WATER QUALITY: CALCIUM AND MAGNESIUM FERTILIZATION ON CONTAINER NURSERY PRODUCTION

By

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WATER QUALITY: CALCIUM AND MAGNESIUM

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PRODUCTION

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PREFACE

Responses to water quality and calcium and magnesium fertilization on container plant production were investigated. The thesis consisted of three separate, according to plant species, 3 x 18 factorial experiments utilizing three water qualities and 18 fertilizer treatments (two levels of dolomite, and 16 combinations of $CaCO_3$ and MgO). Water quality significantly affected plant growth, and $CaCO_3$ and MgO combinations were superior to dolomite as a Ca and Mg source.

I express my appreciation to Dr. Stuart Akers for his guidance, support, patience, and time, which was invaluable in this endeavor. I also wish to express my gratitude to Dr. Carl Whitcomb whose guidance and assistance in the study provided me with the background and the help I needed. I am also grateful to Dr. P. L. Claypool for his expertise, time, and help with the statistics of the study. I am obliged to Dr. David Buchanan, Dr. Michael Smith, Pat Ager, and Brenda Simons for their time and help. Finally, I want to thank all those people who have encouraged, supported, and understood me during my years as an OSU graduate student, especially my parents.

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CHAPTER I

INTRODUCTION AND REVIEW OF THE LITERATURE

Container nurseries use large quantities of water for plant production, thus water management plays a key role in the quality of plants produced. Water management involves effective use of water quantity and quality (10). Water quality concerns chemical materials dissolved in water, which may induce toxicity or salinity hazards for plants and enhance or diminish the nutritional status of container media (6,22). This study examined effects of different water qualities on growth and development of three different plant species grown in containers using soiless medium. Since magnesium and calcium are minerals commonly dissolved in irrigation water, the effect of different water qualities on magnesium and calcium fertilization were also examined.

Two of three water qualities used in this study were high enough in chlorine (Cl), sodium (Na), and bicarbonate (HCO_3) to be potential problems. Both Cl and Na are highly soluble and can produce symptoms of marginal and tip burn of older leaves (8,13). Bicarbonate is also very soluble, and readily combines with Na (11). High levels of $NaHCO_3$ can decrease concentrations of Ca and Mg in leaves and increase the absorption of P (7,20). Increased P absorbtion may cause interference with the metabolism of Fe and other micronutrients in the plant (7,20). Preliminary information on water quality effects on plant growth and quality would include nutritional and toxicity problems.

Dolomite is presently the standard source of Ca and Mg for container nursery production. However, Mg deficiencies have been reported with the use of dolomite due to physical and chemical factors which occur after dolomite has been solubilized. Thus, new sources of Ca and Mg are being investigated.

An experiment examining effects of water quality on growth of container grown <u>Nandina domestica</u> was conducted by Tayrien and Whitcomb (19). That study involved three water qualities in combination with two levels of $CaCO_3$, three levels of MgO, and three levels of dolomite (19). Combinations of $CaCO_3$ and MgO proved to be a better source of Ca and Mg than dolomite with all three water qualities (19). Moreover, $CaCO_3$ and MgO have solubilities of 14.0 and 6.2 mg l^{-1}, whereas dolomite has a solubility of 320 mg l^{-1} (22). This means that MgO provides slower release of Mg than dolomite. Therefore, if a combination of $CaCO_3$ and MgO can supply adequate levels of Ca and Mg to plants, then $CaCO_3$ and MgO may be future Ca and Mg sources for container nursery production.

Toxicity and Salinity Problems

Toxicity and salinity problems can result from irrigation with poor quality water. These problems can be important as they reduce growth and salability of container plants. A complete water quality analysis can provide information necessary to determine if problems exist. Some categories for water quality determinations are presented in Table I. Boron (B), sodium (Na), chlorine (Cl), bicarbonates (HCO_3), and carbonates (CO_3) cause toxic or saline effects on plants (5,7,22). However, only those ions which were potential problems in this study will be discussed.

Chloride (Cl^-) is highly soluble and is passively taken up (7,13) Chloride accumulates in leaves to a greater degree than Na (4). Injury from excessive Cl^- concentrations is characterized by reduced leaf growth with leaves having marginal and tip scortch (8). Whitcomb (22) noted that Cl^- concentrations above 40-60 ppm. (mg kg^{-1}) may be harmful to some sensitive foliage crops. In general, Cl^- is not considered a major water quality problem for nurseries, however some areas do have excessive Cl^- levels in their irrigation water.

Sodium readily combines with bicarbonate, chloride, sulfate, and nitrate to increase the soluble salt content of container media and plants (2). Excessive concentrations of Na in plants have been observed to cause leaf burn, leaf drop, and stem dieback (8). Potential injury from Na is generally categorized by the sodium absorption ratio or the

TABLE I

VALUES FOR WATER ANALYSIS DETERMINATIONS

Determination	Expressed as	Good	Good To Injurious	Injurious To Unsatisfactory
Boron				
Whitcomb	mg/kg	0.5	0.5-1.2	1.5-3.0
Gauch	mg/kg	0.5	0.5-2.0	2.0 +
Furuta	mg/kg	0.5	0.5-2.0	4.0 +
Chloride				
Whitcomb	mg/kg		40-60	
Gauch	meq/kg	5	5-10	10 +
Electrical Conductivity				
Furuta	mmho/cm	0.75	0.75-3.0	3.0 +
Total Soluble Salts				
Whitcomb	mg/kg	500	500-1600	1600 +
Sodium, % of Cations				
Gauch	%	60	60-75	75 +
SAR, Sodium Adsorption Ratio				
Furuta		5	5-15	15 +
Whitcomb		10	10-15	15 +

percent of the cations which Na composes (see Table I) (6,7,22). Sodium is considered a major water quality problem (8).

High levels of $CO_3^{=}$ and HCO_3^{-} have been reported to cause chlorosis and deposits of Ca and Mg to build up on leaves (6,22). Generally, the combined levels of Ca^{++} and Mg^{++} should be higher than the combined levels of $CO_3^{=}$ and HCO_3^{-} (11,22). High levels of $NaHCO_3$ (sodium bicarbonate) have been reported to decrease the concentration of Ca and Mg in leaves and increase the absorption of phosphorus which in turn may interfere with Fe metabolism in the plant (20). High HCO_3^{-} causes injury indirectly by disturbing balances and interactions among other ions.

Absorption and Interaction

Transpiration is important in the passive absorption of highly soluble compounds of B, Ca, Cl, K, Mg, Na, and N (NO_3 form) (7,8,12,13). Hot, dry weather causes high transpiration rates. Transpiration can be important relative to Ca and Mg fertilization and to toxicity and salinity damage caused by elements such as B, Cl, and Na.

Active transport of ions requires a metabolic input of energy and is characterized by selective, unidirectional movement of ions (1,3,7,13). A currently accepted theory on active transport encompasses two mechanisms for active ion uptake. Both mechanisms involve an ATP energy source and some sort of a carrier (possibly a protein) (3,14). One mechanism has more selectivity and functions when ions are in relatively high concentrations.

Interactions among ions relative to their active uptake are controlled by the availability and specificity of binding sites on carriers (17). The degree of specificity associated with a binding site determines the degree of competition an ion will encounter (17). For instance, Epstein (3) found that Na, Ca, and Mg could not effectively limit K uptake at low levels of fertility, however at higher levels of fertility, Ca and Na interfered with K uptake. The change in competition between ions as a result of the level of fertility introduces an important consideration for mineral nutrition experiments where a range of elemental concentrations are tested.

Generally, K, Ca, and Mg are considered to compete for the same binding sites (17). In citrus, a K and Ca antagonism was found to be greater than a K and Mg antagonism, however, just the opposite effect occurred on tung (18). So, a species effect can further complicate such interactions. In contrast to antagonistic effects, Viets (21) as shown a promotive effect on absorption on various ions by Ca. Calcium's promotive effect has been attributed to its role in maintaining membrane integrity (7). Calcium has been reported to increase the transmembrane electropotential gradient and to help maintain the selectivity characteristics of membranes (7). Also, an increase in Mg has been shown to promote N absorption and to prevent B toxicity

(16,18). These considerations indicate a balance of elements, in appropriate concentrations, is the key to maximizing plant growth through mineral nutrition.

Calcium and Magnesium Nutrition

Calcium and Magnesium are essential elements in the life cycle of higher plants, and no other element can totally substitute for them. If proper Ca and Mg nutrition is not maintained, deficiency or toxicity symptoms may appear. Furthermore, plant growth and development are affected before toxicity or deficiency symptoms become apparent (22). Since irrigation water often contains relatively high levels of Ca and Mg, the quantity of those elements applied should be calculated and included as part of the total fertilization program.

A calcium deficiency results in the termination of meristematic activity in the tips of roots, leaves, and stems (terminal buds) (1,9,20). Cell expansion in root tips is inhibited to a greater extent than cell division (9). Calcium is relatively immobile, consequently younger leaves exhibit the first leaf symptoms (1,9,22). Younger leaves exhibit chlorosis along their margins. These areas eventually will become necrotic if treatment is ignored (1). Young leaves may develop a hooked tip (1) while older leaves may brittle with the margins curling upward to form a cupped appearance (22).

