THE EFFECT OF CALCIUM FERTILIZATION AND GA BIOSYNTHESIS INHIBITING GROWTH REGULATORS ON BRACT NECROSIS IN 'GUTBIER V-14 GLORY' POINSETTIA

By

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PREFACE

The purpose of this study was to determine the effect of N-P-K and dolomite fertilization rates, paclobutrazol, and other gibberellin biosynthesis inhibiting growth regulators on the performance and the development of bract necrosis in 'Gutbier V-14 Glory' poinsettia. Three experiments were performed. The first experiment used two rates of N-P-K and three rates of dolomite fertilization. The second experiment used five rates of paclobutrazol applied as a soil drench. In the third experiment, four gibberellin biosynthesis inhibiting growth regulators were used. These were, paclobutrazol, ancymidol, and chlormequat, applied as foliar sprays, and paclobutrazol and daminozide applied as soil drenches.

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CHAPTER I

INTRODUCTION

Poinsettia (Euphorbia pulcherrima Willd.) is an important floricultural crop with a wholesale sales value of 157 million dollars in 1988 (National Agriculture Statistics Board, 1989). It is the number one selling flowering pot plant in the United States.

'Gutbier V-14 Glory' is a popular cultivar because of its large bract size and bright red color; however, it has a tendency to develop bract necrosis (Wilfret, 1981). This is more pronounced when grown in southern regions of the U.S.

There have been several factors indicated as causes of the development of bract necrosis. These include excess salt deposition at the ends of pitted veins (Nell and Barrett, 1986), frequent irrigation intervals (Nell and Barrett, 1986), high N fertilization (Nell and Barrett, 1986; Ku, 1988), high NH_4-N (Nell and Barrett, 1985), and Ca deficiency (Woltz and Harbaugh, 1986; Harbaugh and Woltz, 1989).

The problem of bract necrosis in poinsettias is similar to leaf edge burn of poinsettia (Bierman, Rosen, and Wilkins, 1990), lettuce tipburn (Thibodeau and Minotti, 1969; Ashkar and Ries, 1971; Barta and Tibbitts, 1986), leaf tipburn of cabbage (Maynard, Gersten and Vernell, 1965;

Aloni, Pashkar and Libel, 1986), leaf tipburn of seedling carrots (Tibbitts, Setiamihardja, Palzkill, and Olszyk, 1983), leaf tipburn of strawberry (Bradfield and Guttridge, 1979), internal browning of brussels sprouts (Maynard and Barker, 1972), brownheart of escarole (Maynard, Gersten, and Vernell, 1962) and blackheart of celery (Geraldson, 1953). These disorders have been linked to a Ca deficiency.

Calcium is translocated in the xylem, and once deposited in the leaf tissue remains primarily immobile (Hanger, 1979). Since Ca transport is in the xylem, it is closely associated with the transpiration rate (Michael and Marschner, 1962). Studies on plants such as cabbage (Maynard, Gersten, and Vernell, 1965; Aloni, 1986), lettuce (Thibodeau and Minotti, 1969; Barta and Tibbitts, 1986), brussels sprouts (Maynard and Barker, 1972), and seedling carrots (Tibbitts, Setiamihardja, Palzkill, and Olszyk, 1983) have linked a Ca shortage in young leaves to a reduction in transpiration due to leaf enclosure which subsequently induces tipburn. It has also been shown that shoot tip cultures in airtight containers exhibit more tip necrosis than those in ventilated containers (Sha, McCown, and Peterson, 1985). Poinsettia bracts have 120-fold less stomata than leaves (Nell and Barrett, 1986) which would reduce the amount of transpiration consequently reducing Ca translocated to the bracts.

Growth regulators are commonly used in the culture of the poinsettia. These reduce the plant height to make a

compact and desirable looking plant, which improves its marketability. Paclobutrazol (Lever, 1986; McDaniel, 1986), daminozide (Riddell, Hageman, J'Anthony, and Hubbard, 1962), chlormequat (Jones and Phillips, 1967) and ancymidol (Coolbaugh and Hamilton, 1976) are all gibberellin biosynthesis inhibiting growth regulators that are used to reduce height.

Paclobutrazol has been recently labeled for use on poinsettia. It can be applied as a soil drench or a foliar spray. The application of paclobutrazol has reduced the incidence of bract necrosis ten-fold (Ku, 1988). It has also reduced incidence of other Ca related disorders such as bitter pit of apple (Greene and Murray, 1983).

The application of daminozide reduced the incidence of tipburn in cabbage (Aloni, Pashkar, and Libel, 1986) and ^{45}Ca concentration of bean was increased with daminozide application (Wieneke, Biddulph, and Woodbridge, 1971).

Chlormequat, labeled for use on poinsettia, was found to increase tissue Ca in poinsettia 8 days after application (Conover and Vines, 1972).

These gibberellin biosynthesis inhibiting growth regulators could possibly reduce the occurrence of necrosis by affecting the Ca distribution in the plant.

In this study, we wished to determine the effect of N-P-K and dolomite application rates on poinsettia quality and the development of bract necrosis. We also wished to determine if extractable Ca was more closely correlated with

bract necrosis than total Ca levels in the tissue. Three harvest dates were used to monitor the movement of Ca into the bracts and transitional bracts to see if there was a critical time of Ca movement into these tissues. We also wished to determine if the application of gibberellin biosynthesis inhibiting growth regulators reduced necrosis by increasing Ca concentrations in the bracts and transitional bracts.

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CHAPTER II

CALCIUM AND N-P-K FERTILIZER EFFECTS ON BRACT NECROSIS OF 'GUTBIER V-14 GLORY' POINSETTIA

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Abstract: Necrotic tissue near the margins of bracts and transitional bracts of poinsettia (Euphorbia pulcherrima Willd.) is a common problem which reduces the market value of the crop. Experiments were conducted to determine the effect of N-P-K and dolomite fertilization on poinsettia performance, bract and transitional bract necrosis, and total and extractable Ca concentrations. Bract necrosis and bract pucker were least at 500 mg.liter^{-1} N-P-K and 5 kg.m^{-3} dolomite. Both extractable and total bract and transitional bract Ca were negatively correlated with bract necrosis. Leaf transpiration and conductance rates were much higher than those of transitional bracts or bracts. Leaf Ca concentrations were also much greater than Ca concentrations in the transitional bracts and bracts. Total Ca concentrations in the bracts and transitional bracts declined greatly 10 to 14 weeks after transplanting.

