THE EFFECT OF FERTILIZER SOURCES AND RATES AND PACLOBUTRAZOL ON SOLUBLE SALT CONCENTRATIONS AND PERFORMANCE OF 'GUTBIER V-14 GLORY' POINSETTIA

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PREFACE

This study was conducted to determine the effects of fertilizer sources and rates plus paclobutrazol on soluble salt concentrations and performance of 'V-14 Glory' poinsettia.

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CHAPTER I

INTRODUCTION

The poinsettia, Euphorbia pulcherrima Willd, was introduced into the United States in 1825 from Mexico (Shanks, 1980). Since then, many new cultivars have been developed, released, and grown for sale during the Christmas season. In 1986, it was the leading pot plant in the U. S. (Tayama et al., 1988). Many bedding plant producers include poinsettia in their production programs because it fits their crop rotation schedules (Tayama et al., 1979). In recent years, the increase in fuel cost has forced some modification in centers of production of poinsettia in the U. S. (Wilfret, 1981). Florida, for instance, has expanded in the last few years to a 2,312,000 dollar industry which sold 903,000 units in 1980 (Wilfret, 1981). The crop is still produced widely, however, throughout the United States. Poinsettia marketability is greatly influenced by the quality of the plant produced. A good quality poinsettia should have no necrotic bracts or chlorotic leaves (Nell and Barrett, 1986). To achieve this quality, growers must carefully monitor cultural practices such as nutrition, pest management, temperature and height control,

and use of growth retardants.

Nutrition of poinsettias has received considerable attention. Problems associated with nutrition usually encountered are due to insufficient, excessive, or interaction of nutrients. Design of suitable fertilization programs and diligent nutritional monitoring are important to success (Knauss and Shadan, 1983; Nelson, 1981; Shanks, 1980).

Fertilization programs include constant liquid fertilization (CLF), interval liquid fertilization, use of controlled-release fertilizers (CRF), or a combination of these (Ecke and Matkin, 1976; Nelson, 1981). In recent years, many growers have chosen the CLF program over the conventional weekly interval method. The former program uses a lower concentration of fertilizer at each application, thus reducing both the risk of fertilizer excess and the chances of falling into a deficient nutrient range (Nelson, 1981).

Controlled-release fertilizers are becoming popular for floriculture crops because they provide greater labor efficiency, since only a one-time application is required (Kovacic and Holcomb, 1981; Nelson, 1981). In addition, several studies have reported that controlled-release fertilizers can increase the efficiency of nutrient recovery by the plant and reduce the possibility of root damage by excessive soluble salts (Barron, 1977; Penningsfeld, 1975). However, once controlled-release fertilizers are applied,

growers are subjected to a set of conditions over which they have less control, especially when fertilizer is incorporated in the growing medium (Ecke and Matkin, 1976). Therefore, growers are frequently advised to choose liquid fertilization rather than a controlled-release fetilizer program.

Growth of poinsettia, both in height and weight, were limited by low Ca, Mg, and K (Stuart and Rocke, 1951). Widmer (1953) described deficiency symptoms in poinsettia including N, P, K, Ca, Mg, B, Na, and F. Potassium was observed to have a marked antagonistic effect on Mg (Cox and Seeley, 1980; Cox and Seeley, 1983; Meyer and Boodley, 1964; Pflantz and Rogers, 1973). According to Cox and Seeley (1983), poinsettias grown in a peat-perlite mix which received 300 mg K/liter CLF, regardless of N level, showed a fairy low and constant level of leaf Mg. In a similar study, they noted the leaf Ca concentration was greatest at low concentrations of K and N (30 mg/liter).

Nitrogen fertility and plant responses to N have been documented better than the other essential elements. Two forms of nitrogen are usually used for fertilization in greenhouse crops, nitrate (NO_3^-) and ammonium (NH_4^+) (Nelson, 1981). Plants sometimes respond differently to these two forms. Poinsettias may be injured if too much nitrogen is provided by NH_4^+ (Nelson, 1981). In recent years, several studies have reported that the increase in ammonium concentration and its use as the main nitrogen

source resulted in stunting, leaf chlorosis, marginal necrosis, and leaf abscission in poinsettias grown in soil or soilless mixes (Boodley, 1970; Byrne and Hasek, 1979; Cox and Seeley, 1984; Gaffney et al., 1982). Thus, there has been a trend to recommend that growers use a complete analysis fertilizer such as 20N-4.4P-16.6K "peat-lite" formulation or other fertilizer where a greater percentage of the N is derived from the nitrate source (Boodley, 1970; Knauss and Shadan, 1983).

According to Ecke (1986), poinsettias are relatively tolerant of high fertility, and sensitive to low levels of N and some micronutrients. He recommended using a CLF of 250 mg N/liter or higher for poinsettia production in soilless "peat-lite" mixes (Ecke and Matkin, 1976). However, a recent study found that CLF of NO_3-N at 84 - 168 mg/liter was sufficient to produce optimal vegetative growth of poinsettia in quartz sand (Gaffney et al., 1982). As mentioned previously, N can have an antagonistic effect on calcium. Growers have a tendency to apply suboptimal levels of elements other than N (Ecke and Matkin, 1976), thus increasing the possibility that high N applications can induce Ca shortages. If the initial Ca application was low, this could be devastating to growers of 'Gutbier V-14 Glory' poinsettias. This cultivar is widely grown, having large bracts, good self-branching ability, and good postharvest quality. It was introduced to commercial producers in the late 1970s (Wilfret, 1981). However, 'V-14' may exhibit

necrotic or deformed bracts and sometimes marginal leaf chlorosis or necrosis, reducing the marketability of the crop. Bract necrosis, instead of merely bract deformities, seem to be more prominent in the Southern U. S. (Wilfret, 1981). Research to characterize the conditions which promote development of necrotic bracts has been limited. Nell and Barrett (1985) found that increased fertilizer and watering, particularly during bract coloration, elevated the incidence of bract necrosis. They suggested the necrosis may be associated with a toxicity of elements transported through pitted vein endings at the tip of bracts.

Donnini (1986) observed that bract necrosis occurred on plants receiving 500 and 700 mg N/liter (from 20N-4.4P-16.6K constant liquid fertilization) on their last sampling date (12 weeks after planting), but plants receiving 100 and 300 mg N/liter had no necrotic bracts at the 12 weeks date. No data were collected at later dates. Others reported that necrosis was lowest when 100 mg N/liter was terminated at bract coloration, whereas continuation of this fertilizer concentration until anthesis resulted in a higher necrosis level similar to 200 and 400 mg N/liter fertilizer treatments (Nell and Barrett, 1986). Bract necrosis in plants grown in a soilless mix receiving 100% NH_4-N was greater than in those receiving half NO_3-N and half NH_4-N (Nell and Barrett, 1986). Necrosis was only observed on transitional bracts, which are the red leaf-shaped organs attached to the stems in the same alternate phyllotaxy as

leaves. The transitional bracts were reported to have a lower stomatal density compared to leaves, by about 20 fold (Nell and Barrett, 1986). This suggests the transitional bract is a low-transpiring organ, with nutrients supplied predominantly via the phloem. However, most Ca transport is via the xylem. It is well established that xylem flow is dependent on the rate of transpiration. When transpiration rate is low, xylem flow would be dependent on the root pressure. This suggests that low-transpiring organs could have an influx of water and Ca from the xylem as long as the root pressure exists. However, low water supply in the root medium and high osmotic potential of the soil solution (for example the presence of soil salinity) would decrease both root pressure and the xylem influx into the low-transpiring organs. Plants have developed mechanisms that restrict transport of calcium in the phloem (Marshner, 1986). These mechanisms are low Ca concentrations in the phloem sap, and precipitation of calcium oxalate crystals along the conducting vessels (Liegel, 1970). Thus other organs in the plant may have adequate Ca levels, while restricted Ca transport to transitional bracts can induce Ca shortages. Calcium concentrations can fall below the critical level required for the maintainance of membrane intergrity if the low-transpiring organs have high growth rates (Marshner, 1986), leading to the typical calcium-deficiency-related disorders, such as tipburn in lettuce and blossom end rot in tomato.

Woltz and Harbaugh (1986) investigated the possibility that bract necrosis was a calcium-deficiency-related disorder. Their investigation supported the hypothesis that Ca is the major factor in marginal bract necrosis of 'Gutbier V-14 Glory' poinsettia. Calcium chloride sprays prevented the necrosis, and the Ca concentration in the sprayed tissue was more than three times that of the necrotic bract marginal tissue (Woltz and Harbaugh, 1986).

It is obvious that poinsettia nutrient content is in a constant state of flux (Criley and Carlson, 1970). Nutritional problems do not always develop at the same time or in the same manner in different plants of the same cultivar (Widmer, 1953). Besides, problems can arise even under the best fertilization program. Thus, growers have to be very skillful in finding the nutritional problems, and results of diagnosis of nutritional abnormalities should be returned to growers in time for correction of problems, since the poinsettia is a short-term crop. Growers are generally encouraged to use three systems for diagnosizing nutritional abnormalities and monitoring nutrients' status in poinsettias. They are visual diagnosis, soil analysis, and foliar analysis (Ecke and Matkin, 1976; Knauss and Shadan, 1983; Nelson, 1981). Each system provides some information which the other does not, therefore, for best results, all three methods should be used to maintain optimum nutrient levels.

Observation of characteristic visual symptoms is

easiest (Nelson, 1981); however, this system can only be used after some damage has occurred. By then, it could be too late for recovery. Besides, nutrients are known to interact or antagonize each other. Thus, it would be difficult to evaluate exactly which deficient or excess elements caused certain symptoms. Consequently, most growers try to incorporate the two other systems into their nutritional monitoring program.

The growing medium is an integral part of greenhouse crop production, providing anchorage, aeration, nutrient retention, and water retention that are essential for healthy plant growth (Nelson, 1981). Presently, there are many different commercially-mixed growing media and growing media components available on the market. A majority of poinsettia growers are choosing soilless mixes over the conventional soil-mixes due to availability and ease of preparation. All components of soilless media have their own unique properties. For example, coarse sand can provide good aeration, but have poor water-holding capacity and poor cation exchange capacity. The reverse would be true for peat. Thus growers will only be able to obtain the optimum mix by using the correct proportion of each component in the soilless media. However, optimum media are rarely achieved, since selection of components for media will generally depend upon their availability and cost. The majority of fertilizer applications during poinsettia production are soil-applied rather than foliar, although Ca may be foliar-

applied (Woltz and Harbaugh, 1986). Consequently, medium testing has become a major part of nutritional monitoring. Medium analysis for greenhouse crop production generally includes a measurement of pH and soluble salt concentrations (Nelson, 1981). Water quality, especially water pH and water alkalinity, can directly or indirectly affect the growing medium pH and soluble salt concentrations. The pH of irrigation water can influence the solubility of fertilizer in solutions and availability of nutrients in the growing medium. Water alkalinity comprised of bicarbonates, carbonates, and hydroxides is a measure of a water's capacity to neutralize acids (Peterson and Ludwig, 1984; Tayama et al., 1988). The alkalinity of water is important and related to pH because alkalinity establishes the buffering capacity of water. Generally, high pH and high alkalinity of irrigation water could cause an increase in media pH. Subsequently, this can lead to a nutritional imbalance. Increase in soil pH, within limits, can cause corresponding increase in medium P, Ca, Mg, and Mo availability, and a corresponding decrease in medium Fe, Mn, Zn, and Cu availability (Nelson, 1981). Since the availability of the elements are spread over a wide range of pH, a recommended pH range of 5.0 to 6.5 or 6.0 to 6.5 is suggested for "peat-lite" or soil mixes, respectively, to assure the greatest availablility of all the essential plant nutrients (Ecke, 1986; Nelson, 1981), with the optimum pH range for poinsettia being 5.7 to 6.5 (Tayama et al., 1988).

Soluble salts commonly refers to the sum total of all soluble mineral residues in the soil (Miller et al., 1981; Nelson, 1981). Mineral elements exist in solution as charged particles called ions which have the ability to carry electrical current (Miller et al., 1981; Nelson, 1981).

Salt concentrations in the medium solution, and in the root cells contribute to the water potential of each. Water flows from an area of low water potential to an area of high water potential. Fertilizer is a source of soluble salts (Nelson, 1981), and influences water potential of the medium. Excess fertilizer, poor drainage, insufficient water, poor water quality, or a combination of these can all lead to a buildup of excess soluble salts. Excess soluble salts in the soil solution can raise the osmotic potential of the solution around the root zone to near the osmotic potential of the solution inside the root. Subsequently, not only is water uptake restricted, but water may move out of the root to the soil solution. Wilting of plants during sunny periods even though the root medium is moist is the first indication of salt injury (Nelson, 1981). If the problem is not corrected early, the roots will die at tips progressing toward the crown. The continued dying of roots severely reduces plant nutrient uptake, and eventually, the plants would suffer deficiencies of many nutrients. Since excess soluble salts can impair plants' nutrient uptake ability and poinsettia production usually involves high

levels of fertilizer, evaluation of soluble salt concentration in the medium throughout the growing season has become a common practice.

Instead of measuring the total osmotic concentration of the medium, the medium soluble salt concentration can be determined by measuring the electrical conductivity of the solution using a electrical conductivity meter (Miller et al., 1981). The higher the salt content, the greater the electrical conductivity. The common methods for soluble salt determinations that are well suited for media which receive liquid fertilization or topdress of controlled-release fertilizer are the saturated paste extract method which is a vacuum filtration of soil paste that is brought to a saturated condition by adding water while stirring, the 1:2 dilution method which uses 1 part of air-dried growing medium and is diluted by 2 parts of distilled water, and the 1:5 dilution method that involves diluting 1 part of air-dried growing medium with 5 parts of distilled water (Donnini, 1986; Miller et al., 1981; Nelson, 1981).

