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# The effect of calcium or silicon on potted miniature roses or poinsettias

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# THE EFFECT OF CALCIUM OR SILICON ON POTTED MINIATURE ROSES OR POINSETTIAS

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## ABSTRACT

Poinsettias are the number one flowering potted plant in the U.S. and it is the most popular Christmas plant sold. Miniature roses have become an increasingly important flowering potted plant. However, growers must overcome production problems to produce a quality finished plant and avoid disease incidence. Supplemental calcium has been proven to increase the amount of good quality flowers and increase disease resistance. Silicon can increase plant growth and crop quality and decrease disease pressures. Two experiments were conducted on miniature rose cultivars 'Sonya' and 'Alto.' The objective of experiment 1 was to determine the effects of preharvest application of calcium nitrate [Ca $(NO_3)_2$], Foli-Cal® (chelated Ca), chelate, Maniplex-Traffic® (chelated Si) or Sil-Matrix® (potassium silicate) applied as a spray or a drench on growth and development. Spray application of Foli-Cal® increased plant growth as indicated by a greater dry weight compared to all other treatment applications. Drench application of Foli-Cal® increased finished quality as indicated by greater flowering, height, width, leaf area, and dry weight.

The objective of experiment 2 was to determine the efficacy of weekly spray applications of biofungicides Sil-Matrix™ (potassium silicate), Fosphite® (phosphoric acid), Kaligreen® (potassium bicarbonate), and Manniplex Traffic® (chelated Si) on powdery mildew on miniature roses compared to a standard fungicide Heritage® (azoxystrobin). Miniature roses treated with Kaligreen®, Heritage® alternated with Foshpite®, or Heritage® alternated with Kaligreen® were not as susceptible to powdery mildew. For the second study of powdery mildew, Kaligreen gave the best control of powdery mildew for cultivar 'Sonja' but treatments for 'Alto' showed no significance.

# CHAPTER 1. INTRODUCTION

Floriculture is a very important part of the ornamental industry. Nursery and floriculture crops have been one of the fastest growing agricultural sectors in the U.S. for the past decade, contributing 16 billion dollars in U.S. horticulture sales in 2005. More than a quarter of the U.S. floriculture sales are from potted flowering plants and foliage plants. The USDA defines floriculture as the cultivation of ornamental and flowering plants. Floriculture crops include flowering plants, foliage plants, bedding and garden plants, propagative material, cut flowers, and cut cultivated greens (Jerardo, 2006).

## 1.1 CALCIUM

Calcium (Ca) is an important element that is found in 3% of the earth's crust (Campbell, 1983). It is essential to living organisms and to plant growth and development. Some of these benefits include stronger cell walls (Anghileri, 1982), increased postharvest life of flowering plants, and increased disease resistance (Starkey and Pederson, 1997). Ca is a major component in the cell wall of most plants in the form of Ca pectate. It is a relatively immobile element, but can become more mobile as the plant ages (Anghileri, 1982). It is essential to plant growth. Plants must have concentrations in the range of 0.1 to 1 mM Ca (Campbell, 1983). Plants that are deficient in Ca may have pale leaf margins and burned leaf edges among other symptoms (Schraer, 1970). However, a plant showing signs of Ca deficiency may be due to uneven distribution of Ca through the plant instead of an overall Ca deficiency (Anghileri, 1982).

## 1.2 SILICON

One of the most abundant elements on earth is silicon (Si) (Belanger et al., 1995) and this element exists as silica (silicon dioxide) or silicates in nature. Sixty percent of the earth's crust is silicon dioxide. Silicates are compounds that are combined with various metals. Silicon has been

shown to benefit agriculture and horticulture by increased plant growth and crop quality, stimulate photosynthesis (Ma and Takahashi, 2002), and protect against fungal diseases such as powdery mildew (Belanger et al., 1995). It is considered an essential element in Japan because it benefits rice in many ways. Some of the benefits include improved degraded paddy fields, increased resistance to blast disease, and alleviated damage caused by brown spot (Ma and Takahashi, 2002).

Calcium and silicon have been shown to benefit plants in many experiments. The primary objective of this experiment was to determine the efficacy of preharvest application of calcium or silicon as a spray or a drench on growth, flowering, and development. The treatments applied were calcium nitrate [Ca $(NO_3)_2$], Foli-Cal® (chelated Ca), chelate, Maniplex-Traffic® (chelated Si) or Sil-Matrix® (potassium silicate) applied at 0, 125, 250, or 500 ppm.

## 1.3 POWDERY MILDEW

Powdery mildew (caused by *Spaerotheca pannosa* var. *rosae*) is one of the primary diseases that affect roses. It is a fungal disease that can be seen on leaves, young shoots and stems, buds, and flowers. It is characterized by a grayish or white powdery growth on the plant (Eken, 2005). Powdery mildew causes leaf curling, yellowing, premature defoliation, and in some cases, death of the plant. Absence of free circulation of air, hot weather, and sunny days followed by heavy dews at night enhance infection(Pemberton, 1908). Powdery mildew has been successfully managed mainly by synthetic, chemical fungicides. However, there has been an increased interest in biofungicides to manage powdery mildew (Eken, 2005) that are less toxic and more environmentally friendly.

Experiments were designed to determine the efficacy of weekly spray applications of biopesticides Sil-Matrix™ (potassium silicate), Fosphite® (phosphoric acid), Kaligreen® (potassium bicarbonate), and Manniplex Traffic® (chelated Si) on powdery mildew.

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# CHAPTER 2: LITERATURE REVIEW

## 2.1 POINSETTIA

The poinsettia, *Euphorbia pulcherrima* (Wiild. Ex Klotzsch), is part of the *Euphorbiaceae* family. It is native to southern Mexico near present day Taxco. The plant was cultivated by the Aztecs who called it Cuetlaxochitl. It served as a symbol of purity to the Indians due to its color. The showy red bracts were used to make a reddish dye and the latex was used to create a medicine for fever (Shanks, 1980).

John Roberts Poinsett introduced the poinsettia to the United States in 1825. He found the plants growing in Taxco when he visited Mexico as the first United States Ambassador to Mexico. After having success with the plants in a greenhouse at his home in South Carolina, he sent plants to botanical gardens and friends. One of his friends sent a plant to John Bartram who was the first nurseryman to sell poinsettias as *Euphorbia pulcherrima* (Wiild. Ex Klotzsch). Many institutions started poinsettia breeding programs in the mid 1950s (Dole and Wilkins, 2005). Towards the end of the 19th century, poinsettias were being grown commercially for Christmas sales thus receiving its common name as the Christmas flower or Christmas star (Shanks, 1980).

Presently, the poinsettia is the number one potted crop sold in the United States (Jerardo, 2002). They are grown for their large bract clusters that display brilliant colors. The center of the bract contains the cyathia which is the true flower. The cyathia can be round to elongate from which small red stamens are produced (Dole and Wilkins, 2005). The foliage shape ranges from entire to lobed and is medium to dark green. Some of the colors for the poinsettias include red, pink, white, purple, and yellow. Poinsettia cultivars are divided into two groups, free branching and restricted branching cultivars. Most poinsettia cultivars are free branching plants that

produce many axillary shoots when pinched. However, the restricted branching cultivars produce only two to four shoots when pinched (Fischer, 2004).

## 2.2 GREENHOUSE PRODUCTION OF POINSETTIAS

Poinsettias are photoperiodic plants that require short day for flower initiation. Photoperiodic plants respond to the day-night cycle (Nelson, 1998). Poinsettias need a dark period of at least 11.75 hours to initiate flowering. Twelve-hour dark periods occur naturally in the Northern Hemisphere in the latter part of September. Flowering takes 6.5- 10 weeks from the start of short days. However, short days should continue until pollen can be seen on the cyathia for proper development of the bract. Eighteen to 21º C is the night temperature used for most cultivars after propagation. When the night temperature is above 21º C, flower initiation may be delayed and if the night temperature goes above 24ºC, flower development may be delayed (Dole and Wilkins, 2005).

The most common method of commercial propagation of poinsettias is by terminal stem cuttings. Some companies grow their own stock plants for cuttings. The temperature should be 24- 25 ºC for rooting of cuttings. Poinsettias grow in a variety of potting media (Dole and Wilkins, 2005). An ideal media should have good drainage, aeration, EC levels of 2.0- 2.5, and a pH level of 5.5-6.5 (Shanks, 1980). Poinsettias that have medium-green leaf color should have EC levels of 2.0 - 2.5 with a pH of 6. Varieties that have dark leaves should have EC levels of 1.5 - 2.0 with a pH of 6. Poinsettias are high light intensity plants that should have 3500- 4500 foot-candles of light during mid October to early November for large colorful bracts. The light intensity should be reduced to 2000 foot candles for the last two to three weeks of the crop finishing preventing fading of the bract color (Fischer, 2004).

A general range for fertilizing poinsettias is 225 - 300 ppm of nitrogen (Dole and Wilkins, 2005). Poinettias require high nutrient levels of major elements, especially nitrogen. However, they are intolerable of high soluble salts in the soil solution (Shanks, 1980). They require high levels of magnesium and molybdenum and are sensitive to both boron deficiencies and boron toxicities. Molybdenum (Mo) deficiencies are common for poinsettias (Nelson, 1998). They usually received Mo through liquid fertilizer at 0.1 ppm. Marginal chlorosis, upward rolling, and edge burn of recently mature leaves can appear when plants are deficient in Mo. Magnesium is provided through liquid fertilizer at 40 - 50 ppm for most growers. Yellow mottling of recently mature leaves that starts at the margin and occurs between the veins are signs of magnesium deficiency. Calcium deficiencies can cause weak stems and/or bract and leaf necrosis. Boron deficiencies cause distortion of terminal growth, leaves, and stems. Yellowing or necrosis of leaf margins of older leaves is caused by boron toxicity (Dole and Wilkins, 2005).

Height control is a problem when growing poinsettias because they are naturally very vigorous, and if the plant height is too great, the stems may break and the plant becomes less marketable. Excessive stretching can be prevented by maximum plant spacing, pinching, high light intensity, and chemical growth retardants. Chemical growth retardants used are Cycocel™ (chlormequat), B-Nine™ (daminozide), A-Rest™ (ancymidol), Bonzi™ (paclobutrazol), and Sumagic™ (uniconazole- p). A common rate for Cycocel™ on poinsettias is 1000 - 1500 ppm (Dole and Wilkins, 2005) or 750 ppm under cool conditions (Fischer, 2004). B-Nine™ should be applied at 750- 2500 ppm and A-Rest™ applied at rates of 1-4 ppm or 1-2 ppm when conditions are cool. Bonzi™ is applied at 5 - 20 ppm as a spray or 2 - 5 ppm in northern climates but is applied at only 0.5 - 3 ppm when applied as a drench. Sumagic™ is applied at a rate of 5 -10 ppm for height control. Sometimes the chemical growth retardants can have undesired effects on

the poinsettias such as bract size reduction. Cycocel™ can cause bract reduction if sprayed after November 1 in southern areas and can cause leaf yellowing if applied after October 15 in the northern United States. Bonzi can also reduce bract size if applied from flower initiation to the end of October. Applications of growth retardants are usually applied after the poinsettias have been pinched and the axillary shoots are 3.8 – 5 cm long (Dole and Wilkins, 2005).

Pinching is performed on poinsettias to produce 4 -7 inflorescenses. There are three types of pinches: soft, hard, and really hard. A soft pinch is made above a young immature leaf by removing the apex, a hard pinch is made above the first fully expanded leaf, and a really hard pinch is done in older stem tissue (Dole and Wilkins, 2005). Falkenstein (2004) suggests a soft pinch to get the maximum amount of breaks in the shortest time period since the other pinches take longer.

## 2.3 PESTS AND DISEASES

The most common pest for poinsettias is the greenhouse whitefly (*Trialeurodes vaporarium*) (Westwood) and the silver leaf whitefly (*Bemisia argentifolii*) (Bellows and Perring) (Shanks, 1980). Other pests that affect poinsettias include fungus gnats, spider mites, aphids, soft scales, or mealybugs (Fischer, 2004). It is important to inspect incoming cuttings for whiteflies and other pests. Insecticides can be applied, avoid over watering, reduce humidity, remove fallen plant material and/or debris, and control algae for control of fungus gnats (Ball, 1985). Predatory nematodes may also be used to control fungus gnats. The media needs to dry out in between watering because if the media stays moist for long periods the larvae of the fungus gnats can become established. The larva feeds on the roots and lower stems tissue of rooted cuttings which prevents root formation (Dole and Wilkins, 2005). Orthene™ (acephate) can be applied for mealybugs and aphids (Ball, 1985).

Several diseases can affect poinsettias. The diseases include root and stem rot, *Botrytis* (Pers) blight, bacterial stem and leaf rot, powdery mildew, fungal blights, and leaf spots. Two viruses that affect poinsettias are the poinsettia mosaic virus and the poinsettia cryptic virus (Dole and Wilkins, 2005). *Botrytis* (Pers) can be controlled with fungicides along with maintaining good air movement, low humidity, and watering early in the morning to allot enough time for the foliage to dry off before sunset (Dole and Wilkins, 2005).

## 2.4 MINIATURE ROSES

The history of miniature roses is relatively unknown. The only known facts are that a miniature rose variety was introduced to England that was a form of *Rosa chinensis minima* (R.Roulettii Correv). By the 1850s it was a popular form of rose (Genders, 1965). A quarter of a century after miniatures were introduced in England and Europe, they lost popularity and disappeared. A century later they were rediscovered by Major Roulet who saw them in a Swiss Alpine village. Henri Correvon propagated the ones he received from Roulet and created the variety Rouletti (Browne, 1974). In the early 1900s, this species was introduced to the west. Genetically, dwarf miniature roses originated from Chinese breeding efforts. The large selection of miniature roses we have today is due to propagation and hybridizing of these plants (Dole and Wilkins, 2005). Many miniature rose cultivars were patented in Canada, the United States, the Netherlands, and Denmark. To this day, Ralph Moore has done more breeding of miniature roses to bring them to their present state of development than any other breeder (Genders, 1965).

Miniature roses differ greatly in type because of their varied ancestry. Their height can vary from 5 - 46 cm tall. Plants 46 cm and less are considered to be miniature. The shape of rose buds vary from a long- pointed tea shape, pear- shaped to large and shapeless. The flowers are carried by the plant singly, in clusters, or show both at the same time. Blossoms have 5- 150

petals. Miniature rose petals can be heart shaped, pointed, double pointed, or quilled like a dahlia. Petals can vary in length from 0.6 to 6.5 cm wide (Pinney, 1964).

## 2.5 GROWING GREENHOUSE MINIATURE ROSES

Miniature roses are propagated from seed, cuttings, and budding (Genders, 1965). Propagation by cutting should be by single leaf-node stem cuttings. If the cuttings are not mature when harvested, they will wilt quickly. Most cultivars grown in greenhouses are grown in 10.2 – 15.2 cm pots. Four to six cuttings are placed in a 10.2 cm pot filled with a substrate that has good moisture retention and adequate drainage. Miniature roses need good aeration. Therefore, a well–drained medium should be used. A good medium should consist of a peat-lite mix with a pH of 5.5 to 6.7. Temperatures during propagation should be as follows: 23 - 24ºC, 20 - 22°C for seven to 10 days after rooting and before the first cutback, 20- 22ºC for two to three weeks of growth after cutback, 19- 22ºC for two to three weeks after the second cutback, and 18ºC for the final three to four weeks before flowering. Light intensity should be approximately 670 fc for 24 h every day. Supplemental lighting has been shown to increase the number of flowering stems per plant and decrease bud abortion during forcing. Light intensity greater than 3000 fc will develop sun scald and shading should be used. The number of flowers per shoot can be increased when incandescent lighting is used (Dole and Wilkins, 2005).

Plants need to be pinched twice to get a well-branched potted plant with many flowering stems. Seven days after propagation, the first pinch is made; a second pinch follows. Three weeks after the first pinch. Height control will be needed for most miniature rose cultivars even though they are genetically dwarf plants. Chemicals used to control the height of the plants are Bonzi (paclobutrazol), A- Rest (ancymidol), and B- Nine (daminozide). Bonzi can be applied 14 to 21 days after the final pinch (Dole and Wilkins, 2005).

## 2.6 PESTS AND DISEASES

Pests that affect miniature roses are spider mites, thrips, aphids, whiteflies, caterpillars, shore flies, and fungus gnats. The two major disease problems are powdery mildew (*Spaerotheca pannosa var roseae*) (Wallr.:Fr) and grey mold (*Botrytis cinerea*) (Pers). Other diseases affecting miniature roses include downy mildew, *Cylindrocladium scoparium* (Ellis and Everh.),*Phytophthora*, *Peronospora* (Dole and Wilkins, 2005), stem canker (*Coniothyrium wernsdorffiae*) (Ellis & Ellis), and black spot (Genders, 1965).

Powdery mildew is the most troublesome of all rose diseases. It can be found on the foliage, buds, stems, and on the petals of the bloom. It can cause the buds to decay at the point of opening. It can interfere with plant functions when found on the leaves of the plant which might these functions include the plant being unable to convert carbohydrates into food required to maintain its health (Genders, 1965). Powdery mildew causes the plant leaves to turn yellow and curl, premature defoliation, and, in some cases death of the plant (Browne, 1974).

The three stages of powdery mildew are the primary stage, reproductive stage, and the spherical capsule stage. Powdery mildew appears as grayish - white spots on the upper and under sides of the leaves causing leaf curl or shriveling in the mycelium or primary stage is comprised of interwoven threads. During the reproductive stage, chains of conidia arise from the mycelium and are elliptical in shape as they form on top of each other end to end. The infection spreads when the conidia drift to other leaves and stems by the air. The reproductive stage is also called the conidia stage. The spherical capsule stage or resting stage is the third stage. During this stage the mycelium stops sending up chains of conidia and the parasite forms brown spherical capsules thus receiving the name *Spaerotheca* for the spherical- shaped capsules and *pannosa* for the

wrinkled shriveled leaves. Absence of free circulation of air, hot weather, and sunny days followed by heavy dews at night all aid in the infection of powdery mildew (Pemberton, 1908).