Necrotic tissue near the margins of bracts and transitional bracts of poinsettia is a common problem which reduces the market value of the crop. 'Gutbier V-14 Glory' is especially susceptible to this problem (Wilfret, 1981). Bract necrosis is increased by a high rate of nitrogen fertilization during bract coloration (Nell and Barrett,

1986; Ku, 1988), frequent irrigation intervals (Nell and Barrett, 1986), and calcium deficiency (Woltz and Harbaugh, 1986, Harbaugh and Woltz, 1989).

Bract necrosis in poinsettia appears to be similar to physiological disorders in other crops, such as lettuce tipburn (Thibodeau and Minotti, 1969), leaf tipburn of cabbage (Maynard, Gersten, and Vernell, 1965; Aloni, Pashkar, and Libel, 1986), leaf tipburn of seedling carrots (Tibbitts, Setiamihardja, Palzkill, and Olszyk, 1983), and leaf tipburn of strawberry (Bradfield and Guttridge, 1979). These disorders have been linked to Ca deficiency. In addition to bract necrosis, leaf necrosis has been reported in poinsettia (Bierman, Rosen, and Wilkins, 1990), which was caused by Ca shortage. In this study, the objectives were to 1) determine the response of 'Gutbier V-14 Glory' to combinations of N-P-K and dolomite fertilization rates, with emphasis on transitional bract and bract necrosis development, 2) determine if these N-P-K and dolomite rates affect the concentration of soluble and total Ca in the leaves, bracts, and transitional bracts, and 3) examine the movement of Ca into the bracts during bract expansion.

Plants were propagated by taking cuttings from 'Gutbier V-14 Glory' stock plants on 18 July 1988. The cuttings were inserted in rooting propagation strips (Oasis, Smithers-Oasis, Kent, Ohio), and placed under intermittent mist. Rooted cuttings were transplanted to 3 liter pots on 17 Aug., then pinched to seven nodes on 6 Sept. No growth

regulators were used to avoid any growth regulator effect on necrosis development (Ku, 1988). Plants were grown in a fiberglass greenhouse with a 17/19C night/day temperature. The potting media was a 3 peat: 1 perlite: 1 vermiculite (by volume) mix amended with 444 $g.m^{-3}$ micronutrients (Micromax, Sierra Chemical Co., Milpitas, Calif.), 593 $g.m^{-3}$ KNO_3, and 889 $g.m^{-3}$ wetting agent (Aquagrow, Aquatrols Corp. of America, Pennsauken, N.J.). The date of first red coloration was 18 Oct. and anthesis occurred on 10 Dec. Final pH ranged from 4.3 to 7.1.

Experimental design was split-plot with N-P-K rate as the main-plot at 500 or 2000 $mg.liter^{-1}$ of a 20N-4.3P-16.6K fertilizer (Peters 20-10-20, W.R. Grace & Co., Folgelsville, Pa.) applied at each irrigation. Dolomite was the subplot at 0, 5, and 10 $kg.m^{-3}$ incorporated in the media at mixing. Each treatment combination was replicated five times, with two-plant subsamples per replication. Three studies, conducted at the same time, were harvested at ten, fourteen, and eighteen weeks after transplanting.

The first experiment was harvested on 28 Oct. Bracts and transitional bracts were combined and counted, and leaves were counted. Transitional bracts were distinguished from leaves by red coloration on the transitional bracts. Tissues were washed in 0.1 N HCl, followed by a detergent solution (Liquinox, Alconox Inc., New York), two deionized water rinses, then dried at 75C, and weighed.

The second harvest was on 26 Nov. Bracts and

transitional bracts were combined and sorted into four sizes; 0-25%, 26-50%, 51-75%, and 76-100% expanded (few bracts had developed, most tissue was transitional bract tissue). Bract expansion was determined by comparing the bracts to samples of each size group based on a fully expanded leaf as 100% expanded. Bracts and transitional bracts were counted together, and leaves were counted. All tissues were washed, dried at 75C, then weighed.

The third harvest was on 20 Dec. Leaves, transitional bracts, and bracts were counted, washed, dried at 75C, then weighed. Bracts and transitional bracts exhibiting even slight necrosis were counted. The number of broken branches was recorded and bract pucker (a failure of the midrib to fully expand) was rated on a scale of 1 to 3, with 3 the most severe. Data were also taken on plant height above the container rim, bract diameter, and canopy area.

Elemental analysis was performed on tissues from the three harvest dates. Samples were ground to 20 mesh and stored in air-tight jars until analyzed. Prior to analysis, samples were redried at 80C for 24 hr. Total Ca was extracted using the ash method (Isaac and Johnson, 1975) and extractable Ca was determined using a 2% acetic acid extraction (Gallaher and Jones, 1976). Standard methods were used for analysis, N by macro-Kjeldahl (Horowitz, 1980), P colorimetrically, and other elements by atomic absorption spectroscopy (Perkin-Elmer, Model 303, Norwalk, Conn.).

On 28 Dec. leaf resistance to water vapor loss and transpiration was measured using a steady-state porometer (LiCor Model 1600, Lincoln, Neb.) on poinsettias fertilized each irrigation with 2000 mg.liter^{-1} N-P-K and 5 kg.m^{-3} dolomite incorporated in the media at mixing. Leaf conductance was calculated as the reciprocal of leaf resistance.

Poinsettia canopy and bract area were not affected by N-P-K rate, but broken branch number and bract pucker increased as N-P-K rate increased (Table 1). Dolomite had no effect on bract area; however, canopy area and broken branch number were both greatest at 5 kg.m^{-3} dolomite. Bract pucker was negatively related to dolomite rate. This supports findings by Woltz and Harbaugh (1986) that bract pucker was greater in plants not receiving foliar Ca sprays than in Ca sprayed poinsettias.

The number of necrotic bracts and transitional bracts were greatest at 2000 mg.liter^{-1} N-P-K and no dolomite incorporated in the media (Table 2). Extractable bract Ca was greatest at 500 mg.liter^{-1} N-P-K and 5 kg.m^{-3} dolomite. Extractable transitional bract, total bract, and total transitional bract Ca concentrations decreased as N-P-K increased.

