	17.0	5.39
0.35 LF	2.25	16	5.87	2.90	25.1	3.52	8.8	3.12
0.55 LF	3.50	15	5.67	1.74	19.1	3.49	4.8	1.65
					28 mol m^{-3} N			
Subirrigation	2.28	20	5.63	10.09	89.0	1.35	38.6	4.29
0.00 LF	1.74	15	5.77	9.44	116.6	0.81	20.3	3.99
0.15 LF	2.20	12	5.80	8.62	92.0	1.52	24.5	3.44
0.35 LF	3.60	12	5.57	5.17	43.6	2.62	14.9	3.14
0.55 LF	6.50	13	5.37	2.93	18.8	3.62	9.4	2.47
LSD			0.15	1.77	36.1	0.61	12.3	0.84
FC			**	***	**	**	**	**
LF			***	***	***	***	***	***
FC*LF			***	*	ns	***	ns	***

NS,*,**,*** Nonsignificant or significant at P=0.05,0.01, or 0.001, respectively. FC=fertilizer concentration applied. LF=leaching fraction.

Table 4.The effect of leaching fraction and fertilizer concentration on plant growth parameters and on nutrient concentrations of poinsettia leaf tissue 16 weeks since planting.

Treatments	Shoot Height	Fresh mass	Dry mass	shoot: root	Leaf area	Bract area	% Dry Mass				
	cm	g	g		m^2	m^2	N	P	K	Ca	MG
						7 mol m^{-3} N					
Sub.	23.5	138.7	19.3	3.92	0.141	0.216	4.57	0.32	3.91	0.78	0.62
0.00 LF	23.0	126.0	17.1	6.39	0.141	0.236	5.03	0.41	3.75	0.74	0.69
0.15 LF	27.5	156.6	20.6	5.32	0.148	0.306	4.80	0.42	3.95	0.82	0.71
0.35 LF	26.0	139.3	18.4	5.00	0.140	0.267	4.87	0.35	3.84	0.83	0.63
0.55 LF	23.5	128.6	16.6	5.91	0.123	0.244	4.67	0.32	3.93	0.98	0.61
						14 mol m^{-3} N					
Sub.	23.8	124.7	16.4	4.94	0.135	0.230	4.60	0.35	3.97	0.84	0.62
0.00 LF	23.2	110.1	15.3	5.29	0.117	0.214	5.03	0.41	3.93	0.95	0.74
0.15 LF	25.0	126.6	16.8	6.82	0.134	0.217	5.07	0.44	3.81	0.73	0.65
0.35 LF	24.2	132.3	17.6	7.33	0.130	0.257	4.97	0.38	4.24	0.95	0.62
0.55 LF	24.5	148.3	19.8	4.68	0.139	0.270	4.90	0.33	3.81	1.02	0.57
						28 mol m^{-3} N					
Sub.	21.3	110.5	14.3	4.87	0.108	0.221	4.63	0.32	4.10	0.94	0.56
0.00 LF	22.2	91.9	12.4	5.67	0.094	0.132	4.87	0.53	4.11	1.17	0.79
0.15 LF	21.2	83.9	11.3	5.79	0.088	0.150	5.03	0.42	4.08	1.08	0.68
0.35 LF	22.8	119.1	15.7	5.85	0.113	0.234	4.93	0.40	4.10	1.09	0.62
0.55 LF	24.7	141.3	18.6	4.23	0.125	0.269	4.73	0.33	3.98	1.13	0.48
LSD 5%	2.7	25.7	3.7	1.55	0.034	0.053	0.38	0.04	-	0.16	0.08
FC	*	**	**	ns	**	**	ns	ns	ns	**	ns
LF	ns	*	ns	**	ns	**	**	***	ns	**	***
FC*LF	ns	*	ns	*	ns	**	ns	**	ns	ns	**

NS, *,**,*** Nonsignificant or significant at P=0.05, 0.01, or 0.001, respectively. FC=applied fertilizer concentration. LF=leaching fraction (leached volume/applied volume).

SECTION II

FERTILIZER CONCENTRATION AND LEACHING VOLUME AND THE AMOUNT OF THE APPLIED NITROGEN LEACHED.

Subject Category: Soils, Nutrition and Fertilizers

Fertilizer Concentration and Leaching Volume and the Amount of the Applied Nitrogen Leached

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Additional index words. Leaching fraction, soluble salts, irrigation, *Euphorbia pulcherrima*.

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Abstract. The influence of fertilizer concentration and leaching volume on the quantity of the applied nitrogen leached from a container grown poinsettia crop was investigated. The quantity of N leached after 10 weeks increased as higher NO_3-N was applied and as higher leaching volumes were used, ranging from 43 mmol NO_3-N (7 mol m^{-3} NO_3-N, 0.00 CCL) to 611 mmol NO_3-N (28 mol m^{-3} NO_3-N, 1.0 CCL). Saturated media extract NO_3-N concentration was higher as lower leaching volumes were used and higher fertilizer concentration was applied. For example with 7 mol m^{-3} N applied, NO_3-N in the media was 27.1 mol m^{-3} when 0 CCL was used, but was 8.6 mol m^{-3} when a 1.0 CCL was used. Shoot height and dry mass were not affected by the treatments. Leaf area was not influenced by the leaching treatments but was larger at 7 mol m^{-3} N than at 14 and 28 mol m^{-3} N.

Yelanich and Biernbaum (1990) demonstrated how both leaching fraction (LF) and fertilizer concentration (FC) applied influence the concentration of elemental nutrients in a peat based media. Different combinations of FC and LF achieved similar media concentrations with greatly different amounts of N applied. However, the amount of nitrate effluent was not measured and would be an important consideration in determining the efficiency of a fertilization method. A better understanding of the quantity of nitrate nitrogen (NO_3-N) lost from container grown plants is also necessary to evaluate the potential for NO_3-N runoff from greenhouses. The objective of this research was to evaluate the effects of different irrigation and fertilization strategies on the quantity of nitrogen (N) leached, media nutrient concentration and growth of vegetative poinsettia.