## 2.7 CALCIUM

Calcium (Ca) is beneficial to production of agricultural crops including horticultural crops such as flowering pot plants. Calcium is involved in various functions of the plant. Some of these functions include cell wall structure, membrane structure and function, involved with ethylene synthesis, influencing senescence, and others (Poovaiah and Leopold, 1973). Calcium has been proven to lengthen postharvest life of flowering plants, increase the amount of marketable flowers, and increase disease resistance (Starkey and Pederson, 1997). Calcium, may also control *Botrytis cinerea* when applied in the forms of Ca - sulfate, chlorate, or nitrate (Capdeville et al., 2004).

Free Ca is toxic to the metabolism of plants which is why Ca is tightly regulated into a cell. Calcium uptake is passive. The Ca concentration in low- transpiring organs such as flowers is low. These organs mainly receive Ca through the phloem and Ca preferentially moves through the xylem (Starkey and Pederson, 1997).

A study at the University of Connecticut suggested that Ca reduces the incidence and severity of bract necrosis often termed bract-edge-burn. Calcium chloride ($CaCl_2$) was applied as a topical spray during bract development at 400 ppm Ca. It is believed that bract-edge-burn and bract necrosis is caused by localized Ca deficiencies in the margins of poinsettia bracts during bract development. Outside of the cell membrane, in the epidermis and plant cell walls are Ca accumulates when sprayed onto a bract (McAvoy and Bible, 1995). Another study showed that varying amounts of $CaCl_2$ prevented leaf senescence, maintained higher chlorophyll levels, and maintained higher protein levels in corn leaf discs. Calcium prevented leaf senescence by

decreasing the amount of free space associated with senescence. Higher chlorophyll levels were maintained when Ca levels were $10^{-4}$ and $10^{-3}$ M. Higher protein levels were maintained at $10^{-3}$ and $10^{-2}$ (Poovaiah and Leopold, 1973).

A study conducted by Starkey and Pederson (1997) investigated the effect of supplemental Ca in the fertilizer solutions for miniature potted roses. Increased levels of Ca improved the postproduction life of the roses. During the experiment, the plants were watered with six different nutrient solutions during the whole production period. The treatments contained varying amounts of $NO_3$-N, $NH_4$-N, P, K, Ca, Mg, Na, Cl, and S. The treatments differed in amounts of Ca ranging from 1.1 to 4.4 *mM* and different ratios of Ca and other cations. The Ca concentration in the different parts of the plant greatly increased. Leaves accumulated the most Ca with 1.15% of dry matter, stems .50%, flowers .49%, and roots contained .38% Ca. Also, the number of good flowers increased with all treatments, but treatment 5, which contained 3.5 mM of Ca, had the most. Treatment 5 increased the amount of good flowers per plant by five flowers. Good flower is a term referring to the quality rating a flower gets when judged. The plants were graded on the amount of yellow leaves, wilted and/or damaged flowers, presence of grey mold, etc. Plants treated with treatments containing 2.5, 3.5, and 4.4 mM of Ca had significantly lower amounts of wilted flowers. Plants that contained low concentrations of Ca in flowers and buds had a tendency to have an increase in infection of grey mold by day 11 of the study (Starkey and Pederson, 1997).

Calcium sulfate ($CaSO_4$) was applied on buds of fresh cut roses prior to harvest at different concentrations and different schedules in separate experiments. Once the buds were harvested, they were inoculated with *Botrytis cinerea* (Pers). The Ca treatment reduced the severity and progress of grey mold and increased vase life of the flowers by 30 percent in the

assay without inoculation. The best results for controlling grey mold after harvest were found when using 10 or 20 mM of $CaSO_4$ one day before harvest (Capdeville et al., 2004).

Extending the longevity of cut flowers is very important. Calcium has been found to increase postproduction longevity and promote bud opening in cut rose flowers. When Ca was applied as Ca $(NO_3)_2$, it lengthened vase life of cut rose flowers and promoted bud opening. The treatment was applied either alone or with 2% sucrose and 200 ppm of 8- hydroxyquinoline citrate. Treatments were applied continuously or as a short term pulse. The rose cultivars used were Sonia, Celica, Samantha, and Mercedes (Michalczuk et al., 1989).

In another study, CaCl delayed senescence, promoted bud opening, and lengthened the postharvest growth period. Cultivars Mercedes and Baroness were used for the experiment. When flower petals go through senescence, the amount of proteins and phospholipids decrease. However, CaCl caused a delay in this process for this experiment. Delaying senescence is very important, especially for marketing purposes. Calcium chloride at 5 m*M* was the optimal rate for cultivar Mercedes and 1m*M* was the optimal rate for Baroness. Flower diameter was also increased for both cultivars as a result of increased bud opening (Torre et al., 1999).

Plant roots are sensitive to calcium deprivation. Also, a lack of calcium can result in structural changes of intracellular organelles, a decrease in cell elongation, and affect cell walls and the permeability of cell membranes to solutes and other ions. Based on this literature review, Ca could benefit poinsettias by reducing incidence and the severity of bract-edge-burn. Calcium has also been shown to benefit miniature roses by reducing the severity and progress of grey mold which is one of the main causes of decreased postharvest life. Calcium should increase the vase life of both plants and improve their postharvest life.

## 2.8 SILICON

Silicon (Si) is the second most abundant element in soils and exists as silica or silicates in nature. It ranges from 1% to 10% or higher in plant dry matter. Silicon can benefit plant growth and development in many ways. Some of these benefits include increased plant growth and crop quality, stimulate photosynthesis, reduced transpiration rate, and increased plant resistance to abiotic and biotic stresses (Ma and Takahashi, 2002). Silicon contributes to greater stalk strength and resistance to lodging by contributing to the structure of cell walls. Si impregnates the walls of epidermal and vascular tissues where it appears to strengthen the tissues, retard fungal infection, and reduce water loss. It increases photosynthesis because of better light interception (Tisdale et al., 1993). Most of the research conducted on the benefits of Si has been conducted on agronomic crops. Benefits to plant growth and development of horticultural crops, however, has also been shown (Ma and Takahashi, 2002).

High levels of Si occur naturally in rice hulls and sugarcane bagasse or industry by-products (Ma and Takahashi, 2002). Silicon sources that are often used in crop production include: calcium silicate slag, sodium silicate, potassium silicate, magnesium silicate, silica gel, and others. Primary Si fertilizers are Ca silicate slag, Ca silicate, and sodium meta silicate (Tisdale et al, 1993).

A study was conducted on the effects of Si on powdery mildew-infected wheat. The results showed that the resistance of wheat infected with powdery mildew was induced with soluble Si in the form of potassium silicate (KSi) at 100 ppm in a nutrient solution. Phytoalexins were produced in plants that were treated with Si in response to powdery mildew infection (Remus-Borel and Menzies, 2005).

The use of sodium silicate (NaSi) sprays was beneficial in a study on poinsettias. The severity and occurrence of bract necrosis decreased greatly when NaSi sprays were used on the cultivar 'Supjibi'. Postharvest bract damage also decreased in this cultivar. The silicates were applied at 100 ppm and were as effective as CaCl sprays at 400 ppm for up to five weeks after the cyathia began to open (McAvoy and Bible, 1995).

Potassium silicate increased the basal stem diameter of zinnias when applied as a drench weekly at 200mg/L. The basal and apical stem diameter was increased for sunflowers with ashed rice hull media incorporated at 100 $g/m^{-3}$, $NaSiO_3$ weekly foliar sprays (50, 100, and 150 mg/L Si), $KSiO_3$ drench (50 and 100 mg/L), and $KSiO_3$ media incorporation at 140 $g/m^{-3}$. Sunflowers were also tested in this experiment. Basal and apical stem diameters increased for sunflowers treated with rice husk ash substrate incorporation at 100 $g/m^{-3}$ Si, $KSiO_3$ at 140 $g/m^{-3}$, foliar $NaSiO_3$ at 50, 100, and 150 mg/L Si, and $KSiO_3$ drench at 50 and 100 mg/L Si (Kamenidou, 2008).

Review of the literature suggests that application of Si could benefit stem development and the overall growth of poinsettias and miniature roses. Stem development is important for poinsettias because the stems break easily when mature. Silicon would also benefit poinsettias and miniature roses by decreasing the severity and occurrence of diseases and of bract necrosis for poinsettias.

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# CHAPTER 3. EFFECTS OF SUPPLEMENTAL CALCIUM OR SILICON ON POINSETTIAS

## 3.1 INTRODUCTION

Poinsettias are the number one flowering potted plant in the U.S. and it is the most popular Christmas plant sold (Jerardo, 2002). Many studies have proven calcium (Ca) to be beneficial to plants. These benefits include increasing longevity of rose flowers (Michalczuk et al., 1989), reduced the incidence and severity of diseases (Starkey and Pederson, 1997), and increasing stem strength. Calcium can be applied as a foliar spray, drench, or as a postharvest holding solution. Calcium in the form of calcium nitrate [Ca $(NO_3)_2$], calcium chloride [$CaCl_2$] or calcium sulfate [$CaSO_4$] have been shown to benefit floriculture crops.

One study indicated that Ca $(NO_3)_2$ gave the highest vase life of all treatments applied when applied at 1000 and 2500 ppm Ca. Rose cultivar Raktagandha was cut at harvest and ten cut rose stems were placed in each treatment solution. The treatments solutions used were citric acid, $Al_2(SO_4)_3$, silver thiosulfate, $Ca(NO_3)_2$, thiourea, sucrose, and water for the control. Vase life of the cut roses was enhanced because $Ca(NO_3)_2$ inhibited ethylene synthesis and prevented vascular blockage (Bhattacharjee and Palalanikumar, 2002).

Silicon (Si) has been shown to benefit not only rice but many other plants such as wheat, roses, cucumbers, and etc. Silicon affected plant growth, stimulated photosynthesis, reduced transpiration rate (Ma and Takahashi, 2002), and reduced the incidence of diseases such as powdery mildew (Bélanger et al, 1995), reduced the incidence and severity of bract edge burn in poinsettias (McAvoy and Bible, 1995), and alleviated abiotic and biotic stress. However, the beneficial effects of Si are usually expressed more clearly when plants are under stressed conditions. Silicon is taken up by plants in the form of silicic acid where it is transported to the shoot. After loss of water, it is polymerized as silica gel on the surface of leaves and stems. Also,

it is the only element that does not cause serious injury to plants in excess amounts (Ma and Takahashi, 2002).

One of the problems with poinsettias is weak stem strength leading to stem breakage. Calcium levels, spacing, and plant growth regulators affect this. There have been studies that suggest Ca helps reduce stem breakage (Kuehny and Branch, 2000; Lawton et al, 1989). Calcium is an important part of the cell wall because it is involved in cross-linkage of pectic molecules (Ferguson and Drøbak, 1988). Based on previous research Ca treatments can benefit poinsettias by increasing stem strength, increasing flower longevity and reducing disease incidence. All of these things are important to produce a quality marketable plant. Poinsettias also incur bract edge burn or bract necrosis. Silicon and Ca have been shown to decrease this (McAvoy and Bible, 1995).

Based on the possible benefits of Ca and Si, the objective of this experiment was to determine the effects of supplemental preharvest Ca or Si on growth, flowering, and development of poinsettias.

## 3.2 MATERIALS AND METHODS

### 3.2.1 Plant Material

Two experiments were conducted, the first being a foliar spray application of treatments at a campus greenhouse at Louisiana State University while the treatments for the second were applied as a drench at the Burden Center in Baton Rouge. *Euphorbia pulcherrima* (Wiild. Ex Klotzsch) 'Orion Red' (Fischer, Boulder, CO) was used for both experiments. 'Orion Red' is part of Fischer's dark leaf varieties and number one selling poinsettia cultivar. It has an early week flower response of 7.5 weeks. It has vibrant, dark red bracts that are fade- resistant. It has

great post- production qualities with medium- vigorous growth habit. This vigorous growth is usually from the time of rooting until the third week of short days (Falkenstein, 2004).

Poinsettias (Fischer, Boulder, CO) were received as rooted cuttings in oasis strips and planted on 7 September 2006 at the Burden Center and on the Louisiana State University campus, both located in Baton Rouge, Louisiana. Greenhouses used at both locations were covered with polycarbonate. Cuttings were planted with one cutting per 15.2 cm pot using a 5:3:2 peat: pine bark: perlite substrate (by volume) with incorporated amendments of 4.75 kg/$m^3$ dolomitic limestone, 0.89 kg/$m^3$ triple superphosphate, and 0.6 kg/$m^3$ Micromax$^{TM}$. The pots were placed on inverted trays on the floor of the greenhouse for experiment 2, the drench study, with 2 pots per tray with 25 cm spacing between pots. The plants for experiment 1 were placed on top of raised benches (30 cm spacing). There were two different spacings because there was more room on the benches to space plants than on the inverted trays. However there was ample room for optimal growth of plants in both experiments. Plants were fertilized with 20-10-20 (20N-4.4P-16.6K) from planting to flowering (The Scotts Co., Maryville, OH). Plants were watered with DI water during flowering until plants were harvested. Plants received 250 ppm nitrogen (N) of fertilizer for experiment 1 and 300 ppm N for experiment 2. Two different concentrations were used because the plants for experiment 2 were lighter in color and needed a higher concentration of fertilizer. The plants were lighter in color because the light intensity was higher at the greenhouse for experiment 2 than experiment 1. Plants were fertilized at every watering with a Siphonex® (Scotts Miracle-Gro Products, Inc., Port Washington, NY) proportioner by hand for experiment 1 and through drip irrigation for experiment 2. Fertigation started after poinsettias were planted and continued until the bracts turned red. After the bracts turned red, DI water was used. Temperature and relative humidity were recorded throughout the

experiment (Figs. 1, 2, 3, & 4). The daily temperature was set at 26º C and the night temperature was set at 20º C.

Poinsettias were pinched on 26 September 2006 at both locations. Five nodes were left on each plant and everything else was removed for the pinch. Plant growth regulators were not needed. Lights in the greenhouse were turned on 22 September 2006 and were turned off on 16 October 2006. Baton Rouge is located in the 8b hardiness zone.

**3.2.2 Preharvest Treatment**

Two experiments were conducted to determine the effects of Ca or Si on growth and flowering of poinsettias. Treatments were applied by a foliar spray for experiment 1 and by a drench for experiment 2. Treatments for both experiments started on 30 September 2006. Five chemical treatments were used with three concentrations for each with deionized water as the control for a total of 16 treatments. Treatments were applied weekly at each location at the rate of 0, 125, 250, and 500 ppm Ca or Si. Both experiments were randomized with four blocks containing 48 plants in each experiment. Both were designed with a 5 by 3 factorial design (5 chemicals at 3 concentrations) and a control (deionized water) with 4 blocks with 3 replicates per block for a total of 12 experimental units per treatment. Poinsettias treated with the control were included in both experiments.

The sources of Ca were:

- Ca nitrate [$Ca(NO_3)_2 \cdot 4H_2O$] (Fischer Scientific International, Fair Lawn, NJ)
- Ca chelate [10 % $Ca(NO_3)_2$ + 37 % proprietary blend of alcohol sugars] (Claw El, Brandt Consolidated, Pleasant Plains, IL)
- Chelate without Ca or Si [37 % proprietary blend of alcohol sugars] (Brandt Consolidated, Pleasant Plains, IL)

The sources of Si were:

- Silicon - chelated Si (Manniplex Traffic) (Parkway Research, Pleasant Plains, IL)
- Silicate - Potassium silicate [$KSiO_2$] (Sil- Matrix) (PQ Corporation, Valley Forge, PA)

For experiment 1, plants were sprayed in increasing increments as the plant grew. The plants were sprayed until runoff, approximately 3.5 mL at week 1 to 18 mL per plant at finish. For experiment 2 the treatments were applied using drip irrigation using a time clock to ensure the same amount was applied for all treatments. The amount of treatment applied increased as the plants grew and ranged from 174 mL at week 1 to300 mL per plant at finish. The control treatment for both experiments was deionized water. Four deionizer columns, cation- bed deionizer, anion- bed deionizer, mixed- bed deionizer and ultra- bed deionizer were set up for the deionized water (Siemens, New Orleans, LA).

**3.2.3 Harvest**

Poinsettias were harvested when the cyathia was present. The plants were cut at the soil surface with hand held pruners. The growth parameters recorded at harvest were days to flower (Julian date), plant height and width, flower diameter, and stem strength. Plant height was measured from the media to the tallest point on the plant. Two widths were measured and the average of the two was recorded. For flower diameter, the two largest flowers were measured. Each flower had two width measurements and then the average was recorded for the diameter of each flower. The flower was considered to be the colored bract of the plant. Stem strength was recorded using a Chatillon force meter (Kuehny and Branch, 2000). The first three stems from the top of each plant were measured for strength (stem strength 1, 2, and 3) once all leaves and flowers were removed from the plant. The force was measured in newtons ($1N=1\ kg{\cdot}m/s^2$). Once

the plant was harvested, the plant was divided into three tissue samples: flowers, leaves, and stems. Samples were dried at 80ºC for 24 h. Once samples were dried, dry weights for all three samples were recorded. Once dry weights were recorded the plant material was ground. Dried plant material was ground with a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass through an 850 µm (20-mesh) screen.

### 3.2.4 Calcium Extraction

Half a gram of ground tissue was removed from each ground tissue sample and placed in a digestion tube with 4mL of concentrated nitric acid ($HNO_3$). Samples remained overnight inside a fume hood at room temperature (25º C).

The tubes were placed in a BD40 digestion block (Bran+Luebe, Germany) set at 120º C. After an hour the tubes were removed from the block to cool down for 25 min. Once the samples were cooled, 4 mL of 30% hydrogen peroxide ($H_2O_2$) were added and samples placed back into the block. This process was repeated until the solution became clear. The clear digested solution was transferred into a 10 mL volumetric flask, brought to volume, and filtered (Whatman #2 slow flow rate filter paper) into a 45 mL plastic vial. Six digestion tubes served as control samples and only nitric acid and hydrogen peroxide added to them.