A method to measure soluble salts that should be well suited for media which have incorporated controlled-release fertilizer is the pour-through method which involves pouring distilled water through the medium surface and collecting the extract (leachate) (Wright, 1986; Yeager et al., 1983). This method does not require collecting medium samples; thus, if controlled-release fertilizer was incorporated, it would not be ruptured and root systems would not be

disturbed. Moreover, since the pour-through method requires no equilibration time, extract collection is rapid, plus it does not require specialized equipment. However, full reliability in interpretating results using this method is still pending (Donnini, 1986).

In recent years there has been an increased use of tissue analysis to determine the nutritional status of poinsettias. Tissue analysis can provide quantitative data for all the essential elements (Nelson, 1981), and be used as a routine guide for managing the fertility program (Criley and Carlson, 1970). Tissue analysis standards are categorized as critical level, normal range, and toxic level (Criley and Carlson, 1970; Ecke and Matkin, 1976; Knauss and Shadan, 1983). The critical level represents the elemental concentration that is associated with deficiency symptoms and severely restricted growth. Elemental concentrations between the critical level and the normal range usually do not provide visual symptoms, but plant growth may be reduced. The normal range represents the elemental concentrations associated with normal growth and performance. The toxic level is the elemental concentration associated with reduced plant growth, occasional necrosis, and many times severe excesses of one element that can induce a deficiency of another element.

Accurate interpretation of tissue analysis results is only possible if sampling is consistent and a uniform tissue type is used, since elemental concentration varies with

plant parts and age (Criley and Carlson, 1970). The recommended index tissue for poinsettias is the most recently mature, fully expanded leaves (Criley and Carlson, 1970; Ecke and Matkin, 1976). Boodley (1974) reported little change in the elemental concentrations of composite samples from all leaves present on 'Paul Mikkelsen' poinsettias from juvenile to mature growth. Others found that recently matured leaves from the newer cultivars frequently showed large changes in elemental concentrations due to sampling date and fertilizer regime (Cox and Seeley, 1983). Currently, growers of newer cultivars should use the established nutrient analysis standards for the older cultivars as a rough guide until standards are well established for a specific cultivar.

Plant height or compactness is a concern among poinsettias growers. The introduction of some shorter cultivars has helped, but problems with excessive stem elongation still exist. Many consumers prefer their plant to be short and compact, but with large (or many) attractive bracts. Before the advent of chemical plant growth regulators growers manipulated poinsettia height by reducing water and nutrients (Nelson, 1981; White and Holcomb, 1974). The effectiveness of stress in reducing height was dependent on the level of stress and stage of crop development (Gilbertz et al., 1984). Plant height and time of flowering were affected most by stress occurring during the middle of the production cycle. Stress successfully reduced the plant

height, but resulted in smaller bract size and increased leaf abscission (Nelson, 1981; White and Holcomb, 1984). Most growers are now using plant growth regulators as the principal means for controlling poinsettia plant height, due to the ease of management and improved plant quality.

The plant growth regulators daminozide, ancymidol, and chlormequat have effectively controlled height of many floriculture crops (Barrett, 1982; Barrett and Bartuska, 1982; McDaniel, 1983; Menhenett and Hanks, 1982/83; Wilfret, 1981). All three are effective on poinsettias. Chlormequat and ancymidol can be used as foliar sprays or soil drenches, and daminozide as a foliar spray only (Shanks, 1980). Chlormequat and daminozide in combination may be used as a foliar spray (Tayama et al., 1988). Spray applications are used widely in the industry because less labor is required. However, results using soil drenches are usually more predictable (Tija and Sheehan, 1986). Soil drenches are usually less phytotoxic and less dependent on prevailing environmental conditions (such as humidity, temperature, and light) (Tija and Sheehan, 1986), but growing media containing large amounts of pine bark may cause soil drenches to be less effective (Barrett, 1982). Growth regulators prevent excessive plant height by reducing internode elongation (Nelson, 1981; Shanks, 1980), but do not reduce the total number of leaves formed (Nelson, 1981). In addition, plants treated with growth regulators have darker green foliage, and thicker, more upright stems (Ecke

and Matkin, 1976; Nelson, 1981). Plant growth regulators may sometimes have undesirable effects. These include reduced bract size, crinkling of bracts, blotchy yellowing of leaves, marginal leaf necrosis, and delayed flowering. Some of these undesirable characteristics can be eliminated or reduced by the proper application techniques.

Paclobutrazol (PP-333) a plant growth regulator that was introduced by the Imperial Chemical Industry (ICI). It is sold commercially as "Bonzi" for use in production of ornamental pot plants (Goulston and Shearing, 1985), and has recently received EPA registration for poinsettia. Paclobutrazol is a pyrimidine derivative that suppresses gibberellin biosynthesis by inhibiting the oxidation of kaurene to kaurenoic acid in the biosynthesis pathway (Couture, 1982; Lever, 1986). Steffens and Wang (1986) reported that paclobutrazol has the greatest effect on tissues which are rapidly growing and developing at the time of treatment or shortly thereafter. Its' primary effect is the reduction of vegetative growth by reducing internode expansion; and a secondary effect is altering the sink strength within the plant by allowing a greater partition of assimilates to contribute to reproductive growth, flower bud formation, fruit formation, and fruit growth (Lever, 1986).

Paclobutrazol was very effective in dwarfing a wide range of crops including fruit trees (Quinlan, 1981; Tukey, 1981), tulips (Menhenett and Hanks, 1982/83), and ornamental species (McDaniel, 1983; McDaniel, 1986; Shanks, 1981;

Wilfret, 1981). Shanks (1981) found PP-333 sprayed or drenched on a wide range of ornamental plants effectively reduced shoot extension. In addition, plants were observed to be darker green and free from any phytotoxicity symptom. Paclobutrazol effectively reduced poinsettia height (McDaniel, 1986), maintained darker green foliage which is attributed to higher levels of chlorophyll per unit leaf area (Hawkins et al., 1985), and enhanced and advanced bract coloration (Goulston and Shearing, 1985). Greene and Murray (1983) found that paclobutrazol enhanced fruit quality by enhancing calcium levels in apples leading to a reduction in storage disorders. Others reported foliar sprays of paclobutrazol frequently caused higher foliar N, Ca, and Mg concentrations than soil drenches (Sansavini et al., 1986).

Paclobutrazol was found to be effective over a wider range of treatment rates than ancymidol (Gianfagna and Wulster, 1986; Menhenett, 1984). It is very effective at low concentration as compared to cycocel, therefore, it is very critical to measure paclobutrazol accurately. Paclobutrazol can be applied either as a foliar spray or as a soil drench (Shanks 1981). When paclobutrazol is sprayed onto the foliage, it accumulates in the leaves and is not translocated into other tissues (Barrett and Bartuska, 1982; Wilfret, 1981). This lack of translocation is probably because chemical taken up by the leaves would have to move through the phloem, at least to the stem where it can be translocated in the xylem. It has been well documented that

paclobutrazol has very limited activity in the phloem, for the primary mode of translocation is almost exclusively in the xylem (Barrett and Bartuska, 1982). Thus as a foliar spray proper stem and shoot coverage are important for maximum uptake (Barrett and Bartuska, 1982). Quinlan and Richardson (1984) found paclobutrazol, when used as a foliar spray, to be most effective if it was deposited on the apical bud or on the soft stem tissue immediately behind it.

As a soil drench, activity varies with the content of the growing medium (Barrett, 1982). Paclobutrazol is not strongly adsorbed by the clay or organic matter in the potting media used (Wainwright and Bithell, 1986), with the exception of pine bark (Barrett, 1982).

According to midwest growers (Lingren, 1986) that have experimented with paclobutrazol, they found it to possess some advantages over other growth regulators. Growers found that paclobutrazol-treated plants showed no yellowing of leaf margins as compared to cycocel-treated plants. Also, they found paclobutrazol to be effective under cloudy, cool conditions as well as under extreme temperatures. However, the effect of paclobutrazol on poinsettias has not been totally consistent, and experience should be gained in its' use before treating large numbers of plants (Tayama et al., 1988).

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CHAPTER II

THE EFFECT OF FERTILIZER SOURCES AND RATES AND PACLOBUTRAZOL ON PERFORMANCE OF 'GUTBIER V-14 GLORY' POINSETTIA

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Abstract. A factorial combination of 3 concentrations of liquid fertilizer (CLF), 2 rates of controlled-release fertilizer (CRF), and 2 growth regulator rates were evaluated in a split plot design on 'V-14 Glory' poinsettias grown as single-pinched plants. At each watering, plants topdressed with 0 or 3.75 g of 12N-5.3P-12.5K CRF/pot were irrigated with 236, 472, or 708 mg of 20N-4.4P-16.6K/473 ml/pot. Six weeks after potting, 4 weeks after pinching, plants were sprayed to run-off with 0 or 50 ul/liter of paclobutrazol. Results show paclobutrazol reduced plant height, shoot length, bract diameter, plant dry weight, and the cumulative number of necrotic bracts compared to controls. As fertilizer concentrations increased, leaf N, P, Mg, and Mn concentrations increased, bract N, P, and K concentrations increased, and leaf Ca and bract Ca and Mg concentrations decreased. Concentrations of Ca, Mg, and Fe in bracts were approximately 3 times less than that in

leaves. Medium soluble salt concentrations were positively related to fertility levels. Liquid fertilizer levels or top dressing did not affect total plant dry weight.

The poinsettia, Euphorbia pulcherrima Willd, was introduced into the United States in 1825 from Mexico (Shanks, 1980). Since then, many new cultivars have been developed, released, and grown for sale during the Christmas season. In 1986, it was the leading pot plant in the U. S. (Tayama et al., 1988). Many bedding plant producers include poinsettia in their production programs because it fits their crop rotation schedules (Tayama et al., 1979). In recent years, the increase in fuel cost has forced some modification in centers of production of poinsettia in the U. S. (Wilfret, 1981). Florida, for instance, has expanded in the last few years to a 2,312,000 dollar industry which sold 903,000 units in 1980 (Wilfret, 1981). The crop is still produced widely; however, throughout the United States. Poinsettia marketability is greatly influenced by the quality of the plant produced. A good quality poinsettia should have no necrotic bracts or chlorotic leaves (Nell and Barrett, 1986). To achieve this quality, growers must carefully monitor the cultural practices throughout the growing season.

Nutrition of poinsettias has received considerable attention. Problems associated with nutrition usually are due to insufficient, excess, or an interaction of nutrients. Design of suitable fertilization programs and diligent

nutritional monitoring are important to success (Knauss and Shadan, 1983; Nelson, 1981; Shanks, 1980).

Fertilization programs include constant liquid fertilization (CLF), interval liquid fertilization, use of controlled-release fertilizers (CRF), or a combination of these (Ecke and Matkin, 1976; Nelson, 1981). In recent years, many growers have chosen the CLF program over the traditional weekly interval method. The former program uses a lower concentration of fertilizer at each application, thus reducing both the risk of fertilizer excess and the chances of falling into a deficient nutrient range (Nelson, 1981).

The use of controlled-release fertilizer is becoming popular because it provides greater labor efficiency, since only a one-time application is required (Kovacic and Holcomb, 1981; Nelson, 1981). In addition, several studies have reported that controlled-release fertilizers can increase the efficiency of nutrient recovery by the plant and reduce the possibility of root damage by excessive soluble salts (Barron, 1977; Penningsfeld, 1975). However, once controlled-release fertilizers are applied, growers are subjected to a set of conditions over which they have less control than when liquid fertilization is used, especially when fertilizer is incorporated in the growing medium (Ecke and Matkin, 1976).

Until recently, controlled-release fertilizer contained only macronutrients. Sierra Chemical Co. has introduced a

series of controlled-release fertilizers containing micronutrients as well as the macronutrients. One of these is the "Poinsettia" formulation 12N-5.3P-12.5K plus minors with a 3 month release rate at an average soil temperature of 21^{0}C. This formulation is designed to deliver more Ca and Mg at the beginning of plant growth, then increase K and Mo toward the end of the production cycle.

According to Ecke (1986), poinsettias are tolerant to high fertility, and sensitive to a low level of N and some micronutrients. A CLF of 250 mg N/liter or higher is recommended for poinsettia production in soilless "peat-lite" mixes (Ecke and Matkin, 1976). However, a recent study found that CLF of NO_3-N at 84 - 168 mg/liter was sufficient to produce optimal vegetative growth of poinsettia in quartz sand (Gaffney et al., 1982). Nitrogen can have an antagonistic effect on calcium. Growers have a tendency to apply suboptimal levels of elements other than N (Ecke and Matkin, 1976), thus increasing the possibility that high N applications can induce shortages of Ca or other elements. 'Gutbier V-14 Glory' is a widely grown cultivar, having large bracts, good self-branching ability, and good postharvest quality. It was introduced to the commercial producers in the late 1970s (Wilfret, 1981). However, 'V-14' may exhibit necrotic or deformed bracts and sometimes marginal leaf chlorosis or necrosis, reducing the marketability of the crop. Research to characterize the conditions which promote development of necrotic bracts has

been limited. Nell and Barrett (1985) found that increased fertilizer (NPK) and watering, particularly during bract coloration, elevated the incidence of bract necrosis. They suggested the necrosis may be associated with a toxicity of elements transported through pitted vein endings at the tip of bracts.