Materials and Methods

The experimental design was a randomized complete block, with four blocks selected for initial plant size. Plants were randomized on one bench in a well ventilated glass greenhouse with cement floors and constant air circulation located in East Lansing, Michigan. Rooted cuttings of Euphorbia pulcherrima Willd. 'V-14 Glory' were planted on 2 April 1990 and were maintained vegetative throughout the course of the experiment. The media used was a commercially available root medium of peat, course vermiculite and perlite (Baccto Professional Growers Mix, Houston TX). The media's initial physical and chemical properties are described in Table 1. The irrigation water had an EC of 0.6 to 0.7 mS cm^{-1} and an alkalinity of 300 to 320 mg $liter^{-1}$ $CaCO_3$. The three nutrient solutions (Table 2) were prepared using $Ca(NO_3)_2$ and KNO_3. Pots were weighed daily and irrigated when they weighed less than 650 g, which corresponded to about 55% of the total water still present. Leaching occurred at this weight after approximately 280 ml of solution had been applied. Nutrient solutions were applied by hand using a beaker. The 5 leaching treatments were estimated by adding increasing amounts of solution to pots with plants and measuring the volume of leachate. It was determined that 0.25, 0.5, 0.75, 1.0, and 1.25 liters of solution were necessary to achieve the 0, 0.25, 0.5, 0.75 and 1.0 container capacities leached (CCL). The pots were weighed before and after each irrigation, and the leachate volume, NO_3-N concentration and EC were determined. Little change occurred in the volume of leachate over the course of the experiment so no modifications were made to the volumes of solution applied. Leachate was collected at every irrigation and evaluated for EC and NO_3-N, but the results are presented as weekly averages.

After 71 days the root medium in each pot were split in half vertically with one half mixed and sampled and one half sectioned into three layers with each sampled separately (Table 2). The root medium samples were analyzed for EC and NO_3-N concentration using the saturated media extract (SME) (Warncke, 1986). Nitrate nitrogen was determined using an ion specific electrode. The shoot height, leaf area and number, and total fresh mass were determined also determined at this time. Shoot dry mass was determined after drying in a forced draft oven at 60°C for 4 days. The whole dried shoot was ground and analyzed for total N.

Results

In general, as a higher CCL was used the concentration of NO_3-N in the leachate was lower and tended to approach the concentration applied (Figure 1). When 28 mol m^{-3} N or 14 mol m^{-3} N were applied there were greater differences between the leaching treatments with higher NO_3-N concentration in the leachate at lower leaching volumes.

The total percentage of N leached (N leached/ N applied) after 71 days increased as higher CCL were used (Table 3). When 0.25 CCL was used the percentage of the applied N leached was 51.4, 58.4 and 49.1% when 7, 14 or 28 mol m^{-3} FC was applied. The percentage of N leached at leaching volumes of 0.75 or 1.00 CCL, regardless of FC, were not significantly different. Some N leaching is reported for the 0 CCL treatments since small volumes (averaged over the entire experiment 11 ml per irrigation) did occasionally drain from the pot with a very high concentration.

The percentage of solution leached were not significantly different between the FC treatments, for 0.25 to 1.00 CCL but varied between FC when a leaching volume of 0.00 CCL was used. The percentage of NO_3-N leached was higher than the percentage of solution leached (Table 3).

The concentration of NO_3-N in the root media was highest when high N concentration was applied and leaching was minimized (Table 4). The NO_3-N concentration was same or higher in the top layer as compared to the lower layers. The NO_3-N concentration was most uniform throughout the pot at lower FC and at higher volumes of leaching (0.75 to 1.00 CCL). Only root medium samples from the 7 mol m^{-3} N treatments which had 0.5 to 1.0 CCL were in the recommended range for NO_3-N of 7 to 14 mol m^{-3} N (Warncke and Krauskopf, 1983). Nitrate-nitrogen concentration in top, middle and bottom layers were highest in treatments receiving higher FC and lower leaching volumes.

There were no significant affects of the treatments on height, break number (data not presented) or total shoot dry mass (Table 5). Fresh mass declined when 7 mol m^{-3} N was applied at 1.00 CCL. Fresh mass was not significantly influenced by leach volume when 14 mol m^{-3} N was applied. When 28 mol m^{-3} N was applied fresh mass was greatest at 0.50 and 0.75 CCL. Leaf area was smaller as higher FC was applied. Leaves greater than 1 mm decrease 16% as FC increased from 7 to 28 mol m^{-3} N but node number was not affected. Percent dry mass of the shoot was higher with increasing FC. Nitrogen concentration in the leaf tissue was generally higher when lower leaching volumes were used.

Discussion

The percent of applied NO_3-N leached from the medium used in this experiment exceeded the percent of water leached (leaching fraction*100). Leaching theory states that the concentration of salt in the leachate will be determined by the amount of salt in the media, the amount of mixing occurring in the media, the volume of leachate, adsorption by the media and the concentration of the applied solution (Wagenet, 1983). High CCL or low FC appear to be conducive to maintaining low levels of elemental accumulation in the media in the media after each irrigation, consequently concentration of NO_3-N in the leachate did not increase over time. In a previous experiment (Yelanich and Biernbaum,1990) we observed relatively low concentrations of NO_3-N in the medium when a leaching volume of 0.68 CCL was used. Kerr and Hanan (1985) demonstrated that the amount of mixing that occurs is a function of the physical properties of the media. If the medium in this experiment had a higher percolation rate (i.e. less mixing) a lower percentage of NO_3-N may have been leached. On the other hand, more N may have been removed if a medium with a slower percolation rate (i.e. more mixing) had been used.

Vegetative poinsettias were successfully grown at concentrations half the recommended rate of 14 mol m^{-3} N (Ecke et. al). These findings are similar to results obtained from our previous experiment (Yelanich and Biernbaum, 1990) in which adequate media concentrations could be obtained with 7 mol m^{-3} even at very high leaching volumes. However, 7 mol m^{-3} did not result in low quantities of NO_3-N runoff when a leaching volume of 0.25 CCL or greater was used. As in our first experiment, poinsettias could be produced with low leaching volumes and lower fertilizer concentrations, thereby eliminating any runoff and preventing any fertilizer from entering the environment.

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Figure 1. The effect of fertilizer concentration (FC) applied and container capacities leached (CCL) on the concentration of NO_3-N in the leachate at different weeks since plantings. Dotted lines indicate the concentration of nitrogen applied. The LSD value is for the 5% level.