Leaf N was highest at 2000 mg.liter^{-1} N-P-K and no dolomite incorporated into the media, while Mn was greatest at the 500 mg.liter^{-1} N-P-K rate and no dolomite (Table 3). Phosphorus, K, and Zn increased with an increase in N-P-K

rate, but Mg decreased and Fe was not affected. Leaf K decreased as dolomite rate increased, and P, Mg, Zn, and Fe were not affected by dolomite rate. Transitional bract P was greatest at 2000 mg.liter^{-1} N-P-K and 5 kg.m^{-3} dolomite (Table 4). Manganese was greatest at 500 mg.liter^{-1} N-P-K and no dolomite. Nitrogen, K, and Zn increased as N-P-K increased, but Mg decreased. Fe was not affected by N-P-K rate. Nitrogen and K decreased as dolomite rate increased and Mg, Zn, and Fe were not affected by dolomite rate. Bract Zn was greatest at 2000 mg.liter^{-1} N-P-K and 5 kg.m^{-3} dolomite while Fe was greatest at the higher N-P-K rate and no dolomite (Table 5). Manganese in the bracts was greatest at 500 mg.liter^{-1} N-P-K and no dolomite. Nitrogen was greatest at the higher N-P-K rate and Mg was lowest at this rate. Phosphorus and K were not affected by N-P-K rate. Nitrogen and K both decreased with increasing dolomite rate and P and Mg were not affected by dolomite rate.

Extractable bract Ca was negatively correlated with bract necrosis (r=.69, P=.0003), while total bract Ca was weakly negatively correlated with necrosis (r=.36,P=.05). Extractable transitional bract Ca was negatively correlated with necrosis in the transitional bracts (r=.59, P=.001), and total Ca in the transitional bracts was also negatively correlated with necrosis in the transitional bracts (r=.65, P=.048).

Total Ca in the bracts and transitional bracts was not affected by N-P-K rate 10 weeks after transplanting (Table

6). Total bract and transitional bract Ca decreased 13%, 14 weeks after transplanting and 29%, 18 weeks after transplanting when N-P-K was increased from 500 to 2000 $mg.liter^{-1}$. Extractable bract and transitional bract Ca was greatest at the lower N-P-K rate at all three harvests. Total Ca in bracts and transitional bracts was not affected by dolomite rate, except 14 weeks after transplanting, but Ca concentration was curvilinearly related to dolomite rate. Extractable Ca in these tissues was not significantly different 10 weeks after transplanting, but 14 weeks after transplanting it was linearly related to dolomite rate and 18 weeks after transplanting it was curvilinearly related to dolomite rate. Total Ca concentrations in the bracts and transitional bracts decreased dramatically between 10 and 14 weeks after transplanting.

At 14 weeks after transplanting, total bract and transitional bract Ca increased with bract size (Table 7). Extractable bract and transitional bract Ca increased also.

Leaf conductance and transpiration was 13 times higher than conductance and transpiration of transitional bracts and bracts (Fig. 1). Calcium concentration in the leaves was also higher than Ca concentrations in the transitional bracts and bracts (Fig. 2).

Poinsettias performed best at 500 $mg.liter^{-1}$ N-P-K and 5 $kg.m^{-3}$ dolomite fertilization. Bract necrosis and bract pucker were least at this rate. Both extractable and total bract and transitional bract Ca were negatively correlated

with bract necrosis, supporting the findings by Woltz and Harbaugh (1986), that necrosis is caused by a Ca deficiency. The higher rate of N-P-K fertilization inhibits the uptake of Ca by the plant. Leaf transpiration and conductance rates are much higher than those of transitional bracts and bracts. Bracts and transitional bracts were found to have 20-fold less stomata than leaves (Nell and Barrett, 1986) which would account for their lower transpiration rates. Leaf tissue also had a much higher Ca concentration than the transitional bracts or bracts. The difference in concentrations appeared to begin between 10 and 14 weeks after transplanting when there was a dramatic reduction in the total Ca concentration in the transitional bracts and bracts. The incorporation of dolomite into the media coupled with Ca sprays recommended by Harbaugh and Woltz (1989), which could be started 10 to 14 weeks after transplanting, would effectively reduce bract and transitional bract necrosis.

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Table 1. Influence of N-P-K and dolomite rate on canopy area, bract area, broken branch number, and bract pucker.

Treatment	Rate	Canopy area (cm^2)	Bract area (cm^2)	Broken branches (number)	Bract pucker (index)
20N-4.3P-16.6K ($mg.liter^{-1}$)	500	8698	4644	0.3	1.5
	2000	8731	4807	2.5	2.3
Significance		NS	NS	**	***
Dolomite ($kg.m^{-3}$)	0	7813	4617	1.0	2.2
	5	9182	4795	1.8	1.7
	10	9147	4763	1.3	1.8
Linear		**	NS	NS	*
Quadratic		*	NS	*	NS

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 2. Influence of dolomite and N-P-K rate on bract and transitional bract necrosis and total and extractable calcium.

Nitrogen	Dolomite	Number necrotic		Extractable Ca (% dry wt.)		Total Ca (% dry wt.)	
		Bracts	Transitional bracts	Bracts	Transitional bracts	Bracts	Transitional bracts
500	0	3.1	6.3	.096	.112	.250	.244
	5	1.3	7.7	.146	.132	.304	.344
	10	2.3	6.9	.134	.128	.282	.322
2000	0	19.7	14.9	.038	.038	.132	.152
	5	5.6	6.0	.062	.070	.192	.234
	10	4.1	3.5	.088	.060	.170	.258
Nitrogen		**	NS	***	***	**	**
Dolomite Linear		**	***	***	*	NS	***
Dolomite Quadratic		NS	NS	*	*	NS	**
D * N Linear		**	***	NS	NS	NS	NS
D * N Quadratic		NS	NS	*	NS	NS	NS

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 3. Influence of dolomite and N-P-K rate on leaf elemental concentration.

		Dry Weight (%)				Dry Weight (ug/g)		
Nitrogen	Dolomite	N	P	K	Mg	Zn	Fe	Mn
500	0	4.19	.387	2.23	.852	42	160	369
	5	4.22	.377	1.84	.800	42	112	179
	10	4.18	.375	1.74	.748	40	116	123
2000	0	6.01	.656	2.74	.666	48	126	317
	5	5.83	.829	2.13	.768	50	132	244
	10	5.57	.784	2.07	.702	53	132	174
Nitrogen		***	***	**	*	*	NS	*
Dolomite linear		**	NS	***	NS	NS	NS	***
Dolomite quadratic		NS	NS	*	NS	NS	NS	*
D * N linear		**	NS	NS	NS	NS	NS	**
D * N quadratic		NS	NS	NS	NS	NS	NS	*

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 4. Influence of dolomite and N-P-K rate on transitional bract elemental concentration.