Donnini (1986) observed that bract necrosis was evident 12 weeks after potting on plants that received 500 and 700 mg N/liter from 20N-4.4P-16.6K fertilizer, but plants that received 100 and 300 mg N/pot had no necrotic bracts at the 12 weeks date. Nell and Barrett (1986) reported that necrosis was lowest when 100 mg N/liter was terminated at bract coloration, whereas continuation of this fertilizer concentration until anthesis resulted in higher necrosis level similar to 200 and 400 mg N/liter fertilizer treatments (Nell and Barrett, 1986). Bract necrosis in plants grown in a soilless mix that were receiving 100% NH_4-N was greater than those receiving half NO_3-N and half NH_4-N (Nell and Barrett, 1986). Necrosis was only observed on transitional bracts, which are the red leaf-shaped organs attached to the stems in the same alternate phyllotaxy as leaves. The transitional bracts were reported to have a lower stomatal density compared to leaves, by about 20 fold (Nell and Barrett, 1986). This suggests the transitional bract is a low-transpiring organ, with nutrients supplied predominantly via the xylem. It is well established that xylem flow is dependent on the rate of transpiration. When

transpiration rate is low, xylem flow would be dependent on root pressure. This suggests that low transpiring-organs could have an influx of water and Ca from the xylem as long as root pressure is possible. However, a low water supply in the root medium and high osmotic potential of the soil solution (for example the presence of soil salinity) would decrease both root pressure and the xylem influx into the low-transpiring organs. Calcium transport in the phloem is limited due to low Ca concentrations in the phloem sap, and precipitation of calcium oxalate crystals along the conducting vessels (Liegel, 1970). Thus other organs in the plant may have adequate Ca levels, while restricted Ca transport to transitional bracts can induce Ca shortages. Calcium concentrations can fall below the critical level required for the maintainence of membrane intergrity if the low-transpiring organs have high growth rates (Marshner, 1986), leading to the typical calcium-deficiency-related disorders, such as tipburn in lettuce and blossom end rot in tomato.

Woltz and Harbaugh (1986) investigated the possibility that bract necrosis was a calcium-deficiency-related disorder. Their investigation supported the hypothesis that Ca is the major factor in marginal bract necrosis of 'Gutbier V-14 Glory' poinsettia. Calcium chloride sprays prevented the necrosis, and the Ca concentration in the sprayed tissue was more than three times that of the necrotic bract marginal tissue.

Plant height or compactness is a concern among poinsettias growers. The introduction of some shorter cultivars has helped, but problems with excessive stem elongation still exist. Many consumers prefer their plants to be short and compact, but with large (or many) attractive bracts. Before the advent of chemical plant growth regulators growers manipulated poinsettia height by reducing water and the nutrients (Nelson, 1981; White and Holcomb, 1974). The effectiveness of stress in reducing height was dependent on the level of stress and stage of crop development (Gilbertz et al., 1984). Plant height and time of flowering were affected most by stress occurring during the middle of the production cycle. Stress successfully reduced the height, but resulted in smaller bract size and increased leaf abscission (Nelson, 1981; White and Holcomb, 1984). Most growers are now using plant growth regulators as the principal means for controlling poinsettia plant height, due to the ease of management and improved plant quality.

The plant growth regulators daminozide, ancymidol, and chlormequat have effectively controlled height of many floriculture crops (Barrett, 1982; Barrett and Bartuska, 1982; McDaniel, 1983; Menhenett and Hanks, 1982/1983; Wilfret, 1981). All three are effective on poinsettias. Chlormequat and ancymidol can be used as a foliar spray or soil drench, and daminozide as a foliar spray only (Shanks, 1980). Chlormequat and daminozide in combination may be

used as a foliar spray (Tayama et al., 1988) Spray applications are used widely in the industry because less labor is required. However, results using soil drenches are usually more predictable (Tija and Sheehan, 1986). Soil drenches are usually less phytotoxic and less dependent on prevailing environmental conditions (such as humidity, temperature, and light) (Tija and Sheehan, 1986), but growing media containing large amounts of pine bark may cause soil drenches to be less effective (Barrett, 1982). Growth regulators reduce plant height by decreasing the internode elongation (Shanks, 1981; Shanks, 1980), but do not reduce the total number of leaves formed (Nelson, 1981). In addition, plants treated with growth regulators have darker green foliage, and thicker, more upright stems (Ecke and Matkin, 1976; Nelson, 1981). Plant growth regulators may sometimes have undesirable effects. These include reduced bract size, crinkling of bracts, blotchy yellowing of leaves, marginal leaf necrosis, and delayed flowering. Some of these undesirable characteristics can be eliminated or reduced by proper application techniques.

Paclobutrazol (PP-333) is a plant growth regulator that was first introduced by the Imperial Chemical Industry (ICI). It is sold commercially as "Bonzi" for use in production of ornamental pot plants (Goulston and Shearing, 1985), and has recently received EPA registration for poinsettia. Paclobutrazol is a pyrimidine derivative that suppresses gibberellin biosynthesis by inhibiting the

oxidation of kaurene to kaurenoic acid in the biosynthesis pathway (Couture, 1982; Lever, 1986). Steffens and Wang (1986) reported that paclobutrazol has the greatest effect on tissues which are rapidly growing and developing at the time of treatment or shortly thereafter. Its' primary effect is the reduction of vegetative growth by reducing internode expansion. A secondary effect is altering the sink strength within the plant by allowing a greater partition of assimilates to contribute to reproductive growth, flower bud formation, fruit formation and fruit growth.

It has been reported to be very effective for dwarfing a wide range of crops including fruit trees (Quinlain, 1981; Tukey, 1981), tulips (Menhenett and Hanks, 1982/1983), and ornamental species (McDaniel, 1983; McDaniel, 1986; Shanks, 1981; Wilfret, 1981). Shanks (1981) found PP-333 sprayed or drenched on a wide range of ornamental plants effectively reduced shoot extension. In addition, plants were observed to be darker green and free from any phytotoxicity symptoms. Greene and Murray (1983) found paclobutrazol enhanced fruit quality in apples by enhancing calcium levels, leading to a reduction in storage disorders. Sansavini et al. (1986) reported that the N, Ca, and Mg concentrations of apple trees that received paclobutrazol foliar spray were higher than the soil drench.

Paclobutrazol effectively reduced poinsettia height (McDaniel, 1986), maintained darker green foliage which is

attributed to a higher level of chlorophyll per unit leaf area (Hawkins et al., 1985), enhanced and advanced bract coloration (Goulston and Shearing, 1985)

Studies have found paclobutrazol to be effective over a wider range of treatment rates than ancymidol (Gianfagna and Wulster, 1986; Menhenett, 1984). Paclobutrazol can be applied either as a foliar spray or as a soil drench (Lever, 1986; Shanks, 1981). When paclobutrazol is sprayed onto the foliage, it accumulates in the leaves and is not translocated into other tissues (Barrett and Bartuska, 1982; Wilfret, 1981). This lack of translocation is probably because the chemical taken up by the leaves would have to move through the phloem, at least to the stem where it can be translocated in the xylem. Paclobutrazol has been reported to have very limited activity in the phloem, for the primary mode of translocation is almost exclusively in the xylem (Barrett and Bartuska, 1982). Thus, as a foliar spray, proper stem and shoot coverage are important for maximum uptake (Barrett and Bartuska, 1982). Quinlain and Richardson (1984) found paclobutrazol, when used as a foliar spray, was most effective if it was deposited on the apical bud or on the soft stem tissue immediately behind it.

As a soil drench, activity varies with the content of the growing medium (Barrett, 1982). Paclobutrazol is not strongly adsorbed by the clay or organic matter in the potting medium (Wainwright and Bithell, 1986), with the exception of pine bark (Barrett, 1982). However, the effect

of paclobutrazol on poinsettias has not been consistent, and experience should be gained in its use before treating large numbers of plants (Tayama et al., 1988).

The purpose of this experiment was to determine the effects of various rates of 20N-4.4P-16.6K constant liquid fertilization, 12N-5.3P-12.5K plus minors controlled-release fertilizer topdress, and paclobutrazol spray on medium pH and soluble salt concentrations, foliar and bract nutrient concentrations , bract necrosis, and growth performance of 'Gutbier V-14 Glory' poinsettia grown in a soilless growing medium (3:1:1 v/v/v of sphagnum peat, vermiculite, and perlite).

Materials and Methods

Rooted terminal cuttings of 'Gutbier V-14 Glory' poinsettia were received 27 August 1986, courtesy of Guthrie Greenhouses, Inc., Guthrie, OK. A total of 108 cuttings were transplanted one cutting per 15 cm x 11.5 cm pot on 5 September, 1986. Cuttings were planted in a (3:1:1 v/v/v) soilless medium of sphagnum peat, vermiculite, and perlite respectively, amended on a per cubic meter basis with 5.94 kg finely ground dolomitic limestone, 1.49 kg single superphosphate (0-8.8-0), 0.89 kg potassium nitrate, 74.25 g FTE 555 (a micronutrient fertilizer, Peters Fertilizer Products, Fogelsville, Pa), and 0.89 kg granular Aqua-Gro wetting agent. The next day, each plant was drenched with

3.4 mg/ml of 5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole (terrazole) and methyl 1-(buthylcarbamoyl)-2-benzimidazolecarbamate (benomyl) fungicide solution. Two monthly soil applications of 0.9 g of 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime (aldicarb) granules per 15 cm pot were applied 19 September and 19 October as a pest control program. Plants were pinched to 7 nodes on 19 September.

A factorial combination of three concentrations of liquid fertilizer (Peters "20-10-20 Peat Lite Special", W. R. Grace., Cambridge, MA), two rates of controlled-release fertilizer (Sierra Poinsettia Mix "12-12-15 plus Minors", Sierra Chemical Co., Milpitas, CA), and two growth retardant (+/-)- (R*,R*)- -[(4-chlorophenyl)methyl]- -(1,1-dimethylethyl)-1H-1,2,4-triazole-1-ethanol (paclobutrazol) rates was established on 8 September, 1986. At every watering, plants that were topdressed with 0 or 3.75 g of 12N-5.3P-12.5K per pot were irrigated with 473 ml/pot of 236, 472, or 708 mg of 20N-4.4P-16.6K per pot. Irrigation timing was determined by using grower's judgment. At no time during the experiment was plain water applied to the plants and all watering dates were recorded. On 17 October (6 weeks after potting, 4 weeks after pinching), plants were sprayed with 0 or 50 ul/liter of paclobutrazol. Plants were spaced 38 x 38 cm on raised benches and arranged in a split plot design with CLF as the main plot, and CRF and paclobutrazol as the sub-plot. Treatments were

replicated three times with three plants per replication. Plants were grown in a fiber-glass greenhouse with temperatures maintained as closely as possible within ranges of 16 - 18^{0}C (night) and 19 - 24^{0}C (day).

After potting, growing medium samples to be used for the soluble salts determination using a 1:2 dilution method (Donnini, 1986; Miller et al., 1981; Nelson, 1981), were taken at 4 week intervals (3 and 31 October and 28 November) from three plants of each treatment in one replicate, for 3 individual samples per treatment per date. Plants from which medium samples were removed were not sampled again.

At each sampling date, approximately 29.6 ml of growing medium was removed from the root zone area per pot, placed into clean plastic bags, and allowed to air dry. Then 14.8 ml of the dried sample was diluted with 29.6 ml of deionized water. The mixture was stirred three times within a twenty minute period, allowed to stand for ten minutes, then electrical conductivity and pH of the solution were measured. The electrical conductivity was measured in millimhos/cm using an EL Hamma Digital Field Conductometer model number TH-250 with a conductivity cell model number EHT-24c (Rosh Pina, Israel). The solution pH was determined by using a Cole-Parmer (Chicago, Illinois) Digi-Sense pH meter LCD model number 5994-10 with a combination electrode Calomel reference cell type Hg/HgCl model number T-5990-35.

After pinching (19 September), 7 biweekly measurements of the top two shoots' length on all plants were made. The

shoot length was determined by measuring the distance from the point of attachment of the shoot to the stem to the furtherest point along the shoot.

Thirteen weeks after potting (5 December), three weeks prior to final harvesting, 3 weekly measurements of the cumulative number of bracts per plant with any necrosis, **even very slight tip necrosis**, was determined. Sixteen weeks after potting (26 December), plants in all treatments were harvested and evaluated for plant height, bract diameter of the top two shoots, elemental concentration of bracts and leaves, and above ground dry weight. Total plant height was measured from the pot rim to the center of the tallest cyathium of each pot. Bract diameter was determined by averaging 2 perpendicular measurements of each bract displayed per plant. Plant dry weight was determined by harvesting plants at medium level and dividing the plants into leaves, bracts, cythia, and stems. Plant parts were separately placed in clean paper bags and dried at 75^{0}C. At the time of harvest, ten to twelve recently-matured leaves and bracts were collected from each plant. The samples were washed in tap water and a liquinox solution, then rinsed twice in deionized water. Total washing time did not exceed 1 minute. Bracts and leaves were placed into separate clean paper bags, dried at 75^{0}C, then their respective dry weights were recorded and added to the dry weight of their corresponding plant parts so that the total dry weight of bracts, leaves, and the entire plant could be calculated.

Then the bract and leaf samples were ground to pass through a 20 mesh screen in a Wiley Mill, and stored in air-tight jars until analysis. Prior to analysis, bract and leaf samples were re-dried at 80^0C for 24 hours. Nitrogen was analyzed by macro-Kjeldahl, P colorimetrically, and K, Ca, Mg, Zn, Fe, and Mn by a Perkin-Elmer 303 atomic absorption spectrophotometer.