### 3.2.5 Calcium Analysis

To determine the concentration of Ca in the poinsettia tissue a colorimetric assay was used, Calcium L3K Assay (Diagnostic Chemical Limited, Oxford, CT). This assay turns bluish purple when added to the samples with a maximum absorption at 660 nm and it contains a Ca complexing dye and Phosphonazo III (Onishi, 1986). A 10 µl aliquot of flower tissue extract was added to a polycarbonate centrifuge tube with 1 ml of the Phosphonazo III solution for both experiments. A 1 µl aliquot of leaf tissue extract and 9 µl of DI water were added with 1 ml of

the Phosphonazo III solution for both experiments. A 10 µl aliquot of stem tissue extract was added to a polycarbonate centrifuge tube with 1 ml of the Phosphonazo III solution for experiment 1. A 5 µl aliquot of stem tissue extract and 5 µl of DI water were added with 1ml of the Phosphonazo III solution for experiment 2. Experiment 2 had a higher absorbency reading than experiment 1 and was diluted. The solution was vortexed with all samples and let stand for 3 minutes at room temperature. The mixed solutions were transferred to disposable cuvettes. A Milton Roy (Genesys 5, Champaign, IL) thermo spectrometer was used at an absorbance of 660 nm. A set of standards were used for each set of samples measured. A standard curve of 0, 30, 60, 90, 120, and 150 mg/l of Ca was made using calcium carbonate ($CaCO_3$) and was used each time samples were measured. The stock solution was prepared from a procedure used by Moorehead and Biggs (1974). This procedure includes 2.5 g of $CaCO_3$ placed in a beaker with 250 ml of DI water. Five ml of HCl were needed to dissolve the $CaCO_3$. Solution was diluted to 1000 ml with DI water and the pH was adjusted to 7.0 ± .5 with potassium hydroxide (KOH).

To calculate the Ca concentration for the tissue samples, a curve was prepared using the absorbency values from the standard solutions when run on the spectrophotometer. The formula from the curve (y=mx+b) was then used to get the concentration. The absorbency reading for the sample was put in place of 'm' and then calculated. The final value was multiplied by the amount of tissue used divided by the volume it was brought up to. Then this number was multiplied since some of the samples were diluted.

### 3.2.6 Statistical Analysis

Both experiments were randomized with four blocks containing 48 plants in each experiment. Both were designed with a 5 by 3 factorial design (5 chemicals at 3 concentrations) and a control (deionized water) with 4 blocks with 3 replicates per block for a total of 12

experimental units per treatment. Poinsettias treated with the control were not included in both experiments. All growth parameters were tested for significance of treatment effects, rate, and an interaction using a multivariate analysis by the GLM procedure in SAS using Manova. LSMEANS was used for mean separation using SAS 9.1.

## 3.3 RESULTS

### 3.3.1 Experiment One (Foliar Spray Experiment)

There was no significant difference in growth parameters days to flower, plant height, stem strength 1, stem strength 2, flower dry weight, leaf dry weight, or stem dry weight for all treatments (Table 3.1). Plant width was significantly affected by chemical and the interaction between chemical and rate. Flower diameter was significantly affected by the interaction between chemical and rate. Stem strength for the third stem (stem strength 3) was significantly affected by the interaction of the chemical and rate. The average stem strength (stem strength 1, 2 and 3) was significantly affected by chemical.

Plant width decreased as rate increased when Ca $(NO_3)_2$ and Ca chelate was applied (Fig. 3.3A). However, plant width increased as rate increased for the chelate. Plants treated with Ca $(NO_3)_2$, Ca chelate, and $KSiO_2$ had greater plant widths than the chelate. Flower diameter decreased as concentration increased with Ca $(NO_3)_2$. Sem strength of the third stem had significance by an interaction between treatment and rate. However, no treatments had more significance over others. Plants treated with Ca $(NO_3)_2$, Ca chelate, and Si chelate had greater average stem strength than the chelate and the control (Fig. 3.3C). The average stem strength decreased as rate increased for Ca $(NO_3)_2$ and the chelate (Fig. 3.3 C). However, the average stem strength increased as concentration of silicate increased and treatment did have an effect on average stem strength (Fig. 3.3 C).

Chemical had no effect on Ca concentration in experiment 1 (Table 3.3). Only plants from the highest rate of each treatment were analyzed for Ca concentration. Other plants were not analyzed since there were few significant differences for growth parameters measured. Tissue sample had an effect for all treatments (Table 3.4).

### 3.3.2 Experiment Two (Drench Experiment)

There were no significant treatment effects for growth parameters days to flower, plant height, plant width, flower diameter, stem strength 1, stem strength 2, stem strength 3, leaf dry weight, or stem dry weight for all treatments. Chemical had no effect on any of the growth parameters measured. Flower dry weight was influenced by rate and the interaction of chemical and rate (Fig. 3.5 and 3.6).

Flower dry weight increased as rate increased for Ca chelate (Fig. 3.4B). The largest flower dry weight occurred with $KSiO_2$ at 250 mg/l Si and the smallest flower dry weight occurred with the chelate at 500 mg/l.

For tissue analysis, chemical had an effect on Ca concentration on stem and flower tissue in experiment 2. Plants treated with Ca chelate gave the highest Ca concentration for stems and flowers. However, Ca chelate was not significantly better than all other treatments for flower tissue (Table 3.7). Only plants from the highest rate of each treatment were analyzed for Ca concentration. Other plants were not analyzed since there was not much significance for growth parameters measured. Tissue sample had an effect for all chemical treatments. The highest Ca concentration was found in leaf tissue samples followed by stem tissue samples (Table 3.8).

Table 3.1. Effect of supplemental foliar applications of treatments on growth parameters of *Euphorbia pulcherrima* 'Orion Red'.

| Treatment | Ca or Si Rate (mg/l) | Days to Flower | Plant Height (cm) | Plant Width (cm) | Flower Diameter Avg (cm) | Stem Strength 1 (N) | Stem Strength 2 (N) | Stem Strength 3 (N) | Stem Strength Average (N) | Flower Dry Weight (g) | Leaf Dry Weight (g) | Stem Dry Weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$Ca(NO_3)_2$** | **125** | 89 | 28.50 | 49.29 | 30.83 | 1.41 | 2.52 | 4.31 | 3.45 | 8.91 | 5.51 | 3.34 |
| | **250** | 89 | 28.17 | 48.58 | 29.44 | 1.73 | 1.99 | 3.50 | 2.75 | 9.43 | 5.47 | 2.94 |
| | **500** | 89 | 27.00 | 46.00 | 28.44 | 1.43 | 1.98 | 2.88 | 2.43 | 8.57 | 6.06 | 3.31 |
| **Ca Chelate** | **125** | 89 | 29.40 | 51.80 | 29.43 | 1.80 | 2.60 | 4.04 | 3.20 | 8.98 | 5.27 | 2.98 |
| | **250** | 88 | 26.46 | 49.23 | 29.89 | 1.36 | 1.84 | 2.92 | 2.38 | 8.97 | 4.31 | 2.41 |
| | **500** | 88 | 26.42 | 42.92 | 25.92 | 1.38 | 2.15 | 3.92 | 2.97 | 7.73 | 5.00 | 3.00 |
| **Chelate** | **125** | 89 | 27.44 | 43.50 | 28.66 | 1.18 | 1.83 | 3.15 | 2.45 | 7.60 | 5.33 | 3.04 |
| | **250** | 89 | 27.44 | 43.72 | 28.74 | 1.54 | 1.98 | 2.67 | 2.32 | 8.40 | 6.18 | 3.26 |
| | **500** | 88 | 30.42 | 44.83 | 28.42 | 1.48 | 1.68 | 3.14 | 2.19 | 7.73 | 4.70 | 2.71 |
| **Si Chelate** | **125** | 88 | 27.91 | 46.41 | 28.99 | 1.59 | 2.12 | 3.35 | 2.45 | 9.05 | 5.26 | 3.06 |
| | **250** | 88 | 30.40 | 43.15 | 27.89 | 1.36 | 2.00 | 3.54 | 2.32 | 8.06 | 4.65 | 2.51 |
| | **500** | 88 | 28.33 | 48.21 | 29.76 | 1.37 | 2.41 | 3.42 | 2.19 | 9.21 | 4.83 | 2.71 |
| **$KSiO_2$** | **125** | 88 | 27.73 | 48.96 | 31.66 | 1.49 | 1.94 | 3.15 | 2.68 | 8.71 | 4.81 | 2.86 |
| | **250** | 89 | 29.82 | 45.91 | 27.72 | 1.45 | 1.95 | 3.05 | 2.83 | 8.64 | 5.06 | 2.76 |
| | **500** | 88 | 29.40 | 48.80 | 30.97 | 1.48 | 1.85 | 3.37 | 3.02 | 9.45 | 5.40 | 3.05 |
| **Control** | | 89 | 28.33 | 48.07 | 29.88 | 1.36 | 1.98 | 2.59 | 1.99 | 8.71 | 4.89 | 2.86 |
| **Treatment** | | NS | NS | * | NS | NS | NS | NS | * | NS | NS | NS |
| **Rate** | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Interaction** | | NS | NS | * | * | NS | NS | * | NS | NS | NS | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 3.2. Effect of supplemental foliar applications of treatments on Ca concentration in leaf, stem, and flower tissue of *Euphorbia pulcherrima* 'Orion Red'.

| Treatment | Ca Concentration (µg/g) | | |
|---|---|---|---|
| | Leaf | Stem | Flower |
| $Ca(NO_3)_2$ | 24903 | 2125 | 1331 |
| Ca Chelate | 14290 | 2002 | 1736 |
| Chelate | 19748 | 2155 | 1449 |
| Si Chelate | 22863 | 2349 | 1308 |
| $KSiO_2$ | 19128 | 1825 | 1414 |
| Control | 1299 | 1825 | 1256 |
| Treatment | NS | NS | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 3.3. Effect of supplemental foliar applications of treatments on Ca concentration in leaf, stem, and flower tissue of *Euphorbia pulcherrima* 'Orion Red'.

| Tissue Type | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | $Ca(NO_3)_2$ | Ca Chelate | Chelate | Si Chelate | $KSiO_2$ | Control |
| Leaves | 25047 | 14290 | 19816 | 22909 | 19050 | 2030 |
| Stems | 2167 | 2002 | 2155 | 2249 | 1825 | 2111 |
| Flowers | 1373 | 1736 | 1449 | 1308 | 1414 | 1253 |
| Tissue Type | * | * | * | * | * | * |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

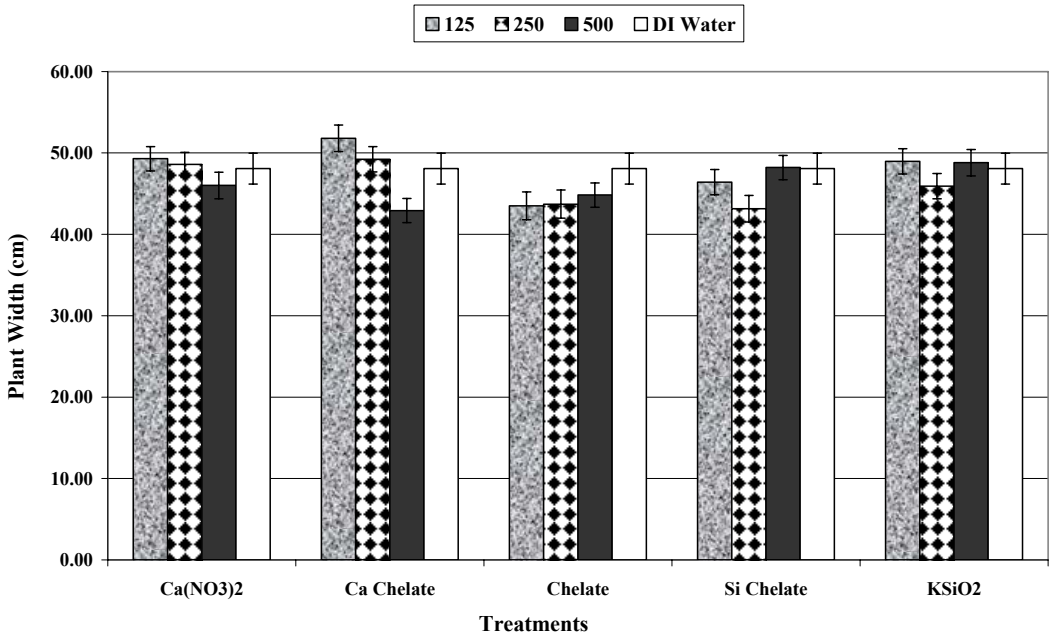


Figure 3.1. Effect of supplemental spray applications of treatments on plant width diameter of *Euphorbia pulcherrima* 'Orion Red'.

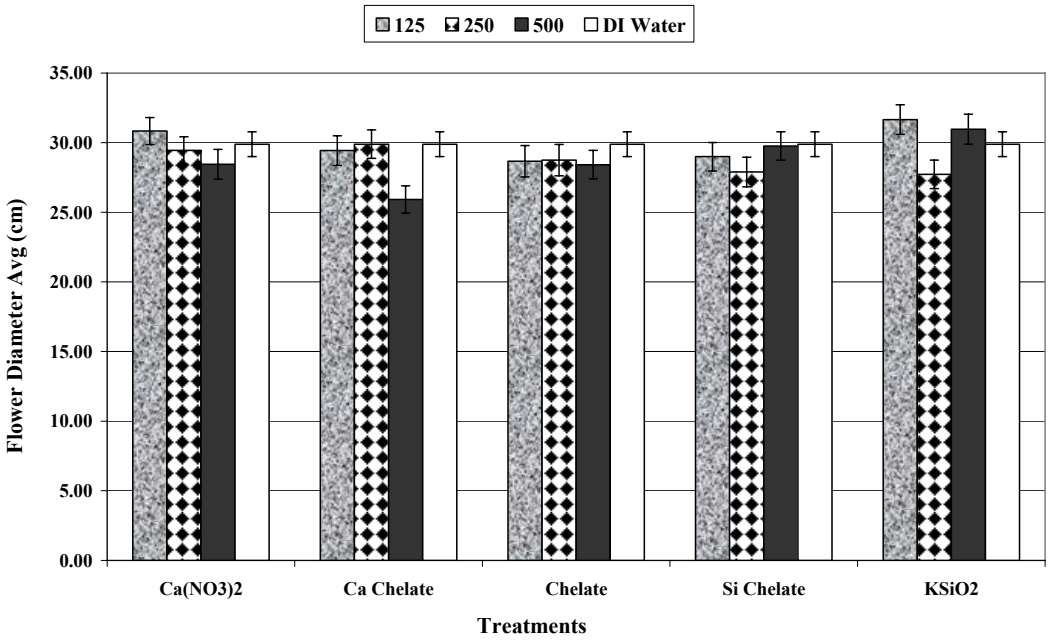


Figure 3.2. Effect of supplemental spray applications of treatments on flower diameter of *Euphorbia pulcherrima* 'Orion Red'.

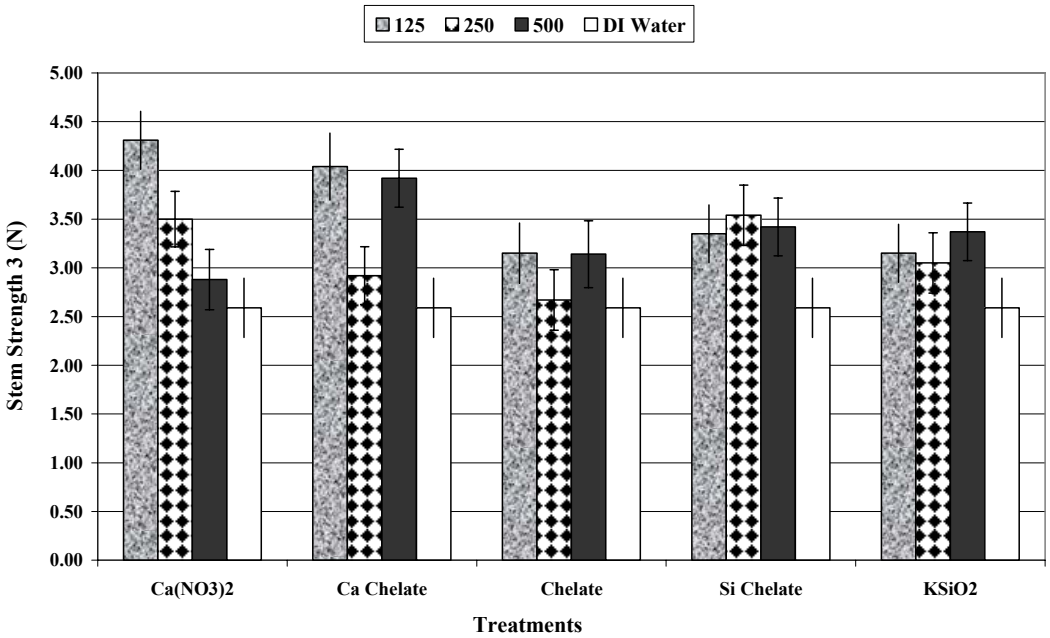


Figure 3.3. Effect of supplemental spray applications of treatments on stem strength of the third stem from the top of *Euphorbia pulcherrima* 'Orion Red'.