		Dry weight (%)				Dry weight (ug/g)		
Nitrogen	Dolomite	N	P	K	Mg	Zn	Fe	Mn
500	0	3.11	.451	2.98	.370	38	51	63
	5	2.98	.441	2.70	.382	39	55	36
	10	2.81	.433	2.57	.348	39	51	22
2000	0	4.72	.562	3.46	.294	42	58	37
	5	4.49	.645	3.01	.346	47	59	39
	10	4.31	.630	3.21	.314	46	53	25
Nitrogen		***	***	**	*	*	NS	NS
Dolomite linear		***	NS	**	NS	NS	NS	***
Dolomite quadratic		NS	NS	*	NS	NS	NS	NS
D * N linear		NS	**	NS	NS	NS	NS	**
D * N quadratic		NS	NS	NS	NS	NS	NS	*

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 5. Influence of dolomite and N-P-K rate on bract elemental concentration.

		Dry weight (%)				Dry weight (ug/g)		
Nitrogen	Dolomite	N	P	K	Mg	Zn	Fe	Mn
500	0	3.05	.516	3.09	.383	39	31	51
	5	2.90	.516	2.89	.398	38	37	41
	10	2.92	.510	2.87	.354	35	37	29
2000	0	3.76	.547	3.31	.244	36	43	28
	5	3.71	.560	2.82	.258	44	38	48
	10	3.58	.526	2.68	.262	42	34	34
Nitrogen		**	NS	NS	*	NS	NS	NS
Dolomite linear		**	NS	**	NS	NS	NS	***
Dolomite quadratic		NS	NS	NS	NS	NS	NS	***
D * N linear		NS	NS	NS	NS	*	**	***
D * N quadratic		NS	NS	NS	NS	NS	NS	***

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 6. Influence of N-P-K and dolomite on total and extractable Ca 10, 14, and 18 weeks after transplanting.

	Bract and transitional bract Ca (% dry wt.)					
	Weeks after transplanting					
	10		14		18	
Treatment	Total	Ext.	Total	Ext.	Total	Ext.
20N-4.3P-16.6K ($mg.liter^{-1}$)						
500	.610	.102	.235	.107	.303	.124
2000	.544	.075	.205	.063	.214	.056
Significance	NS	**	*	**	**	***
Dolomite ($kg.m^{-3}$)						
0	.591	.094	.187	.076	.198	.080
5	.628	.088	.239	.089	.289	.101
10	.512	.085	.234	.090	.290	.094
Linear	NS	NS	***	**	NS	***
Quadratic	NS	NS	**	NS	NS	*

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 7. Influence of bract size on total and extractable Ca concentration and total and extractable Ca per bract 14 weeks after transplanting.

Bract size	Ca (% dry wt.)		Ca (mg.bract^{-1})	
(% expanded)	total	ext.	total	ext.
0 - 25	.151	.065	46	19
26 - 50	.206	.098	289	135
51 - 75	.302	.083	636	175
LSD .05	.026	.007	53	19

Figure 1. Conductance and transpiration of leaves, transitional bracts, and bracts.