Results and Discussion

Over the 7 biweekly sampling dates, shoot length was positively correlated with CLF rate and CRF treatment, but was curvalinearly related to the CLF and paclobutrazol treatments between 6 and 14 weeks after pinching (Table 1, 2). The CRF topdress increased shoot length of plants that received 236 mg/pot CLF on all sampling dates, and increased shoot length of plants receiving 472 mg/pot on week 2, but decreased shoot length of plants that received 708 mg/pot CLF on weeks 4, 6, and 10 (Table 1). After paclobutrazol spray (4 weeks after pinching), shoot lengths of sprayed plants in all CLF treatments were reduced on all the remaining sampling dates (Table 2).

Plants that received 236 mg/pot CLF without CRF had shorter shoots than plants receiving 472 or 708 mg/pot CLF with no CRF on all sampling dates (Table 1). However, there was no significant difference between plants receiving 472 or 708 mg/pot CLF with no CRF between 4 and 14 weeks after

pinching. When there was CRF topdressed, plants receiving 472 mg/pot CLF had longer shoots than plants fertilized with 708 mg/pot CLF between 4 and 14 weeks after pinching, and plants receiving 236 mg/pot CLF on week 14. In addition, the degree of compactness on paclobutrazol treated plants was greater than for the untreated plants. The shorter shoot length and increase in plant compactness caused by paclobutrazol showed that the foliar spray was effective in suppressing stem internode elongation (Shanks, 1981). Unlike plant height, which only shows the vertical height of the plant, shoot length characterizes plant size and compactness. In our experiment, the foliar spray of paclobutrazol significantly suppressed final plant height, but by only 1 cm (Table 3). McDaniel (1986) reported a similar finding. The reduction of 1 cm in plant height has little commercial significance. This shows that shoot length should be included when evaluating paclobutrazol's effectiveness.

Bract diameter was positively correlated to CLF interacted with CRF treatment, but was curvalinearly related to CLF interacted with paclobutrazol treatment (Table 4, 5). The CRF topdress increased bract diameter of plants receiving 236 mg/pot CLF, but did not affect bract diameter of the two other treatments. Bract diameter of plants in all CLF treatments was reduced by paclobutrazol spray. Regardless of CRF or paclobutrazol, plants that received 708 mg/pot CLF frequently had smaller bracts than plants

fertilized with 236 or 472 mg/pot CLF. Growth regulators (Ecke, 1986) or high fertilizer rates (Nell and Barrett, 1986) have been reported to reduce bract size. These findings agree with our results.

Leaf, cyathium, stem, and total dry weights were linearly correlated to CLF and interaction with CRF, and paclobutrazol treatments, while bract dry weight showed a curvalinear relationship (Table 5). Leaf dry weight of plants that received 236 mg/pot CLF minus CRF, regardless of paclobutrazol, was less than for plants that received 472 or 708 mg/pot CLF minus CRF; however, the other plant parts did not show a similar response. Plants not treated with paclobutrazol that received 236 or 708 mg/pot CLF plus CRF frequently had less leaf, bract, and stem dry weights than plants that received 472 mg/pot CLF plus CRF and no paclobutrazol; while paclobutrazol-treated plants that received 472 or 708 mg/pot CLF plus CRF frequently had less stem and bract dry weights than paclobutrazol-treated plants that received 236 mg/pot CLF plus CRF. All plant part dry weights of plants that received 236 mg/pot CLF plus paclobutrazol and the cyathium and stem dry weights of plants that received 472 mg/pot CLF minus paclobutrazol increased with the CRF topdressed; however, most of the other treatments were not benefited by the 3.75 g/pot CRF topdressing. Paclobutrazol did not reduce leaf dry weight regardless of fertilizer rate, but reduced most of the stem and bract dry weights of plants within each of the CLF and

CRF treatments. Total dry weight generally followed trends of bract and stem dry weights. Nelson (1981) reported that growth regulators reduce plant height by reducing internode elongation, but do not reduce the total number of leaves formed. In addition, the dry weight reduction could be attributed to the undesirable effect of growth regulator (Ecke, 1986), or to high rate of fertilizer application (Nell and Barrett, 1986).

Medium pH and soluble salt concentrations were linearly related to CLF on all sampling dates (Table 9). Medium pH decreased and soluble salt concentrations increased as CLF rate increased. Medium pH of plants fertilized with CRF were significantly different from plants receiving no CRF 4 and 12 weeks after potting (Table 7). Although plants that received paclobutrazol spray showed significant differences on all sampling dates (Table 8), this increase is of little commercial significance. Initially, medium soluble salt concentrations of plants were significantly correlated to CRF, later sampling dates (8 and 12 weeks after potting) showed significant relationship with the CRF and paclobutrazol treatment (Table 9). Most of the medium soluble salt concentrations showed significant correlation with CRF treatment regardless of paclobutrazol treatment. These results indicate paclobutrazol has a negligible effect in causing any change in medium pH and soluble salt concentrations. Regardless of fertilizer source, medium pH decreased and medium soluble salt concentrations increased

as plant age increased. The decrease in medium pH and the increase of soluble salt concentrations reflects the gradual accumulation of nutrients in the medium.

Water pH can affect the solubility of fertilizers in solution and the availability of nutrients in the growing medium (Peterson and Ludwig, 1984). In our experiment, the irrigation water usually had a pH of above 7.0, which was in the described optimum range (Peterson and Ludwig, 1984). Most of the media pH's were in the optimum range of 5.7 to 6.5 for poinsettias (Tayama et al., 1988) on all sampling dates. This indicates pH did not limit nutrient availability to the plants. Also, medium soluble salt concentrations for plants that received 472 and 708 mg/pot CLF treatment and plants that received CRF and paclobutrazol treatments were in the satisfactory range for established plants (Donnini, 1986; Miller et al., 1981; Nelson, 1981), but plants in the 236 mg/pot CLF treatment were in the low fertility range (Miller et al., 1981; Nelson, 1981). Since plants were receiving CLF treatment, this low salt level should not cause any problem; however, it might be a deficient level (Nelson, 1981).

Leaf N concentrations increased and K concentrations decreased with paclobutrazol spray (Table 11), but these changes are of little commercial significance. Foliar N concentrations showed a positive linear correlation with CLF treatment, but leaf Mg concentrations showed a curvalinear trend (Table 12). Both leaf P and Fe concentrations showed

a curvalinear relationship with CLF interacted with paclobutrazol treatment (Table 13). Plants that received 708 mg/pot CLF had greater leaf P and Fe concentrations with paclobutrazol treatment, while paclobutrazol did not affect leaf P and Fe concentrations of plants that received 236 or 472 mg/pot CLF.

Leaf Ca concentrations showed a negative correlation with CLF and interaction with CRF, and paclobutrazol treatments, but leaf Zn and Mn concentrations showed a curvalinear relationship to CLF (Table 14). Regardless of the CLF and paclobutrazol treatments, most leaf Ca and Zn concentrations showed no significant differences with the CRF topdress, whereas most leaf Mn concentrations were increased with the CRF topdress. Also, most of the Ca, Zn, and Mn concentrations showed no significant differences with paclobutrazol spray in the CLF and CRF treatments.

Most bract N concentrations increased and Ca and Mg concentrations decreased as the fertilizer rate increased (Table 15, 16, 17). Bract N concentrations showed a positive linear relationship to the CLF and paclobutrazol treatments, while bract Ca and Mg concentrations showed a curvalinear relationships. Bract N concentrations were decreased in plants that received 708 mg/pot CLF and CRF treatments (Table 15), while the other treatments did not affect bract N concentrations. Bract Ca and Mg concentrations of plants within each CLF treatment were not affected by paclobutrazol spray, but bract N concentrations

of plants within each CLF treatment was increased with paclobutrazol spray (Table 14).

Bract P and K concentrations were curvalinearly related to the CLF, CRF, and paclobutrazol treatments, while bract Zn and Fe concentrations showed a positive linear correlation (Table 18). In general, bract P, K, and Fe concentrations increased as the fertilizer rate increased regardless of the paclobutrazol treatment, but Zn concentrations were not affected.

All the leaf N, K, Ca, Mg, Zn, and Mn concentrations were in the normal range for poinsettias (Ecke and Matkin, 1976). Leaf P concentratons of plants that received 472 and 708 mg/pot CLF treatment exceeded the "toxic" level and plants that received 236 mg/pot CLF were in the described normal range (EcKe and Matkin, 1976). Also, most of the Fe concentrations were below the normal level (Ecke and Matkin, 1976). Since there is not an elemental analysis key for bracts, the bract analysis results in this experiment were compared to the standardized key for foliar elemental analysis (Ecke and Matkin, 1976). The bract analysis results showed most of the K and Zn concentrations were in the normal range, most of the N and Mg concentrations were below the normal range, Ca and Fe concentrations were below the critical level, and P concentrations exceeded the "toxic" level (Ecke and Matkin, 1976).

On all the sampling dates, paclobutrazol significantly decreased the cumulative number of necrotic bracts (Table

3). The cumulative number of necrotic bracts increased as plant age increased. The severity of necrosis observed was very minor, therefore the crop still possessed marketable quality. In addition, the magnitude of difference in necrotic bracts between paclobutrazol-treated and untreated plants increased as plant age increased.

The incidence of bract necrosis can be attributed to possible high soluble salt salt concentrations, water stress, or Ca suppression (Marshner, 1986; Nell and Barrett, 1986; Woltz and Harbaugh, 1986).

Although shoot length and dry weight of plants receiving 708 mg/pot CLF showed reduction in growth, the medium soluble salt concentrations for 708 mg/pot CLF were in a normal range for established plant growth (Donnini, 1986; Miller et al., 1981; Nelson, 1981).

The bract is a low-transpiring organ, with nutrients supplied predominantly via the phloem. However, most Ca transport is via the xylem. Therefore, if transpiration rate is restricted due to water stress or other environmental factors, then bracts could develop marginal necrosis. All the watering in this experiment was based on grower's judgement, and at no time were plants at the wilting point. A total of 34 waterings (473 ml/pot/watering) was recorded over the 16-week period (average a watering about every 3 days). This indicates water stress was not the major factor that induced bract necrosis.

Leaf Ca concentrations were in the normal range, while bract Ca concentration was more than 50% less than the leaf Ca concentration. In addition, the low Ca concentration in the bracts coincided with the relatively high concentrations of N and K in the bracts. Since N and K were reported to have an antagonistic effect on Ca uptake, high concentrations of N and K application may have induced Ca shortages. More research should be conducted to determine the role of soluble Ca in this problem.

The results of this research showed that plants which received 472 or 708 mg 20N-4.4P-16.6K/pot constant liquid fertilization did not benefit from the 3.75 g 12N-5.3P-12.5K/pot controlled-release fertilizer topdress. Plants that received 236, 472, or 708 mg/pot constant liquid fertilization were of marketable quality, although leaves of plants fertilized with 236 mg/pot CLF were slightly lighter green than plants that received 708 mg/pot CLF. Plants receiving 472 mg/pot CLF generally had similar shoot length and leaf dry weights to plants that received 708 mg/pot. In addition, plants that received 708 mg/pot CLF normally had smaller bracts than plants that were fertilized with 472 mg/pot CLF. This indicates 472 mg/pot CLF was the optimum rate for poinsettia growth in this experiment.

Paclobutrazol foliar spray was effective in suppressing shoot internode elongation and bract necrosis. The reduction of bract necrosis may have practical implications.

Since the high fertilizer rate (708 mg/pot CLF)

suppressed plant growth, increasing the plant compactness, then less growth retardant may be required on plants that receive high or rates of fertilizer.

Table 1. Influence of constant liquid fertilization and controlled-release fertilizer topdress on shoot length.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Shoot length (cm) Weeks after pinching 2	4[z]	6	8	10	12	14
236	0	3.8	8.0	10.5	12.7	15.0	16.3	16.9
	3.75	4.8	9.0	11.9	14.5	17.0	18.3	18.7
472	0	4.3	8.9	12.0	14.9	17.2	18.3	18.9
	3.75	5.0	9.4	12.6	15.5	17.9	19.3	19.8
708	0	4.9	9.2	12.4	15.0	17.3	18.6	19.3
	3.75	4.7	8.4	11.4	14.1	15.6	17.9	18.5
CLF linear x CRF[y]		***	***	***	***	**	**	**
CLF quadratic x CRF		NS	NS	NS	NS	NS	NS	NS
$LSD_{0.05}$ CRF within CLF		0.4	0.6	0.8	0.9	1.1	1.1	1.0

[z] Paclobutrazol foliar-sprayed (5o ul/liter) was applied four weeks after pinching (16 October).
[y] Constant liquid fertilization (CLF), and controlled-release fertilizater (CRF).
,*,NS Significantly different at 1% (**), 0.1% (***), or not significant (NS).

Table 2. Influence of constant liquid fertilization and paclobutrazol on shoot length.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Paclobutrazol (ul/liter)	Shoot length (cm) Weeks after pinching 2	4[z]	6	8	10	12	14
236	0	4.4	8.7	12.0	15.0	17.1	18.5	19.0
	50	4.2	8.3	10.4	12.2	14.9	16.1	16.6
472	0	4.8	9.5	13.8	17.3	19.5	20.9	21.4
	50	4.4	8.7	10.9	13.1	15.6	16.6	17.3
708	0	4.8	8.7	12.6	15.8	17.9	19.3	19.9
	50	4.8	8.9	11.1	13.3	15.9	17.2	17.8
CLF linear x GR[y]		NS	NS	NS	NS	NS	NS	NS
CLF quadratic x GR		NS	NS	**	**	**	**	**
$LSD_{0.05}$ GR within CLF		0.4	0.6	0.8	0.9	1.1	1.1	1.0

[z] Paclobutrazol foliar-sprayed (50 ul/liter) was applied four weeks after pinching (16 October).
[y] Constant liquid fertilization (CLF), and paclobutrazol (GR).
*, NS Significantly different at 1% (**) or not significant (NS).