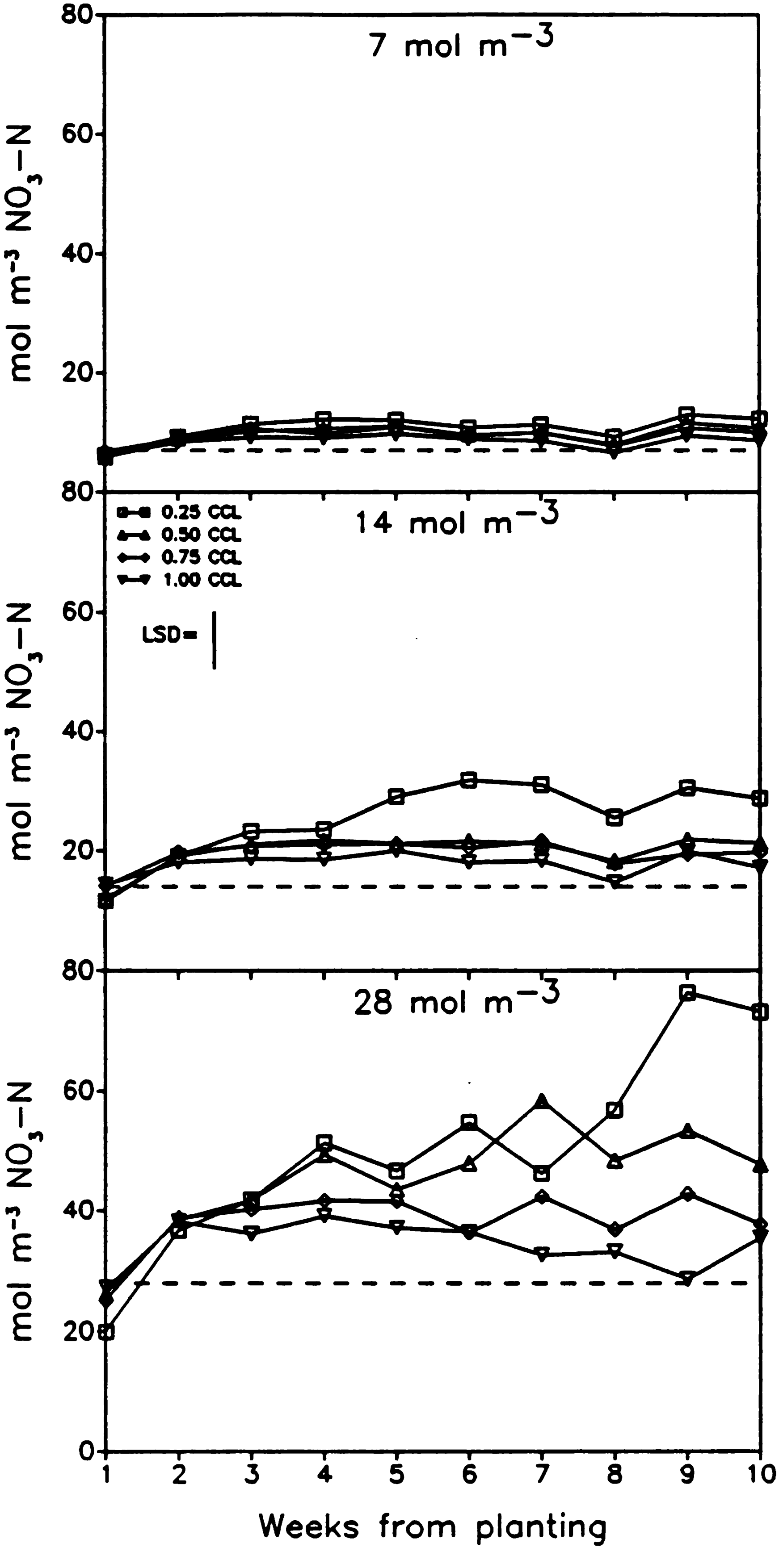
7 mol m−3
14 mol m−3
28 mol m−3
0.25 CCL
0.50 CCL
0.75 CCL
1.00 CCL
LSD=
mol m−3 NO3−N
Weeks from planting
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10

Table 1. Media physical properties. Pot used was 12 cm wide at the top and 11.5 cm tall.

	Top Layer 10.5 cm-8.0 cm	Middle Layer 8.0 cm-4.0 cm	Bottom Layer 4.0 cm-0.0 cm	Whole Pot 10.5 cm-0.0 cm
Container Capacity[y] cm^3	313	313	216	841
Initial[z] pH	5.9	5.7	5.7	5.9
Initial[z] EC (SME) $mS\ cm^{-1}$ at 25°C	1.07	1.52	1.82	1.38
Bulk Density $g\ cm^{-3}$	0.15	0.16	0.21	0.17
Container Volume cm^3	490	488	293	1271
Air Porosity $cm^3\ cm^{-3}$	0.24	0.15	0.17	0.19
Water Porosity $cm^3\ cm^{-3}$	0.64	0.64	0.74	0.66

[y] Volume of available and unavailable water at saturation.
[z] Media was sampled after plants were watered in after planting.

Table 2. Fertilizer concentration of N, K and Ca from fertilizer grade calcium nitrate and potassium nitrate.

Treatment	Nitrogen $mol\ m^{-3}$	Potassium $mol\ m^{-3}$	Calcium $mol\ m^{-3}$
1	7	3	2
2	14	6	3
3	28	12	7

Table 3. Effect of leaching volume and concentration on the quantity of NO_3-N applied and leached after 71 days of culture.