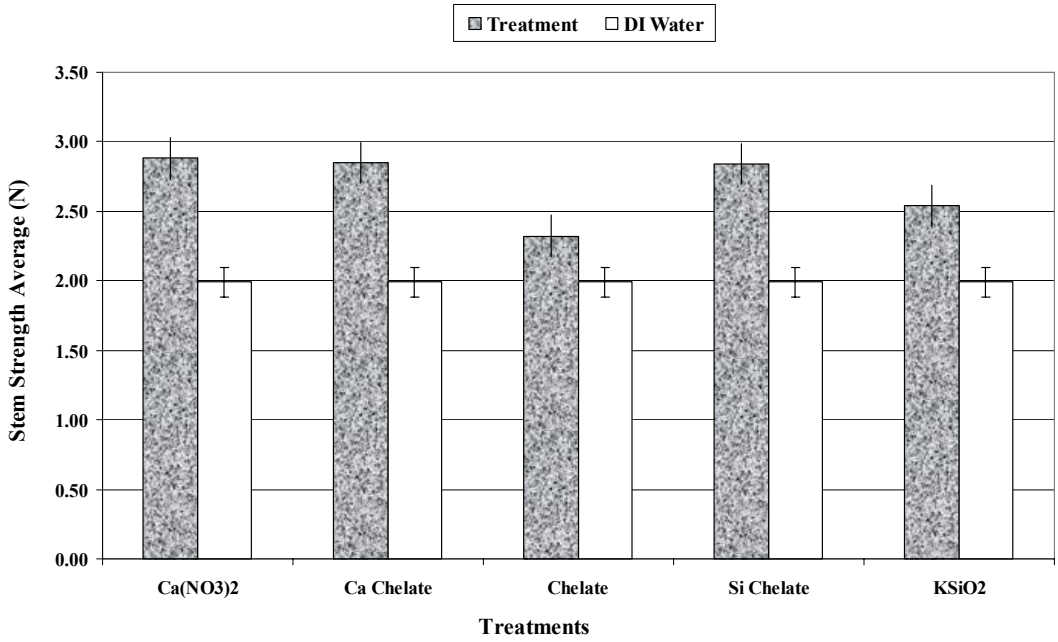


Figure 3.4. Effect of supplemental spray applications of treatments on stem strength average of *Euphorbia pulcherrima* 'Orion Red'.

Table 3.4. Effect of supplemental drench applications of treatments on growth parameters of *Euphorbia pulcherrima* 'Orion Red'

| Treatment | Ca or Si Rate (mg/l) | Days to Flower | Plant Height (cm) | Plant Width (cm) | Flower Diameter Avg (cm) | Stem Strength 1 (N) | Stem Strength 2 (N) | Stem Strength 3 (N) | Stem Strength Average (N) | Flower Dry Weight (g) | Leaf Dry Weight (g) | Stem Dry Weight (g) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **$Ca(NO_3)_2$** | **125** | 119 | 30.00 | 46.96 | 28.15 | 2.81 | 3.55 | 5.61 | 3.79 | 8.75 | 8.03 | 5.37 |
| | **250** | 120 | 29.42 | 49.67 | 31.42 | 3.52 | 4.27 | 4.81 | 4.27 | 11.70 | 8.41 | 5.56 |
| | **500** | 119 | 30.83 | 50.10 | 32.13 | 2.67 | 3.87 | 5.79 | 4.03 | 11.08 | 8.91 | 5.28 |
| **Ca Chelate** | **125** | 119 | 31.83 | 49.13 | 27.38 | 2.46 | 3.92 | 5.30 | 3.95 | 9.24 | 7.61 | 5.45 |
| | **250** | 119 | 28.75 | 48.79 | 30.29 | 2.70 | 3.92 | 4.58 | 3.73 | 9.72 | 8.81 | 5.32 |
| | **500** | 120 | 29.33 | 51.42 | 30.17 | 3.29 | 3.80 | 4.90 | 4.04 | 11.11 | 9.53 | 5.62 |
| **Chelate** | **100** | 119 | 29.42 | 48.17 | 30.81 | 2.77 | 3.64 | 5.29 | 4.01 | 8.88 | 8.15 | 5.49 |
| | **200** | 121 | 30.48 | 48.79 | 30.89 | 2.20 | 3.04 | 4.49 | 3.27 | 9.57 | 8.42 | 5.76 |
| | **400** | 119 | 26.95 | 44.05 | 27.09 | 1.76 | 2.78 | 4.90 | 3.21 | 6.93 | 6.78 | 4.74 |
| **Si Chelate** | **125** | 120 | 27.93 | 48.23 | 28.88 | 2.64 | 3.24 | 4.39 | 3.32 | 9.44 | 8.84 | 6.02 |
| | **250** | 119 | 32.15 | 53.37 | 31.54 | 3.97 | 3.93 | 5.22 | 4.43 | 12.04 | 9.49 | 6.35 |
| | **500** | 121 | 31.33 | 51.42 | 33.03 | 2.90 | 4.24 | 5.18 | 4.00 | 10.78 | 8.10 | 5.41 |
| **$KSiO_2$** | **125** | 121 | 30.34 | 51.45 | 31.27 | 2.91 | 4.04 | 5.34 | 4.02 | 11.58 | 8.40 | 5.40 |
| | **250** | 120 | 30.93 | 51.92 | 29.99 | 3.31 | 3.10 | 5.28 | 4.25 | 13.04 | 9.84 | 6.56 |
| | **500** | 121 | 31.42 | 53.71 | 32.96 | 3.68 | 4.72 | 5.00 | 4.52 | 11.27 | 7.53 | 5.36 |
| **Control** | | 120 | 29.97 | 48.23 | 31.19 | 2.74 | 3.58 | 4.92 | 3.81 | 9.98 | 8.64 | 6.18 |
| **Treatment** | | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS |
| **Rate** | | NS | NS | NS | NS | NS | NS | NS | NS | * | NS | NS |
| **Interaction** | | NS | NS | NS | NS | NS | NS | NS | NS | * | NS | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 3.5. Effect of supplemental drench applications of treatments on Ca concentration in leaf, stem, and flower tissue of *Euphorbia pulcherrima* 'Orion Red'.

| Treatment | Ca Concentration (µg/g) | | |
|---|---|---|---|
| | Leaf | Stem | Flower |
| **$Ca(NO_3)_2$** | 15154 | 4113 | 2382 |
| **Ca Chelate** | 17166 | 4306 | 2461 |
| **Chelate** | 13333 | 3001 | 1597 |
| **Si Chelate** | 19604 | 3089 | 1764 |
| **$KSiO_2$** | 18694 | 3567 | 2095 |
| **Control** | 2014 | 173 | 1186 |
| **Treatment** | NS | * | * |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 3.6. Effect of supplemental drench applications of treatments on Ca concentration in leaf, stem, and flower tissue of *Euphorbia pulcherrima* 'Orion Red'.

| Tissue Type | Treatment | | | | | |
|---|---|---|---|---|---|---|
| | **$Ca(NO_3)_2$** | **Ca Chelate** | **Chelate** | **Si Chelate** | **$KSiO_2$** | **Control** |
| **Leaves** | 15324 | 16735 | 16957 | 19604 | 18694 | 173 |
| **Stems** | 1868 | 2153 | 1166 | 1544 | 1982 | 1111 |
| **Flowers** | 2191 | 2464 | 1465 | 1764 | 2057 | 1185 |
| **Tissue Type** | * | * | * | * | * | * |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

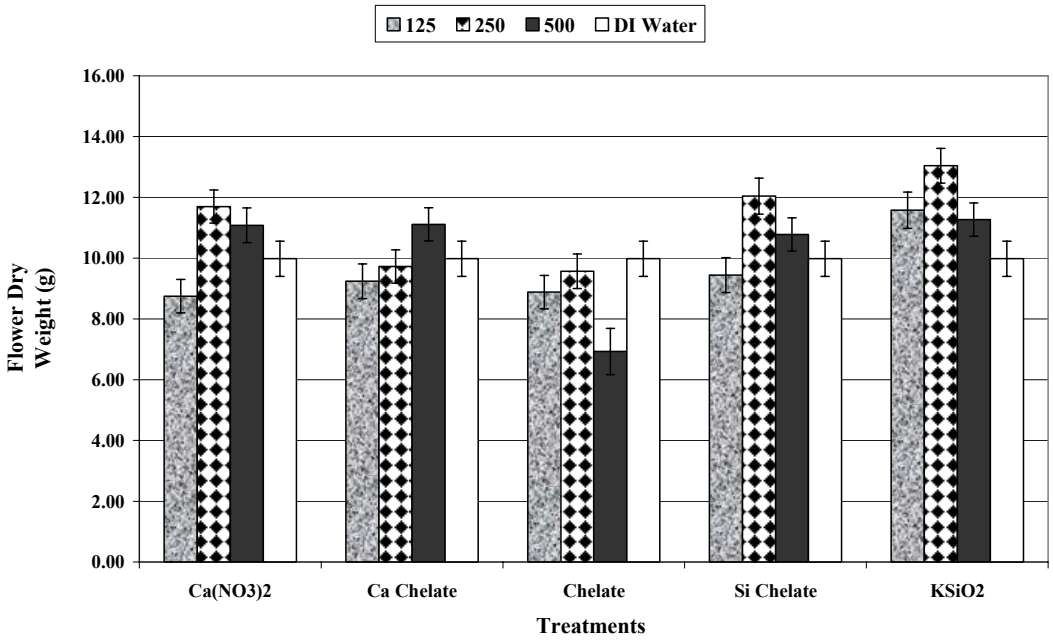


Figure 3.5. Effect of supplemental drench applications of treatments on flower dry weight of *Euphorbia pulcherrima* 'Orion Red'.

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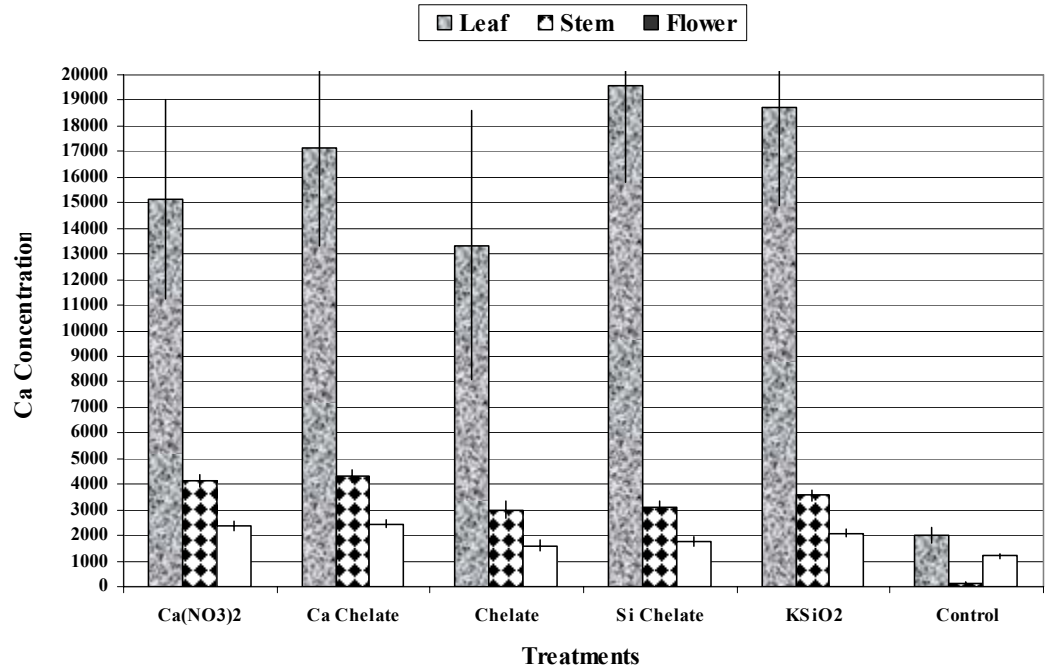


Figure 3.6. Effect of drench treatments on Ca concentration of *Euphorbia pulcherrima* 'Orion Red'.

## 3.4 DISCUSSION

The results of treatment application by foliar spray showed that chemical and the interaction between rate and chemical had an effect on growth of poinsettias. Calcium chelate, $Ca(NO_3)_2$, and $KSiO_2$ had significantly greater plant widths from plants treated with the chelate. Calcium nitrate, Ca chelate, and Si chelate had significantly better stem strength for the average of all three stems over the chelate. Poinsettias have a tendency for the lateral branches to break from the main stem of self-branching types (Lawton, 1989). Also, stem breakage varies depending on the crop and time of year (Faust et al., 1997). Calcium has been shown to play a role in cell wall structure and is an important part of the cell wall since it is involved in cross-linkage of pectic molecules. Pectate is an important compound in plant cell walls and more than 60% of the Ca in the plant is found in cell walls (Ferguson and Drøbak, 1988). Also, Si has been found to deposit in cell walls of xylem vessels and modulate lignin (Marschner, 1986). Supplemental Ca or Si applied as a foliar spray appears to enhance the cell wall and thus increase stem strength of poinsettia.

Results from the tissue analysis in the foliar application experiment showed that Ca concentration was not significantly affected by chemical treatment and tissue type. Leaf tissue contained the highest Ca concentration for both experiments. This is due to Ca moving upwards in the xylem, especially to parts that have a high transpiration rate (Starkey and Pederson, 1997). External factors such as mineral nutrient concentration and temperature and internal factors such as metabolic activity can influence the Ca level in plant tissue. For foliar application of mineral nutrients, the nutritional status of the plant determines the rate at which the plant takes up the mineral nutrients being applied (Marschner, 1986). The Ca level of poinsettias should be within

1500 and 1750 µg/g and all of the samples were within this range or higher for the foliar experiment (Dole and Wilkins, 2005).

For the drench experiment, $KSiO_2$ and Si chelate had greater flower dry weights than plants treated with all other treatments. For tissue analysis of the drench experiment, treatment had a significant effect on flower and stem samples. Calcium chelate gave the highest Ca concentration for stem and flower samples. However, Ca chelate was not significantly higher than other treatments for flower samples. This may suggest that Ca chelate had the highest Ca concentration because this treatment was chelated which helps elements become more available to the plant. Chelates prevent nutrients from leaching, increase the mobility of plant nutrients, and increase the uptake potential of nutrients to plants (Datnoff et. al, 2001). Also, leaf samples contained the highest Ca concentration out of the different plant tissue samples. Calcium is immobile in the phloem and therefore preferentially moves in the xylem. Low- transpiring organs, such as flowers, have lower Ca concentrations because nutrients are supplied to them through the phloem (Marschner, 1986).All of the samples were in the sufficient Ca range for the drench experiment except for the stem tissues treated by the control. These samples were deficient.

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# CHAPTER 4. EFFECTS OF PREHARVEST CALCIUM OR SILICON ON MINIATURE ROSES

## 4.1 INTRODUCTION

The rose is one of the most popular flowers in the world. Roses are the best-selling fresh cut flowers in the U.S. About 1.3 billion stems of roses are bought each year (Jerardo, 2007). The rose is the most famous landscape plant and the most economically important landscape plant in the U.S. Although roses are popular they can be susceptible to diseases such as leaf yellowing, powdery mildew, rust, black spot, and rose mosaic (Dole and Wilkins, 2005). However, calcium (Ca) and silicon (Si) have been shown to reduce fungus and other biotic or abiotic stresses. Calcium has been proven to benefit plants in various ways. It is involved in membrane function and structure and cell wall structure, it reduces respiration and ethylene production, reduces the incidence and severity of diseases, and increases stem strength (Poovaiah and Leopold, 1973).

Gerasopoulos and Chebli (1999) used calcium chloride ($CaCl_2$) as a preharvest spray or as a postharvest dip on gerberas. The plants were treated with 0, 0.5, 1.0, or 1.5% $CaCl_2$ preharvest by applying four sprays at scape lengths of 10, 20, 30, or 40 cm. Calcium chloride was applied postharvest by dipping the plants for 1 h or by injecting scapes 3-5 cm below the capitulum until run-off at the cut edge. The highest Ca content in the scapes was obtained with the scape injection of 1.5% $CaCl_2$. The preharvest spray of 1.0 or 1.5% $CaCl_2$ extended vase life of four days and resulted in a 7-12% decrease in stem bending. Scapes dipped in 1.0- 1.55 $CaCl_2$ postharvest had an increase in vase life by 4 days and a decrease in stem bending by 1-2% per day (Gerasopoulos and Chebli, 1999). These experiments suggest that similar treatments may benefit miniature rose production.

Silicon is beneficial to a wide variety of plants including rice, wheat, barley, cucumber, and roses. Silicon can reduce abiotic and biotic stress (Ma and Takahashi, 2002). It reduced the

severity of fungal diseases such as powdery mildew of barley, cucumbers and roses and blast and sheath blight of rice (Voogt, 1991; Ma and Takahashi, 2002). It has reduced injury of plants due to climate changes such as rice injury caused by typhoons (Datnoff et al., 2001). In a study conducted by Chérif and Bélanger (1992), cucumbers were grown in recirculating nutrient solutions that were amended with 0, 100, or 200 ppm of potassium potassium silicate ($K_2SiO_2$). Silicon in the form of $K_2SiO_2$ reduced plant mortality, root decay, and yield losses due to *Pythium ultimum* (Chérif and Bélanger, 1992).

Leaf yellowing and other problems that growers encounter when growing roses can decrease the aesthetic value of the plant and increase crop loss. However, Ca or Si could benefit miniature roses by decreasing leaf yellowing or stress that the plant is undergoing during production. Calcium or Si could, also, lengthen the time of flowering which is important for increasing plant quality. The objective of this experiment was to determine the effects of Ca or Si on growth and development of potted miniature roses 'Sonja' and 'Alto'.

## 4.2 MATERIALS AND METHODS

### 4.2.1 Plant Material

Two experiments with treatments providing supplemental Ca and Si were conducted. Experiment 1 was a foliar spray application of treatments in a campus greenhouse at Louisiana State University and in experiment 2 treatments were applied by drench in a greenhouse at the Burden Center. *Rosa chinensis minima* (R.Roulettii Correv) 'Sonja' and 'Alto' (Nurserymen's Exchange, Vista, CA) were used for these experiments. 'Sonja' is the company's most difficult miniature rose to grow because it is more susceptible to pests and diseases. 'Alto' is one of the company's easiest miniature roses to grow and has a better postharvest life than 'Sonja'.