A deficiency of Mg produces the common symptom of extensive interveinal chlorosis (1). Magnesium is immobile in the plant, consequently the basal leaves are affected first (1,22). A reddening along the margins of the leaves, caused by the development of anthocyanin pigments, is a symptom of magnesium deficiency (1,9). In addition, necrotic spotting may occur with acute deficiency (1,9). Whitcomb (22) reported a slight yellowing on the margin of older leaves occurs before the leaves drop on many woody species.

For comparative purposes, Table II presents 'typical' ranges of concentration for selected elements found in plants, rain water, and tap water (9). Relatively low concentrations found in rain or tap water seem to indicate the water supply would not add appreciable amounts of mineral elements for plant growth. However, during container plant production, container media is exposed to large quantities of water which carry relatively large amounts of dissolved minerals. This observation is supported by recent research which has shown a strong water quality influence on Ca and Mg nutrition for container nursery production (19,23).

Whitcomb et al. (22,23) analyzed four water qualities in conjunction with four dolomite rates and two container media on the growth of geraniums and gardenias. Optimum plant growth was produced when concentrations of Ca and Mg found in the irrigation water were inversely correlated with dolomite rates. High rates of dolomite (4.748 kg m^{-3}) and

TABLE II

TYPICAL CONCENTRATIONS OF MINERAL ELEMENTS

Element	Plant Foliage mg kg^{-1} in dry matter	Rain Water mg kg^{-1}	Tap Water mg kg^{-1}
N	15,000-35,000	0.5-3.0	0.1-2.0
K	15,000-50,000	0.2-8.0	0.4-3.0
Ca	10,000-50,000	0.8-6.0	1.0-110
Mg	2,500-10,000	0.2-1.5	0.2-14
S	1,000-3,000	0.5-25	2.0-20
Na	200-2,000	0.5-18	2.6-34
Cl	100-1,000	2.0-300	8.0-21
B	15-100	---	0.03-1.0

very hard water suppressed plant growth regardless of any combination with the other treatments (22,23).

Dolomite is almost exclusively used as the fertilizer source for calcium and magnesium in container nursery production. Equivalent amounts of calcium and magnesium are released when pure dolomite is dissolved in deionized water. However, use of dolomite (calcium and magnesium carbonates) in containers does not result in the uniform availability of Ca^{++} and Mg^{++} to plants (22). Differences in availability between Ca^{++} and Mg^{++} are a result of physical and chemical reactions which occur after solubilization. Magnesium ions are strongly hydrated (more so than Ca^{++}) and are more subject to leaching (22). These characteristics give Ca^{++} an advantage over Mg^{++} for binding sites on the cation exchange complex (CEC) of the container media, and Ca^{++} has been reported to displace Mg^{++} on the CEC (20,22). Thus, when dolomite dissolves prior to the end of plant production, Ca^{++} is found strongly adsorbed to the CEC and functions as a slow release fertilizer. On the other hand, Mg^{++} is weakly adsorbed and eventually lost by displacement and leaching (22). Therefore a long term, slow release form of Mg^{++} is needed for container production. For this reason, a combination of $CaCO_3$ and MgO were examined as potential substitutes for dolomite. In comparison to dolomite these two chemicals are much less soluble which gives them the potential of being long term, slow release sources of Ca^{++} and Mg^{++}.

CHAPTER II

MATERIALS AND METHODS

Japanese holly, _Ilex crenata_ 'Convexa', and dwarf gardenia, _Gardenia jasminoides_ 'Radicans' were planted from 2.25 inch liners (propagated cuttings) on January 11 and January 18, 1985 respectively. Begonias, _Begonia semperflorens_, were planted from seeded plugs on November 15, 1984. Standard six inch plastic pots were used with a soiless media consisting of a 2-1-1 mix, by volume, of pine bark, peat and sand. This mix was amended with 18-6-12 Osmocote at 7.12 kg m^{-3} and micromax at 0.89 kg m^{-3}. All plants were randomly placed in blocks that were parallel to the polytube heating system which ran under the benches next to the side of the greenhouse.

The experiment was divided into three (according to species) randomized complete block designs with six replications per treatment. Treatments included three water qualities (deionized, tap, and high bicarbonate [HBC]). Table III lists analyses of the three water sources. Eighteen fertilizer treatments (for calcium and magnesium) included dolomite (20% calcium and 10% magnesium) and combinations of calcium carbonate (39% calcium) and magnesium oxide (58% magnesium). Table IV lists the 18 fertilizer treatments. Data was analyzed as three separate (according to species) 3

TABLE III

IRRIGATION WATER REPORT[1]

Determinations[2]	Deionized	Tap	HBC
Bicarbonate	37	262	494
Boron	0.03	0.11	0.35
Calcium	0	42	32
Carbonate	0	0	0
Chloride	11	50	50
Magnesium	1	16	40
Nitrate	0	0	0
Potassium	0	4	3
Sodium	3	27	54
Sulfate	0	16	15
ph	6.5	7.9	8.3
Electric Conductivity mmho/cm	0.06	0.4	0.6
Total Dissolved Solids mg kg	38	269	397
Sodium, % of Cations	11.9	17.4	22.3
Adjusted Sodium Adsorption Ratio	0	1.6	2.7

[1]Samples analyzed by Servi-Tech, Inc., of Dodge City, Kansas on January 22, 1985.

[2]First ten determinations are expressed in mg kg^{-1}

TABLE IV

FERTILIZER TREATMENTS[1]

Calcium Carbonate As Calcium ($kg\ m^{-3}$)	Magnesium Oxide As Magnesium ($kg\ m^{-3}$)	Dolomite ($kg\ m^{-3}$)
0	0	0
0	0.178	0
0	0.356	0
0	0.534	0
0.237	0	0
0.237	0.178	0
0.237	0.356	0
0.237	0.534	0
0.475	0	0
0.475	0.178	0
0.475	0.356	0
0.475	0.534	0
0.712	0	0
0.712	0.178	0
0.712	0.356	0
0.712	0.534	0
0	0	2.374
0	0	4.748

[1]Fertilizers and rates in a horizontal row represent one treatment. Each treatment was used in factorial combination with three water qualities for each of the three species.

x 18 factorials (3 levels of water quality x 18 levels of fertilizers). The 18 levels of fertilizer were 16 combinations of $CaCO_3$ and MgO plus 2 rates of dolomite.

The study was conducted at the Oklahoma State University Nursery Research Station, Stillwater, Oklahoma, in a 28 x 72 ft. quonset style greenhouse having an air-inflated double layered polyethylene covering. Water sources were stored in the greenhouse in one 110 and two 200 gallon polyolefin agri-tanks. Water was applied, as needed, with a plastic beaker which supplied 285 ml per container per watering.

Infestations of spider mites were controlled during the growing period for gardenia and Japanese holly. This was accomplished using a combination of Temik 10% G, Kelthane EC, and Di-Syston 15% G. Gardenia and Japanese holly were topdressed with Osmocote 18-6-12 after three months growth, and Japanese holly plants were pruned to uniform heights after four months growth.

Four types of data were taken during 1985 for each of the three species. Data taken on Begonia after three months of growth consisted of: visual grade, mature leaf visual grade, fresh top weight, and fresh root weight. Gardenia data taken after six months of growth included: Branch count, visual grade, fresh top weight, and fresh root weight. Data from Japanese holly was the same type data as for gardenia and was also taken after six months.

CHAPTER III

RESULTS AND DISCUSSION

Analysis of variance tables (Appendix) indicate water quality significantly affected growth and development of all species tested. Tap or deionized water (depending on criteria measured) produced significantly more growth or better quality begonias than HBC water (Table V). Deionized water produced significantly greater growth and quality for gardenia and Japanese holly, and tap water produced significantly better results than HBC water for Japanese holly in three out of four criteria measured (Table VI). Poor growth and quality of plants irrigated with HBC water could in part be attributed to salinity damage caused by excessive Na and Cl in the water. Tip burn of lower leaves, a symptom characteristic of salinity damage was found on 57% of Japanese holly irrigated with HBC water. In contrast only 4% irrigated with tap water and 0% irrigated with deionized water had symptoms.