Leach CCL	No. of appl.	Applied Solution Liters	Leached Solution Liters	Leached Solution % Applied	Applied NO_3-N mmol	Leached NO_3-N mmol	Leached NO_3-N % Applied
			7 mol m^{-3} N				
0.00	24	6.0	0.3	5.0	43.3	1.9	4.4
0.25	19	9.3	3.1	33.4	66.8	34.3	51.4
0.50	19	13.8	7.1	51.4	98.2	70.1	69.4
0.75	19	19.2	12.0	62.5	136.4	113.3	84.0
1.00	18	21.8	15.9	73.0	154.1	132.1	86.7
			14 mol m^{-3} N				
0.00	22	5.6	0.7	1.3	80.3	0.3	0.0
0.25	20	9.8	3.2	32.2	139.7	80.0	58.4
0.50	19	14.2	8.0	56.5	200.0	161.0	80.0
0.75	19	18.5	11.8	63.8	261.0	231.1	86.4
1.00	19	22.7	16.6	73.1	319.9	293.3	92.6
			28 mol m^{-3} N				
0.00	18	4.7	0.3	6.0	134.6	16.4	11.4
0.25	15	7.6	2.4	31.0	213.7	99.5	49.1
0.50	18	13.6	7.1	51.9	383.3	301.3	80.8
0.75	19	19.0	12.0	63.0	535.2	457.6	84.6
1.00	18	21.8	15.9	73.1	611.7	546.2	87.8
LSD 5%	3	2.1	1.4	3.7	43.4	35.3	6.7
FC	**	ns	ns	ns	***	***	*
CCL	**	***	***	***	***	***	***
FC*CCL	NS	ns	ns	*	***	***	***

NS, *,**,*** Non-significance or significant at P= 0.05,0.01 or 0.001.
FC=fertilizer concentration applied. CCL=container capacity leached.

Table 4. Effect of concentration and leaching volume on medium NO_3-N concentrations and EC.

Volume Leached CCL	Top Layer NO_3-N mmol liter^{-1}	Middle Layer NO_3-N mmol liter^{-1}	Bottom Layer NO_3-N mmol liter^{-1}	Combined Layers NO_3-N mmol liter^{-1}	Combined Layers EC mS cm^{-1}
			7 mol m^{-3} N		
0.00	26.0	25.9	26.5	27.1	3.41
0.25	19.5	13.8	13.1	16.1	2.07
0.50	12.5	10.2	9.4	12.8	1.73
0.75	9.3	8.0	8.2	9.3	1.27
1.00	10.1	7.8	8.3	8.6	1.15
			14 mol m^{-3} N		
0.00	62.7	52.8	55.9	58.1	6.03
0.25	35.0	33.5	33.5	37.2	3.71
0.50	17.8	19.6	18.7	21.3	2.29
0.75	16.5	15.7	14.9	19.3	2.09
1.00	18.4	16.0	12.6	17.2	1.88
			28 mol m^{-3} N		
0.00	114.9	70.4	67.9	93.6	9.32
0.25	71.2	55.1	59.5	62.8	6.22
0.50	36.6	37.5	39.2	40.6	4.09
0.75	33.4	30.9	27.8	32.7	3.30
1.00	34.6	27.5	26.1	30.1	3.08
LSD	3.0	2.9	3.7	11.4	0.77
FC	***	***	***	***	***
CCL	***	***	***	***	***
CCL*FC	***	***	***	***	***

NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001. FC=fertilizer concentration applied. CCL=container capacity leached.

Table 5. Effect of leaching volume and concentration on the vegetative growth of poinsettia.

Volume Leached	Shoot Fresh Mass	Shoot Dry Mass	Leaf Area	Leaf Number	Shoot Nitrogen	Percent Dry Mass
CCL	g	g	cm^2		mg N/ 100mg dry mass	
			7 mol m^{-3} N			
0.00	63.0	10.80	2403	65	3.8	17
0.25	55.0	9.35	1947	57	3.9	17
0.50	55.4	9.60	1996	61	3.2	17
0.75	53.9	9.42	1901	58	3.2	17
1.00	43.4	7.52	1430	50	3.3	17
			14 mol m^{-3} N			
0.00	49.0	9.17	1711	54	3.8	19
0.25	57.8	10.24	2090	61	3.8	18
0.50	50.3	8.58	1788	56	3.2	17
0.75	53.2	9.23	1870	58	3.8	17
1.00	48.0	8.58	1620	54	2.9	18
			28 mol m^{-3} N			
0.00	36.0	7.21	1207	40	4.0	20
0.25	46.1	8.47	1574	49	4.1	18
0.50	60.3	11.20	1796	56	3.6	19
0.75	59.8	10.61	1954	54	3.7	18
1.00	40.4	7.68	1361	44	3.7	19
LSD	14.6	2.64	593	12	0.7	1
FC	NS	NS	*	**	NS	***
CCL	*	NS	NS	NS	*	NS
FC*CCL	*	NS	NS	NS	NS	NS

NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001, respectively. FC=fertilizer concentration applied. CCL=container capacity leached.

SECTION III

POINSETTIA FERTILIZATION AND THE INFLUENCE OF PPF AND RELATIVE HUMIDITY

Subject Category: Soils, Nutrition and Fertilizers

Poinsettia Fertilization And The Influence of PPF and Relative Humidity

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__Abstract.__ Two experiments were conducted to evaluate the effect of fertilizer concentration and environmental factors on the growth of poinsettia. In Experiment 1 poinsettias were grown under 5 fertilizer regimes (4, 7, 14, 28 and 42 mol m^{-3} N) with 3 photosynthetic photon fluxes (PPF) (2, 9, and 12 mol m^{-2} day^{-1}). In Experiment 2 poinsettias were produced with 3 fertilizer concentrations (4, 14, 42 mol m^{-3} N) under 2 relative humidities (50% and 70%). In experiment 1 plants were much larger when grown using 9 and 12 mol m^{-2} d^{-1} PPF than at 2 mol m^{-2} d^{-1}. Plant height, dry mass, leaf area and bract area were not influenced by fertilizer concentration at 2 mol m^{-2} d^{-1}. Plant height, dry mass, leaf area and bract area when grown at 9 or 12 mol m^{-2} d^{-1} were not significantly different in the range of fertilizer concentrations of 7 to 28 mol m^{-3} N. Plant height, dry mass, leaf area and bract area were smaller when grown at 4 or 42 mol m^{-3} N, with plants grown using 9 mol m^{-2} d^{-1} being smaller than those grown with 12 mol m^{-2} d^{-1}.
In experiment 2 node length was larger at the higher RH. Height was largest at 50% RH when grown using 42 mol m^{-3} N. Height of the plants grown with 70% RH was largest when grown using 14 mol m^{-3} N. Poinsettias tolerated a wide range of media nutrient concentration with little effect on growth, but decreased growth was observed when the fertilizer concentration applied was greater than 28 mol m^{-3} N.