Miniature roses were cultivated in a greenhouse under a natural photoperiod on the Louisiana State University campus in Baton Rouge, Louisiana and the Burden Center which is also in Baton Rouge. Unrooted cuttings (7.6 cm) of 'Sonja' were stuck on 2 March 2007 (experiment 1) and unrooted cuttings of 'Sonja' and 'Alto' were stuck on 8 October 2007 (experiment 2). Cuttings were planted with four cuttings per 11.4 cm pot using a 3:1 (by volume) peat/perlite mixture that consisted of 0.3 $m^3$ of compressed peat moss and 0.1 $m^3$ of perlite amended with .5 kg/$m^3$ of micromax and 2.3 kg/$m^3$ of dolomitic limestone. Cuttings were placed under a misting system until cuttings calloused and roots formed (13 days). Mist nozzles were placed every 91.4 cm along the misting system (Netafim, Israel). Once roots formed, the misting system was turned off and plants were hand watered in experiment 1 and irrigated via a drip system for experiment 2. Plants were fertigated at every watering with a liquid fertilizer 15-5-15 (15N-2.2P-12.5K) (The Scotts Co., Maryville, OH) at 200- 300 ppm N. Fertigation began as soon as plants were removed from the misting system and were fertigated until harvest. Relative humidity and temperature (set points were at 20°C for day temperature and 22°C for night) were recorded inside the greenhouse throughout the growing season (Figs. 5, 6, 7, 8). Containers were spaced on benches (20 cm spacing) for experiment 1 and on inverted trays on the floor of the greenhouse at the Burden Center for experiment 2 (17.8 cm spacing). There are two different spacings because there was more space on the benches than the floor of the greenhouse for experiment 2.

Miniature roses must be pruned twice during production to produce a quality plant (Dole and Wilkins, 2005). However, three prunings were done for experiment 1 because the plants were not uniform after two prunings. Plants were initially pruned at 2.5 cm by measuring from the base of the media to the top of the plant with hand- held pruners and 1.3 cm above the initial

pruning for the second pruning for both experiments. For the third pruning, any plant material that reached over 10.2 cm was removed.

### 4.2.2 Treatment Application

Containers were placed in four randomized blocks and treatment application was initiated 9 May 2007 (experiment 1) and the same experiment was replicated beginning 14 December 2007 (experiment 2). Five chemical treatments were used by three concentrations and one control to make a total of 16 treatments. Each block contained 48 plants in each experiment. Both experiments were designed with a 5 by 3 factorial design (5 chemicals at 3 concentrations) and a control (deionized water) with 4 blocks and 12 experimental units per treatment and 3 replications for each treatment. Roses treated with the control were included in both experiments. Treatments were applied weekly at each location at the rate of 0, 125, 250, or 500 mg/l of Ca or Si.

The sources of Ca were:

- Ca nitrate [$Ca(NO_3)_2 \cdot 4H_2O$] (Fischer Scientific International, Fair Lawn, NJ)
- Ca chelate [10 % $Ca(NO_3)_2$ + 37 % proprietary blend of alcohol sugars] (Claw El, Brandt Consolidated, Pleasant Plains, IL)
- Chelate without Ca or Si [37 % proprietary blend of alcohol sugars] (Brandt Consolidated, Pleasant Plains, IL)

The sources of Si were:

- Si chelate (Manniplex Traffic) (Parkway Research, Pleasant Plains, IL)
- Potassium silicate [$KSiO_2$] (Sil- Matrix) (PQ Corporation, Valley Forge, PA)

For experiment 1, plants were sprayed in increasing increments as the plant grew. The plants were sprayed until runoff (as directed to do so on the chemical labels), approximately 2.8-

3.7 mL per plant. For experiment 2 the treatments were applied using a time clock to ensure the same amount was applied for all treatments and a drip irrigation system was used to saturate plant media. The amount of treatment applied increased as the plants grew and ranged from 140-296 mL per plant. The control treatment for both experiments was deionized water. Four deionizer columns, cation- bed deionizer, anion- bed deionizer, mixed- bed deionizer and ultra-bed deionizer, were used for the deionized water (Siemens, New Orleans, LA).

**4.2.3. Harvest**

Miniature roses were harvested when three flowers was present. The plants were cut at the media surface with hand held pruners. The growth parameters recorded at harvest were; number of buds, plant height, plant width, and leaf area. The average plant (average height and width) from each pot was chosen for the leaf area and the leaf area was multiplied by 4 to represent the four plants grown in the pot. The plants were washed with 0.2N HCl acid, rinsed with DI water and then dried before recording leaf area. A Li- 300 Area Meter was used to measure leaf area (Li- Cor, Inc., Lincoln, NE). The acid wash was to remove any treatment residue remaining on the plant that might affect nutrient analysis.

**4.2.4 Calcium Extraction**

Once the plants were harvested, samples were dried at 80ºC for 24 h and dry weights for all plant samples were recorded. Plant samples were ground with a Wiley mill (Thomas Scientific, Swedesboro, NJ) to pass through an 850 μm (20-mesh) screen. Half a gram was removed from each ground tissue sample and placed in a digestion tube with 4mL of concentrated nitric acid ($HNO_3$). Samples remained overnight inside a fume hood at room temperature (25ºC).

The tubes were placed in a BD40 digestion block (Bran+Luebe, Germany) set at 120 ºC. After an hour the tubes were removed from the block to cool down for 25 min. Once the samples were cooled, 4 mL of 30% hydrogen peroxide ($H_2O_2$) was added and placed back into the block. This process was repeated until the solution became clear. The clear digested solution was transferred into a 10 mL volumetric flask, brought to volume, and filtered (Whatman #2 slow flow rate filter paper) into a 45 mL plastic vial. Six digestion tubes served as control samples and only nitric acid and hydrogen peroxide added to them.

**4.2.5. Calcium Analysis**

To determine the concentration of Ca in the miniature rose tissue a colorimetric assay was used, Calcium L3K Assay (Diagnostic Chemical Limited, Oxford, CT). This assay turns bluish purple when added to the samples with a maximum absorption at 660 nm and it contains a Ca complexing dye and Phosphonazo III (Onishi, 1986). A 2 µl aliquot of tissue extract and 8 µl of DI water were added with 1 ml of the Phosphonazo III solution for experiment 1 and for 'Sonja' in experiment 2. A 3 µl aliquot of tissue extract and 7 µl of DI water were added with 1 ml of the Phosphonazo III solution for 'Alto' in experiment 2. The solution was vortexed and allowed to stand for 3 min at room temperature. The mixed solutions were transferred to disposable cuvettes. A Milton Roy (Genesys 5, Champaign, IL) thermo spectrometer was used at an absorbance of 660 nm for the samples measured. Standard solutions of 0, 30, 60, 90, 120, and 150 mg/l of Ca were made using $CaCO_3$. The stock solution was prepared from a procedure used by Moorehead and Biggs (1974) where 2.5 g of $CaCO_3$ were placed in a beaker with 250 ml of DI water. Five ml of HCl were needed to dissolve the $CaCO_3$. Solution was diluted to 1000 ml with DI water and the pH was adjusted to 7.0 ± 0.5 with KOH.

To calculate the Ca concentration for the tissue samples, a curve was prepared using the absorbency values from the standard solutions when run on the spectrophotometer. The formula from the curve (y=mx+b) was then used to get the concentration. The absorbency reading for the sample was put in place of 'm' and then calculated. The final value was multiplied by the amount of tissue used divided by the volume it was brought up to. Then this number was multiplied since some of the samples were diluted.

### 4.2.6 Statistical Analysis

All growth parameters were tested for significance of treatment effects, rate, and an interaction using a multivariate analysis by the GLM procedure in SAS using Manova. LSMEANS was used for mean separation using SAS 9.1.

## 4.3 RESULTS

### 4.3.1 Experiment One (Foliar Spray Experiment)

There was no treatment, rate, or interaction effect for all of the growth parameters measured (Table 4.1). There was also no significance for Ca concentration of miniature roses. The highest Ca concentration was with plants treated with $KSiO_2$ and the lowest concentration was with $Ca(NO_3)_2$ (Table 4.2).

Table 4.1. Effect of supplemental foliar applications of chemical treatments on growth parameters of *Rosa chinensis minima* 'Sonja'.

| Treatment | Ca or Si Rate (mg/l) | Bud Number | Plant Height (cm) | Plant Width (cm) | Plant Dry Weight (g) | Leaf Area ($cm^2$) |
|---|---|---|---|---|---|---|
| **$Ca(NO_3)_2$** | **125** | 2.70 | 15.33 | 24.31 | 3.49 | 356.37 |
| | **250** | 2.01 | 13.33 | 24.41 | 3.63 | 427.89 |
| | **500** | 1.90 | 13.63 | 24.01 | 3.25 | 383.00 |
| **Ca Chelate** | **125** | 2.61 | 17.03 | 25.11 | 3.97 | 450.57 |
| | **250** | 2.61 | 14.93 | 23.91 | 4.01 | 420.47 |
| | **500** | 2.50 | 13.93 | 23.31 | 3.55 | 356.25 |
| **Chelate** | **125** | 1.90 | 14.13 | 23.71 | 3.34 | 377.85 |
| | **250** | 2.50 | 13.33 | 23.71 | 3.66 | 446.92 |
| | **500** | 2.30 | 14.93 | 23.21 | 3.56 | 341.78 |
| **Si Chelate** | **125** | 2.30 | 13.13 | 24.21 | 3.62 | 333.71 |
| | **250** | 1.99 | 14.83 | 23.01 | 3.43 | 363.63 |
| | **500** | 3.39 | 14.83 | 25.11 | 3.92 | 447.76 |
| **$KSiO_2$** | **125** | 2.70 | 14.43 | 23.01 | 3.49 | 325.81 |
| | **250** | 1.71 | 14.03 | 22.01 | 3.16 | 390.52 |
| | **500** | 2.91 | 14.23 | 24.81 | 3.43 | 347.62 |
| **Control** | | 2.00 | 15.30 | 23.70 | 3.16 | 387.59 |
| **Treatment** | | NS | NS | NS | NS | NS |
| **Rate** | | NS | NS | NS | NS | NS |
| **Interaction** | | NS | NS | NS | NS | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 4.2. Effect of supplemental foliar applications of chemical treatments on Ca concentration of *Rosa chinensis minima* 'Sonja'.

| Treatment | Ca Concentration (µg/g) |
|---|---|
| **$Ca(NO_{3)2}$** | 45895 |
| **Ca Chelate** | 54480 |
| **Chelate** | 51385 |
| **Si Chelate** | 50556 |
| **$KSiO_2$** | 54862 |
| **Control** | 2184 |
| **Treatment** | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

### 4.3.2 Experiment Two (Drench Experiment)

The chemical, rate, or an interaction had an effect on miniature roses 'Sonja' for all growth parameters measured (Table 4.4). However, only the chemical had an effect on "Alto". The rate and the interaction between rate and chemical had no effect on the growth parameters measured (Table 4.4). Chemical had an effect on Ca concentration for 'Sonja' and 'Alto' but rate and the interaction between rate and chemical had no effect for both cultivars (Table 4.3).

For miniature rose 'Sonja', the number of buds per plant, plant height, plant width, and leaf area were all influenced by an interaction between rate and chemical. Chemical had an influence on all growth parameters measured. Rate had an effect on plant height and leaf area. The number of buds per plant increased as rate increased for plants treated with $Ca(NO_3)_2$ and Ca chelate. The number of buds decreased as rate increased for plants treated with chelate and $KSiO_2$. The largest bud number occurred with plants treated with Ca chelate and was significantly higher than all other treatments. The least amount of buds was with plants treated with Si chelate, chelate, and $KSiO_2$ (Fig. 4.1). Plant height decreased for plants treated with Ca chelate and $KSiO_2$. Height was greatest with plants treated with Ca chelate at all rates. The shortest height was with plants treated with chelate at 250 and 500 mg/l Ca, Si chelate at all rates, $KSiO_2$ at all rates, and chelate at 500 mg/l (Fig. 4.2). Plant width and leaf area decreased as rate increased for plants treated with Ca chelate and Si chelate. The smallest plant width was with Si chelate, chelate, and $KSiO_2$. Leaf area was smallest with plants treated with Si chelate, chelate, and $KSiO_2$. Ca chelate was significantly higher than all other treatments for plant width and leaf area (Table 4.4). Dry weight decreased as rate increased for plants treated with Ca chelate, chelate, and Si chelate. The smallest dry weight was with plants treated with Si chelate and chelate. Dry weight was largest with Ca chelate over all other treatments (Fig. 4.4). For

tissue analysis, the highest Ca concentration was with plants treated with $Ca(NO_3)_2$ at 500 mg/l Ca and the lowest concentration was with Si chelate at 250 mg/l Si. As rate increased for treatments, the Ca concentration increased for Ca chelate and $KSiO_2$ (Table 4.3).

For 'Alto', only treatment had an effect on the growth parameters measured. Calcium chelate had the greatest effect on all growth parameters over all treatments. The number of flower buds was greatest with Ca chelate and was significantly higher than all other treatments (Fig 4.6). Ca chelate was significantly higher than all other treatments for plant height as well. Plant height decreased as rate increased for plants treated with the chelate and Si chelate (Fig 4.7). Plant width increased as rate increased when the Ca chelate was applied but decreased as rate increased for the chelate and Si chelate. Plant width was greatest with Ca chelate and it was significantly greater than all other treatments (Fig. 4.8). Dry weight increased as rate increased for all treatments applied except for plants treated with $KSiO_2$. Ca chelate gave the greatest dry weight and Si chelate, chelate, and $KSiO_2$ gave smaller dry weights (Fig. 4.9). Leaf area increased as rate increased for Ca chelate and $KSiO_2$ but decreased as rate increased for chelate and Si chelate. Ca chelate gave the largest leaf area and was significant from all other treatments. Si chelate, chelate, and $KSiO_2$ gave smaller leaf areas (Fig. 4.10). For tissue analysis, the highest Ca concentration occurred with plants treated with Ca chelate at 250 mg/l Ca. Ca concentration increased when rate of the Ca chelate and $KSiO_2$ increased (Table 4.3).

Table 4.3. Effect of supplemental drench applications of treatments on Ca concentration of *Rosa chinensis minima* 'Sonja' and *Rosa chinensis minima* 'Alto'.

| | 'Sonja' | | 'Alto' | |
|---|---|---|---|---|
| **Treatment** | **Ca or Si Rate (mg/l)** | **Ca Concentration (µg/g)** | **Ca or Si Rate (mg/l)** | **Ca Concentration (µg/g)** |
| **$Ca(NO_3)_2$** | 125 | 50837 | 125 | 87096 |
| | 250 | 49547 | 250 | 101800 |
| | 500 | 61460 | 500 | 96057 |
| **Ca Chelate** | 125 | 51560 | 125 | 88933 |
| | 250 | 52529 | 250 | 103078 |
| | 500 | 54420 | 500 | 100660 |
| **Chelate** | 125 | 40880 | 125 | 80442 |
| | 250 | 37753 | 250 | 75724 |
| | 500 | 43306 | 500 | 65279 |
| **Si Chelate** | 125 | 33440 | 125 | 66535 |
| | 250 | 27145 | 250 | 48745 |
| | 500 | 28795 | 500 | 54745 |
| **$KSiO_2$** | 125 | 36220 | 125 | 90132 |
| | 250 | 40600 | 250 | 91950 |
| | 500 | 43300 | 500 | 89523 |
| **Control** | | 1527 | | 1941 |
| **Treatment** | | * | | * |
| **Rate** | | NS | | NS |
| **Interaction** | | NS | | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

Table 4.4. Effect of supplemental drench applications of treatments on growth parameters of *Rosa chinensis minima* 'Sonja' and *Rosa chinensis minima* 'Alto'.

| | 'Sonja' | | | | | | 'Alto' | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **Ca or Si Rate (mg/l)** | **Flower Bud Number** | **Plant Height (cm)** | **Plant Width (cm)** | **Dry Weight (g)** | **Leaf Area ($cm^2$)** | **Ca or Si Rate (mg/l)** | **Flower Bud Number** | **Plant Height (cm)** | **Plant Width (cm)** | **Dry Weight (g)** | **Leaf Area ($cm^2$)** |
| **$Ca(NO_3)_2$** | **125** | 1.42 | 10.83 | 20.29 | 3.19 | 223.38 | **125** | 0.33 | 8.21 | 18.50 | 2.71 | 206.38 |
| | **250** | 1.63 | 9.85 | 17.31 | 2.39 | 168.15 | **250** | 0.20 | 7.40 | 17.54 | 2.93 | 171.31 |
| | **500** | 2.32 | 11.40 | 21.05 | 3.22 | 231.24 | **500** | 0.25 | 8.29 | 18.42 | 3.04 | 223.70 |
| **Ca Chelate** | **125** | 3.65 | 15.57 | 26.80 | 4.76 | 383.77 | **125** | 0.67 | 13.71 | 23.11 | 5.46 | 340.15 |
| | **250** | 4.39 | 15.17 | 25.86 | 4.45 | 288.39 | **250** | 2.00 | 17.23 | 27.02 | 5.48 | 360.22 |
| | **500** | 5.58 | 14.67 | 18.89 | 4.15 | 233.62 | **500** | 1.67 | 16.58 | 28.08 | 6.11 | 401.23 |
| **Chelate** | **125** | 1.59 | 11.18 | 15.96 | 2.34 | 196.42 | **125** | 0 | 7.00 | 17.18 | 2.30 | 153.73 |
| | **250** | 0.36 | 5.63 | 15.49 | 1.76 | 100.39 | **250** | 0 | 6.25 | 15.80 | 2.27 | 139.98 |
| | **500** | 0.29 | 6.03 | 16.59 | 1.49 | 127.86 | **500** | 0 | 6.05 | 15.32 | 1.71 | 95.51 |
| **Si Chelate** | **125** | 0.82 | 7.06 | 16.59 | 1.96 | 117.98 | **125** | 0.18 | 8.12 | 17.41 | 2.41 | 154.93 |
| | **250** | 0.92 | 9.26 | 15.94 | 1.46 | 98.93 | **250** | 0 | 7.14 | 15.69 | 1.42 | 76.21 |
| | **500** | 0.21 | 6.30 | 14.61 | .96 | 79.01 | **500** | 0.26 | 6.64 | 15.61 | 1.10 | 63.49 |
| **$KSiO_2$** | **125** | 1.54 | 8.91 | 16.77 | 1.90 | 171.47 | **125** | 0.28 | 7.06 | 16.76 | 2.49 | 139.17 |
| | **250** | 1.30 | 8.91 | 17.70 | 2.79 | 181.80 | **250** | 0.13 | 6.53 | 15.64 | 2.60 | 140.44 |
| | **500** | 0.97 | 7.85 | 16.66 | 2.04 | 137.02 | **500** | 0.45 | 8.15 | 17.62 | 2.35 | 140.46 |
| **Control** | | 1.33 | 8.50 | 19.30 | 2.57 | 186.16 | | 0 | 9.1 | 18.17 | 2.85 | 191.53 |
| **Treatment** | | * | * | * | * | * | | * | * | * | * | * |
| **Rate** | | NS | * | NS | NS | * | | NS | NS | NS | NS | NS |
| **Interaction** | | * | * | * | NS | * | | NS | NS | NS | NS | NS |

Values significant (*) or not significant (NS) at the $P \leq 0.05$ level.