Significant water quality * fertilizer interactions occurred with all test plants (Appendix). All water quality * fertilizer interactions are based on a differential number of means which formed the water quality main effect (16 for $CaCO_3$ and MgO combinations and 2 for dolomite rates). Only

TABLE V

EFFECTS OF WATER QUALITY ON THE GROWTH AND QUALITY OF BEGONIA

W[1]	FRESH TOP WEIGHT (grams)	W	VISUAL GRADE *3	W	MATURE LEAF VISUAL *	W	FRESH ROOT WEIGHT (grams)
2	406.91a2	1	7.04a	1	9.14a	2	8.94a
1	392.51b	3	6.51b	2	9.14a	1	8.46ab
3	391.60b	2	6.37b	3	8.65b	3	8.25b

[1]Water quality: (1)deionized, (2) tap, and (3) HBC

[2]Means in a vertical column fol[1]owed by the same letter are not significantly different at LSD 0.0

[3](*) Water quality * fertilizer interaction; data must be further investigated

TABLE VI

EFFECTS OF WATER QUALITY ON THE GROWTH AND QUALITY OF GARDENIA AND JAPANESE HOLLY

Plant Species	W[1]	Fresh Top Weight (grams)	Visual Grade	Branch Count	Fresh Root Weight (grams)
			*[3]	*	*
	1	62.77a[2]	7.62a	93.70a	20.97a
Gardenia	2	58.30b	6.95b	85.52b	17.21b
	3	54.87b	6.82b	81.56b	17.18b
			*		
	1	49.56a	7.35a	21.50a	23.13a
Japanese Holly	2	41.95b	6.19b	20.47b	20.81b
	3	31.86c	4.40c	19.59b	16.45c

[1]Water quality: (1) deionized, (2) tap, and (3) HBC

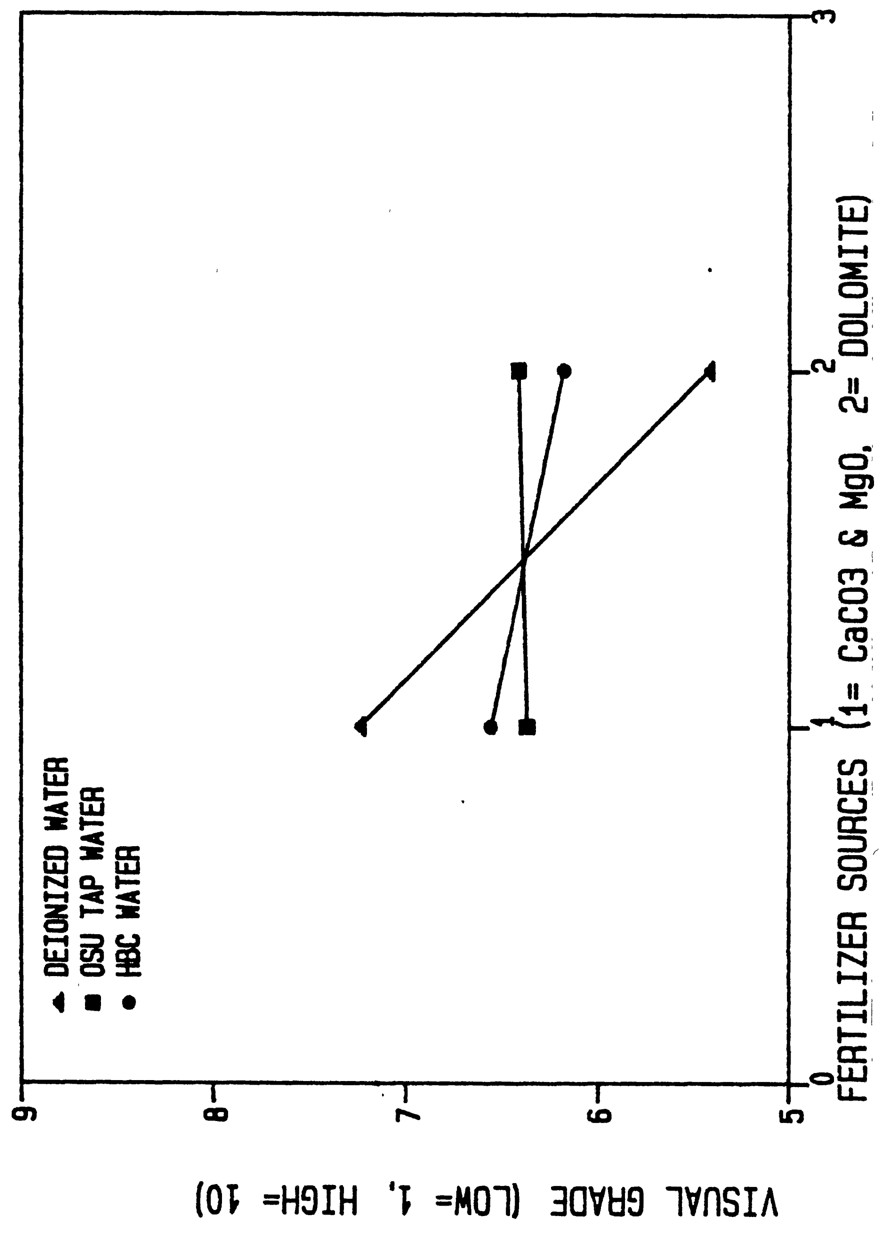
[2]Means in a vertical column followed by the same letter are not significantly different at the 0.05 level.

[3](*) Water quality * fertilizer interaction; data must be further investigated.

when deionized water was used for irrigation was there a large difference in begonia visual grade due to fertilizer source (Figure 1). All fertilizer treatments did not tend to show deionized water was significantly better than tap water and HBC water, but overall deionized water was significantly better. This suggests additional Ca and Mg provided by tap waters modified the effects of fertilizer sources. A decrease in visual grade of mature leaves with HBC water (Figure 2) resulted from chlorosis of basal leaves. In this case, dolomite performed poorly with HBC water, but performed well with deionized and tap waters.

Water quality * fertilizer interactions were found when plant growth and quality data were analyzed for gardenia and Japanese holly (Figures 3-5). The following observations were based on averages, so all fertilizer treatments do not necessarily follow the tendencies stated. For both plants there was a decrease in growth and quality when deionized water was combined with dolomite. However, in some cases, combinations of tap or HBC water with dolomite either did not decrease plant responses to the same degree or caused an opposite response. For example, gardenia visual grade and root weight were only slightly altered when dolomite was used instead of $CaCO_3$ and MgO with HBC water (Figure 3 and 4). The graph showing a water quality * fertilizer interaction with Japanese holly (Figure 6) illustrated a strong water quality effect and reduction in visual grade when different water qualities were combined with dolomite.

Figure 1. Mean begonia visual grade for each water quality at each fertilizer source. Lines connecting means indicate the effect of fertilizer source on visual grade for a specific water quality. Water * fertilizer interaction occurs when the lines are not parallel. This means the differences between water qualities for one fertilizer source should be approximately the same for another source. Note that all water quality * fertilizer interactions are based on a differential number of means which formed the water quality main effect (16 for $CaCO_3$ and MgO rate combinations and 2 for dolomite rates). The interaction indicated by this graph was shown to be significant by analysis of variance (Appendix).



DEIONIZED WATER
OSU TAP WATER
HBC WATER
FERTILIZER SOURCES (1= CaCO3 & MgO, 2= DOLOMITE)
VISUAL GRADE (LOW= 1, HIGH= 10)

Figure 2. Mean mature leaf visual grade of begonias for each water quality at each fertilizer source. Lines connecting means indicate the effect of fertilizer source on mature leaf visual grade (degree of chlorosis) for a specific water quality. The interaction indicated by this graph was shown to be significant by analysis of variance.