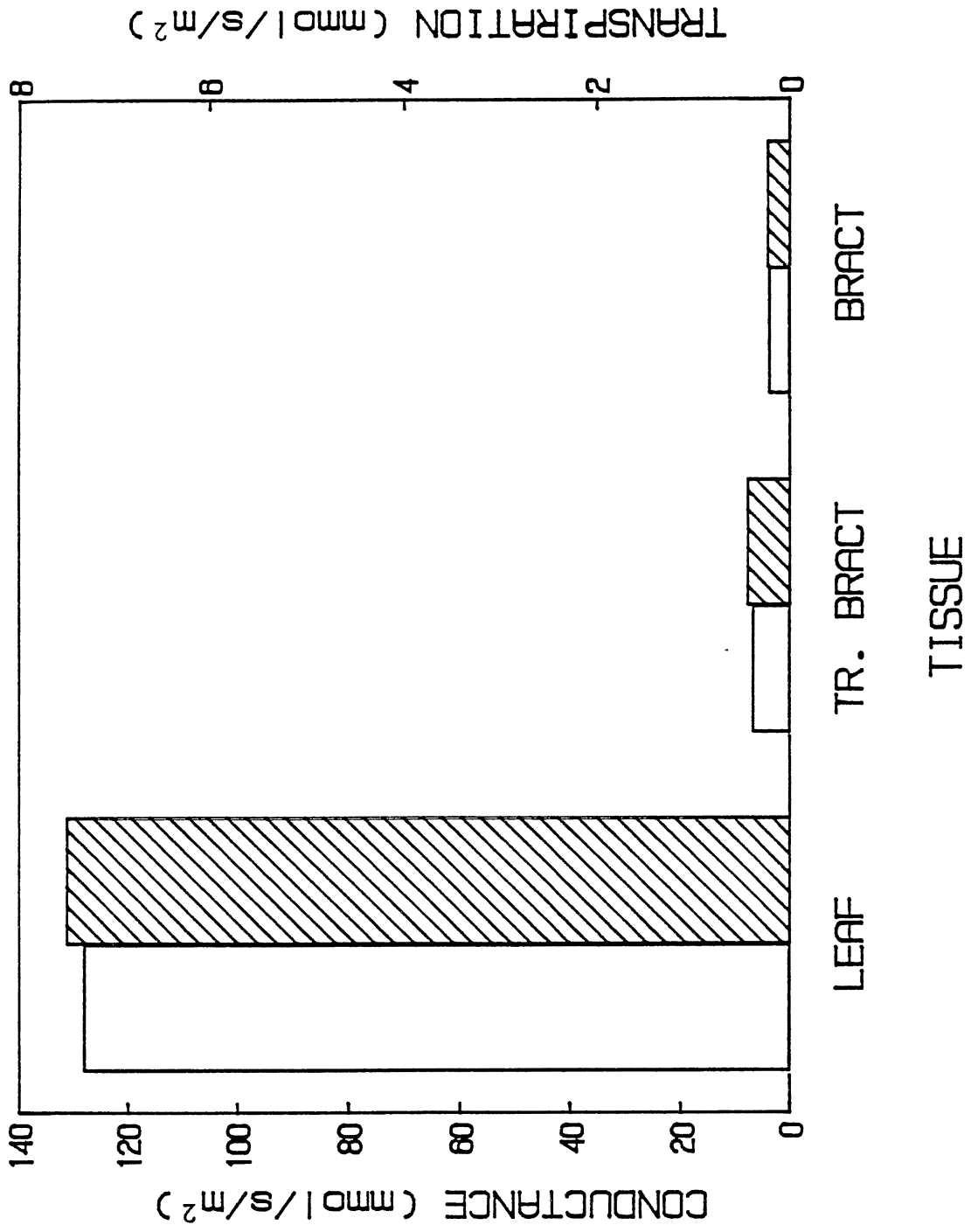
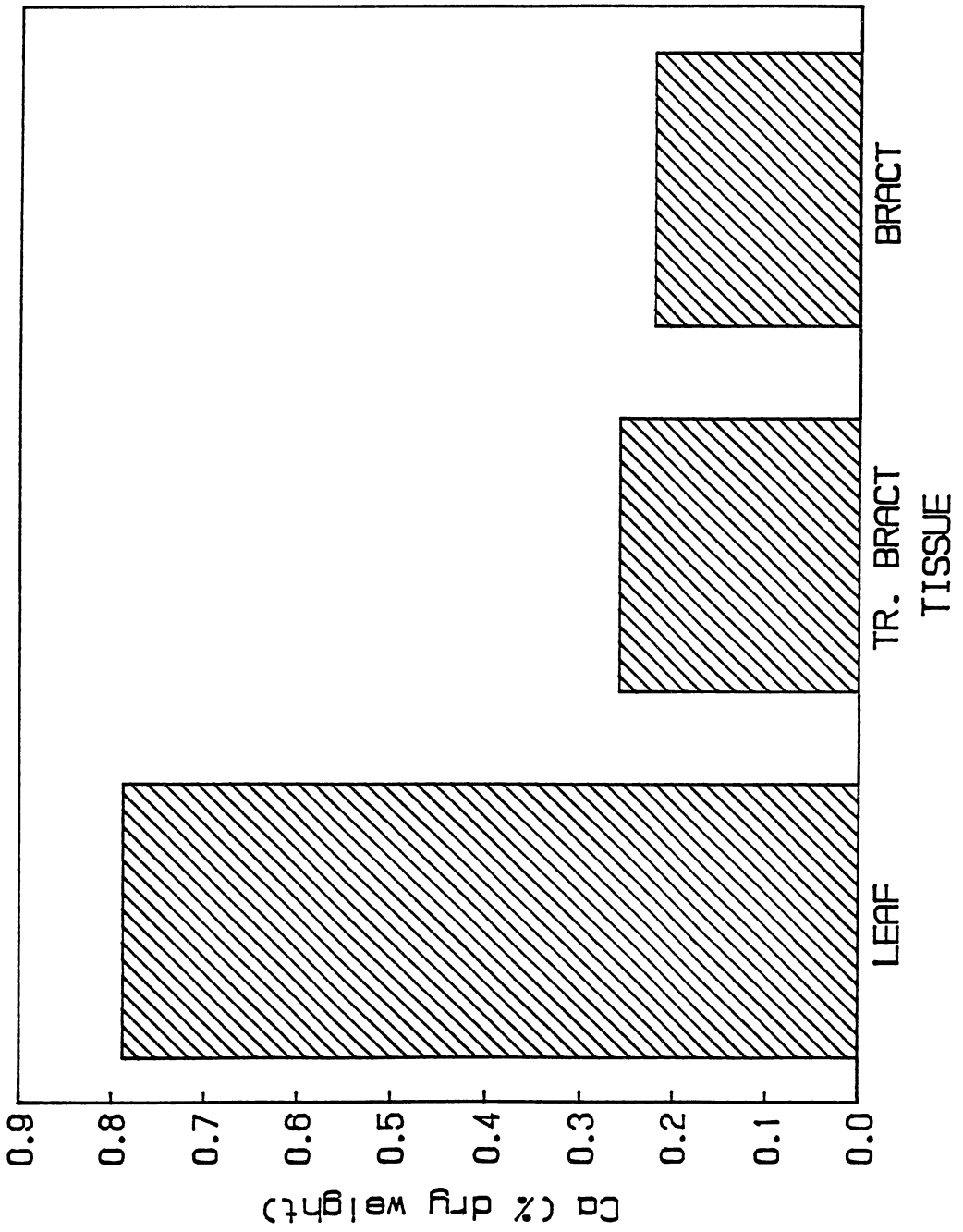

CONDUCTANCE (mmol/s/m²)
TRANSPIRATION (mmol/s/m²)
140
120
100
80
60
40
20
0
8
6
4
2
0
LEAF
TR. BRACT
BRACT
TISSUE

Figure 2. Calcium concentration in leaves, transitional bracts, and bracts.


0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
Ca (% dry weight)
LEAF
TR. BRACT
BRACT
TISSUE

CHAPTER III

THE INFLUENCE OF GIBBERELLIN BIOSYNTHESIS INHIBITING GROWTH REGULATORS ON BRACT NECROSIS IN 'GUTBIER V-14 GLORY' POINSETTIA

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Abstract: Two experiments were performed to examine the effects of gibberellin biosynthesis inhibiting growth regulators on the development of bract and transitional bract necrosis in poinsettia (Euphorbia pulcherrima Willd.). In the first experiment, five rates of paclobutrazol were applied. Paclobutrazol reduced bract and transitional bract necrosis. In the second experiment, other gibberellin biosynthesis inhibiting growth regulators were applied. Growth regulators decreased necrosis in the transitional bracts and paclobutrazol-drench and daminozide reduced necrosis in the bracts; however, Ca concentrations in the transitional bracts and bracts were not necessarily increased. Chemical names used: (2RS,3RS)-1-(4-chlorophenyl)-4,4-dimethyl-2-(1,2,4-triazol-1-yl) pentan-3-ol), (paclobutrazol), butanedioic acid mono (2,2-dimethylhydrazide), (daminozide), 2-chloroethyltrimethyl ammonium chloride, (chlormequat), α-cyclopropyl-α-(4-methoxyphenyl)-5-pyrimidinemethanol, (ancymidol).

Poinsettia is the number one selling flowering pot plant in the United States with wholesale sales of 157 million dollars in 1988 (National Agriculture Statistics Board, 1989). Red cultivars are the most popular, and the 'Gutbier V-14 Glory' cultivar is widely grown because of its

large bract size and bright red color; however, it tends to develop bract necrosis (Wilfret, 1981).