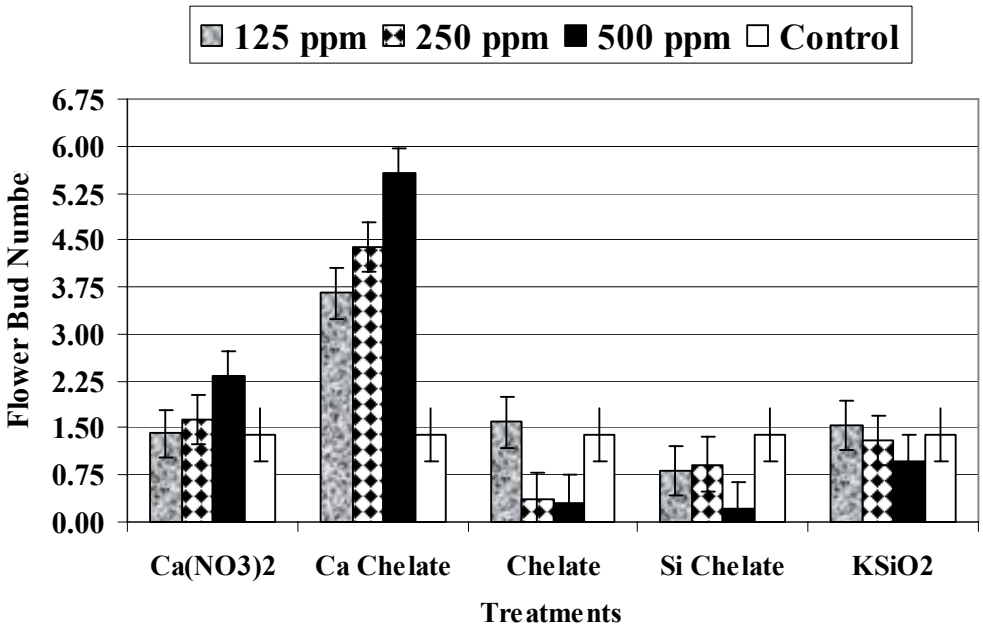


Figure 4.1. Effect of supplemental drench application of treatments on flower bud number of *Rosa chinensis minima* 'Sonja'.

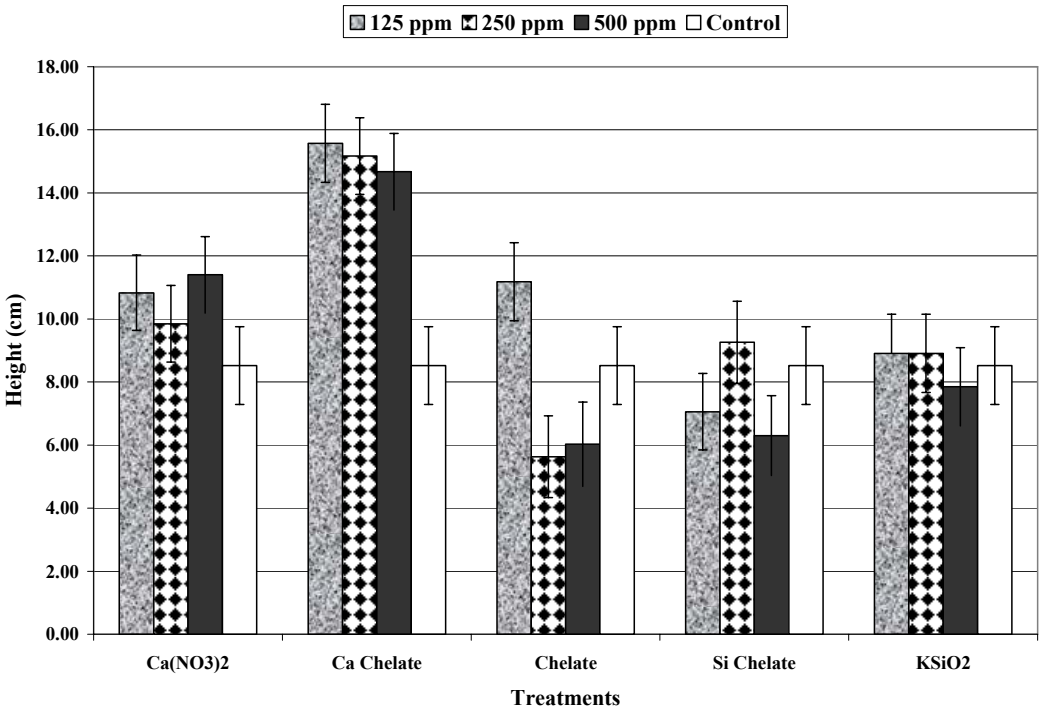


Figure 4.2. Effect of supplemental drench application of treatments on plant height of *Rosa chinensis minima* 'Sonja'.

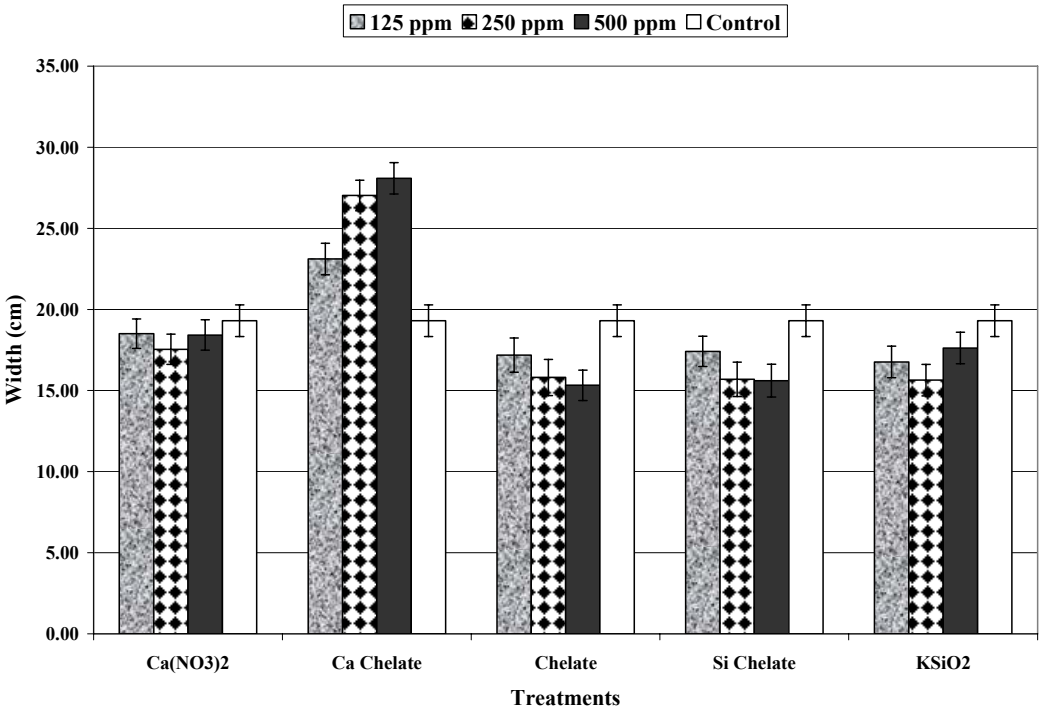


Figure 4.3. Effect of supplemental drench application of treatments on plant width of *Rosa chinensis minima* 'Sonja'.

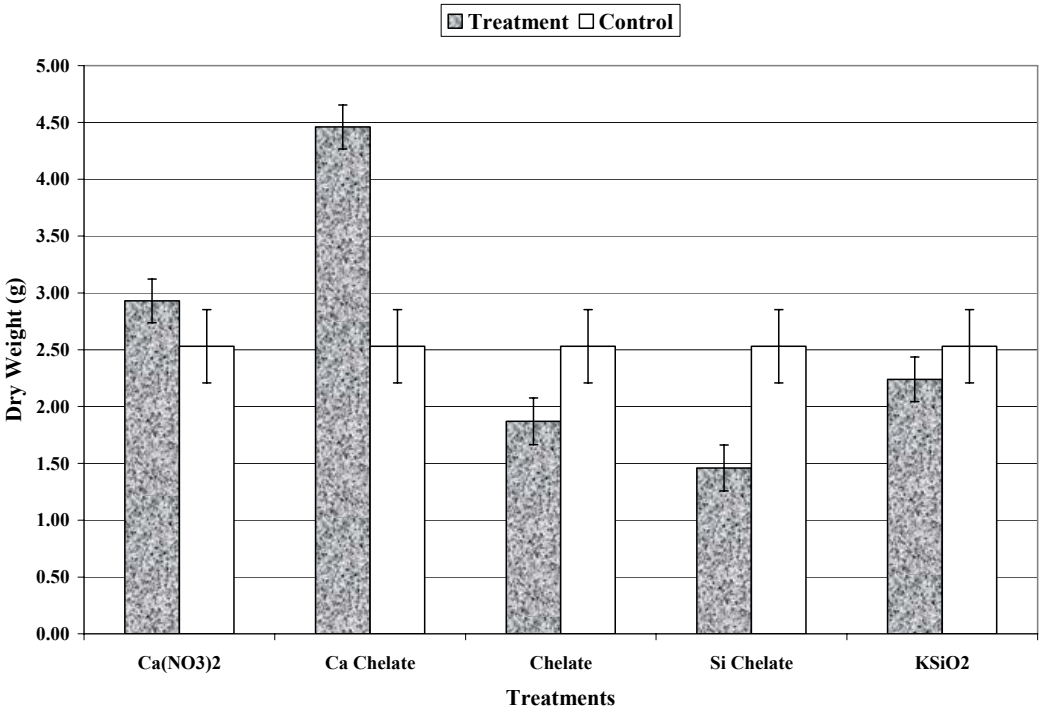


Figure 4.4. Effect of supplemental drench application of treatments on plant dry weight of *Rosa chinensis minima* 'Sonja'.

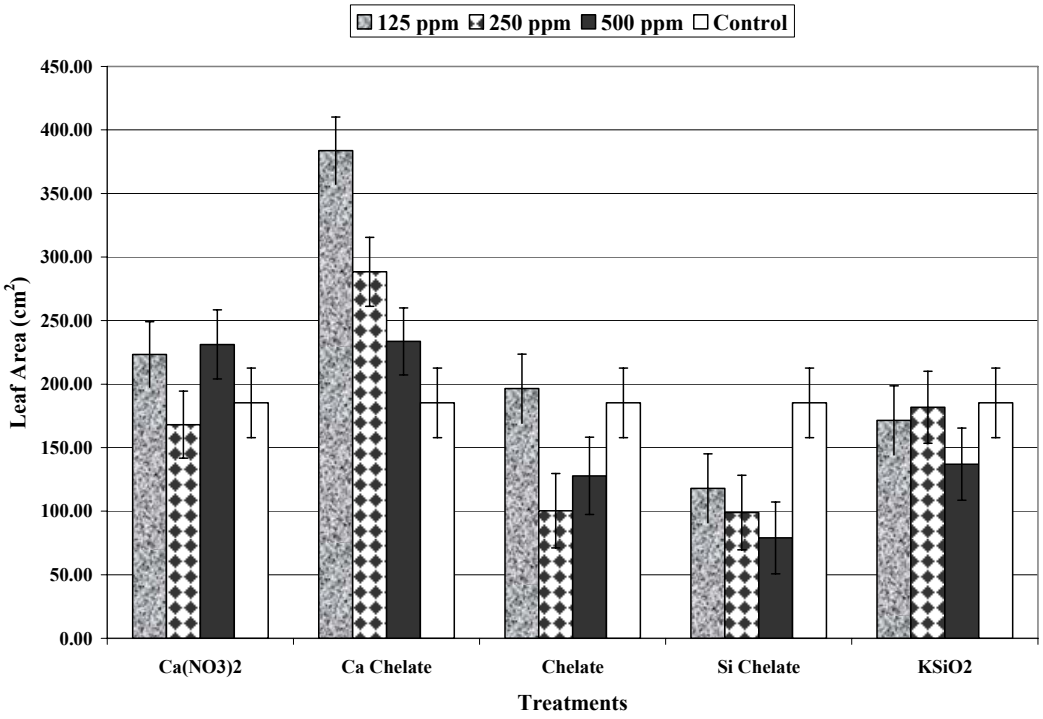


Figure 4.5. Effect of supplemental drench application of treatments on leaf area of *Rosa chinensis minima* 'Sonja'.

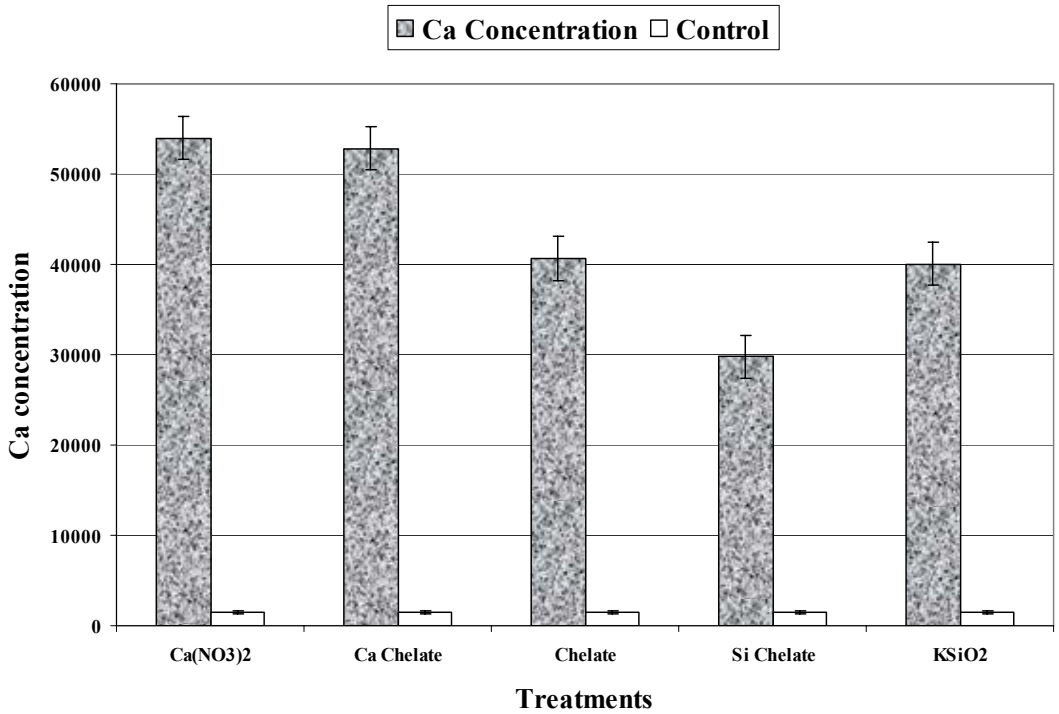


Figure 4.6. Effect of supplemental drench application of treatments on Ca concentration of *Rosa chinensis minima* 'Sonja'.

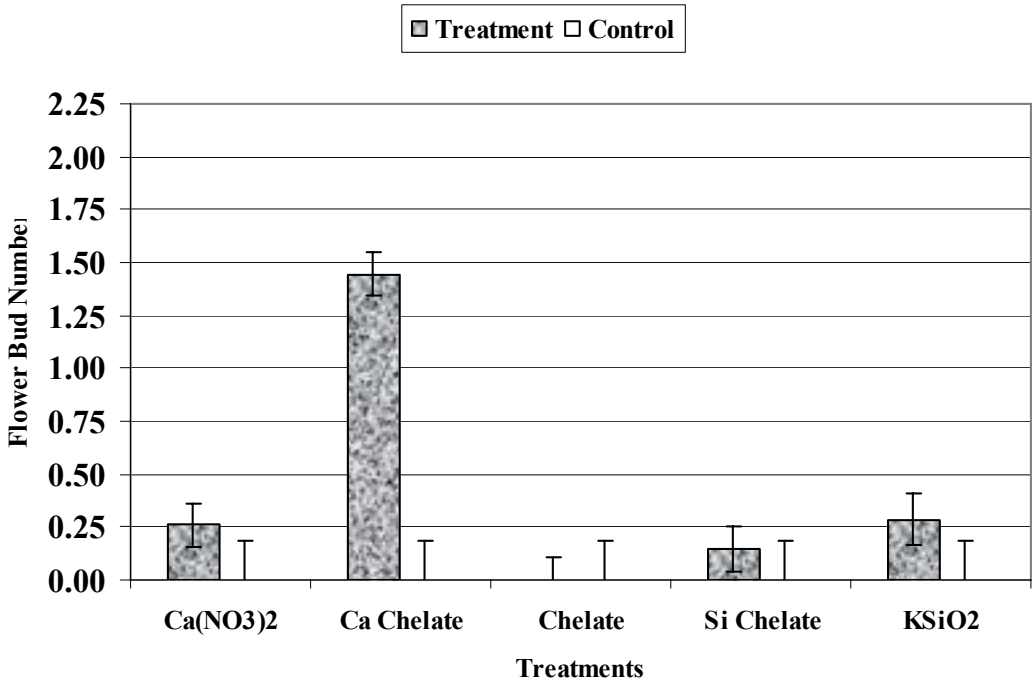


Figure 4.7. Effect of supplemental drench application of treatments on flower bud number of *Rosa chinensis minima* 'Alto'.