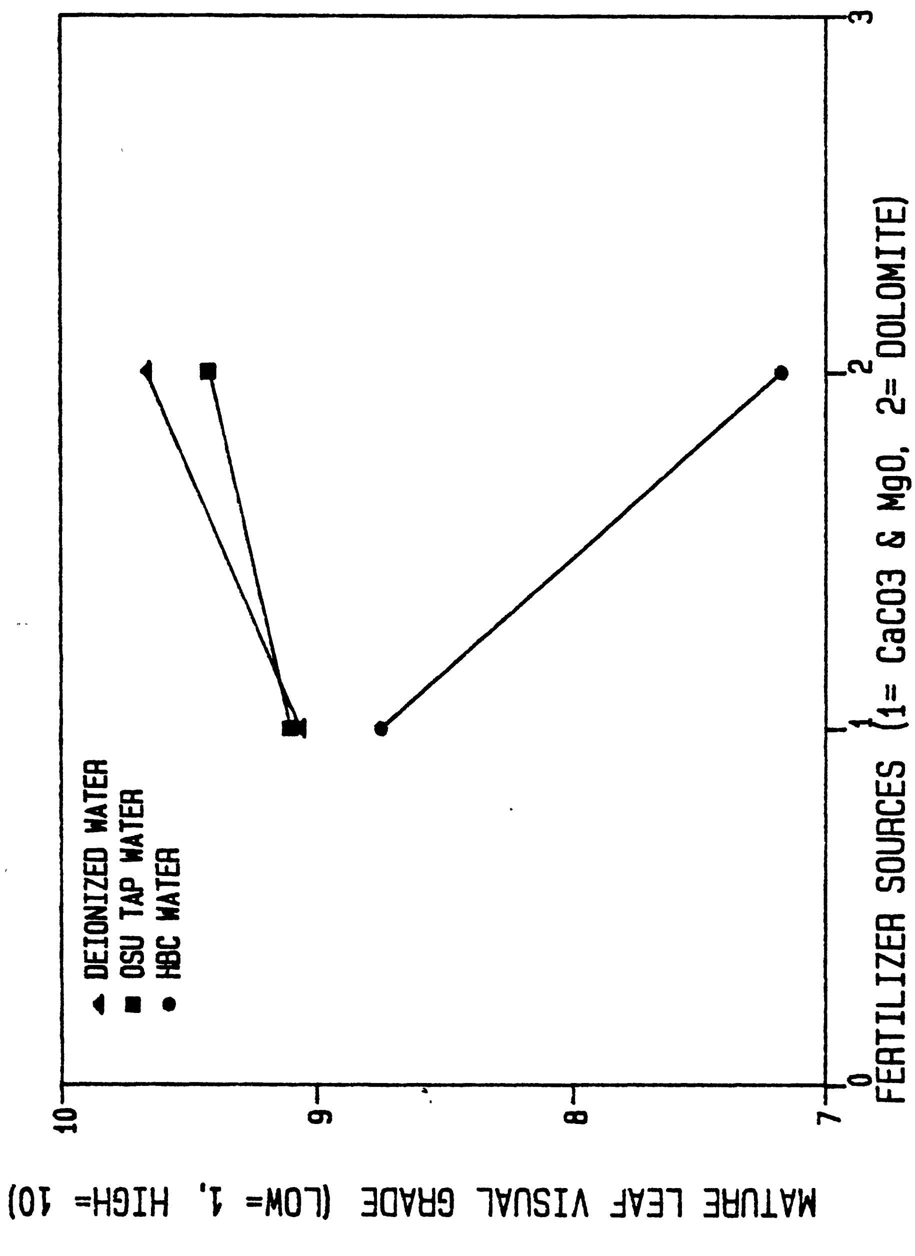

DEIONIZED WATER
OSU TAP WATER
HBC WATER
MATURE LEAF VISUAL GRADE (LOW= 1, HIGH= 10)
10
9
8
7
0
1
2
3
FERTILIZER SOURCES (1= CaCO3 & MgO, 2= DOLOMITE)

Figure 3. Mean gardenia visual grade for each water quality at each fertilizer source. Lines connecting means indicate the effect of fertilizer source on visual grade for a specific water quality. The interaction indicated by this graph was shown to be significant by analysis of variance.

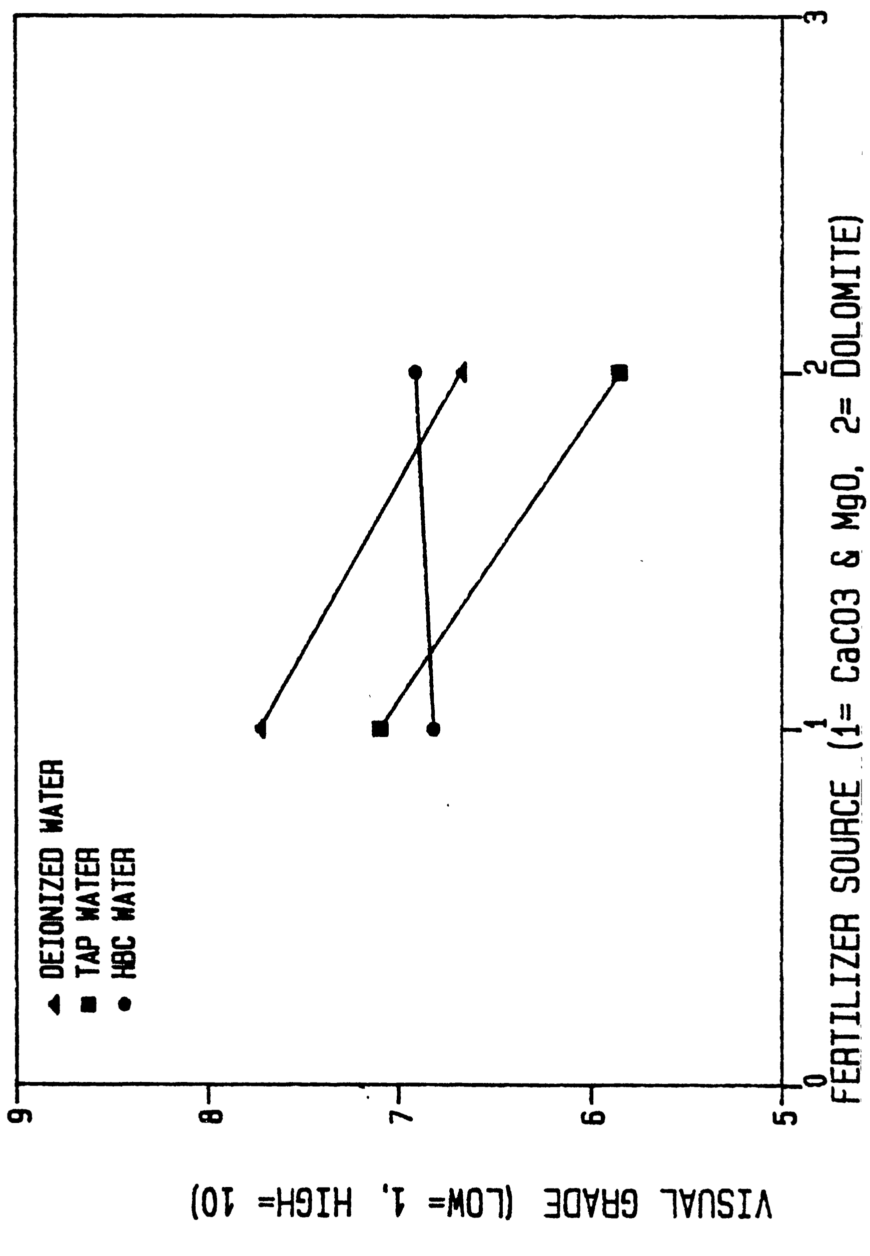

DEIONIZED WATER
TAP WATER
HBC WATER
FERTILIZER SOURCE (1= CaCO3 & MgO, 2= DOLOMITE)
VISUAL GRADE (LOW= 1, HIGH= 10)
0
1
2
3
5
6
7
8
9

Figure 4. Mean gardenia branch count for each water quality at each fertilizer source. Lines connecting means indicate the effect of fertilizer source on visual grade for a specific water quality. The interaction indicated by this graph was shown to be significant by analysis of variance.