Table 3. Influence of paclobutrazol on the cumulative number of necrotic bracts and plant height.

Paclobutrazol (ul/liter)	Cumulative number of necrotic bracts[z] Weeks after pinching 11	12	13	Plant height[y] (cm)
0	3.2	7.4	14.7	25.6
50	0.4	0.8	4.0	24.6
	***	***	***	*

[z] None of the bract necrosis was severe. It was characterized as slight tip "burn" or slight marginal necrosis.
[y] Height measurements were made 16 weeks after potting (14 weeks after pinching), 26 December.
*,*** Significantly different at 5% (*), and 0.1% (***).

Table 4. Influence of constant liquid fertilization and controlled-release fertilizer topdress on bract diameter[z].

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Bract diameter (cm) Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
0	40.9	41.1	39.1
3.75	42.6	41.7	38.5
CLF linear x CRF[y]		*	
CLF quadratic x CRF		NS	
LSD $_{0.05}$ CRF within CLF		1.4	

[z] Bract diameter measurements were made 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF) and controlled-release fertilizer (CRF).
*,NS Significantly different at 5% (*), or not significant (NS).

Table 5. Influence of constant liquid fertilization and paclobutrazol on bract diameter[z].

Paclobutrazol (ul/liter)	Bract diameter (cm) Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
0	43.3	44.1	40.8
50	40.2	38.7	36.8
CLF linear x GR[y]		NS	
CLF quadratic x GR		*	
LSD $_{0.05}$ GR within CLF		1.4	

[z]Bract diameter measurements were made 16 weeks after potting, (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF) and paclobutrazol (GR).
*,NS Significantly different at 5% (*) or not significant (NS).

Table 6. Influence of constant liquid fertilization, controlled-release fertilizer topdress, and paclobutrazol on leaf, bract, cythaium, stem, and total dry weight[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Paclobutrazol (ul/liter)	Dry weight (g) Leaf	Bract	Cyathium	Stem	Total
236	0	0	8.9	16.4	2.0	6.7	33.9
	0	50	8.1	13.3	1.9	5.5	28.7
	3.75	0	9.9	16.6	2.2	6.9	35.5
	3.75	50	10.6	16.5	2.8	7.2	37.1
472	0	0	10.7	16.4	2.0	6.7	35.8
	0	50	9.6	13.9	2.1	5.7	31.3
	3.75	0	11.7	18.3	2.5	7.8	40.4
	3.75	50	11.2	13.4	2.4	6.4	33.4
708	0	0	10.4	15.6	2.3	6.9	35.2
	0	50	10.6	13.6	2.3	6.3	32.8
	3.75	0	10.5	16.2	2.4	6.8	36.0
	3.75	50	9.5	13.2	2.0	5.7	30.4
CLF linear x CRF x GR[y]			*	*	**	*	*
CLF quadratic x CRF x GR			NS	*	NS	NS	NS
$LSD_{0.05}$ CRF and GR within CLF			1.1	1.9	0.4	0.8	3.7

[z] All dry weight measurements were made 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF), controlled-release fertilizer (CRF), and paclobutrazol (GR).
*,**,NS Significantly different at 5% (*), 1% (**), or not significant (NS).

Table 7. Effect of controlled-release fertilizer topdress on medium pH.

Controlled-release fertilizer 12N-5.3P-12.5K (mg/pot)	Medium pH Weeks after potting 4	8	12
0	6.88	6.13	6.19
3.75	6.39	6.16	6.11
	***	NS	**

,*,NS Significantly different at 1% (**), 0.1% (***), or not significant (NS).

Table 8. Effect of paclobutrazol on medium pH.

Paclobutrazol (ul/liter)	Medium pH Weeks after potting 4[z]	8	12
0	6.70	6.11	6.11
50	6.56	6.19	6.20
	*	**	***

[z] Paclobutrazol foliar-sprayed four weeks after pinching (16 October).

*,**,*** Significantly different at 5% (*), 1% (**), or 0.1% (***).

Table 9. Influence of constant liquid fertilization on medium pH and soluble salt concentration.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Medium pH Weeks after potting			Medium soluble salt concentration (mmhos/cm)[z] Weeks after potting		
	4	8	12	4	8	12
236	6.92	6.25	6.34	0.33	0.40	0.57
472	6.55	6.12	6.11	0.65	0.81	1.00
708	6.43	6.07	6.00	0.95	0.97	1.36
Linear	**	*	**	***	***	***
Quadratic	NS	NS	NS	NS	NS	NS

[z] 1:2 dilution v/v growing medium/dilution water.
*,**,***,NS Significantly different at 5% (*), 1% (**), 0.1% (***), or not significant (NS).

Table 10. Influence of controlled-release fertilizer topdress and paclobutrazol on medium soluble salt concentrations[z].

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Paclobutrazol (ul/liter)	Medium soluble salt concentrations (mmhos/cm) Weeks after potting 4[y]	8	12
0	0	0.55	0.79	0.99
0	50		0.65	1.12
3.75	0	0.73	0.70	0.97
3.75	50		0.77	0.83
$LSD_{0.05}$ CRF and GR within CLF		0.08	0.11	0.18

[z] 1:2 dilution v/v growing medium/distilled water.
[y] Paclobutrazol foliar-sprayed (50 ul/liter) was applied four weeks after pinching (16 October).

Table 11. Influence of paclobutrazol on leaf N and K concentrations[z].

Paclobutrazol (ul/liter)	N (%)	K (%)
0	4.84	2.21
50	4.99	1.97
	*	***

[z] Leaf elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
*,*** Significantly different at 5% (*), or 0.1% (***).

Table 12. Influence of constant liquid fertilization on leaf N and Mg concentrations[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	N (%)	Mg (%)
236	4.20	0.76
472	5.00	0.73
708	5.55	0.63
Linear	***	***
Quadratic	NS	*

[z] Leaf elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
*,***,NS Significantly different at 5% (*), 0.1% (***), or not signifiacnt (NS).

Table 13. Influence of constant liquid fertilization and paclobutrazol on leaf P and Fe concentrations[z].

Paclobutrazol (ul/liter)	Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
		P (%)	
0	0.55	0.87	0.99
50	0.56	0.82	1.10
CLF linear x GR[y]		*	
CLF quadratic x GR		*	
LSD $_{0.05}$ GR within CLF		0.06	
		Fe (ug/g)	
0	79	103	94
50	80	91	108
CLF linear x GR		NS	
CLF quadratic x GR		*	
LSD $_{0.05}$ GR within CLF		13	

[z] Leaf elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF), and paclobutrazol (GR).
*,NS Significantly different at 5% (*), or not significant (NS).

Table 14. Influence of constant liquid fertilization, controlled-release fertilizer topdress, and paclobutrazol on leaf Ca, Zn, and Mn concentrations[z].

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Paclobutrazol (ul/liter)	Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
			Ca (%)	
0	0	1.46	1.29	1.02
0	50	1.48	1.34	1.27
3.75	0	1.34	1.40	1.14
3.75	50	1.42	1.18	1.09
CLF linear x CRF x GR[y]			**	
CLF quadratic x CRF x GR			NS	
$LSD_{0.05}$ CRF and GR within CLF			0.13	
			Zn (ug/g)	
0	0	28	29	31
0	50	31	29	23
3.75	0	26	34	24
3.75	50	26	26	23
CLF linear x CRF x GR			*	
CLF quadratic x CRF x GR			*	
$LSD_{0.05}$ CRF and GR within CLF			5	
			Mn (ug/g)	
0	0	70	81	94
0	50	78	100	110
3.75	0	83	102	108
3.75	50	91	95	115
CLF linear x CRF x GR			NS	
CLF quadratic x CRF x GR			*	
$LSD_{0.05}$ CRF and GR within CLF			10	

[z] Leaf elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF), controlled-release fertilizer (CRF), and paclobutrazol (GR).
*,**,NS Significantly different at 5% (*), 1% (**), or not significant (NS).

Table 15. Influence of constant liquid fertilization and paclobutrazol on bract N, Ca, and Mg conentrations[z].

Paclobutrazol (ul/liter)	Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
		N (%)	
0	2.78	3.41	3.92
50	2.92	3.69	4.27
CLF linear x GR[y]		*	
CLF quadratic x GR		NS	
LSD $_{0.05}$ GR within CLF		0.13	
		Ca (%)	
0	0.46	0.43	0.25
50	0.49	0.37	0.30
CLF linear x GR		NS	
CLF quadratic x GR		**	
LSD $_{0.05}$ GR within CLF		0.05	
		Mg (%)	
0	0.32	0.32	0.27
50	0.37	0.29	0.26
CLF linear x GR		*	
CLF quadratic x GR		*	
LSD $_{0.05}$ GR within CLF		0.03	

[z] Bract elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF), and paclobutrazol (GR).
*,**,NS Significantly different at 5% (*), 1% (**), or not significant (NS).

Table 16. Influence of constant liquid fertilization and controlled-release fertilizer topdress on bract N concentrations[z].

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
0	2.81	3.53	4.20
3.75	2.89	3.57	4.00
CLF linear x CRF[y]		**	
CLF quadratic x CRF		NS	
$LSD_{0.05}$ CRF within CLF		0.13	

[z] Bract elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
[y] Constant liquid fertilization (CLF), and controlled-release fertilization (CRF).
** Significantly different at 1% (**).

Table 17. Influence of controlled-release fertilizer topdress on bract Ca and Mg concentrations[z].

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Ca (%)	Mg (%)
0	0.40	0.32
3.75	0.37	0.30
	*	*

[z] Bract elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
* Significantli different at 5% (*).

Table 18. Influence of constant liquid fertilization, controlled-release fertilizer topdress, and paclobutrazol on bract P, K, Zn, and Fe concentrations.

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Paclobutrazol (ul/liter)	Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application) 236	472	708
			P (%)	
0	0	0.56	0.73	0.76
0	50	0.64	0.71	0.76
3.75	0	0.62	0.71	0.73
3.75	50	0.59	0.69	0.72
CLF linear x CRF x GR			*	
CLF quadratic x CRF x GR			*	
$LSD_{0.05}$ CRF and GR within CLF			0.04	
			K (%)	
0	0	3.05	3.63	3.48
0	50	3.10	3.42	3.76
3.75	0	3.06	3.41	3.64
3.75	50	2.93	3.32	3.60
CLF linear x CRF x GR			NS	
CLF quadratic x CRF x GR			**	
$LSD_{0.05}$ CRF and GR within CLF			0.16	
			Zn (ug/g)	
0	0	27	27	28
0	50	28	26	25
3.75	0	26	28	23
3.75	50	23	24	23
CLF linear x CRF x GR			*	
CLF quadratic x CRF x GR			NS	
$LSD_{0.05}$ CRF and GR within CLF			3	
			Fe (ug/g)	
0	0	26	28	30
0	50	36	30	34
3.75	0	26	29	25
3.75	50	27	26	35
CLF linear x CRF x GR			**	
CLF quadratic x CRF x GR			NS	
$LSD_{0.05}$ CRF and GR within CLF			5	

*,**,NS Significantly different at 5% (*), 1% (**), or not significant (NS).

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CHAPTER III

COMPARISON OF TOPDRESSED CONTROLLED-RELEASE FERTILIZER AND CONSTANT LIQUID FERTILIZATION ON PERFORMANCE OF 'GUTBIER V-14 GLORY' POINSETTIA

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Abstract. Performance of single-pinched poinsettias (*Euphorbia pulcherrima* Willd, 'Gutbier V-14 Glory') topdressed with 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (CRF), or 236, 472, or 708 mg 20N-4.4P-16.6K/pot constant liquid fertilization (CLF) were evaluated in a randomized complete block design. The plants receiving CRF frequently had smaller bracts, shorter shoots, less dry weights, lower cumulative number of necrotic bracts, and lower soluble salt concentrations than plants receiving constant liquid fertilization. Leaf N and P concentrations, and bract N, P, K concentrations of plants fertilized with CRF were lower, while bract Ca concentrations of plants receiving CRF were greater.

The poinsettia, Euphorbia pulcherrima Willd, was introduced into the United States in 1825 from Mexico (Shanks, 1980). In 1986, it was the leading pot plant in the U.S. (Tayama et al., 1988). Poinsettia marketability is influenced by the quality of the plant produced. A good quality poinsettia should have no necrotic bracts or chlorotic leaves (Nell and Barrett, 1986). To achieve this quality, growers must carefully monitor the cultural practices throughout the growing season.

Fertilization programs include constant liquid fertilization (CLF), interval liquid fertilization, use of controlled-release fertilizers (CRF), or a combination of these (Ecke and Matkin, 1976; Nelson, 1981). In recent years, many growers have chosen the CLF program over the traditional weekly interval method. The former program uses a lower concentration of fertilizer at each application, thus reducing both the risk of fertilizer excess and the chances of falling into a deficient nutrient range (Knauss and Shadan, 1983; Nelson, 1981).

The use of controlled-release fertilizer is becoming popular because it provides greater labor effeciency, since only a one-time application is required (Kovacic and Holcomb, 1981; Nelson, 1981). In addition, several studies have reported that controlled-release fertilizers can increase the efficiency of nutrient recovery by the plant and reduce the possibility of root damage by excessive soluble salts (Barron, 1977; Penningsfeld, 1975). However,

once controlled-release fertilizers are applied, growers would be subjected to a set of conditions over which they have less control (Ecke and Matkin, 1976), especially when the fertilizer is incorporated in the growing medium. Therefore, growers are frequently advised to choose liquid fertilization rather than a controlled-release fertilizer program.