The use of growth regulators is a common practice in poinsettia culture to produce a more compact, better looking crop. Paclobutrazol (Hedden and Graebe, 1985; Lever, 1986; McDaniel, 1986), daminozide (Riddell, Hageman, J'Anthony, and Hubbard, 1962), chlormequat (Jones and Phillips, 1967), and ancymidol (Coolbaugh and Hamilton, 1976) are all gibberellin biosynthesis inhibiting growth regulators. These growth regulators have been used on poinsettias to reduce height (Larson, 1985).

Paclobutrazol is a recently introduced growth regulator that is labeled for use on poinsettia. It can be applied as a soil drench or a foliar spray. The application of paclobutrazol reduced the incidence of bract necrosis in poinsettia ten-fold (Ku, 1988). It also reduced incidence of other Ca related disorders such as bitter pit of apple (Greene and Murray, 1983).

The application of daminozide reduced the incidence of tipburn in cabbage (Aloni, Pashkar, and Libel, 1986) and ^{45}Ca translocation to bean shoots increased with daminozide application (Wieneke, Biddulph, and Woodbridge, 1971).

Chlormequat was found to increase tissue Ca in poinsettia 8 days after application (Conover and Vines, 1972).

We wished to determine 1) the effect of the gibberellin biosynthesis inhibitor, paclobutrazol, on bract and

transitional bract necrosis, 2) the effect of paclobutrazol on total and extractable Ca concentrations in bracts and transitional bracts, 3) the effectiveness of leaf tissue Ca concentrations as an indicator for Ca concentrations and necrosis in the transitional bracts and bracts, and 4) the effect of different gibberellin biosynthesis inhibiting growth regulators on the development of bract and transitional bract necrosis and total and extractable Ca levels in these tissues. Two experiments were performed, one using various rates of paclobutrazol and the other using different growth regulators with different methods of application.

Plants for both experiments were propagated by using cuttings from 'Gutbier V-14 Glory' stock plants on 18 July 1988. The cuttings were inserted in propagation strips (Oasis, Smithers-Oasis, Kent, Ohio) and placed under intermittent mist. Rooted cuttings were transplanted into 3 liter pots on 17 Aug. The medium was a 3 peat: 1 perlite : 1 vermiculite (by volume) mix amended with 444 $g.m^{-3}$ micronutrients (Micromax, Sierra Chemical Co., Milpitas, Calif.), 593 $g.m^{-3}$ KNO_3, 889 $g.m^{-3}$ wetting agent (Aquagrow, Aquatrols Corp. of America, Pennsauken, N.J.), and 5 $kg.m^{-3}$ dolomite. Plants were fertilized at each irrigation with 20N-4.3P-16.6K fertilizer (Peters 20-10-20, W.R. Grace and Co., Fogelsville, Penn.) at 2000 $mg.liter^{-1}$ and were pinched to seven nodes on 6 Sept. The plants were grown in a fiberglass greenhouse with a temperature of 17/19C

night/day. Anthesis occurred on 10 Dec.

Experiment 1 The experimental design was a randomized complete block with four replications, each containing two subsamples. Treatments were, a paclobutrazol drench at 0, .1, .2, and .4 mg active ingredient/pot which was applied on 9 Oct. Data taken included bract area, canopy area, plant height above the pot rim, broken branch number, bract number, transitional bract number, leaf number, and dry weights of leaves, bracts, and transitional bracts. On 14 Nov., red color development was rated on a scale of 1 to 4 with 4 indicating the most red coloration. Elemental concentrations were determined on leaves, bracts and transitional bracts. Tissues were washed in a 0.1 N HCl solution, followed by a detergent solution (Liquinox, Alconox, Inc., New York), then 2 deionized water rinses, and oven-dried at 75C. Samples were ground to 20 mesh and stored in air-tight jars until analyzed. Prior to analysis, samples were redried at 80C for 24 hr. Total Ca was extracted using the ash method (Isaac and Johnson, 1975) and extractable Ca was obtained using a 2% acetic acid extraction (Gallaher and Jones, 1976). Standard methods were used for analysis, N by macro-Kjeldahl (Horowitz, 1980), P colorimetrically, and other elements by atomic absorption spectroscopy. Data was analyzed using trend analysis.

Experiment 2 The second experiment was a randomized complete block design with five replications and two

subsamples. Treatments were a control (where no growth regulator was applied), paclobutrazol, ancymidol, and chlormequat applied as a soil drench at .2 mg, .6 mg, and .7 g active ingredient/pot respectively. Paclobutrazol and daminozide were applied as foliar sprays to runoff at 75.0 μg and 7.5 g per liter active ingredient respectively. Growth regulators were applied on 9 Oct. Data collected were the same as in experiment 1. Data was analyzed using Duncan's multiple range test.

Experiment 1 Paclobutrazol rate was negatively correlated with red coloration of the bracts while canopy area, bract area, and broken branch number were curvilinearly related to paclobutrazol treatment (Table 1). Paclobutrazol significantly decreased necrosis in both transitional bracts and bracts (Table 2). Extractable Ca in the transitional bracts increased linearly with the application of paclobutrazol. Total transitional bract Ca was curvilinearly related to paclobutrazol rate, but extractable and total Ca in the bracts was reduced by the application of paclobutrazol.

Neither total nor extractable leaf Ca were correlated with Ca concentrations in the bracts and transitional bracts or with necrosis in these tissues (Table 3). Total and extractable bract Ca were correlated with necrosis in both the transitional bracts and bracts, and total transitional bract Ca was strongly correlated with necrosis in both bracts and transitional bracts.

Leaf N, Zn, Fe, and Mn were not affected by the application of paclobutrazol; however, P was curvilinearly related to paclobutrazol rate (Table 4). Potassium was greatest when no paclobutrazol was applied and Mg was greatest at the 0.1 mg rate. Transitional bract Zn and Fe were not affected by paclobutrazol application. Nitrogen, P, K, Mg, and Mn were curvilinearly related to paclobutrazol rate. Bract P, Mg, Zn, and Fe were not affected by paclobutrazol rate. Nitrogen was curvilinearly related to paclobutrazol application. Bract K increased and Mn decreased as paclobutrazol rate increased.

Experiment 2 Red coloration of bracts and transitional bracts was delayed by the application of growth regulators with daminozide causing the greatest delay (Table 5). Canopy area was reduced only by paclobutrazol applied as a soil drench. Bract area was reduced by paclobutrazol-drench, ancymidol, and chlormequat. Broken branch number was reduced by paclobutrazol-spray and drench, and by daminozide.