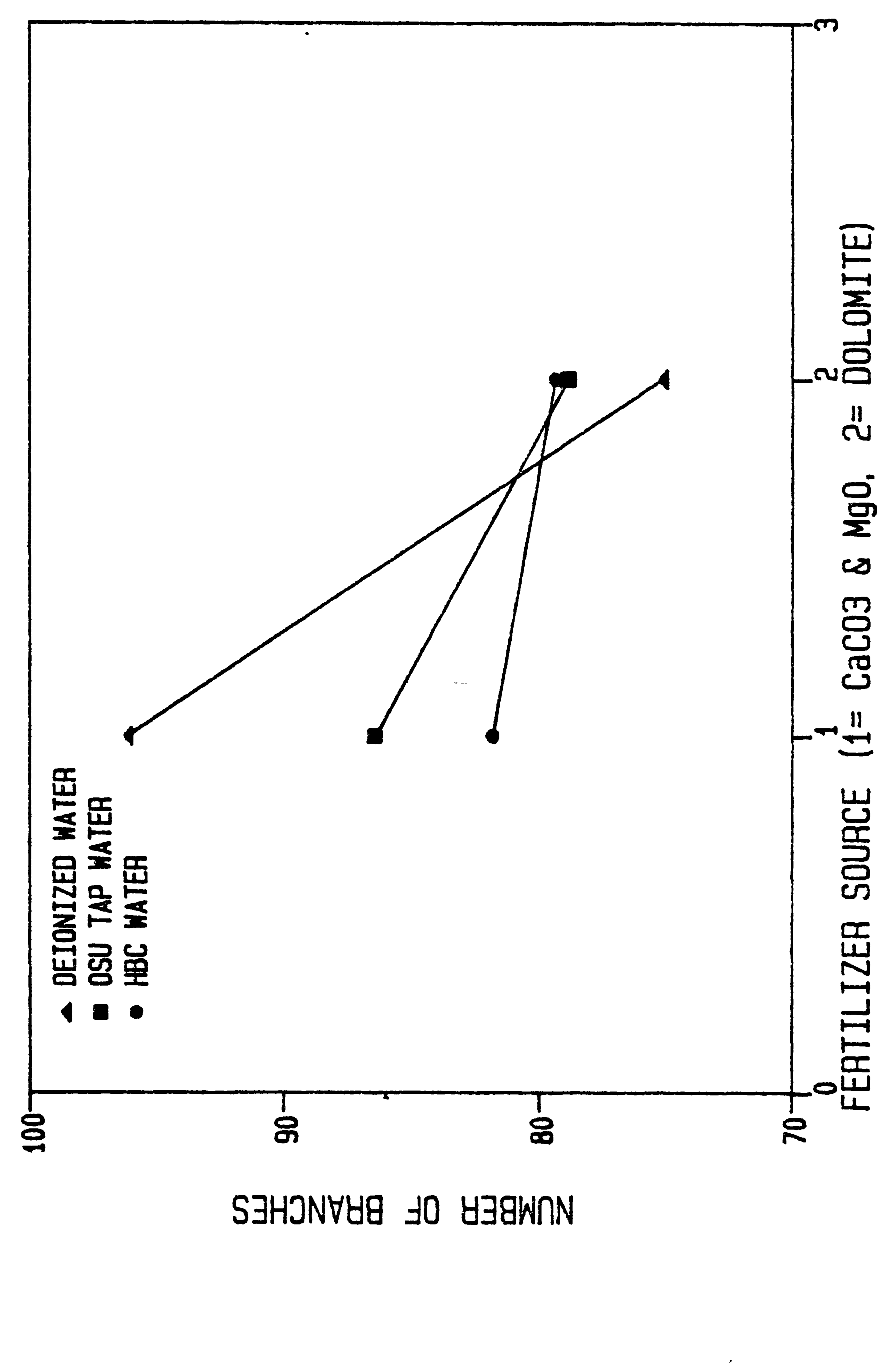
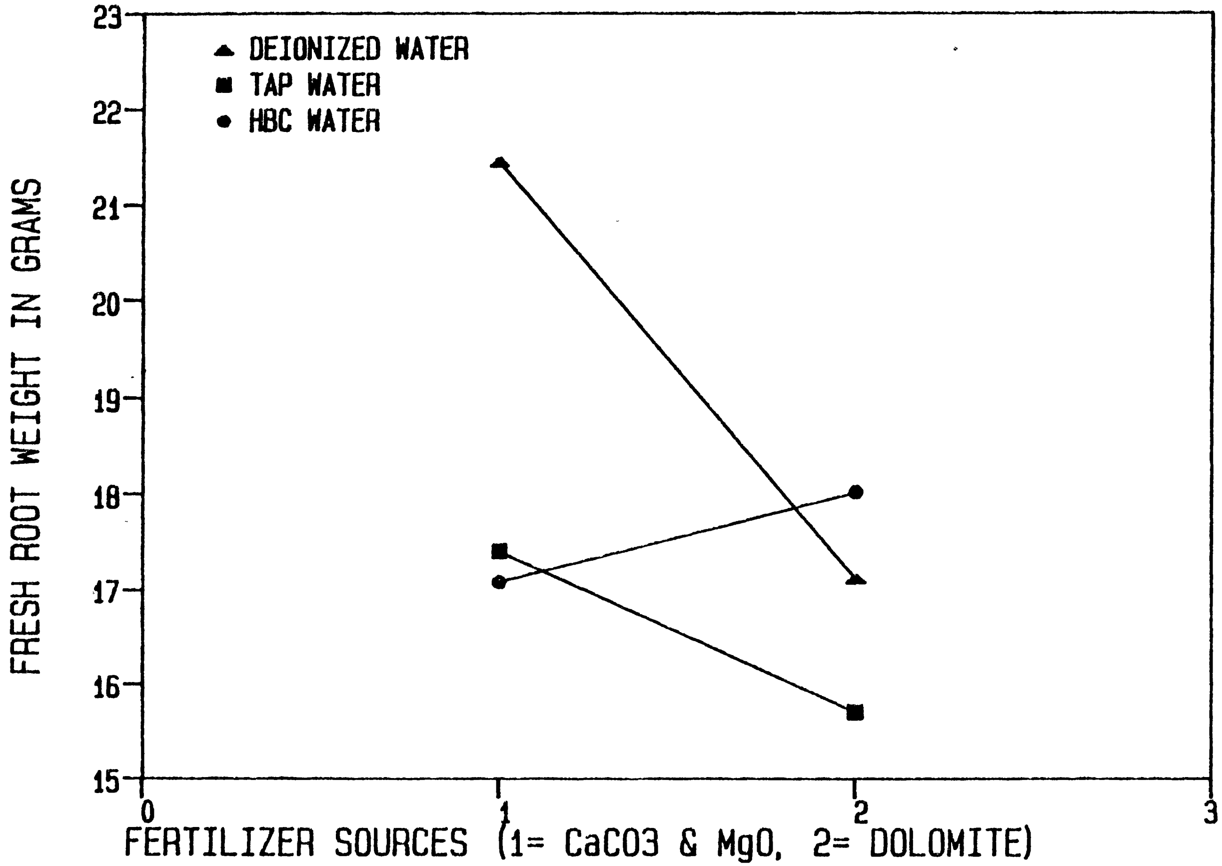
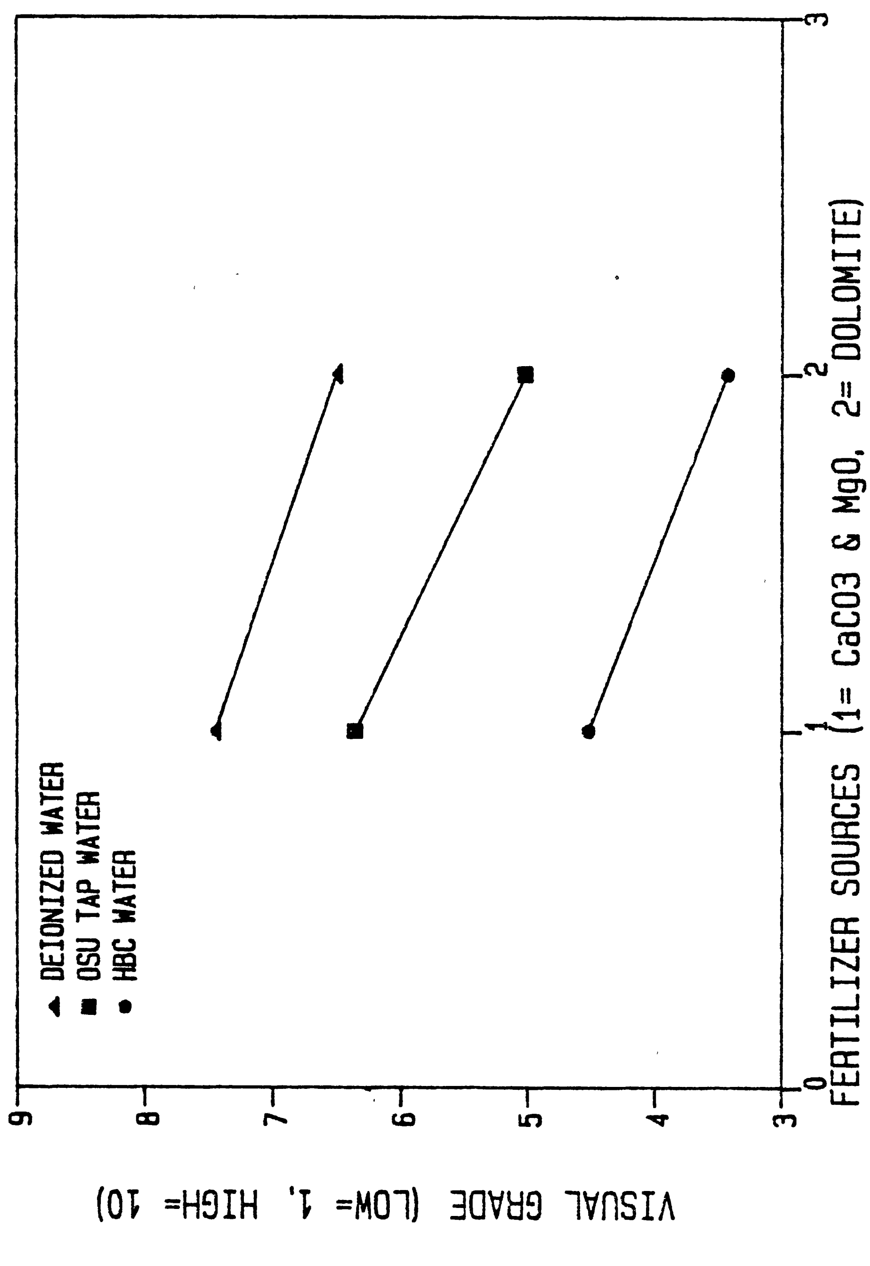

DEIONIZED WATER
OSU TAP WATER
HBC WATER
NUMBER OF BRANCHES
100
90
80
70
0
1
2
3
FERTILIZER SOURCE (1= CaCO3 & MgO, 2= DOLOMITE)

Figure 5. Fresh root weight means of gardenia for each water quality at each fertilizer source. Lines connecting means indicate the effect of fertilizer source on visual grade for as specific water quality. The interaction indicated by this graph was shown to be significant by analysis of variance.



DEIONIZED WATER
TAP WATER
HBC WATER
FRESH ROOT WEIGHT IN GRAMS
23
22
21
20
19
18
17
16
15
0
1
2
3
FERTILIZER SOURCES (1= CaCO3 & MgO, 2= DOLOMITE)

Figure 6. Mean visual grade for Japanese holly for each water quality at each fertilizer source. Line connecting means indicate the effect of fertilizer source on visual grade for a specific water quality. The interaction indicated by this graph was shown to be significant by analysis of variance.