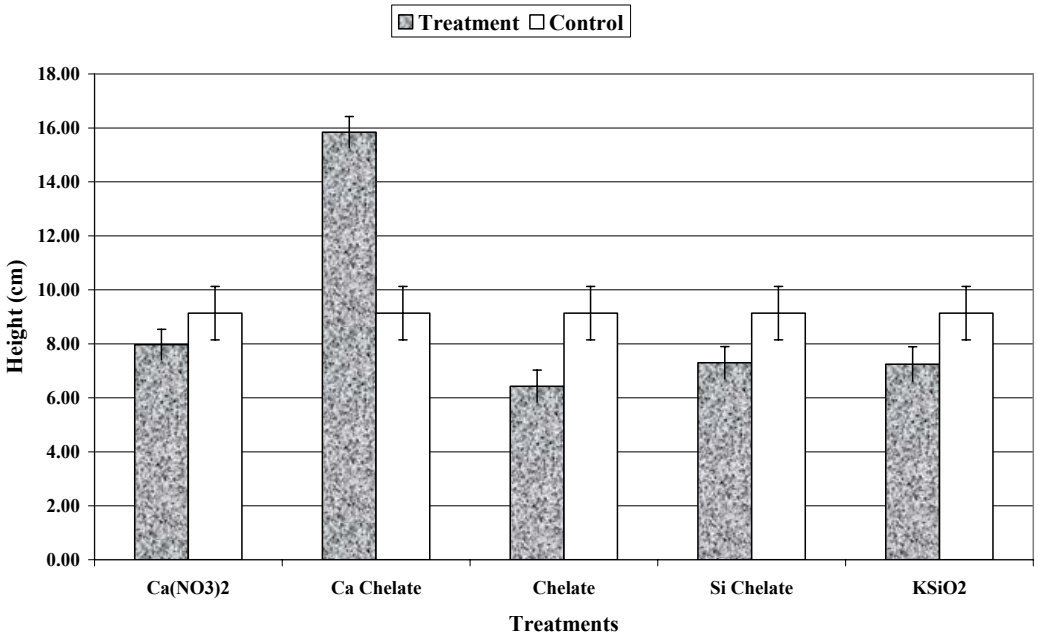


Figure 4.8. Effect of supplemental drench application of treatments on plant height of *Rosa chinensis minima* 'Alto'.

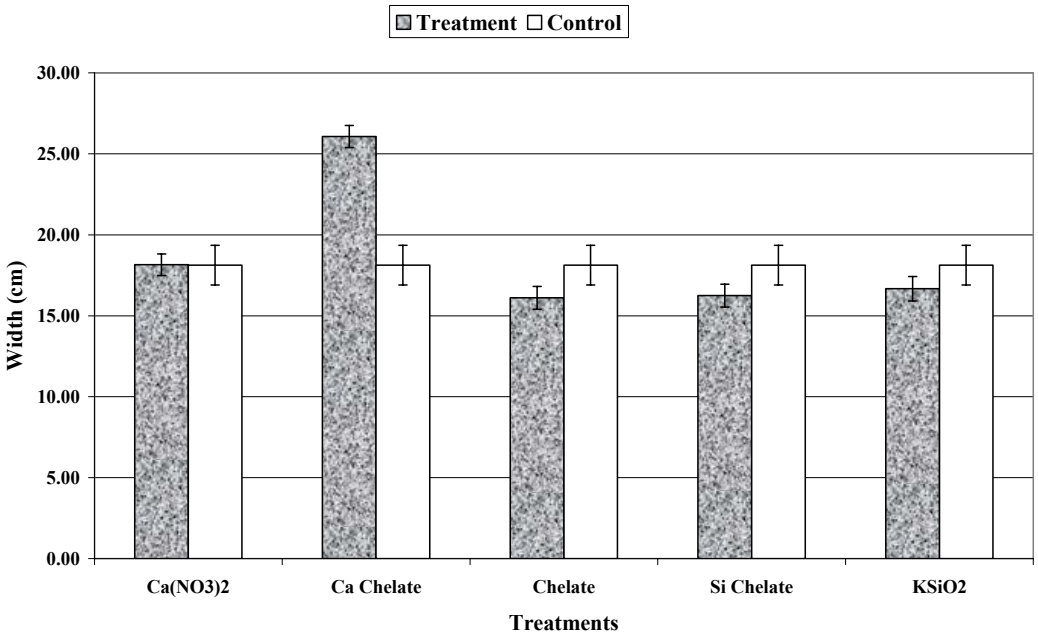


Figure 4.9. Effect of supplemental drench application of treatments on plant width of *Rosa chinensis minima* 'Alto'.

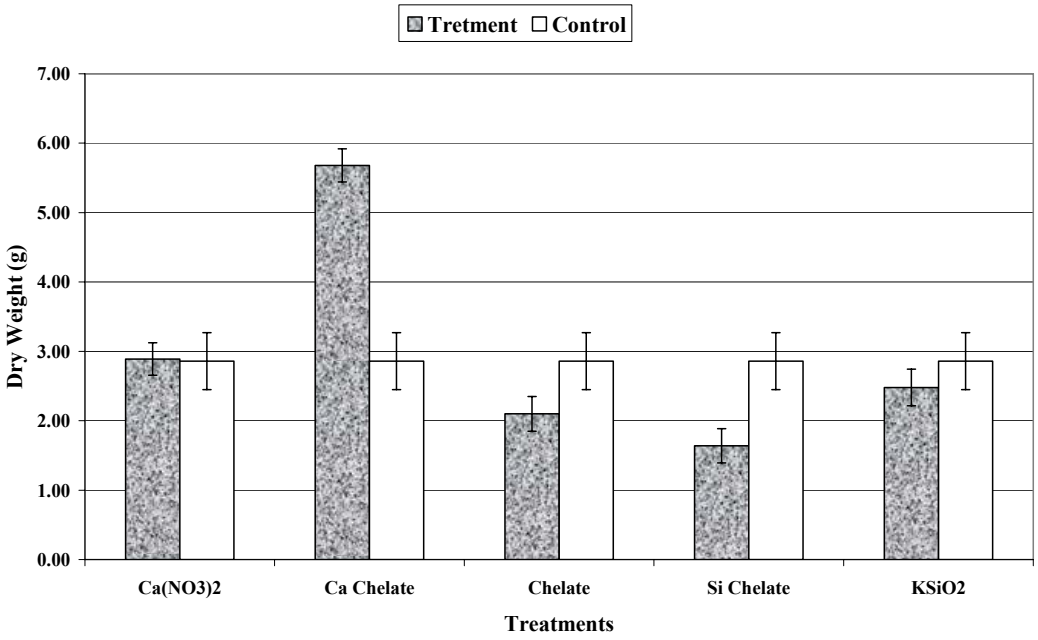


Figure 4.10. Effect of supplemental drench application of treatments on plant dry weight of *Rosa chinensis minima* 'Alto'.

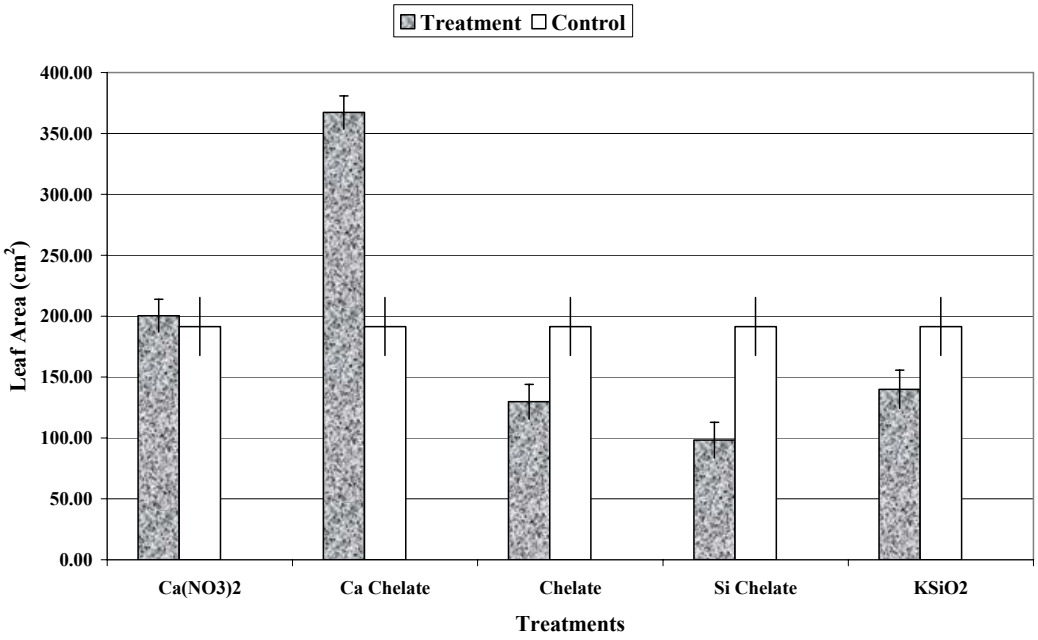


Figure 4.11. Effect of supplemental drench application of treatments on leaf area of *Rosa chinensis minima* 'Alto'.

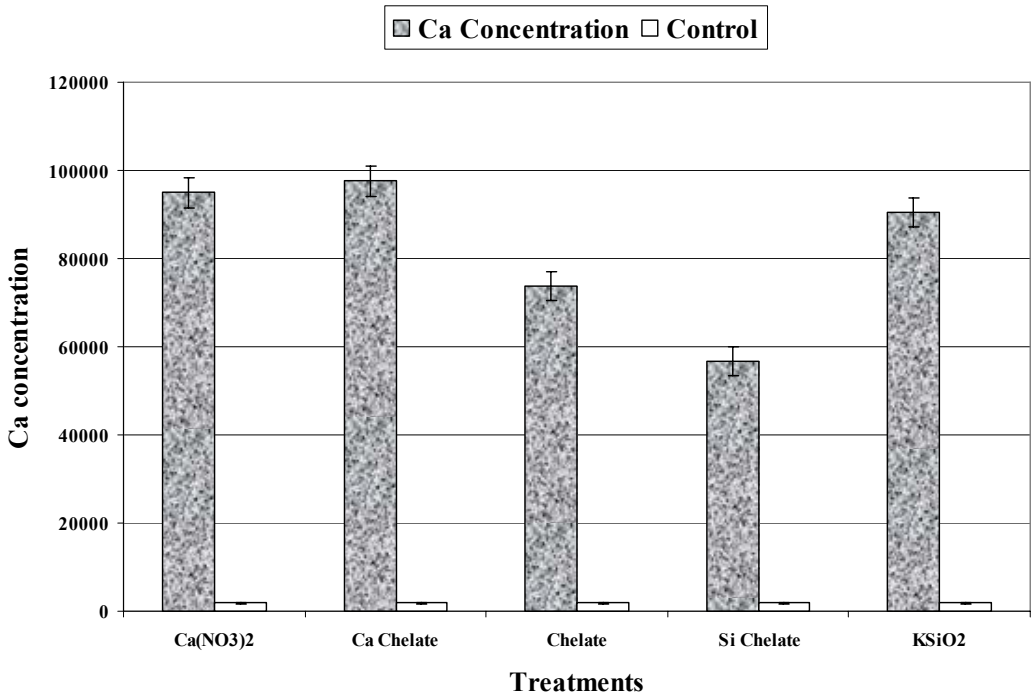


Figure 4.12. Effect of supplemental drench application of treatments on calcium concentration of *Rosa chinensis minima* 'Alto'.

## 4.4 DISCUSSION

None of the chemicals applied as a spray effected the growth parameters measured. Also, there was no significance of chemical spray effect on Ca concentration. This indicates that supplemental Ca was not absorbed by the plant. The treatments might not have been absorbed. Nutrients applied foliarly are rapidly absorbed by plant foliage but this absorption decreases greatly after the first few hours of application. Evaporation of the nutrients applied occurs within minutes of being applied foliarly so absorption occurs from residues in some state of dehydration. The rate at which the mineral element is taken up by leaves usually declines with leaf age due to an increase in the thickness of the cuticle, an increase in membrane permeability, and a decrease in metabolic activity. Transport of nutrients that are absorbed foliarly occurs in the phloem. However, mobility of Ca from cell to cell and in the phloem is very low (Marschner, 1986).

Drench application of treatments applied to 'Sonja' and an interaction between treatment and rate effected the growth parameters measured. Supplemental Ca chelate gave significantly better results for all growth parameters measured over all treatments. This indicates that Ca chelate might be absorbed more readily because of the chelate which helped bind Ca allowing it to be more readily available to the plant for a longer period of time. Except for flower bud number, all growth parameters measured decreased as the rate of Ca chelate increased. This would suggest that Ca chelate should be applied at 125 mg/l Ca for best results. Tissue analysis showed that chemical treatment had an effect on Ca concentration. The highest Ca concentration was with plants treated with $Ca(NO_3)_2$. However, it was not significantly higher than Ca chelate.

For drench application of treatments applied to 'Alto', only treatment had an effect on growth parameters measured. Calcium chelate gave the best results over all other treatments for

all growth parameters. Similar to that of 'Sonja'. For tissue analysis, Ca chelate, $Ca(NO_3)_2$, and $KSiO_2$ gave the highest Ca concentration for tissue samples.

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# CHAPTER 5. EFFECTS OF BIOFUNGICIDES ON POWDERY MILDEW OF MINIATURE ROSES

## 5.1 INTRODUCTION

Powdery mildew, *Spaerotheca pannosa* var *roseae* (Wallr.:Fr), is the worst most economically important fungal diseases in roses. It causes leaf distortion, leaf yellowing, premature defoliation, reduced photosynthesis, increased transpiration and respiration, and in some cases death of the plant and reduced yields by approximately 20 to 40 % (Pemberton, 1908). Powdery mildew fungi occur in many different climates and are distributed by the wind. The white powdery growth is usually found on the upper side of the leaves but can be found on the underside of the leaves, bud, and even flowers. Sometimes it can be challenging to control (Eken, 2005).

Synthetic fungicides have been the primary chemical used to control rose powdery mildew. However, there are recent reports indicating that biofungicides have a good potential for controlling rose powdery mildew. Some effective microorganisms used as biocontrol agents include *Pseudomyza flocculosa, Pseudomyza rugulosa,* and *Tilletiopsis minor. Pseudomyza flocculosa* is more effective than *Pseudomyza rugulosa* because it is not as affected by climatic changes (Eken, 2005).

Continual use of many synthetic fungicides is not environmentally friendly and many synthetic fungicides are more toxic than biofungicides (Eken, 2005). Also, if a synthetic fungicide is overused it will not be as effective in controlling the rose powdery mildew (Eken, 2005). The objective of this experiment was to determine the efficacy of biopesticides: Sil-Matrix® (potassium silicate), Fosphite® (phosphoric acid), Kaligreen® (potassium bicarbonate), or Manni- Plex (chelated silicon) compared to commonly used synthetic pesticide Heritage® on rose powdery mildew, *Spaerotheca pannosa var rosea* (Wallr.:Fr).

## 5.2 MATERIALS AND METHODS

### 5.2.1 Plant Material

Two experiments with foliar spray treatments providing supplemental Ca or Si were conducted. *Rosa chinensis minima* (R.Roulettii Correv) 'Sonja' was used in experiment 1 and both 'Sonja' and 'Alto' (Nurserymen's Exchange, Vista, CA) were used in experiment 2. 'Sonja' is the company's cultivar that is the hardest to grow because it is not as resistant to pests and diseases as 'Alto' which is the best cultivar for pests and diseases.

Miniature roses were cultivated in a greenhouse on the Louisiana State University campus in Baton Rouge, Louisiana. Unrooted cuttings (7.6 cm) of 'Alto' were stuck on 2 March 2006 (experiment 1) and unrooted cuttings of 'Sonja' and 'Alto' were stuck on 8 October 2007 (experiment 2). Four unrooted cuttings were planted per 11.4 cm container. The media was a 3:1 (by volume) peat/perlite mixture that consisted of 0.3 $m^3$ of compressed peat moss and 0.1 $m^3$ of perlite amended with .5 kg/$m^3$ of micromax and 2.3 kg/$m^3$ of dolomitic limestone. Cuttings were placed under a misting system until cuttings calloused and roots formed (13 days). Mist nozzles were placed every 91.4 cm along the misting system (Netafim, Israel). The misting system was set to mist the plants every 6 minutes for 30 seconds. Once roots formed, the misting system was turned off and plants were hand watered. Plants were fertigated at every watering with a liquid fertilizer 15-5-15 (15N-2.2P-12.5K) (The Scotts Co., Maryville, OH) at 250 ppm N. Plants were fertilized at each watering with a siphonex (Scotts Miracle-Gro Products, Inc., Port Washington, NY) for both experiments. Fertigation began as soon as the plants were removed from the misting system and fertigation lasted until harvest. Relative humidity and temperature (set points were at 20°C for day temperature and 22°C for night) were recorded inside the greenhouse

throughout the growing season (Fig 9, 10, 11, 12). Containers were spaced on benches (20 cm spacing) for both experiments.