Until recently, controlled-release fertilizers contained only macronutrients. Sierra Chemical Co. has introduced a series of controlled-release fertilizers containing micronutrients as well as the macronutrients. One of these is the "Poinsettia" formulation 12N-5.3P-12.5K plus minors with a 3 month release rate at an average soil temperature of 21^{0}C. This formulation is designed to deliver more Ca and Mg at the beginning of plant growth, then increase K and Mo toward the end of the production cycle.

According to Ecke (1986), poinsettias are tolerant of high fertility, and sensitive to low levels of N and some micronutrients. A CLF of 250 mg N/liter or higher is recommended for poinsettia production in soilless "peat-lite" mixes (Ecke and Matkin, 1976). However, a recent study found that CLF of NO_3-N at 84 - 168 mg/liter was sufficient to produce optimal vegetative growth of poinsettia in quartz sand (Gaffney et al., 1982). Nitrogen can have an antagonistic effect on calcium. Growers have a tendency to apply suboptimal levels of elements other than N

(Ecke and Matkin, 1976), thus increasing the possibility that high N applications can induce shortages of Ca or other elements. 'Gutbier V-14 Glory' is a widely grown cultivar, having large bracts, good self-branching ability, and good postharvest quality. It was introduced to commercial producers in the late 1970s (Wilfret, 1981). However, 'V-14' may exhibit necrotic or deformed bracts and sometimes marginal leaf chlorosis or necrosis, reducing the marketability of the crop. Bract necrosis, instead of merely bract deformities seem to be more prominent in the Southern U. S. (Wilfret, 1981). Research to characterize the conditions which promote development of necrotic bracts has been limited. Nell and Barrett (1985) found that increased fertilizer (NPK) and watering practices, particularly during bract coloration, elevated the incidence of bract necrosis. They suggested the necrosis may be associated with a toxicity of elements transported through pitted vein endings at the tip of bracts.

Donnini (1986) observed that bract necrosis occurred on plants receiving 500 and 700 mg N/liter (from 20N-4.4P-16.6K constant liquid fertilization) on their last sampling date (12 weeks after planting), but plants that were receiving 100 and 300 mg N/liter had no necrotic bracts 12 weeks after potting. No data were collected at later dates. Others reported that necrosis was lowest when 100 mg N/liter was terminated at bract coloration, whereas continuation of this fertilizer concentration until anthesis resulted in more

bract necrosis (Nell and Barrett, 1986). Bract necrosis in plants grown in a soilless mix that were receiving 100% NH_4-N was greater than in those receiving half NO_3-N and half NH_4-N (Nell and Barrett, 1986). Necrosis was only observed on transitional bracts, which are the red leaf-shaped organs attached to the stems in the same alternate phyllotaxy as leaves. The transitional bracts were reported to have a lower stomatal density compared to leaves, by about 20 fold (Nell and Barrett, 1986). This suggests the transitional bract is a low-transpiring organ, with nutrients supplied predominantly via the phloem. However, most Ca transport is via the xylem. It is well established that xylem flow is dependent on the rate of transpiration. When transpiration is low, xylem flow would be dependent on the root pressure. This suggests that low-transpiring organs could have an influx of water and Ca from the xylem as long as the root pressure exists. However, a low water supply in the root medium and high osmotic potential of the soil solution (for example the presence of soil salinity) would decrease both root pressure and the xylem influx into the low-transpiring organs. Calcium transport in the phloem is limited due to low Ca concentrations in the phloem sap, and precipitation of calcium oxalate crystals along the conducting vessels (Liegel, 1970). Thus other organs in the plant may have adequate Ca levels, while restricted Ca transport to transitional bracts can induce Ca shortages. Calcium concentrations can fall below the critical level required

for the maintainance of membrane intergrity if the low-transpiring organs have high growth rates (Marshner, 1986), leading to the typical calcium-deficiency-related disorders, such as tipburn in lettuce and blossom end rot in tomato.

Woltz and Harbaugh (1986) investigated the possibility that bract necrosis was a calcium-deficiency-related disorder. Their investigation supported the hypothesis that Ca is the major factor in marginal bract necrosis of 'Gutbier V-14 Glory' poinsettia. Calcium chloride sprays prevented the necrosis, and the Ca concentration in the sprayed tissue was more than three times that of the necrotic bract marginal tissue.

The influence of a recently released Sierra Poinsettia Mix 12N-5.3P-12.5K ("12-12-15 Plus Minors, Sierra Chemical Co., Milpitas, CA) on poinsettia performance including incidence of bract necrosis has not been widely investigated. The purpose of this study, therefore, was to compare the performance of 'Gutbier V-14 Glory' poinsettias fertilized by the recommended topdress rate of 12N-5.3P-12.5K controlled-release fertilizer to performance of plants that received varying rates of 20N-4.4P-16.6K constant liquid fertilization.

Materials and Method

Rooted terminal cuttings of 'Gutbier V-14 Glory' poinsettia were received 27 August, 1986, courtesy of

Guthrie Greenhouses, Inc., Guthrie, OK. A total of 72 cuttings were transplanted one per 15 cm x 11.5 cm pot on 5 September, 1986. Cuttings were planted in a 3:1:1 (v/v/v) soilless medium of sphagnum peat, vermiculite, and perlite respectively, amended on a per m^3 basis with 5.94 kg finely ground dolomitic limestone, 1.49 kg single superphosphate (0-8.8-0), 0.89 kg potassium nitrate, 74.25 g FTE 555 (a micronutrient fertilizer, Peters Fertilizer Products, Fogelville, Pa), and 0.89 kg granular Aqua-Gro wetting surfactant. The next day and monthly thereafter, each plant was drenched with 3.4 mg/ml of 5-ethoxy-3-trichloromethyl-1,2,4-thiadiazole (terrazole) and methyl 1-(butylcarbamoyl)-2-benzimidazolecarbamate (benomyl) fungicide solution. Two monthly soil applications of 0.9 g of 2-methyl-2-(methylthio) propionaldehyde O-(methylcarbamoyl) oxime (aldicarb) granules per plant was applied 19 September and 19 October as a pest control program. Plants were pinched to 7 nodes on 19 September.

Four experimental treatments were established 8 September including three liquid fertilizer rates of 236, 472, and 708 mg of 20N-4.4P-16.6K (Peters "20-10-20 Peat Lite Special", W. R. Grace Co., Cambridge, MA) per 15 cm pot (473 ml/pot at each application) and one controlled-release fertilizer topdressed rate (the recommended rate) of 7.5 g 12N-5.3P-12.5K ("Sierra Poinsettia Mix 12-12-15 Plus Minors", Sierra Chemical Co., Milpitas, CA) per 15 cm pot. Treatments were replicated three times with three pots per

replication in a randomized complete block design, with pots spaced 38 cm x 38 cm on raised benches in a fiberglass greenhouse. Throughout the experiment, plants that were topdressed with 7.5 g of 12N-5.3P-12.5K per pot were irrigated with plain water (473 ml/pot) at each watering. At no time during the experiment was plain water applied to plants in the liquid fertilization treatments. Irrigation timing was determined using grower's judgement and all watering dates were recorded. Temperatures were maintained as closely as possible within ranges of 16 - 18^{0}C (night) and 19 - 24^{0}C (day).

After potting, growing medium samples for pH and soluble salt determination (1:2 dilution method) (Donnini, 1986; Miller et al., 1981; Nelson, 1981) were taken at 4 week intervals (3 and 31 October and 28 November) from three plants of each treatment in one replicate, for three individual samples per treatment per date. Plants from which medium samples were removed were not sampled again.

At each sampling date, approximately 29.6 ml of growing medium was removed from the root zone area per pot, placed into clean plastic bags, and allowed to air dry. Then 14.8 ml of the dried sample was diluted with 29.6 ml of deionized water. The mixture was stirred three times within a twenty minute period, allowed to stand for ten minutes, then electrical conductivity and pH of the solution were measured. The electrical conductivity was measured using an EL Hamma Digital Field Conductometer model number TH-250

with a conductivity cell number EHT-24c (Rosh Pina, Israel). The solution pH was determined using a Cole-Parmer Digi-Sense pH meter (Chicago, Illinois).

After pinching (19 September), 7 biweekly measurements of the top two shoots' length on all plants were made. The shoot length was determined by measuring the distance between the point of attachment of the shoot to the stem to the furthest point along the shoot.

Thirteen weeks after potting (5 December), three weekly measurements of the cumulative number of bracts per plant with any necrosis, **even very slight tip necrosis**, was determined. Sixteen weeks after potting (14 weeks after pinching), 26 December, plants in all treatments were harvested and evaluated for plant height, bract diameter of the top two shoots, elemental concentrations of bracts and leaves, and above ground dry weight. Total plant height was measured from the pot rim to the center of the tallest cyathium of each pot. Bract diameter was determined by averaging 2 perpendicular measurements of each bract displayed per plant. Plant dry weight was determined by harvesting plants at growing medium level, and dividing the plants into leaves, bracts, cythia, and stems. Plant parts were separately placed in clean paper bags and dried at 75^{0}C. At the time of harvest, ten to twelve recently matured leaves and bracts were collected from each plant. The samples were washed in tap water and a liquinox solution (P-free detergent), then rinsed twice in deionized water.

Total washing time did not exceed one minute. Bracts and leaves were placed separately into clean paper bags, dried at 75^{0}C, then their respective dry weights were measured and added to the dry weight of their corresponding counterparts so that the total dry weight for each individual plant could be obtained. The bract and leaf samples were ground to pass through a 20 mesh screen in a Wiley Mill and stored in air-tight jars until analysis. Prior to analysis, bract and leaf samples were re-dried at 80^{0}C for 24 hours. Nitrogen was analyzed by macro-Kjeldahl, P colorimetrically, and K, Ca, Mg, Zn, Fe, and Mn by a Perkin-Elmer model 303 atomic absorption spectrophotometer.

Results and Discussion

Plant height 16 weeks after potting, regardless of fertilizer treatment, was not significantly different from the control (controlled-release fertilizer) (Table 1). However, shoot length was affected by fertilizer treatment (Table 2). Shoot lengths of plants receiving CLF were not different from the control plants on 2 and 4 weeks after pinching, except plants that received 472 mg/pot CLF on week 4 had longer shoots than the control plants. Plants receiving 472 and 708 mg/pot CLF had longer shoots than in the control plants from 6 to 14 weeks after pinching, while the 236 mg/pot CLF showed no significant difference.

Bract size of plants receiving either 236 or 472 mg/pot

CLF was larger than for control plants, while 708 mg/pot CLF showed no significant difference (Table 1). High fertilizer rates (Nell and Barrett, 1986) have been reported to reduce bract size. These findings agree with our results.

Dry weights of leaves and bracts at all CLF rates were greater than for plants treated with CRF (Table 3). Stem and cyathium dry weights of plants at all CLF rates were not different from the control plants. Total plant dry weight generally followed trends of leaf and bract dry weights.

All plants which received CLF had greater leaf N and P concentrations than control plants (Table 4). Plants that received CLF frequently had greater leaf Mg concentrations and lower leaf Zn and Mn concentrations than the control plants (Table 4, 6). Leaf K concentrations and most leaf Ca and Fe concentrations of plants receiving CLF were not different from the control plants (Table 4, 6).

Constant liquid fertilization increased bract N, P, and K concentrations, and decreased bract Ca concentration compared to CRF (Table 5). Bract Mg, Zn, and Fe concentrations were usually not affected (Table 5, 6). All rates of CLF were generally more effective in supplying N, P, and K than the manufacturer's recommended topdress rate of CRF. Leaf and bract Ca concentrations were frequently lower when plants were fertilized with CLF than CRF, which may be due to the competitive absorption between K and Ca (Cox and Seeley, 1983).

All the leaf elemental concentrations, of plants

receiving controlled-release fertilizer, were in the normal range, with the exception of N which was below the described critical level (Ecke and Matkin, 1976). This low N concentration was reflected in the dry weight and the leaf N concentration of plants throughout the experiment. Plants had low dry weight and exhibited slight leaf chlorosis. Bract elemental analysis of plants receiving the 7.5 g/pot CRF topdress showed bract P, K, Mg, and Zn concentrations to be in the described normal range, N and Fe concentrations below the critical level, and Ca concentrations below the normal range for poinsettia (Ecke and Matkin, 1976).

The cumulative number of necrotic bracts for plants in all fertilizer treatments increased as plant age increased (Table 7). Plants receiving constant liquid fertilization had a significantly higher number of necrotic bracts than control plants on all sampling dates.

Nell and Barrett (1986) reported that necrosis was lowest when the 100 mg N/liter level of fertilizer was terminated at bract coloration, whereas continuation of this fertilizer until anthesis resulted in higher necrosis level similar to 200 and 400 mg N/liter fertilizer treatments.

They also reported that the transitional bracts have a lower stomatal density compared to leaves, by about 20 fold (1986). This suggests that the bract is a low-transpiring organ, with nutrients supplied predominently via the phloem. However, most Ca transport is via the xylem. Therefore, if

transpiration rate is restricted due to water stress or other environmental factors, then bracts could develop marginal necrosis. All the watering in this experiment was based on grower's judgement, and at no time were plants at the wilting point. A total of 34 waterings (473 ml/pot) was recorded over a 16-week period, averaging about a watering every 3 days. This indicates that water stress was not a factor that induced the bract necrosis.

Leaf Ca concentrations were in the normal range, while bract Ca concentration was more than 50% less than the leaf Ca concentration. In addition, the low Ca concentration in the bracts of plants receiving CLF coincided with the relatively high concentrations of N and K in bract, while plants receiving CRF topdress did not show such a trend. Since N and K were reported to have an antagonistic effect on Ca uptake (Cox and Seeley, 1983), high concentrations of N and K application may have induced Ca shortages in plants receiving CLF. This also explains the lower magnitude of necrosis in plants receiving CRF compared to the plants fertilized with CLF. Additional research is needed to determine the relationship of soluble Ca to bract necrosis.