The production environment, a consideration in many greenhouse operators fertilization programs (Hanan, 1978), has not been taken into consideration in published fertilization recommendations for ornamental greenhouse crops. Armitage and Tsujita (1979) found that for highest flower yields, roses grown under supplemental photosynthetic photon flux (PPF) required a higher fertilizer concentration than those grown under ambient PPF. Hydroponically grown lettuce yield (Knight and Mitchell, 1983) was largest under elevated PPF in with higher nitrogen (N) concentration in the solution, indicating a greater N demand as photosynthetic activity increased. Depa et al. (1986) found that while dry mass of hydroponically grown chrysanthemum was higher at higher PPF, nutrient concentrations in the leaves remained constant. Gislerod and Mortensen (1990) reported that Hiemalis begonias grown in growth chambers required a higher nutrient concentration at 90% RH than at 60% RH for maximum growth. Gislerod et al. (1987) found that the media concentration of N and K was lowest in plants grown under higher RH as compared to lower RH. The effect of humidity on plant development has been investigated in other studies (Krizek et al. 1971; Mortensen, 1986; Hoffman and Rawlins, 1971), but how humidity influences plant nutrient requirements was not reported.

In previous research (Yelanich, 1990) investigating the affect of fertilizer concentration and leaching fraction on media nutrient concentration, poinsettias were produced with fertilizer concentrations at half the commonly recommended 14 mol m^{-3} N (Ecke et. al, 1990). It is unknown if poinsettias could be grown with these lower fertilizer solutions concentrations in different environments. Our hypothesis was that the optimal media nutrient concentration for plant growth is influenced by the production environment. The objective of this research was to determine if PPF and RH will influence the root media nutrient concentration required for poinsettia growth. If true, specific fertilization or media testing recommendations could then be made based on PPF or RH conditions.

Materials and Methods

Two experiments were conducted in glass greenhouses located in East Lansing, Michigan. Rooted cuttings of Euphorbia pulcherrima 'V-14 Glory' were planted on 25 August 1989 in a 75% Canadian sphagnum peat moss (Fison Peat Co., Vancouver, B.C.) and 25% coarse vermiculite medium with an initial nutrient charge of 3 kg m^{-3} dolomitic lime and 1.2 kg m^{-3} KNO_3. The root medium was placed in 1.5 liter plastic pots (15 cm wide at the top by 12 cm tall) and had physical properties of 0.12 cm^3 cm^{-3} air porosity, 0.62 cm^3 cm^{-3} water porosity, and held 946 ml of water (available and unavailable) at container capacity. The irrigation water had an electrical conductivity (EC) of 0.6 to 0.7 mS and an alkalinity of 300 to 320 mg $liter^{-1}$ $CaCO_3$. The fertilizer solutions were made from a base solution containing $MgSO_4$, H_3PO_4, and a soluble trace element mix (STEM, W.R. Grace Co., Fogelsville, Pa) to which KNO_3 and NH_4NO_3 were added to achieve the fertilizer treatments concentrations described in Table 1. The pots were fertilized with 1 liter of the solution when the pot, media and plant mass declined to approximately 500 g. One liter of solution applied resulted in leaching of approximately 0.55-0.58 container capacities. Our goal in using such high leaching volumes was to maintain uniform media nutrient concentrations across PPF and RH treatments.

Expt. 1, evaluating the effects of PPF and FC, was conducted in a 17 m x 10 m greenhouse section. The experimental design was a split plot, blocked by location in the house (3 blocks). The main plot was PPF, with one bench for each PPF treatment. The fertilizer treatment subplots were completely randomized on each bench. Three PPF environments were produced by growing plants under ambient sunlight plus high pressure sodium lamps (approximately 100 μmol m^{-2} sec^{-1} for 9 hours per day), ambient sun light, or 75% shade from saran cloth above the plants. The average PPF at the top of the plants over the 16 week period were 12, 9, or 2 mole m^{-2} day^{-1}, respectively. The average air temperature over the 15 week period was 20.3°C (±0.8).

Plants were harvested every 3 weeks for a total of 5 harvests. At each sampling date shoot fresh and dry mass, plant height, leaf and bract area and number, and node number per branch were evaluated. Media samples were evaluated at each sampling date by saturated media extract (SME) for pH, EC and NO_3-N concentration (Warncke, 1986). Nitrate nitrogen was determined by an ion specific electrode. In all media samples, the surface 1 cm of media was not included to evaluate only the root zone concentration of salts. The experiment was terminated on 8 December.

Expt. 2, was conducted in four, 4 m x 5 m greenhouse sections in order to evaluate the effects of RH and FC on poinsettia growth. The experimental design was a split plot, which was blocked by location of the sections within the range (2 blocks). The main plot was RH with the subplot fertilizer treatments randomized within the section. Two RH environments were created by supplementing one environment with a cool air humidifier which ran 24 hr day^{-1}. The RH (determined from wet and dry bulb temperature measurements) for the two environments, averaged over the entire experiment, were 50% RH (35%-65%) for the ambient chambers and 70% RH (55%-85%) for the supplemented environment. The average air temperatures of the 50% and 70% RH were 21.9°C (±2.5) and 21.1°C (±1.8) (respectively) over the 15 week period. Plants and root media were sampled every 5 weeks for a total of 3 sampling periods. Data collection was the same as in Experiment 1. Experiment 2 was terminated on 7 December 1989.

Results

Expt. 1. Media EC (Figure 1) and NO_3-N (data not shown) concentrations at each FC continued to increase until week 9 when they stabilized. Differences in root media EC occurred between PPF treatments at weeks 6, 9 and 15 (Figure 1), and for NO_3-N at weeks 3 and 15 (data not shown). The 12 mol m^{-2} day^{-1} PPF treatment had lower media EC and NO_3-N concentrations when 4 mol m^{-3} N was applied, than the 2 or 9 mol m^{-2} day^{-1} treatments up until week 15. Media NO_3-N concentration of the 4, 7, 14, 28 and 42 mol m^{-3} N FC treatments were (respectively) 3.0 (±1.3), 7.3 (±2.8), 13.7 (±4.2), 24.2 (±6.2) and 33.4 (±7.6) mol m^{-3} NO_3-N averaged over PPF and weeks. The root media pH was lower in treatments receiving higher FC. Media pH of the 4, 7, 14, 28 and 42 mol m^{-3} N FC treatments were 5.7 (±0.3), 5.4 (±0.2), 5.1 (±0.3), 5.0 (±0.4) and 5.0 (±0.5) averaged over PPF and weeks.