Paclobutrazol applied as a drench and daminozide applied as a spray reduced necrosis in the bracts, but there was no effect on total bract Ca from the application of growth regulators (Table 6). Extractable Ca in the bracts was less in plants treated with daminozide than all other treatments. In the transitional bracts, the application of growth regulators reduced the incidence of necrosis with the greatest reduction found in the application of paclobutrazol

as a drench and daminozide as a spray (Table 7). Total Ca was highest in transitional bracts treated with ancymidol, chlormequat, or daminozide, while extractable Ca was greatest in transitional bracts treated with chlormequat.

Leaf N, Mg, Zn, and Fe concentrations were not significantly different from the control (Table 8). Only paclobutrazol applied as a drench affected P and K. Manganese was significantly decreased by the application of daminozide. Transitional bract N was significantly increased by the application of growth regulators (Table 9). Phosphorus, K, and Mg were all greatest with the application of paclobutrazol-drench. Zinc was not affected by the application of growth regulators. Iron was greater than the control with paclobutrazol applied as a drench and ancymidol significantly reduced Fe. Manganese was significantly reduced by the application of paclobutrazol-spray and daminozide. In the bracts, N was greatest with the application of paclobutrazol as a drench or spray (Table 10). Phosphorus, Mg, Zn, and Fe were not affected by growth regulators. Potassium was greatest with paclobutrazol-spray, but Mn decreased with the application of paclobutrazol as a drench or spray, chlormequat, and daminozide.

The application of paclobutrazol decreased bract and transitional bract necrosis, and total and extractable Ca concentrations in the transitional bracts were increased with paclobutrazol application. Total and extractable Ca

concentrations in the bracts decreased as paclobutrazol rate increased. This suggests that another factor is involved in the effect of paclobutrazol reduction of necrosis in addition to an increase in Ca concentration. Leaf tissue Ca concentrations were not correlated with Ca concentrations in the transitional bracts or bracts, indicating that leaf tissue Ca is not a good indicator of Ca concentrations in these tissues. Leaf tissue Ca was also not correlated with the development of necrosis in the transitional bracts and bracts so it is not a good indicator of the possibility of necrosis development. Paclobutrazol-drench and daminozide reduced necrosis in the bracts, and all growth regulators reduced necrosis in transitional bracts; however, this reduction in necrosis was not necessarily due to an increase in total or extractable Ca concentrations in the transitional bracts or bracts suggesting that another factor is involved in the reduction of necrosis by growth regulators.

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Table 1. Influence of paclobutrazol on color rating, canopy area, bract area, and broken branches.

Paclobutrazol mg/pot ai	Color rating (index)	Canopy area (cm^2)	Bract area (cm^2)	Broken branch (number)
0	3.4[z]	2175	927	2.8
.1	2.8	1136	429	.6
.2	2.0	1085	353	.5
.4	2.1	1096	323	.2
Linear	**	**	***	**
Quadratic	NS	**	***	*
Cubic	NS	NS	NS	NS

*, **, ***, NS No significance (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

[z] Plants were rated on a scale of 1 (least) to 4 (most) red color development in the transitional bracts and bracts.

Table 2. Influence of paclobutrazol on transitional bract and bract necrosis and total and extractable Ca.

Paclobutrazol (mg/pot ai)	Necrosis (%)		Extractable Ca (% dry wt.)		Total Ca (% dry wt.)	
	Transitional bracts	Bracts	Transitional bracts	Bracts	Transitional bracts	Bracts
0	54	38	.084	.116	.224	.204
.1	3	5	.066	.088	.314	.163
.2	1	3	.105	.066	.345	.163
.4	2	2	.109	.053	.327	.144
Linear	***	***	*	**	***	**
Quadratic	***	***	NS	NS	***	NS
Cubic	***	***	NS	NS	NS	NS

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1% (**), or 0.1% (***).

Table 3. Correlation coefficients (r) of total and extractable Ca and tissue for paclobutrazol drench.

	Leaf Ca		Bract Ca		Transitional bract Ca		Necrosis	
	Total	Ext.	Total	Ext.	Total	Ext.	Bract	Transitional bract
Total leaf Ca	.	.72***	.14	.14	.20	.20	.28	.32
Extractable leaf Ca		.	.04	.14	.22	.14	.24	.28
Total bract Ca			.	.42*	.50**	.20	.52**	.62***
Extractable bract Ca				.	.59***	.19	.57***	.57***
Total transitional bract Ca					.	.30	.84***	.86***
Extractable transitional bract Ca						.	.32	.17
Bract necrosis								.82***

*, **, *** Significant at 5% (*), 1% (**), or 0 .1% (***).

Table 4. Influence of paclobutrazol on leaf, transitional bract and bract elemental concentrations.

Paclobutrazol (mg ai/pot)	Dry weight (%) N	P	K	Mg	Dry weight (µg/g) Zn	Fe	Mn
			Leaf				
0	5.5	.831	2.63	.864	40	107	173
0.1	5.3	1.296	2.20	1.030	36	116	203
0.2	5.5	1.360	2.31	.887	36	100	194
0.4	5.3	1.282	2.34	.866	36	101	213
Linear	NS	**	NS	NS	NS	NS	NS
Quadratic	NS	**	**	NS	NS	NS	NS
Cubic	NS	NS	*	*	NS	NS	NS
			Transitional bract				
0	3.9	.588	3.29	.311	44	55	36
0.1	5.6	.748	3.75	.386	44	72	37
0.2	5.7	.799	3.83	.421	48	78	46
0.4	5.5	.799	3.91	.396	43	63	49
Linear	***	***	***	**	NS	NS	***
Quadratic	***	**	**	**	NS	NS	NS
Cubic	**	NS	NS	NS	NS	NS	*
			Bract				
0	3.4	.611	4.06	.315	40	47	41
0.1	4.8	.668	4.15	.265	37	33	33
0.2	4.7	.658	4.21	.295	38	40	33
0.4	4.5	.633	4.23	.290	39	43	32
Linear	***	NS	**	NS	NS	NS	*
Quadratic	***	NS	NS	NS	NS	NS	NS
Cubic	**	NS	NS	NS	NS	NS	NS

NS, *, **, *** Nonsignificant (NS) or significant at 5% (*), 1%, (**), or 0.1% (***).

Table 5. Influence of growth regulators on color rating, canopy area, bract area, and broken branch number.