There were few differences between fertilizer sources on medium pH on all sampling dates (Table 8). Initially, pH was generally above the optimum range of 5.7 to 6.5, while later sampling dates showed medium pH to be in the optimum range (Tayama et al., 1988). This suggests that plants receiving either CLF or CRF had optimum nutrient

availability potential after the initial sampling dates as long as there were no other limiting factors.

Medium soluble salt concentrations of plants receiving the two higher rates of constant liquid fertilization were higher than for plants fertilized with controlled-release fertilizer on all sampling dates, while 236 mg/pot constant liquid fertilization showed no significant difference (Table 8). The soluble salt concentrations, regardless of fertilizer treatment, increased as plant age increased, although the magnitude of increase was greater in constant liquid-fertilized plants. The medium soluble salt concentrations of plants receiving 472 or 708 mg/pot of constant liquid fertilization were in the satisfactory range for established plants on all sampling dates (Donnini, 1986; Miller et al., 1981; Nelson, 1981), whereas the salt concentrations for plants receiving 236 mg/pot CLF or 7.5 g/pot CRF were in the low fertility range between 4 to 8 weeks after potting. On the last sampling date (week 12), all plants except those fertilized with CRF, had medium soluble salt concentrations in the normal range (Miller et al., 1981; Nelson, 1981).

Controlled-release fertilizer releases nutrients gradually from the capsule in the presence of moisture. In our experiment, the CRF was topdressed on the medium surface and the plants were irrigated by overhead watering, thus there was intermittent drying of the medium surface between waterings (Lunt and Oertli, 1962; Sharma, 1979; Simpson et

al., 1975). While the medium is moist, the nutrients of CRF are released at a rate sufficient to match the requirement of the crop, without excessive accumulation in the medium (Barron, 1977; Penningsfeld, 1975; Whitcomb, 1984). This indicates that there should have been minimal loss of nutrients by leaching. The smaller magnitude of increase in soluble salt concentrations of controlled-release fertilized plants as compared to CLF fertilized plants, and the low salt concentrations for plants receiving CRF suggest the elemental absorption of the plants was at maximum capacity, fertilizer release rates decreased with time, or both.

According to the manufacturer, the 7.5 g/pot controlled-release fertilizer should be equivalent to 250 mg N/liter constant liquid fertilization. However, the results showed plants received 236, 472, or 708 mg/pot CLF tended to have greater bract diameters, shoot lengths, and total dry weights than plants fertilized with the 7.5 g 12N-5.3P-12.5K/pot CRF. At termination (16 weeks after potting), plants that received 7.5 g/pot CRF had 741 mg N/plant which was less than plants fertilized with CLF by 50% or more. This suggests that the low magnitude of soluble salt concentrations was primarily due to a decrease in elemental release rate with time rather than increased N absorption. The decrease in elemental release rate could be due to depletion of the fertilizer. This CRF formulation would probably be more effective if it was designed to have a higher N content.

Plants receiving 7.5 g/pot CRF always had a lower cumulative number of necrotic bracts than plants receiving CLF treatments. This indicates high N concentrations can antagonize Ca uptake and the lower number of necrotic bracts could also be related to the higher Ca concentration that was released by this formulation in the early growth period.

Additional research including periodic sampling of the fertilizer capsules and foliar analysis would be needed to determine the actual elemental concentrations in the fertilizer at different stages of plant development.

Table 1. Influence of constant liquid fertilization and controlled-release fertilizer topdress on plant height and bract diameter[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/ application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Plant height (cm)	Bract diameter (cm)
0	7.5	25.0	38.7
236	0	24.4	42.8***
472	0	25.6	43.5***
708	0	25.2	40.6

[z] Height and bract diameter measuremnets were made 16 weeks after potting (14 weeks after pinching), December 26.
*** Significantly different at 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 2. Influence of constant liquid fertilization and controlled-release fertilizer topdress on shoot length.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/ application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Shoot length (cm) Weeks after pinching 2	4	6	8	10	12	14
0	7.5	4.2	8.3	11.2	13.3	15.6	17.2	17.8
236	0	3.9	8.3	11.4	14.2	16.3	17.6	18.4
472	0	4.3	9.2*	13.3***	16.9***	18.9***	20.2***	20.6***
708	0	4.7	9.0	12.9**	16.1***	18.0***	19.6**	20.0**

*,**,*** Significantly different at 5% (*), 1% (**), or 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 3. Influence of constant liquid fertilization and controlled-released fertilizer topdress on leaf, bract, cyathium, stem, and total dry weight[z].

Constant liquid fertilization (mg/pot/application)	Controlled-release fertilizer (g/pot)	Dry weight (g)				
		Leaf	Bract	Cyathium	Stem	Total
0	7.5	7.0	11.7	2.2	7.4	28.3
236	0	8.9***	16.4***	2.0	6.7	33.9***
472	0	10.7***	16.4***	2.0	6.7	35.8***
708	0	10.4***	15.6***	2.3	6.9	35.2***

[z] All dry weights measurement were made 16 weeks after potting (14 weeks after pinching), December 26.
*** Significantly different at 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 4. Influence of constant liquid fertilization and controlled-release fertilizer topdress on leaf N, P, K, Ca, and Mg concentrations[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Dry weight (%) N	P	K	Ca	Mg
0	7.5	2.62	0.34	2.25	1.56	0.65
236	0	4.16***	0.50***	2.12	1.46	0.77***
472	0	5.01***	0.85***	2.23	1.29***	0.72*
708	0	5.46***	0.98***	2.14	1.02	0.61

[z] Leaf elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.

*,*** Significantly different at 5% (*) or 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 5. Influence of constant liquid fertilization and controlled-released fertilizer topdress on bract N, P, K, Ca, and Mg concentrations[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Dry weight (%) N	P	K	Ca	Mg
0	7.5	1.72	0.37	2.61	0.58	0.35
236	0	2.70***	0.56***	3.05***	0.50*	0.33
472	0	3.42***	0.73***	3.63***	0.45***	0.32
708	0	4.01***	0.76***	3.48***	0.26***	0.27*

[z] Bract elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.
*,*** Significantly different at 5% (*) or 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 6. Influence of constant liquid fertilization and controlled-release fertilizer topdress on minor element concentration in leaf and bract[z].

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Leaf Dry weight (ug/g) Zn	Fe	Mn	Bract Dry weight (ug/g) Zn	Fe
0	7.5	35	102	102	26	28
236	0	28**	75***	70***	27	26
472	0	29*	93	81***	27	28
708	0	31	96	94	28	30

[z] Leaf and bract elemental concentrations were measured 16 weeks after potting (14 weeks after pinching), 26 December.

*,**,*** Significantly different at 5% (*), 1% (**), or 0.1% (***) from 7.5 g 12N-5.3P-12.5K/pot controlled-released fertilizer (control treatment).

Table 7. Influence of constant liquid fertilization and controlled-release fertilizer topdress on the cumulative number of necrotic bracts.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Cumulative number of necrotic bracts[z] Weeks after pinching 11	12	13
0	7.5	0.2	2.0	2.1
236	0	2.7***	6.6***	11.9***
472	0	2.4***	6.1***	12.8***
708	0	2.3***	6.1***	14.2***

[z] None of the bract necrosis was severe. It was characterized as slight tip "burn" or slight marginal necrosis.
*** Significantly different at 0.1% (***) from the 7.5 g 12N-5.3P-12.5K/pot controlled-release fertilizer (control treatment).

Table 8. Influence of constant liquid fertilization and controlled-release fertilizer topdress on medium pH and medium soluble salt concentrations.

Constant liquid fertilization 20N-4.4P-16.6K (mg/pot/application)	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Medium pH Weeks after potting			Medium soluble salt concentrations (mmhos/cm)[z] Weeks after potting		
		4	8	12	4	8	12
0	7.5	6.89	6.03	6.34	0.33	0.40	0.53
236	0	7.12*	6.16	6.31	0.23	0.39	0.62
472	0	6.85	6.05	6.13*	0.57*	0.96***	1.03*
708	0	6.57**	6.00	5.97**	0.89***	1.01***	1.33**

[z] 1:2 dilution v/v growing medium/distilled water.
*,**,*** Sinificantly different at 5% (*), 1% (**), or 0.1% (***) from 7.5 g 12N-5.3P-12.5K controlled-release fertilizer (control plant).

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CHAPTER IV

THE EFFECT OF VARIOUS RATES OF INCORPORATED CONTROLLED-RELEASE FERTILIZER ON LEACHATE SOLUBLE SALT CONCENTRATIONS AND PERFORMANCE OF 'GUTBIER V-14 GLORY' POINSETTIA

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Abstract. Four rates of a controlled-release fertilizer (CRF), 12N-5.3P-12.5K plus minors, were evaluated on poinsettias (Euphorbia pulcherrima Willd, 'Gutbier V-14 Glory') grown as single-pinched plants. The four fertilizer levels tested were 4.8 g, 7.2 g, 9.6 g, or 12.0 g incorporated material per 15 cm x 11.5 cm pot. At each watering, plants were irrigated with 473 ml/pot tap water. The initial leachate pH and soluble salt concentrations were determined two weeks after potting, then later samplings were made 4 weeks after potting and monthly thereafter. In addition, 3 plants per replication (three replications) were harvested at monthly intervals after potting and evaluated for apical shoot length, total dry weight, and leaf

elemental concentrations. Results show shoot length, dry weight, leachate pH and soluble salt concentrations were linearly related to fertilizer rate on most sampling dates. The leaf N, P, Mg, Zn, Fe, and Mn concentrations showed positive linear correlation with fertilizer rates on most sampling dates, while K and Ca concentrations showed no significant differences. The recommended incorporation rate of 7.5 g/pot CRF was insufficient to produce plants of marketable quality. Plants receiving the incorporated rate of 12.0 g/pot CRF were better quality than plants receiving 4.8, 7.5, or 9.6 g/pot CRF. However, these plants were still considered to be of lower commercial grade, due mainly to foliage quality, rather than bract quality. Nitrogen availability appeared to be the most limiting factor when using this CRF. At the 8 and 12 weeks, tissue N concentrations were below the normal range of 4-6 % and all were below, at or near critical level of 3%.

Controlled-release fertilizers are becoming popular for floriculture crops because they provide greater labor efficiency, since only a one-time application is required (Kovacic and Holcomb, 1981; Nelson, 1981). In addition, several studies have reported that controlled-release fertilizers can increase the efficiency of nutrient recovery by the plant and reduce the possibility of root damage by excessive soluble salts (Barron, 1977; Penningsfeld, 1975). However, once controlled-release fertilizers are applied, growers are subjected to a set of conditions over which they have less control than when liquid fertilization is used (Ecke and Matkin, 1976).

Until recently, controlled-release fertilizers contained only macronutrients. Sierra Chemical Co. has introduced a series of controlled-release fertilizers containing micronutrients as well as the macronutrients. One of these is the "Poinsettia" formulation 12N-5.3P-12.5K

("12-12-15) plus minors with a 3 month release rate at an average soil temperature of 21^{0}C. This formulation's lifespan is not affected by water, but soil temperature.

One problem associated with collection and preparation of media samples for soluble salts testing where controlled-release fertilizer is incorporated in the medium is possible rupturing of the fertilizer particles, resulting in erroneous readings. A method to measure soluble salts that should be well suited for a medium containing controlled-release fertilizer is the pour-through method which involves pouring distilled water through the medium surface and collecting the extract (leachate) (Donnini, 1986; Wright, 1986; Yeager et el., 1983). This method does not require collecting medium samples, thus, if controlled-release fertilizer was incorporated, it would not be ruptured and root systems would not be disturbed. Moreover, since the pour-through method requires no equilibration time, extract collection is rapid. Full reliability in interpreting results using this method is still pending, and more research is needed (Donnini, 1986).

The objective of this experiment was to determine the effects of various rates of incorporated Sierra poinsettia fertilizer (12N-5.3P-12.5K plus minors) on leachate soluble salts concentrations and pH, foliar elemental concentrations, and performance of 'Gutbier V-14 Glory' poinsettias grown in a soilless growing medium (Metro Mix 360).

Materials and Methods

Rooted terminal cuttings of 'Gutbier V-14 Glory' poinsettia cuttings were received 27 August 1986, courtesy of Guthrie Greenhouses, Inc., Guthrie, OK. Cuttings were transplanted into 15 cm x 11.5 cm pots 12 September 1986, with one plant per pot. Plants were grown in Metro Mix 360 (W. R. Grace Co., Cambridge, MA) a commercial soilless medium containing sphagnum peat moss, processed pine bark ash, vermiculite, washed granite sand, a wetting agent, and starter nutrients. The exact ingredients and concentrations of the starter nutrients are not known. Four rates of a 3-month formulation controlled-release fertilizer (Sierra Poinsettia Mix 12N-5.3P-12.5K ("12-12-15") plus Minors by Sierra Chemical Co., Milpitas, CA), were incorporated in the medium. Each treatment contained three replications and nine pots per replicate in a completely randomized design. The four fertilizer levels tested were 3.58 kg, 5.37 kg, 7.16 kg, and 8.95 kg incorporated per cubic meter (4.8 g, 7.2 g, 9.6 g, or 12.0 g per 15 cm x 11.5 cm pot).