Two mol m^{-2} d^{-1} PPF grown plants had a lower node number (11 vs 13) than 9 or 12 mol m^{-2} d^{-1} PPF treatments. There were no significant interactions between PPF and FC until the week 15 sampling for fresh mass (data not shown), dry mass and height (Figure 2). Plant height, dry mass, leaf area and bract area were not influenced by the FC treatment when grown under 2 mol m^{-2} d^{-1} PPF (Figure 2 A-D). Dry mass, leaf area and bract area were decreased when FC was 28 mol m^{-3} N or greater when grown under 9 mol m^{-2} d^{-1} PPF. Dry mass, leaf area and bract area were less when 42 mol m^{-3} N was applied when grown under 12 mol m^{-2} d^{-1} PPF. Dry mass and leaf area were significantly less when 4 mol m^{-3} N was applied when grown under 9 mol m^{-2} d^{-1} PPF. Plant heights were smaller when 42 mol m^{-3} was applied when grown under 9 mol m^{-2} d^{-1} PPF.

Expt. 2. Media EC and NO_3-N concentration at each FC varied little during the three sampling periods and were not affected by the RH treatments (Figure 1).

Fresh mass (not shown), dry mass, leaf area, and bract area (Table 1) were smaller than the 4 or 14 mol m^{-3} N treatment when 42 mol m^{-3} N was applied. Shoot height decreased with increasing FC at 50% RH. Shoot height was greatest when 14.3 mol m^{-3} N was applied with the 70% RH treatment . Node number (data not shown) was unaffected by RH or FC but node length (data not shown), measured on the sixth node of the third stem, significantly increased from 2.0 to 2.2 cm with the increase in RH.

Discussion

Our objective was to test if higher concentrations of nutrients would be required in the media to compensate for the higher growth rates as PPF increased. However there were no effects of FC on plant growth at any of the PPF treatments within the range of 7 to 14 mol m^{-3} N. Increasing PPF had the greatest affect on plant growth at fertilizer concentrations greater than 28 mol m^{-3} N, but growth was reduced in these treatments at all PPF.

Plant growth was not greatly influenced by the relative humidities used in this experiment. Other studies (Mortensen,1986; Krizek et al., 1971) using more extreme RH (55-60% to 90-95% and 40% to 90% respectively) observed greater differences in growth with increased humidity than observed in this experiment. The goal of this experiment was to test if higher FC would be required to compensate for the increased growth at the higher RH. The largest responses was the limited growth which was observed at the 42 mol m^{-3} N, regardless of the RH used.

The fertilizer treatments used in these experiments resulted in a wide range of media nutrient concentrations but only small differences in shoot growth except at the highest FC. For example a 589% increase in NO_3-N concentration in the media resulted in a 15% decrease in height. This finding supports previously reported conclusions (Yelanich and Biernbaum, 1990) that poinsettias are tolerant to wide ranges of fertilizer concentrations.

Within the range of FC treatments which produced acceptable (Warncke and Krauskopf, 1983) media EC and NO_3-N levels no clear optimal was observed to which environment and media concentration could be related. It appears that while the optimal FC can vary with RH and PPF the differences observed were not commercially important. Under the range of conditions in this experiment, it appears there is no need for modified FC or media testing guidelines based on PPF or RH.

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Table 1. Fertilizer concentration of N, K and electrical conductivity (EC) in the various treatments[z].

Nitrogen mmol $liter^{-1}$	Potassium mmol $liter^{-1}$	Solution EC mS cm^{-1} at 25° C
	Experiment 1	
3.6	1.7	1.1
7.1	3.4	1.5
14.3	6.7	2.3
28.6	13.5	3.8
42.9	20.3	4.8
	Experiment 2	
3.6	1.7	1.1
14.3	6.7	2.3
42.9	20.3	4.8

[z] For all treatments: 1.03 mmol $liter^{-1}$ Mg, 1.01 mmol $liter^{-1}$ S, 3.3 mmol $liter^{-1}$ P, alkalinity of 1.16 mmol $liter^{-1}$ $CaCO_3$

Table 2. Effect of relative humidity and fertilizer concentration on growth of poinsettia 16 weeks after planting.

Treatment	Plant Height cm	Dry Mass g	Leaf Area cm^{-2}	Bract Area cm^{-2}
		50% RH		
4 mol m^{-3}	33.0	19.3	2048	3067
14 mol m^{-3}	27.6	19.1	1995	3051
42 mol m^{-3}	24.5	11.2	1338	1234
		70% RH		
4 mol m^{-3}	30.9	18.6	1836	3411
14 mol m^{-3}	33.4	20.7	1856	3516
42 mol m^{-3}	26.3	12.2	1157	1892
LSD 5%	3.4	2.0	421	181
RH	NS	NS	NS	NS
FC	**	***	*	***
RH*FC	**	NS	NS	NS

NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001, respectively. RH=relative humidity. FC=fertilizer concentration applied.

Figure 1. Effect of fertilizer concentration and PPF (upper graph) or relative humidity (lower graph) on electrical conductivity of saturated media extracts in the two experiments. NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001, respectively. RH=relative humidity. FC=fertilizer concentration applied.