Treatment	Color rating (index)[z]	Canopy area (cm^2)	Bract area (cm^2)	Broken branches (number)
Control	3.7a[x]	2193a	984a	2.8a
Paclobutrazol-spray	2.4c	1883a	859ab	.9c
Paclobutrazol-drench	1.3d	1009b	418c	.6c
Ancymidol-drench	3.1b	1851a	709b	2.0ab
Chlormequat-drench	2.9b	1793a	780b	1.8b
Daminozide-drench	2.1c	1869a	878ab	.2c

[x] Mean separation in within columns by Duncan's multiple range test, 5% level.
[z] Plants were rated on a scale of 1 (least) to 4 (most) red color development in the transitional bracts and bracts.

Table 6. Effect of growth regulators on necrotic bracts and total and extractable Ca concentrations.

Treatment	Necrotic bracts (%)	Total Ca (% dry wt.)	Extractable Ca (% dry wt.)
Control	14a[z]	.166a	.087a
Paclobutrazol-spray	16a	.154a	.061ab
Paclobutrazol-drench	3b	.250a	.074ab
Ancymidol-drench	15a	.154a	.075ab
Chlormequat-drench	11a	.152a	.065ab
Daminozide-spray	4b	.152a	.060b

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table 7. Influence of growth regulators on transitional bract necrosis and total and extractable Ca concentrations.

Treatment	Necrotic transitional bracts (%)	Total Ca (% dry wt.)	Extractable Ca (% dry wt.)
Control	40a[z]	.577b	.050bc
Paclobutrazol-spray	11c	.502b	.043c
Paclobutrazol-drench	3c	.605b	.071abc
Ancymidol-drench	22b	1.323a	.068abc
Chlormequat-drench	11c	1.285a	.086a
Daminozide-spray	6c	1.295a	.077ab

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table 8. Influence of selected growth regulators on leaf elemental concentrations.

	Dry weight (%)				Dry weight (µg/g)		
Growth regulator	N	P	K	Mg	Zn	Fe	Mn
Control	5.5abc[z]	.849b	2.70a	.779a	40a	118abc	217ab
Paclobutrazol-spray	5.8a	.883b	2.48ab	.825a	42a	121ab	184bc
Paclobutrazol-drench	5.5bc	1.186a	2.29b	.875a	36a	107c	203abc
Ancymidol-drench	5.4c	.983b	2.44ab	.872a	67a	114abc	252a
Chlormequat-drench	5.6abc	1.007ab	2.51ab	.828a	46a	111bc	225ab
Daminozide-spray	5.7ab	1.027ab	2.59a	.838a	41a	123a	145c

[z] Mean separation by Duncan's multiple range test, 5% level.

Table 9. Influence of selected growth regulators on transitional bract elemental concentrations.

Growth regulator	Dry weight (%)				Dry weight (µg/g)		
	N	P	K	Mg	Zn	Fe	Mn
Control	4.2c[z]	.676b	3.27b	.319b	54a	61b	48ab
Paclobutrazol-spray	4.7b	.693b	3.45b	.314b	50a	63b	31c
Paclobutrazol-drench	5.5a	.854a	3.75a	.396a	52a	74a	51a
Ancymidol-drench	4.5b	.649b	3.37b	.324b	42a	49c	38bc
Chlormequat-drench	4.6b	.737b	3.45b	.334b	56a	52bc	38bc
Daminozide-spray	4.7b	.672b	3.51b	.357ab	42a	55bc	31c

[z] Mean separation by Duncan's multiple range test, 5% level.

Table 10. Influence of selected growth regulators on bract elemental concentrations.

	Dry weight (%)				Dry weight (µg/g)		
Growth regulator	N	P	K	Mg	Zn	Fe	Mn
Control	3.5c[z]	.670a	3.31b	.284a	40a	43a	41a
Paclobutrazol-spray	4.3ab	.626a	3.83a	.288a	39a	49a	31cd
Paclobutrazol-drench	4.6a	.707a	3.58ab	.276a	48a	43a	35bc
Ancymidol-drench	3.9bc	.652a	3.40b	.297a	49a	41a	38ab
Chlormequat-drench	3.9bc	.654a	3.52ab	.296a	40a	39a	35bc
Daminozide-spray	4.0bc	.644a	3.60ab	.290a	41a	44a	26d

[z] Mean separation by Duncan's multiple range test, 5% level.

CHAPTER IV

SUMMARY

Poinsettia is an important floricultural crop with a wholesale sales value of 157 million dollars in 1988, which makes it the number one selling flowering pot crop in the United States. Red cultivars, especially 'Gutbier V-14 Glory', are the most popular. However, this cultivar tends to develop bract necrosis, which is a browning and dying-back of the bracts. The bracts are commonly thought of as the poinsettia 'flower'. The occurrence of bract necrosis is more prevalent in poinsettias grown in southern parts of the United States.

The problem of bract necrosis development has been linked to a calcium deficiency. The relationship of bract necrosis development with N-P-K fertilizer, dolomite rates, and gibberellin biosynthesis inhibiting growth regulators was investigated. In the first experiment, three rates of dolomite and two rates of N-P-K fertilizer were used. No growth regulators were applied to the poinsettias. N-P-K level did not affect canopy or bract area, but broken branch number and incidence of bract puckering increased at the higher N-P-K rate. Calcium uptake was inhibited by higher rates of N-P-K fertilizer, and this inhibition of Ca uptake increased greatly between ten and fourteen weeks after

transplanting. The number of necrotic bracts and transitional bracts increased significantly at the higher rate of N-P-K and the lowest rate of dolomite. Extractable Ca was strongly negatively correlated with bract necrosis, but total Ca was only weakly negatively correlated with necrosis.

Calcium concentrations were greater in leaves than in transitional bracts and bracts, and transpiration was much greater in leaves than bracts. Since Ca is transported in the xylem stream, lower transpiration rates would reduce the amount of Ca moving into the bracts and transitional bracts.

In a second study, four soil-applied rates of paclobutrazol, a gibberellin biosynthesis inhibiting growth regulator, were used. Paclobutrazol was negatively correlated with necrosis and positively correlated with total transitional bract Ca. Since paclobutrazol reduced bract necrosis, we decided to determine if other gibberellin biosynthesis inhibiting growth regulators would reduce bract necrosis and increase bract Ca. The growth regulators used were ancymidol, chlormequat, daminozide, and paclobutrazol applied as both a foliar spray and a soil drench. The application of these growth regulators reduced necrosis but the reduction in necrosis was not correlated with increased total or extractable Ca concentrations in the bracts.

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