DEIONIZED WATER
OSU TAP WATER
HBC WATER
FERTILIZER SOURCES (1= CaCO3 & MgO, 2= DOLOMITE)
VISUAL GRADE (LOW= 1, HIGH= 10)
0
1
2
3
3
4
5
6
7
8
9

Only visual grade for begonias and gardenias displayed significant water quality * $CaCO_3$ * MgO interaction, thus overall the effect of $CaCO_3$ plus MgO on growth responses was not influenced by water quality. In addition, only Japanese holly showed significant water quality * dolomite interactions. Although there were no significant differences between dolomite rates. Water quality * dolomite interactions for top weight, visual grade, and root weight revealed responses for tap water and dolomite rates were higher for the 2.374 kg m^{-3} rate than the 4.748 kg m^{-3} rate which was an opposite pattern from the responses with the other two water qualities.

All test plants had significantly greater fresh top weight and better visual quality with $CaCO_3$ and MgO combinations (Table VII). There was no significant fertilizer effect on mature leaf visual grade and fresh root weight of begonia or on fresh root weight of gardenia or on Japanese holly branch counts (Table VIII). Based on these results, $CaCO_3$ and MgO were selected as better sources of Ca and Mg than dolomite. However, in most cases addition of $CaCO_3$ or MgO was not effective for begonia production (Tables IX and X). Additional $CaCO_3$ improved growth and quality of gardenia and Japanese holly production (Table XI).

Marginal, mottled chlorosis of terminal leaves was found on 46 of the 324 Japanese hollies examined. Three of these plants were watered with deionized water, 20 with tap water, and 23 with HBC water. Dolomite or high rates of

TABLE VII

EFFECTS OF DIFFERENT FERTILIZERS ON THE GROWTH AND QUALITY OF BEGONIA

BEGONIA Trt.[1]	Fresh Top Weight (grams)	Visual Grade	Mature Leaf Visual Grade	Fresh Root Weight (grams)
C & M	399.46a	6.72a	8.97a	8.52a
Dolo.	377.36b	6.00b	8.75a	8.75a

[1]Treatments: C & M equals $CaCO^3$ & MgO rate combinations, and Dolo. equals dolomite rates.

TABLE VIII

EFFECTS OF DIFFERENT FERTILIZERS ON THE GROWTH AND QUALITY OF GARDENIA AND JAPANESE HOLLY

		Gardenia and Japanese Holly			
Plant Species	Trt.	Fresh Top Weight (grams)	Visual Grade	Branch Count	Fresh Root Weight (grams)
Gardenia	C & M	59.27a	7.21a	88.08a	18.64a
	Dolo	53.68b	6.48b	77.71b	16.95a
&					
Japanese Holly	C & M	41.78a	6.11a	20.67a	20.43a
	Dolo.	35.84b	4.98b	19.37a	17.75b

[1]Treatments: C & M equals $CaCO^3$ & MgO rate combinations, and Dolo. equals dolomite rates.

TABLE IX

EFFECTS OF CALCIUM CARBONATE ON GROWTH AND QUALITY OF BEGONIA

R Ca^1	Fresh Top Weight (grams)	R	Visual Grade	R	Mature Leaf Visual Grade	R	Fresh Root Weight (grams)
1	410.88a	1	7.17a	2	9.33a	1	9.03a
3	401.08a	3	7.11a	4	9.07ab	2	8.5ab
4	395.42a	4	6.67a	1	8.92ab	3	8.35b
2	390.47a	2	5.93b	3	8.47b	4	8.22b

[1]Rates expressed as kg m^{-3} of calcium from calcium carbonate. Rate 1 = 0, 2 = 0.237, 3 = 0.475, and 4 = 0.712. These rates are equivalent to 0, 0.4, 0.8, and 1.2 lbs yd.

TABLE X

EFFECTS OF MAGNESIUM OXIDE ON GROWTH AND QUALITY OF BEGONIA

R Mg[1]	Fresh Top Weight (grams)	R	Visual Grade	R	Mature Leaf Visual Grade	R	Fresh Root Weight (grams)
1	423.96a[2]	1	7.38a	2	9.47a	1	9.04a
2	413.01a	2	7.07ab	1	9.09ab	2	8.76ab
3	388.72b	3	6.27b	4	8.83bc	3	8.29b
4	372.15b	4	5.71c	3	8.49c	4	8.10b

[1]Rates expressed as kg m^{-3} magnesium from magnesium oxide. Rate 1 = 0.0, 2 = 0.178, 3 = 0.356, and rate 4 = 0.534. These rates are equivalent to 0, 0.3, 0.6, and 0.9 lbs yd^{-3}.

TABLE XI

EFFECTS OF CALCIUM CARBONATE ON GROWTH AND QUALITY OF GARDENIA AND JAPANESE HOLLY

Plant Species	R[1]	Fresh Top Weight (grams)	R	Visual Grade	R	Branch Count	R	Fresh Root Weight (grams)
Gardenia	3	62.92a[2]	3	7.47a	3	93.10a	3	20.69a
	4	60.26ab	4	7.42a	4	91.31a	4	19.44ab
	2	57.39b	2	7.13ab	1	84.13b	2	17.64bc
	1	56.52b	1	6.83b	2	83.80b	1	16.79c
Japanese Holly	3	43.21a	3	6.47a	3	21.53a	3	21.83a
	2	42.10a	2	6.19ab	4	20.85a	4	20.14a
	1	41.51a	1	5.94b	2	20.38a	2	20.13a
	4	40.32a	4	5.82b	1	19.92a	1	19.61a

[1]Rate expressed as kg m^{-3} of calcium from calcium carbonate. Rate 1 = 0, 2 = 0.237, 3 = 0.475, and 4 = 0.712. These rates are equivalent to 0, 0.4 0.8, and 1.2 lbs yd^{-3}.

[2]Means in a vertical column followed by the same letter are not significantly different at the 0.05 level.

TABLE XII

EFFECTS OF MAGNESIUM OXIDE ON GROWTH AND QUALITY OF GARDENIA AND JAPANESE HOLLY

Plant Species	R[1]	Fresh Top Weight (grams)	R	Visual Grade	R	Branch Count	R	Fresh Root Weight (grams)
Gardenia	1	60.46a[2]	1	7.36a	1	92.33a	1	20.31a
	2	59.69a	2	7.23a	2	88.74a	2	19.16ab
	4	59.07a	3	7.14a	3	85.67a	4	17.89bc
	3	57.87a	4	7.12a	4	85.58a	3	17.21c
Japanese Holly	1	43.29a	1	6.44a	2	21.33a	1	20.89a
	2	43.25a	2	6.32a	1	21.28a	4	20.83a
	4	42.07a	4	6.11a	3	20.25a	2	20.43a
	3	38.53b	3	5.56b	4	19.81a	3	19.56a

[1]Rates expressed as kg m^{-3} of magnesium from magnesium oxide. Rate 1 = 0, 2 = 0.178, 3 = 0.356, and 4 = 0.534. These are equivalent to 0, 0.3, 0.6, and 0.9 lbs yd^{-3}.

[2]Means in a vertical column followed by the same letter are not significantly different at the 0.05 level.

$CaCO_3$ and MgO were fertilizers for most of the affected plants in the deionized and tap water categories. However, there was no consistent pattern with fertilizer treatments for plants that were irrigated with HBC water.

Fertilizer treatments selected by main effects for each test species were as follows: begonia - $CaCO_3$ = 0 kg m^{-1} and MgO = 0 kg m^{-1}, gardenia - $CaCO_3$ = 0.475 kg m^{-1} and MgO = 0 kg m^{-1} and MgO = 0 kg m^{-1}.

Representative interactions between $CaCO_3$ and MgO on plant growth and quality are presented by Figures 7 and 8. Because of such interactions, no specific rate combinations for the two fertilizers could be established.

When a water quality component is considered with fertilizer treatments, a total of 54 treatment combinations exist (18 fertilizer combinations x 3 water qualitities). A ranking of the top fifteen treatment combinations for gardenia illustrates the lack of superiority of any one treatment (Table XIII). The top treatment (C3M1 W1), based on main effect selections, was not in the top fifteen treatments for fresh top weight, visual grade, or branch count, and was ranked 14th for fresh root weight.

Figure 7. Mean begonia visual grade for all eighteen fertilizer treatments. Each group of four, connected by lines, represents four levels of MgO at one level of $CaCO_3$. If a pattern formed by a group of four differs from another group's pattern to a minimum degree, then an interaction between the two fertilizers ($CaCO_3$ and MgO) has occurred. The interaction indicated by this graph was shown to be significant by analysis of variance. Treatment combinations listed below.

Treatment Number	$CaCO_3$ (kg m^{-3})	MgO (kg m^{-3})	Dolomite (kg m^3)
1	0	0	0
2	0	0.178	0
3	0	0.356	0
4	0	0.534	0
5	0.237	0	0
6	0.237	0.178	0
7	0.237	0.356	0
8	0.237	0.534	0
9	0.475	0	0
10	0.475	0.178	0
11	0.475	0.356	0
12	0.475	0.534	0
13	0.712	0	0
14	0.712	0.178	0
15	0.712	0.356	0
16	0.712	0.534	0
17	0	0	2.374
18	0	0	4.748

[1]Fertilizers and rates in a horizontal row represent one treatment. Each treatment was used in a factorial combina tion with three water qualities for each of the three species.