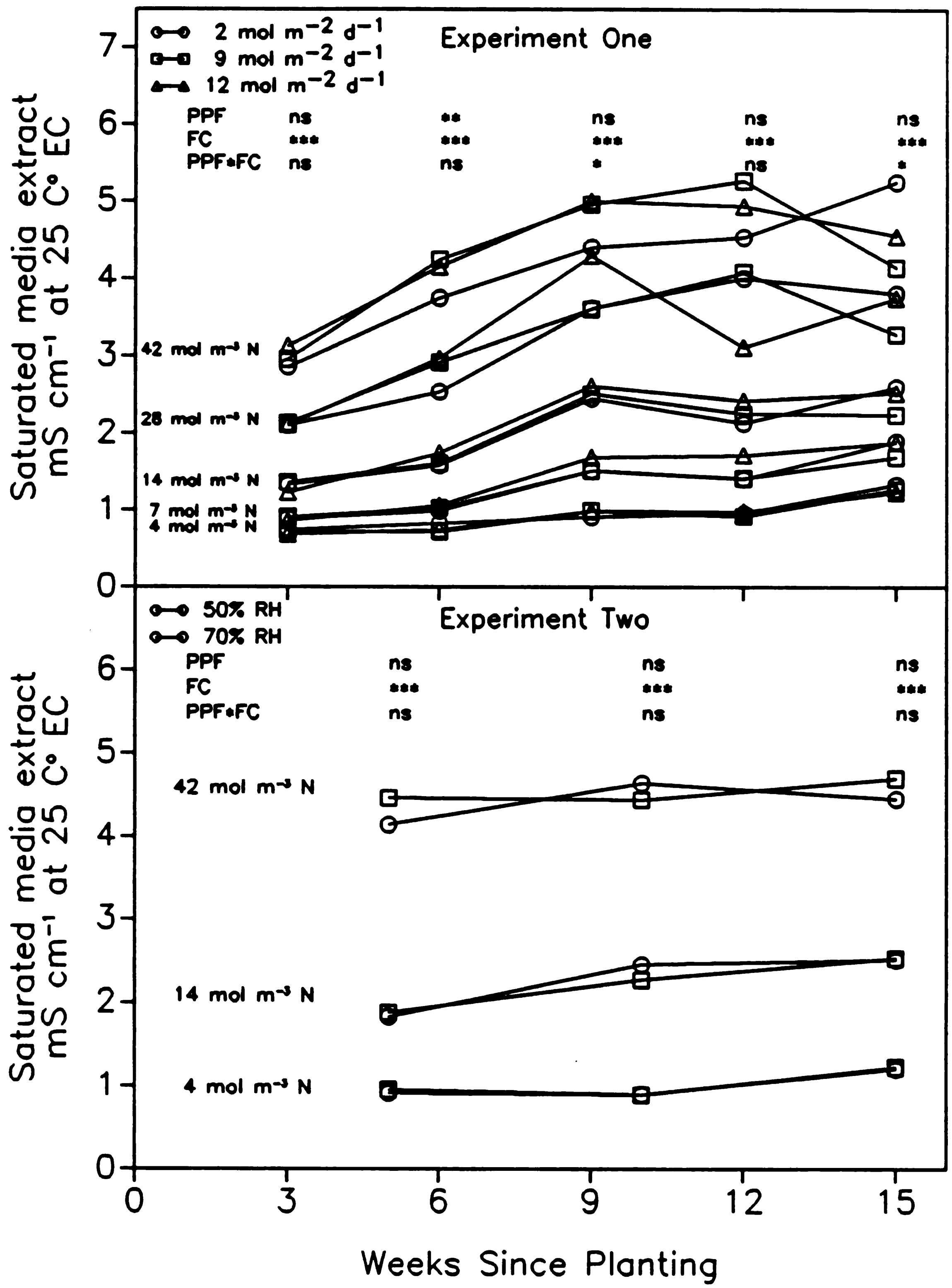

2 mol m-2 d-1
9 mol m-2 d-1
12 mol m-2 d-1
Experiment One
PPF ns ** ns ns ns
FC *** *** *** *** ***
PPF*FC ns ns * ns *
42 mol m-3 N
28 mol m-3 N
14 mol m-3 N
7 mol m-3 N
4 mol m-3 N
Saturated media extract
mS cm-1 at 25 C° EC
50% RH
70% RH
Experiment Two
PPF ns ns ns
FC *** *** ***
PPF*FC ns ns ns
42 mol m-3 N
14 mol m-3 N
4 mol m-3 N
Weeks Since Planting

Figure 1. Effect of fertilizer concentration and PPF (upper graph) or relative humidity (lower graph) on electrical conductivity of saturated media extracts in the two experiments. NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001, respectively. RH=relative humidity. FC=fertilizer concentration applied.