After potting, each plant was watered then drenched with 3.4 mg/ml of 5-ethoxy-3-trichoromethyl-1,2,4-thiadiazole (terrazole) and methyl 1-(buthylcarbamoyl)-2-benzimidazolecarbamate (benomyl) fungicide solution. Plants were given the same fungicide drench monthly thereafter. Two monthly soil applications of 0.90 g of 2-methyl-2-(methylthio) propionaldehyde o-(methylcarbamoyl) oxime

(aldicarb) granules per plant were applied 19 September and 19 October as a pest control program. Plants were pinched to 7 nodes 19 September, 1986.

Throughout the experiment, plants were irrigated with tap water, 473 ml/pot at each watering. Irrigation timing was determined using grower judgement and all watering dates were recorded. A total of 26 waterings were recorded (averaging about a watering every 3 days). Plants were spaced 38 cm x 38 cm on raised benches in a fiberglass covered greenhouse with temperatures maintained as closely as possible within ranges of 16 - 18^{0}C (night) and 19 - 24^{0}C (day).

Two weeks after potting (26 September), the leachate soluble salts concentrations were determined by using the pour-through method (Donnini, 1986; Wright, 1986; Yeager et al., 1983). Plants were irrigated with 473 ml/pot of tap water and the leachate was collected for use in soluble salts determinations. The inital 80 - 100 ml of the leachate was collected and the electrical conductivity and pH were measured immediately. The electrical conductivity of the tap water was also measured, and subtracted from the electrical conductivity of the leachate. Electrical conductivity was measured in millimhos/cm using TH-250 with a conductivity cell model number EHT-24c (Rosh Pina, Israsel). The pH was determined by using a Cole-Parmer Digi-Sense pH meter (Chicago, Illinois). Leachate soluble salts and pH were then determined monthly (10 October, 7

November, and 5 December).

Three plants per replication (3 replications) were harvested at one month intervals after potting and evaluated for apical shoot length, total dry weight, and leaf elemental concentrations. Plant dry weight was determined after plants were dried at 75^0C. During the first sampling date, four to five recently matured leaf samples were collected from each plant, and pooled by treatment for elemental analysis. Therefore, the results of the first sampling were not included in the statistical analysis, but are presented with the other data in Table 2. On the later sampling dates, eight to ten recently matured leaves were collected from each plant. Leaves were washed in tap water and a liquinox (P-free detergent) solution, then rinsed twice in deionized water. Total washing time did not exceed one minute. Then, the leaf samples were placed into clean paper bags, dried at 75^0C, and weighed and added onto their corresponding counterpart dry weights so that the total individual plant dry weight could be obtained. The leaves were then ground to pass through a 20 mesh screen in a Wiley Mill and stored in air-tight jars until analysis. Prior to analysis, ground leaf samples were re-dried at 80^0C for 24 hours. Nitrogen was analyzed by macro-Kjeldahl, P colorimetrically, and K, Ca, Mg, Zn, Fe, and Mn by atomic absorption spectroscopy.

Results and Discussion

Shoot length 4 weeks after potting was curvalinearly related to fertilizer rate, then shoot length at later sampling dates showed a positive linear relationship (Table 1). Plant dry weight was greatest using 9.6 g 12N-5.3P-12.5K controlled-release fertilizer per pot 4 and 8 weeks after potting, but by the twelfth week after potting there were no significant differences between fertilizer treatments.

Foliar N concentrations increased linearly with fertilizer rate on all sampling dates that were statistically analysed (Table 2). A similar trend was noted for samples taken 4 weeks after potting; however, data could not be statistically analysed. Nitrogen concentrations decreased between samples taken 4 weeks after potting and those taken 12 weeks after potting. Others (Boodley, 1970; Cox and Seeley, 1983) reported little change in leaf N concentrations of plants receiving CLF as plant age increased. Initially, most N concentrations were in the normal range of 4.0 to 6.0%, then at weeks 8 and 12 sampling dates all N concentrations were near or well below the critical level of 3% (Ecke and Matkin, 1976). Chlorotic leaves, typical of N shortage, were noted on plants with 4.8 or 7.2 g 12N-5.3P-12.5K/pot 4 weeks after potting. Plants in all treatments eventually developed chlorotic leaves, increasing in severity with time. Foliar P concentrations

increased linearly with fertilizer treatment on weeks 8 and 12 (Table 2). Generally, leaf P concentrations decreased at later sampling dates, with the highest concentrations on week 4. All leaf P concentrations were within the normal range for poinsettia, except two exceeded the "toxic" level of 0.7% (Ecke and Matkin, 1976).

Fertilizer treatments had no significant effect on foliar K and Ca concentrations on any sampling dates (Table 2). Leaf K concentrations decreased and Ca increased as plant age increased. Foliar K concentrations were in the normal range on all sampling dates (Ecke and Matkin, 1976). During the two earlier sampling dates, most foliar Ca concentrations were above the critical level and approached the normal range, then later sampling showed concentrations in the normal range (Ecke and Matkin, 1976).

Foliar Mg concentrations were greatest using 12 g 12N-5.3P-12.5K/pot (Table 2). Leaf Mg concentrations generally increased as plant age increased. Most foliar Mg concentrations remained in the normal range (Ecke and Matkin, 1976).

Foliar Zn and Fe concentrations first decreased between 4 and 8 weeks after potting, then increased between 8 and 12 weeks after potting (Table 2). There was little change in Mn concentrations between 4 and 8 weeks after potting, then leaf Mn concentrations increased between 8 and 12 weeks after potting. Foliar Zn, Fe, and Mn showed linear correlation with fertilizer treatment on week 8, then 12

weeks after potting, only leaf Mn concentrations were linearly related to fertilizer rate. In our experiment, most Zn concentrations were in the normal range (Ecke and Matkin, 1976). During weeks 4 and 8, most foliar Fe concentrations approached the normal range, and all leaf Mn concentrations were below the critical level except one reading which was in the normal range of 80 - 300 (Ecke and Matkin, 1976). Leaf samples taken 12 weeks after potting showed leaf Fe concentrations were in the normal range and most Mn concentrations approached the normal range (Ecke and Matkin, 1976).

Leachate pH was negatively correlated with the fertilizer rate on all sampling dates (Table 3). Leachate pH tended to increase from 2 weeks after potting to 8 weeks after potting, then stabilize between weeks 8 and 12. The pH increase was probably related to the gradual depletion of the nutrients in the medium, since the incorporated fertilizer is acid-based, plus an accumulation of Ca from the water source.

The recommended pH range for soilless media is 5.0 to 6.5 (Ecke, 1986), with the optimum pH range of 5.7 to 6.5 (Tayama et al., 1988). In our experiment, all except two of the leachate pH's were within this range (Tayama et al., 1988). This indicates that pH did not limit nutrient availability to the plants. Soluble salt concentrations were positively related to fertilizer rate on all sampling dates, except week 8 (Table 3). Initially, leachate soluble

salt concentrations ranged from 4.4 to 7.7 mmhos/cm, then the final sampling showed a range of 1 to 1.5 mmhos/cm. According to Donnini (1986) working with plants on a constant liquid fertilization program, it was indicated that leachate soluble salt concentrations below 5.7 mmhos/cm will not suppress plant growth and concentrations above 7.2 mmhos/cm may restrict plant growth or be toxic. However, a lower limit for soluble salts that would limit plant growth was not defined. On week 2, leachate soluble salt concentration of the highest fertilizer treatment was above the normal range defined by Donnini (1986). Thereafter, all leachate soluble salt concentrations were within the described normal range (Donnini, 1986).

Boodley (1974) reported that total soluble salt concentrations of a medium parallels the nitrate content in the medium. Similar results were shown in other studies (Hershey and Paul, 1982; Donnini, 1986). According to the manufacturer, the controlled-release fertilizer (12N-5.3P-12.5K) has a 3-month lifespan, and the nutrients' release is only influenced by medium temperature. In our experiment, the leachate soluble salt concentrations of all fertilizer treatments decreased rapidly with time. During week 8, all treatments showed more than a 50% decrease in the leachate soluble salt concentrations. This decrease could be partially due to an increase in the rate of N uptake by the plants (Kofranek and Lunt, 1966). The higher leachate soluble salt concentration on the initial sampling date

indicates there was a greater amount of N being released than the plant absorbed, which is similar to the results of Hershey and Paul (1982). Leachate soluble salts decreased during later sampling dates suggesting that elemental absorption of the plants increased, fertilizer release rates decreased, or both.

Plants that received 4.8 g of fertilizer per pot had 216 mg N/plant 6 weeks after potting. Samples taken 8 and 12 weeks after potting had 361 and 544 mg N/plant, respectively. This is an increase of 145 mg N/plant between weeks 4 and 8, and a 183 mg N/plant increase between weeks 8 and 12. Plants that received 12 g fertilizer/pot had an increase of 399, and 139 mg N/plant for weeks 4 to 8 and 8 to 12, respectively. This suggests that the decrease in soluble salt concentration was primarily due to a decrease in elemental release rate rather than increased N absorption. Futhermore, even plants that received the highest fertilizer rates were low in N by 8 weeks after potting indicating that either the elemental release rate was not adequate, or the fertilizer was depleted.

Plants receiving the recommended incorporation rate of 7.5 g/pot 12N-5.3P-12.5K CRF had shorter shoots, lower N concentrations, and more chlorosis (due to low N concentrations) than plants fertilized with 9.6 or 12.5 g/pot CRF. This indicates 7.2 g/pot controlled-release fertilizer was not sufficient to produce poinsettias of marketable quality. Plants that received 12.0 g/pot CRF

were of better quality than plants in the other treatments; however, the foliage quality was still less than desired, but bract quality was satisfactory.

The leachate soluble salt concentrations of all treatments were decreased by approximately 50% between 2 to 4 and 4 to 8 weeks after potting, then the magnitude of difference was smaller between 8 to 12 weeks after potting. The leachate method tended to reflect the nutrient status of the medium at the time of sampling, although it was difficult to relate actual readings to plant growth values. I considered the leachate method to be a practical means for measuring soluble salts, although further study should be conducted to establish suitable ranges for each crop and stage of growth.

Table 1. Influence of controlled-release fertilizer on shoot length and dry weight.

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Shoot length (cm) Weeks after potting 4	8	12	Dry weight (g) Weeks after potting 4	8	12
4.8	5.3	10.9	14.7	6.0	16.6	23.9
7.2	5.7	12.1	15.4	6.6	21.3	27.8
9.6	6.0	12.8	17.1	7.4	23.3	30.0
12.0	5.7	13.3	17.3	6.9	22.4	27.1
Linear	**	**	*	*	**	NS
Quadratic	**	NS	NS	NS	*	NS
Cubic	NS	NS	NS	NS	NS	NS

*,**,NS Significantly different at 5% (*), 1% (**), or not significant (NS).

Table 2. Effect of controlled-release fertilizer on leaf elemental concentrations.

Elements	Weeks after potting	Controlled-release fertilizer 12N-5.3P-12.5K (g/pot) 4.8	7.2	9.6	12.0	L	Q	C
N (%)	4	3.61	4.13	4.26	4.57	-	-	-
	8	2.18	2.46	2.80	3.19	***	NS	NS
	12	2.28	2.52	2.76	3.15	***	NS	NS
P (%)	4	0.62	0.71	0.58	0.76	-	-	-
	8	0.31	0.31	0.38	0.43	**	NS	NS
	12	0.41	0.37	0.43	0.56	*	NS	NS
K (%)	4	3.18	3.01	2.95	3.11	-	-	-
	8	2.01	2.08	2.16	2.17	NS	NS	NS
	12	1.88	1.83	1.83	2.03	NS	NS	NS
Ca (%)	4	0.69	0.60	0.53	0.62	-	-	-
	8	0.68	0.66	0.70	0.63	NS	NS	NS
	12	2.04	1.77	1.97	1.88	NS	NS	NS
Mg (%)	4	0.44	0.42	0.39	0.45	-	-	-
	8	0.31	0.32	0.36	0.40	***	NS	NS
	12	0.76	0.68	0.75	0.81	NS	*	NS
Zn (ug/g)	4	45	39	42	50	-	-	-
	8	17	17	24	33	**	NS	NS
	12	62	46	50	70	NS	NS	NS
Fe (ug/g)	4	79	75	70	93	-	-	-
	8	45	48	59	72	***	NS	NS
	12	127	116	133	140	NS	NS	NS
Mn (ug/g)	4	22	29	31	43	-	-	-
	8	17	25	33	42	***	NS	NS
	12	49	58	75	91	***	NS	NS

*,**,***,NS Significantly different at 5% (*), 1% (**), 0.1% (***), or not significant (NS).

Table 3. Influence of controlled-release fertilizer on leachate pH and leachate soluble salt concentrations.

Controlled-release fertilizer 12N-5.3P-12.5K (g/pot)	Leachate pH Weeks after potting				Leachate soluble salt concentrations (mmhos/cm)[z] Weeks after potting			
	2	4	8	12	2	4	8	12
4.8	6.16	6.35	6.81	6.60	4.04	2.13	1.14	0.83
7.2	6.02	5.97	6.53	6.47	5.26	3.00	1.69	1.05
9.6	5.91	5.77	6.31	6.05	6.46	3.77	1.80	1.46
12.0	5.90	5.70	6.29	6.26	7.72	4.57	1.69	1.32
Linear	***	***	***	**	***	***	NS	*
Quadratic	*	NS	NS	NS	NS	NS	NS	NS
Cubic	NS	NS	NS	*	NS	NS	NS	NS

[z] Tap water soluble salts values have been subtracted from value shown in the table. Tap water soluble salts reading = 0.41, 0.52, 0.43, 0.41 mmhos/cm on 2, 4, 8, and 12 weeks after potting, respectively.

*,**,***,NS Sigificantly different at 5% (*), 1% (**), 0.1% (***), or not significant (NS).

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