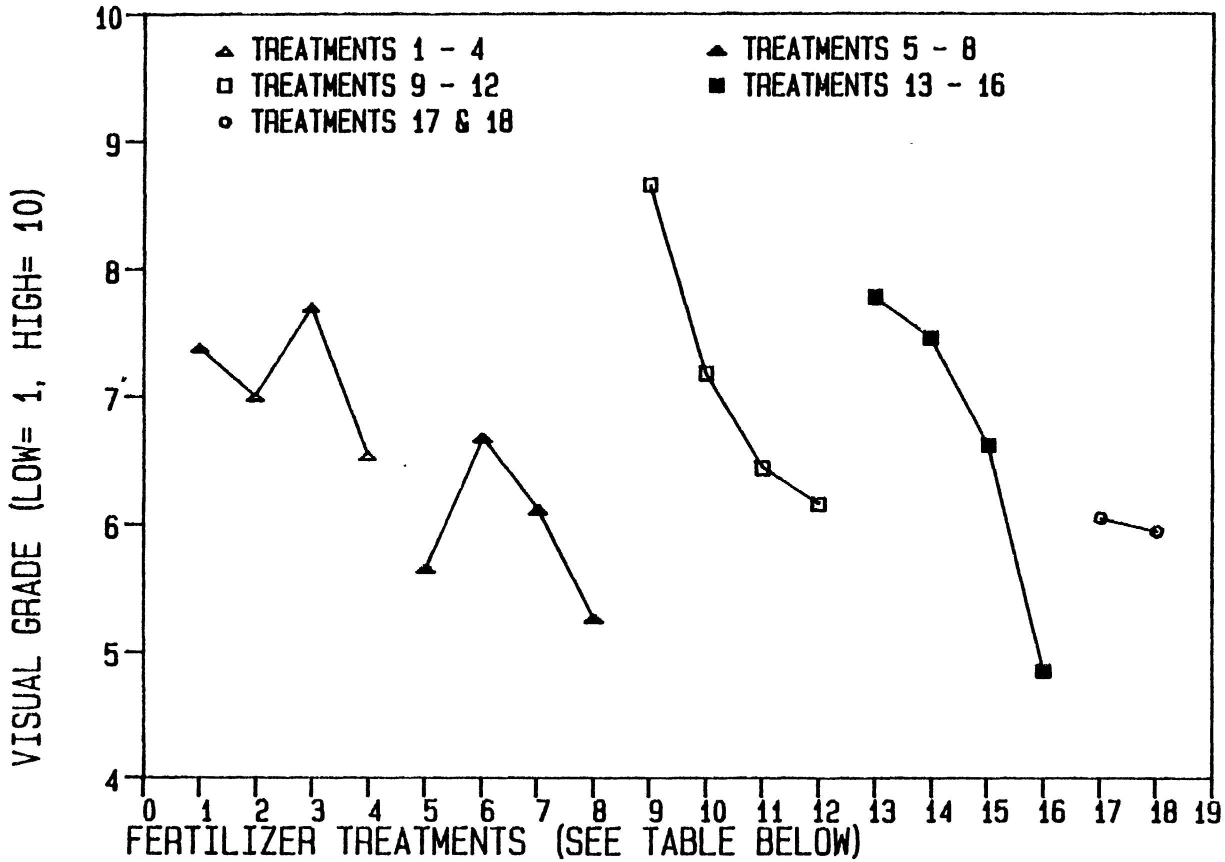

TREATMENTS 1 - 4
TREATMENTS 5 - 8
TREATMENTS 9 - 12
TREATMENTS 13 - 16
TREATMENTS 17 & 18
VISUAL GRADE (LOW= 1, HIGH= 10)
FERTILIZER TREATMENTS (SEE TABLE BELOW)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19

Figure 8. Fresh top weight means of gardenia for all 18 fertilizer treatments. Each group of four, connected by lines, represents four levels of MgO at one level of $CaCO_3$ The interaction indicated by this graph was shown to be significant by analysis of variance. Treatment combinations listed below.

Treatment number	$CaCO_3$ ($kg\ m^{-3}$)	MgO ($kg\ m^{-3}$)	Dolomite ($kg\ m^{-3}$)
1	0	0	0
2	0	0.178	0
3	0	0.356	0
4	0	0.534	0
5	0.237	0	0
6	0.237	0.178	0
7	0.237	0.356	0
8	0.237	0.534	0
9	0.475	0	0
10	0.475	0.178	0
11	0.475	0.356	0
12	0.475	0.534	0
13	0.712	0	0
14	0.712	0.178	0
15	0.712	0.356	0
16	0.712	0.534	0
17	0	0	2.374
18	0	0	4.748

[1]Fertilizers and rates in a horizontal row represent one treatment. Each treatment was used in a factorial combina tion with three water qualities for each of the three species.

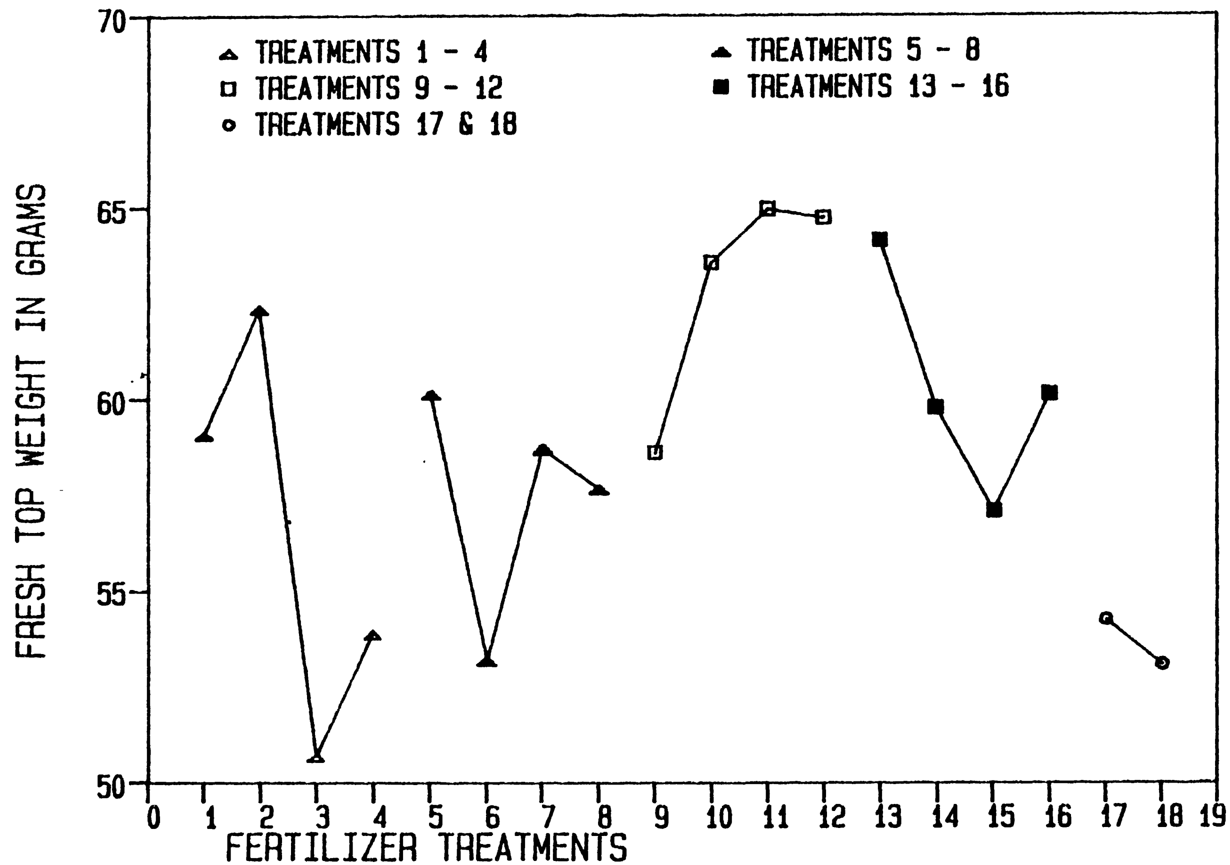

TREATMENTS 1 - 4
TREATMENTS 5 - 8
TREATMENTS 9 - 12
TREATMENTS 13 - 16
TREATMENTS 17 & 18
FRESH TOP WEIGHT IN GRAMS
50
55
60
65
70
0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19
FERTILIZER TREATMENTS