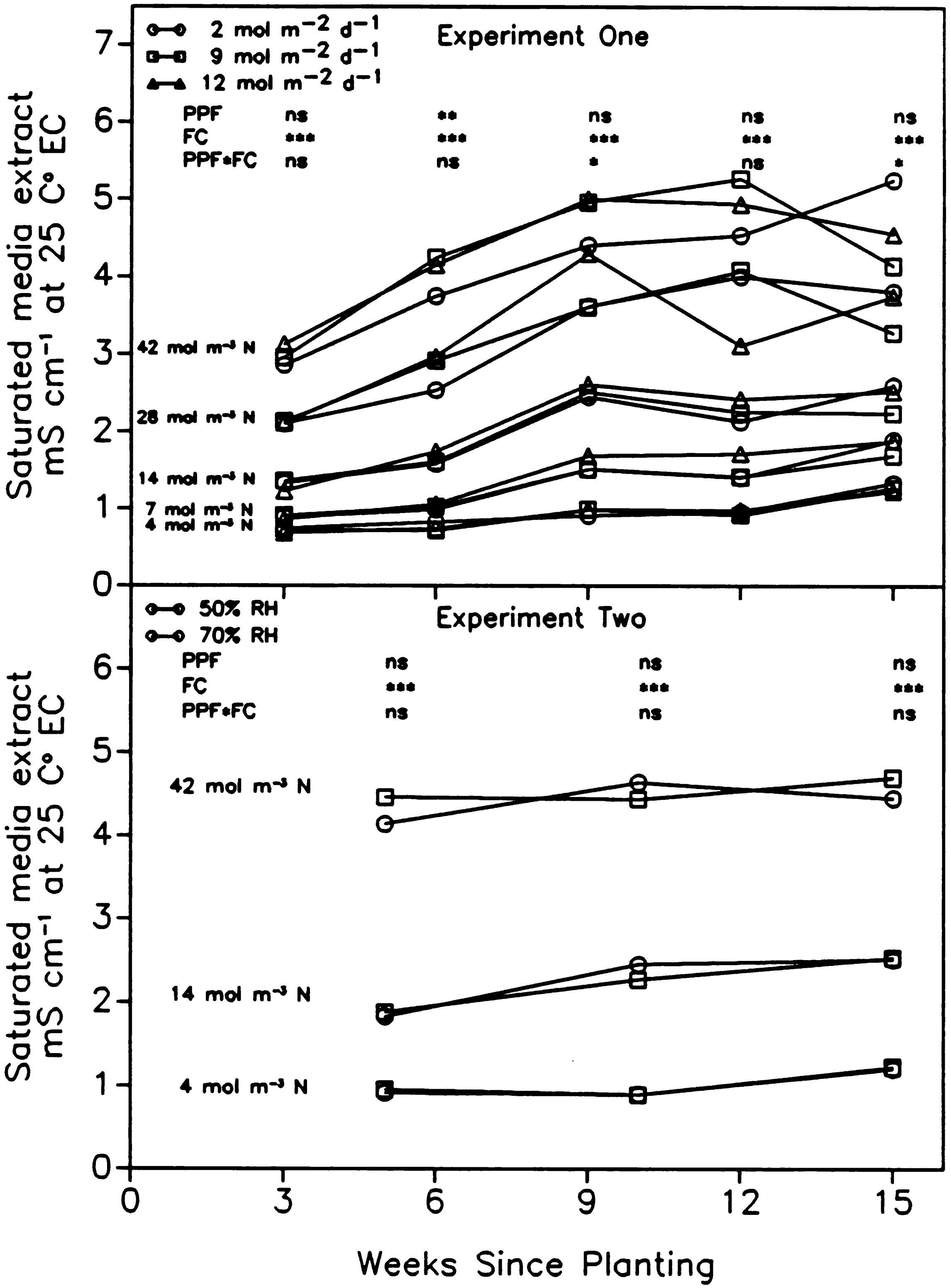
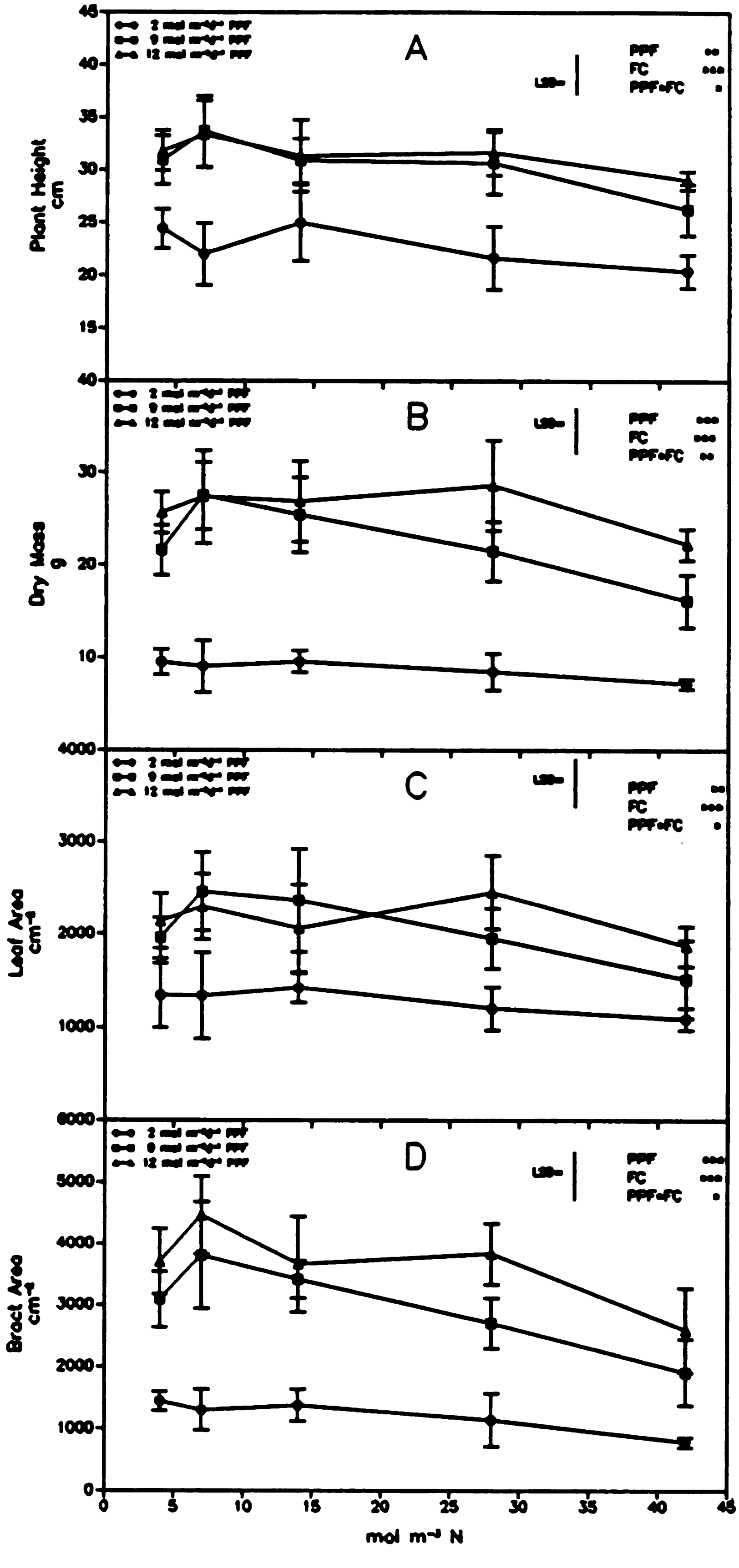

2 mol m⁻² d⁻¹
9 mol m⁻² d⁻¹
12 mol m⁻² d⁻¹
Experiment One
PPF ns ** ns ns ns
FC *** *** *** *** ***
PPF*FC ns ns * ns *
42 mol m⁻³ N
28 mol m⁻³ N
14 mol m⁻³ N
7 mol m⁻³ N
4 mol m⁻³ N
50% RH
70% RH
Experiment Two
PPF ns ns ns
FC *** *** ***
PPF*FC ns ns ns
42 mol m⁻³ N
14 mol m⁻³ N
4 mol m⁻³ N
Saturated media extract mS cm⁻¹ at 25 C° EC
Weeks Since Planting

Figure 2. Effect of fertilizer concentration (FC) and photosynthetic photon flux (PPF) on plant height (A), dry mass (B), leaf area (C) and bract area (D) of poinsettia 16 weeks after planting. EC, averaged over the week 6 to week 15 samples, was 0.99, 1.48, 2.22, 3.50, and 4.60 mS cm^{-1} (SME) for the 4, 7, 14 28 and 42 mol m^{-3} N FC treatments. NS, *,**,*** Nonsignificance or significant at P= 0.05,0.01 or 0.001, respectively.


A
B
C
D
PPF
FC
PPF×FC
LSD=
Plant Height cm
Dry Mass g
Leaf Area cm-2
Bract Area cm-2
mol m-3 N