TABLE XIII

RANK OF TOP FIFTEEN TREATMENT COMBINATIONS
FOR GARDENIA

Nutr[1]	W[2]	Fresh Top Weight gms	Nutr	W	Visual Grade	Nutr	W	Branch Count	Nutr	W	Fresh Root Weight gms
C2M3	1	71.00	C4M3	1	8.60	C2M3	1	110.50	C3M2	1	32.20
C3M4	3	70.00	C1M1	1	8.50	C1M1	1	110.17	C4M1	1	29.17
C4M1	2	69.17	C3M2	1	8.40	C4M2	1	105.33	C4M2	1	26.17
C1M2	2	69.00	C3M4	3	8.33	C3M2	1	102.80	C3M4	3	25.50
C3M2	1	68.80	C4M4	1	8.20	C2M1	1	102.67	C1M1	1	24.83
C4M1	1	68.00	C2M3	1	8.00	C3M3	1	102.33	C4M1	2	24.33
C3M3	2	67.33	C1M4	1	8.00	C4M1	2	102.00	C2M1	1	22.83
C2M1	1	67.17	C3M3	1	8.00	C4M1	1	100.50	C3M3	3	21.75
C4M2	1	67.00	C1M2	2	8.00	C3M1	3	99.83	C3M2	3	21.17
C4M3	1	66.67	C1M2	1	7.83	C1M1	2	99.00	C3M3	1	20.50
C3M4	2	66.50	C2M1	1	7.83	C1M2	1	98.00	C4M3	1	20.50
C3M3	1	66.00	C4M1	1	7.83	C3M4	3	97.50	C2M1	2	20.50
C1M2	1	65.00	C4M2	1	7.83	C4M4	1	97.40	C1M4	1	19.67
C1M1	1	64.83	C3M3	2	7.83	C4M2	2	97.00	C3M1	1	19.50
C1M4	1	64.17	C3M4	2	7.83	C1M4	1	95.00	C2M4	3	19.50

[1]Nutrients: C = $CaCO_3$ (1 = 0, 2 = 0.237, 3 = 0.475, and 4 = 0.712 kg m^{-3}),
M = MgO (1 = 0, 2 = 0.178, 3 = 0.356, and 4 = 0.534 kg m^{-3})
[2]W = Water quality (1 = deionized, 2 = tap, and 3 = HBC).

CHAPTER IV

SUMMARY AND CONCLUSIONS

Water quality significantly affected container plant growth. The responses of Japanese holly to the three water qualities were significantly separated. For that species, deionized water was the best treatment followed by the tap and HBC water respectively. In addition, salinity injury was found with the use of HBC water on Japanese holly. Water quality * fertilizer interactions were present for both begonia and gardenia. These interactions suggested that additional Ca and Mg provided by tap and HBC waters modified the effects of fertilizer sources. Thus, water quality was shown to influence Ca and Mg fertilization.

Calcium carbonate and magnesium oxide were significantly better sources of Ca and Mg than dolomite. However, interactions between $CaCO_3$ and MgO compounded by water quality effects made a determination on specific rate combinations uncertain. Therefore, it is recommended that each nursery test different combinations of $CaCO_3$ and MgO with their water supply on nursery crops of their interest.

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APPENDIX

BEGONIA ANALYSIS OF VARIANCE

Source	TOP WEIGHT DF	TOP WEIGHT F Value	TOP WEIGHT PR > F	VISUAL GRADE DF	VISUAL GRADE F Value	VISUAL GRADE PR >	MATURE LEAF VISUAL GRADE DF	MATURE LEAF VISUAL GRADE F Value	MATURE LEAF VISUAL GRADE PR > F	ROOT WEIGHT DF	ROOT WEIGHT F VALUE	ROOT WEIGHT PR > F
Replication	5	86.47	0.0001 *[a]	5	1.17	0.3230	5	4.64	0.0005 *	5	49.21	0.0001 *
Water Quality	2	3.07	0.0481 *	2	6.31	0.0021 *	2	3.87	0.0221 *	2	3.80	0.0235 *
Fertilizer	17	4.22	< .005 *	17	7.82	< .005 *	17	1.97	0.0132 *	17	2.19	0.0050 *
Dolomite	1	2.44	0.1198	1	0.04	0.8483	1	0.51	0.4797	1	0.01	0.9331
M & C	15	4.22	< .005 *	15	8.43	< .005 *	15	2.15	< 0.01 *	15	2.45	< 0.005*
$CaCO_3$	3	2.13	0.0971	3	11.51	0.0001 *	3	2.46	0.062 @[b]	3	2.61	0.0512 @
MgO	3	15.21	0.0001 *	3	18.52	0.0001 *	3	4.21	0.0065 *	3	3.64	0.0136 *
[C * M][1]	9	1.26	0.2609	9	4.40	0.0001 *	9	1.48	0.1550	9	2.03	0.0368 *
Dolo. vs M & C	1	6.02	0.0148 *	1	7.82	< .01 *	1	0.52	> 0.1	1	0.47	> 0.1
[Water * Fert.]	34	1.06	0.3871 *	34	2.80	0.0001 *	34	1.53	0.0362 *	34	0.84	0.7212
Error	265	EMS-- 2595.0137 C.V.-- 12.8314		265	EMS-- 2.1161 C.V.-- 21.9116		265	EMS-- 3.0677 C.V.-- 85.3349		265	EMS-- 3.4908 C.V.-- 21.8537	

[a]Significantly different (*), alpha = 0.05

[b]Nearly significant (@)

[1]Brackets [ ] denote interactions.

GARDENIA ANALYSIS OF VARIANCE

Source	TOP WEIGHT DF	TOP WEIGHT F Value	TOP WEIGHT PR > F	VISUAL GRADE DF	VISUAL GRADE F Value	VISUAL GRADE PR > F	BRANCH COUNT DF	BRANCH COUNT F Value	BRANCH COUNT PR > F	ROOT WEIGHT DF	ROOT WEIGHT F Value	ROOT WEIGHT PR > F
Replication	5	1.09	0.3642	5	2.19	0.0547 @[b]	5	2.81	0.0171 *	5	0.97	0.4388
Water Quality	2	10.12	0.0001 *[a]	2	8.77	0.0002 *	2	9.70	0.0001 *	2	15.13	0.0001 *
Fertilizers	17	2.01	0.0113 *	17	1.55	0.0781	17	2.28	0.0033 *	17	3.33	0.0001 *
Dolomite	1	0.07	0.7998	1	0.25	0.6216	1	0.72	0.4039	1	0.19	0.6684
M & C	15	1.87	< 0.025*	15	1.23	> 0.1	15	1.99	< 0.025*	15	3.59	< 0.005*
$CaCO_3$	3	3.71	0.0123 *	3	2.82	0.0393 *	3	3.88	0.0099 *	3	6.27	0.0005 *
MgO	3	0.52	0.6711	3	0.40	0.7588	3	1.70	0.1658	3	3.85	0.0103 *
[C * M][1]	9	1.76	0.0760 @	9	1.02	0.4278	9	1.43	0.1744	9	2.35	0.0151 *
Dolo. vs M & C	1	5.99	< 0.025*	1	7.60	< 0.01 *	1	8.07	< 0.005*	1	2.72	0.1
[Water * Fert.]	34	1.16	0.2533	34	1.44	0.0624 @	34	1.53	0.0351 *	34	1.60	0.0235 *
Error	265	EMS-- 167.3217 C.V.-- 22.0552		265	EMS-- 2.2645 C.V.-- 21.1085		265	EMS-- 426.6477 C.V.-- 23.7612		265	EMS-- 33.9258 C.V.-- 31.5632	

[a]Significantly different (*), alpha = 0.05.

[b]Nearly significant (@).

[1]Brackets [ ] denote interactions.

JAPANESE HOLLY ANALYSIS OF VARIANCE

	TOP WEIGHT			VISUAL GRADE			BRANCH COUNT			ROOT WEIGHT		
Source	DF	F Value	PR > F	DF	F Value	PR > F	DF	F Value	PR > F	DF	F Value	PR > F
Replication	5	8.00	0.0001 *[a]	5	4.38	0.0008 *	5	9.65	0.0001 *	5	11.82	0.0001 *
Water Quality	2	91.51	0.0001 *	2	135.64	0.0001 *	2	4.14	0.0169 *	2	36.51	0.0001 *
Fertilizers	17	2.02	0.0109 *	17	3.56	0.0001 *	17	1.87	0.0210 *	17	1.23	0.2430
Dolomite	1	0.31	0.5852	1	0.76	0.3929	1	0.23	0.6390	1	0.02	0.8807
M & C	15	1.46	> 0.1	15	2.43	< 0.005*	15	1.96	< 0.025*	15	0.94	> 0.10
$CaCO_3$	3	1.09	0.3552	3	3.48	0.0167 *	3	1.36	0.2538	3	1.98	0.1153
MgO	3	3.78	0.0112 *	3	6.44	0.0004 *	3	1.66	0.1744	3	0.80	0.4970
[C * M][1]	9	0.74	0.6780	9	0.82	0.5953	9	2.08	0.0318 *	9	0.63	0.7716
Dolo. vs M & C	1	12.19	< 0.005*	1	23.44	< 0.005*	1	2.30	> 0.1	1	6.75	< 0.01 *
[Water * Fert.]	34	1.13	0.2904	34	1.48	0.0487 *	34	0.72	0.8706	34	1.00	0.4790
Error	265	EMS-- 92.9859 C.V.-- 23.4487		265	EMS-- 1.7637 C.V.-- 22.2026		265	EMS-- 23.7522 C.V.-- 23.7488		265	EMS-- 33.9727 C.V.-- 28.9554	

[a]Significantly different (*), alpha = 0.05.

[1]Brackets [ ] denote interactions.

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