Miniature roses must be pruned twice during production to produce a quality plant (Dole and Wilkins, 2005). However, three prunings were done for experiment 1 because the plants were not uniform after two prunings. Plants were initially pruned at 2.5 cm, measured at the base of the soil to the top of the plant the initial cutback with hand held pruners and 1.3 cm above the initial pruning for the second pruning for both experiments. For the third pruning, any plant material that reached over 10.2 cm was removed.

**5.2.2 Preharvest Treatment**

Both experiments were randomized with four blocks containing 39 plants in each block for experiment 1 and 35 plants per block for experiment 2. Eight treatments with 20 experimental units per treatment were used for experiment 1 and 10 treatments with 14 experimental units per treatment for experiment 2. To determine the effects of biofungicides on powdery mildew of miniature roses, two different experiments were conducted. Biofungicides were applied by a foliar spray for both experiments. Treatments for experiment 1 started 10 May 2007 and on 24 December 2007 for experiment 2.

Biofungicides used:

- Sil- Matrix™ [ 29% Potassium silicate] (PQ Corporation, Valley Forge, PA)
- Fosphite® [ 53% Mono- and dipotassium salts of Phosphorous Acid] (JH Biotech, Inc., Ventura, CA)
- Kaligreen® [ 82% Potassium bicarbonate] (Toagosei Co., Ltd., Tokyo, Japan)
- Manni- Plex Traffic [ 4% Potash and 5% Silicon] (Parkway Research, Pleasant Plains, IL)

Manni- Plex Traffic was used in experiment 2 but not experiment 1. CapSil was added to all treatments applied at a rate of .6ml/L to ensure uniform spreading and coverage. CapSil is a 100% blend of organo-silicone and non-ionic surfactants (Aquatrols, Paulsboro, NJ). All of the biofungicides were alternated with Heritage® every other week which created 8 treatments for experiment 1 and 10 treatments for experiment 2 with DI water as the control for both experiments. The active ingredient in Heritage® is azoxystrobin (50%) (Syngenta, Greensboro, NC). The rates for the treatments included: Sil- Matrix$^{TM}$ (7.5ml/L), Fosphite® (4 ml/L), Kaligreen® (2.4 g/L) [$LD_{50}$: 3358mg/kg], Manni-Plex Traffic (1.38ml/L)and Heritage® (225 mg/ 100gal) [$LD_{50}$: >5000mg/kg].

Twelve plants were inoculated with rose powdery mildew (*Spaerotheca pannosa*) (Wallr.:Fr) and placed randomly in each block (Fig 5.3). Rose leaves infected with powdery mildew were rubbed onto leaves of healthy miniature roses that were to act as the inoculated plants. Plants that were inoculated were placed inside of a plastic container held together by pvc pipes. The plants that were placed inside of the container were inoculated twice a week until growth of powdery mildew appeared. Once the plants were infected they were placed into the blocks with the healthy plants. For both experiments, plants were sprayed weekly in increasing increments as the plants grew. The treatment plants were sprayed until runoff (as directed to on the labels), approximately 2.9- 4.7 mL per plant. The control treatment for both experiments was deionized water. Four deionizer columns, cation- bed deionizer, anion- bed deionizer, mixed-bed deionizer and ultra- bed deionizer were set up for the deionized water (Siemens, New Orleans, LA).

The treated plants were graded weekly using a visual quality rating scale from 0 – 5. Five being a dead plant, 4 was a plant with approximately100% of the leaves infected with powdery

mildew, 3 was defined as 75% of the leaves infected with powdery mildew, 2 was defined as 50% of the leaves infected with powdery mildew, 1 was defined as 25% of the leaves infected with powdery mildew, and 0 was considered a healthy plant with no visible powdery mildew infection. The rating began when powdery mildew was visible on the plant.

0 0 0 0 0 0 0 0 0

0 x 0 0 x 0 0 x 0

0 x 0 0 x 0 0 x 0

0 x 0 0 x 0 0 x 0

0 0 0 0 x 0 0 x 0

0 0 0 0 0 0 0 0 0

Figure 5.1. Diagram of experimental design. "0" is a non-inoculated treatment plant and "x" is an inoculated host plant (Dr. Ferrin).

### 5.2.3 Harvest

Miniature roses were harvested after 6 weeks of rating for experiment 1 and after 9 weeks of rating for experiment 2. The plants were cut at the soil surface with hand held pruners. Plant dry weight was the only growth parameter measured.

### 5.2.4 Statistical Analysis

Weekly ratings were tested for significance of treatment effect, weekly effect and an interaction between the two using the MIXED procedure and LSMEANS for mean separation in SAS. 9.1.

## 5.3 RESULTS

### 5.3.1 Experiment One

The treatment, week, and interaction between treatment and week had an effect on disease incidence of miniature roses 'Sonja' (Table 5.2). Sil- Matrix$^{TM}$, Heritage® alternated

with Sil- Matrix™, and the control (DI water) was the least effective for control of powdery mildew. Heritage® alternated with Kaligreen®, Kaligreen®, and Heritage® alternated with Fosphite® gave better control of powdery mildew.

The amount of powdery mildew infection was very low on host plants and thus the disease pressure was also low the first two weeks of the experiment. However, the host plants were completely infected with powdery mildew after the third week and therefore the disease pressure was high during week 3 and after. Plants treated with Sil-Matrix™, Heritage® alternated with Sil- Matrix™, or the control had a more rapid rate of infection at week 3 and this trend continued until the end of the experiment. Miniature roses treated with Heritage® alternated with Kaligreen®, Kaligreen®, or Heritage® alternated with Fosphite® were not as susceptible to powdery mildew.

Table 5.1 Effect of foliar applications of chemical treatments on powdery mildew of *Rosa chinensis minima* 'Sonja' average weekly disease rating (0-5).

| **Treatment** | **Disease Rating** | | | | | | |
|---|---|---|---|---|---|---|---|
| | **Week 1** | **Week 2** | **Week 3** | **Week 4** | **Week 5** | **Week 6** | **Treatment** |
| **Sil- Matrix** | 1.4 | 1.6 | 2.6 | 3.4 | 4.7 | 4.9 | NS |
| **Fosphite** | 1.1 | 1.4 | 1.6 | 2.4 | 3.7 | 4.0 | NS |
| **Kaligreen** | 1.1 | 1.3 | 1.4 | 2.0 | 3.0 | 3.4 | * |
| **Heritage (H)** | 1.4 | 1.4 | 1.9 | 2.2 | 3.5 | 4.1 | * |
| **H/Sil- Matrix** | 1.4 | 1.6 | 2.4 | 3.0 | 4.5 | 4.3 | * |
| **H/Fosphite** | 1.1 | 1.3 | 1.8 | 2.3 | 3.2 | 3.6 | * |
| **H/Kaligreen** | 1.2 | 1.2 | 1.5 | 2.3 | 2.9 | 3.2 | * |
| **DI water** | 1.1 | 1.5 | 2.2 | 3.3 | 4.3 | 4.5 | * |
| **Week** | * | * | * | * | * | * | |

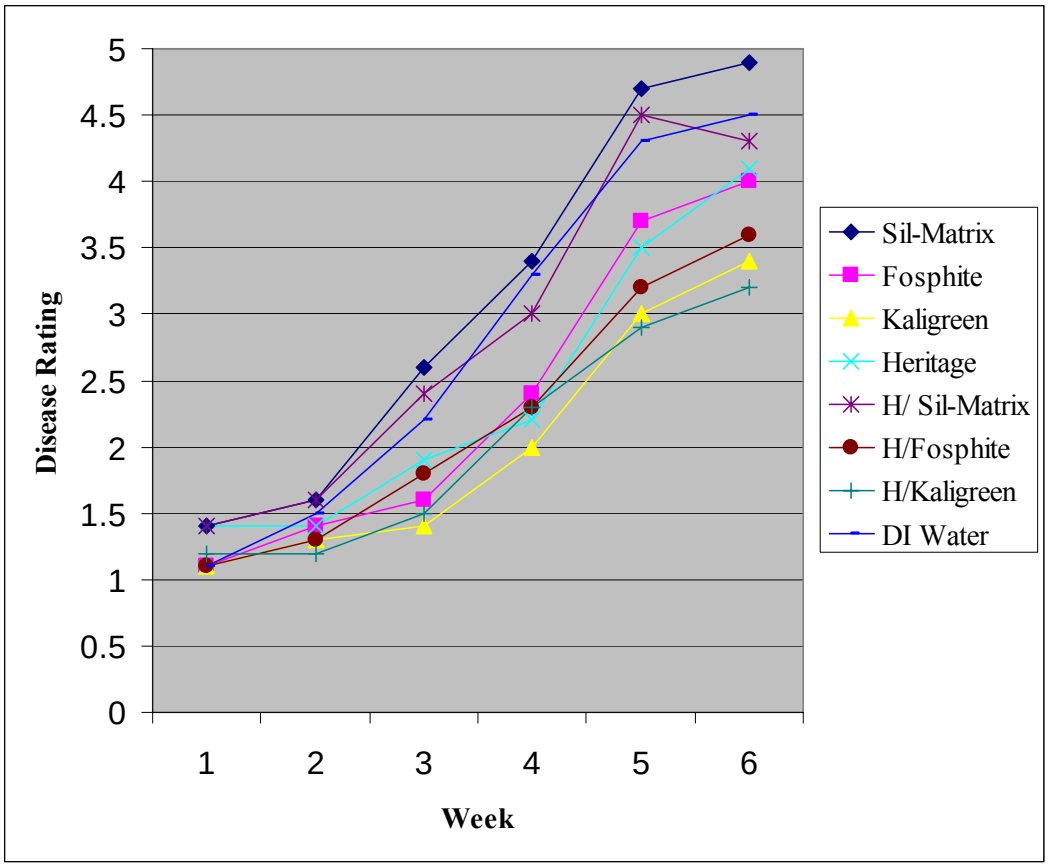


Figure 5.2. Effect of foliar application of treatments of *Rosa chinensis minima* cultivar 'Alto'. 0= no disease, 1= 25% infection, 2= 50% infection, 3= 75% infection, 4= 100% infection, and 5= dead plant.

### 5.3.2 Experiment Two

Treatment, week, and interaction between treatment and week had an effect on miniature roses 'Sonja' (Table 5.3). Kaligreen® had the best control of powdery mildew. Plants treated with the control and Manni- Plex Traffic gave the worst protection against powdery mildew. A separation between treatments occurred during the third week. Sil- Matrix™ and Heritage® alternated with Foshpite® decreased disease pressure in week 6 and Heritage® alternated with Kaligreen® decreased disease pressure in week 7 over other treatments.

For 'Alto', only week had an effect on miniature roses 'Alto' for the disease rating (Table 5.4). There were no significant differences for the first 3 weeks of ratings when the disease pressure was low. However, a separation between treatments occurred at week 4 (Fig. 5.6). The

disease pressure was lower for ‘Alto’ than for ‘Sonja’ which is the company’s hardest miniature rose to grow.

Table 5.2 Effect of foliar applications of chemical treatments on powdery mildew of *Rosa chinensis minima* ‘Sonja’ average weekly disease rating (0-5)

| Treatment | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Treatment |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sil- Matrix** | 0.0 | 0.1 | 0.1 | 0.3 | 0.8 | 0.9 | 1.1 | 1.6 | 1.8 | NS |
| **Fosphite** | 0.1 | 0.4 | 0.6 | 0.7 | 1.3 | 1.4 | 1.4 | 1.7 | 1.6 | NS |
| **Kaligreen** | 0.0 | 0.0 | 0.1 | 0.2 | 0.6 | 0.8 | 1.0 | 1.1 | 1.1 | * |
| **Heritage (H)** | 0.0 | 0.1 | 0.2 | 0.5 | 1.0 | 1.3 | 1.6 | 1.6 | 1.8 | * |
| **H/Sil- Matrix** | 0.0 | 0.1 | 0.2 | 0.9 | 1.0 | 1.2 | 1.4 | 1.5 | 1.7 | * |
| **H/Fosphite** | 0.0 | 0.2 | 0.4 | 0.6 | 1.1 | 1.0 | 1.2 | 1.4 | 1.5 | * |
| **H/Kaligreen** | 0.0 | 0.3 | 0.4 | 0.7 | 1.2 | 1.2 | 1.1 | 1.3 | 1.3 | * |
| **DI water** | 0.0 | 0.4 | 0.7 | 1.2 | 1.7 | 1.6 | 1.7 | 2.0 | 2.2 | * |
| **Manni-Plex Traffic** | 0.1 | 0.2 | 0.4 | 0.9 | 1.5 | 1.8 | 1.9 | 2.4 | 2.4 | * |
| **H/ Manni-Plex Traffic** | 0.0 | 0.0 | 0.4 | 0.7 | 1.3 | 1.4 | 1.6 | 1.8 | 1.8 | * |
| **Week** | NS | * | * | * | * | * | * | * | * | |

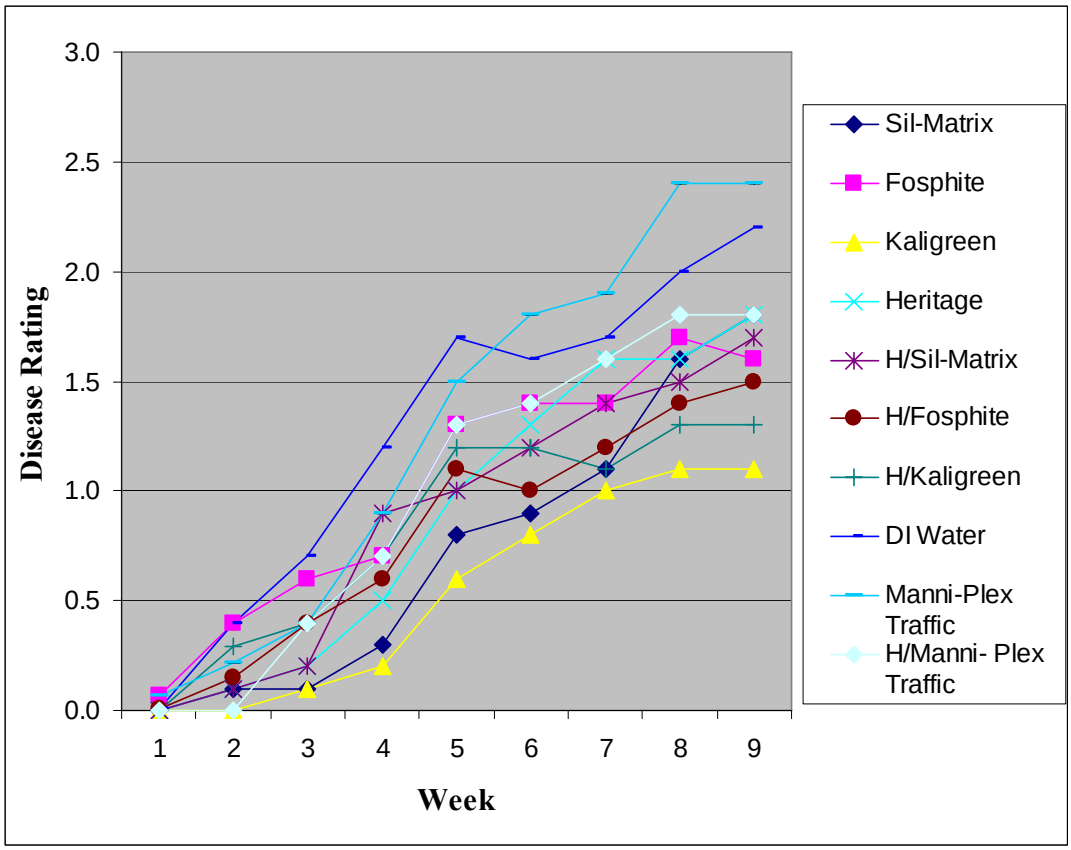


Figure 5.3 Effect of foliar application of treatments of *Rosa chinensis minima* cultivar 'Sonja'. 0= no disease, 1= 25% infection, 2= 50% infection, 3= 75% infection, 4= 100% infection, and 5= dead plant.

Table 5.3 Effect of foliar applications of chemical treatments on powdery mildew of *Rosa chinensis minima* 'Alto' average weekly disease rating (0-5).

| Treatment | Week 1 | Week 2 | Week 3 | Week 4 | Week 5 | Week 6 | Week 7 | Week 8 | Week 9 | Treatment |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sil- Matrix** | 0.0 | 0.0 | 0.0 | 0.3 | 0.7 | 1.0 | 1.2 | 1.2 | 1.4 | NS |
| **Fosphite** | 0.0 | 0.0 | 0.1 | 0.2 | 0.8 | 1.0 | 1.0 | 1.2 | 1.3 | NS |
| **Kaligreen** | 0.0 | 0.0 | 0.0 | 0.2 | 0.6 | 0.9 | 0.9 | 1.0 | 1.1 | NS |
| **Heritage (H)** | 0.0 | 0.1 | 0.1 | 0.6 | 1.0 | 1.0 | 1.1 | 1.3 | 1.4 | NS |
| **H/Sil- Matrix** | 0.1 | 0.0 | 0.0 | 0.2 | 0.5 | 1.0 | 1.0 | 1.2 | 1.4 | NS |
| **H/Fosphite** | 0.0 | 0.0 | 0.0 | 0.3 | 0.6 | 0.8 | 0.9 | 1.0 | 1.0 | NS |
| **H/Kaligreen** | 0.0 | 0.0 | 0.0 | 0.3 | 0.6 | 0.8 | 0.9 | 1.3 | 1.2 | NS |
| **DI water** | 0.0 | 0.1 | 0.2 | 0.7 | 1.0 | 1.0 | 1.0 | 1.3 | 1.2 | NS |
| **Manni-Plex Traffic** | 0.1 | 0.1 | 0.0 | 0.4 | 0.7 | 1.0 | 1.0 | 1.0 | 1.1 | NS |
| **H/ Manni-Plex Traffic** | 0.0 | 0.0 | 0.0 | 0.4 | 0.6 | 0.9 | 1.1 | 1.2 | 1.2 | NS |
| **Week** | NS | NS | NS | * | * | * | * | * | * | |

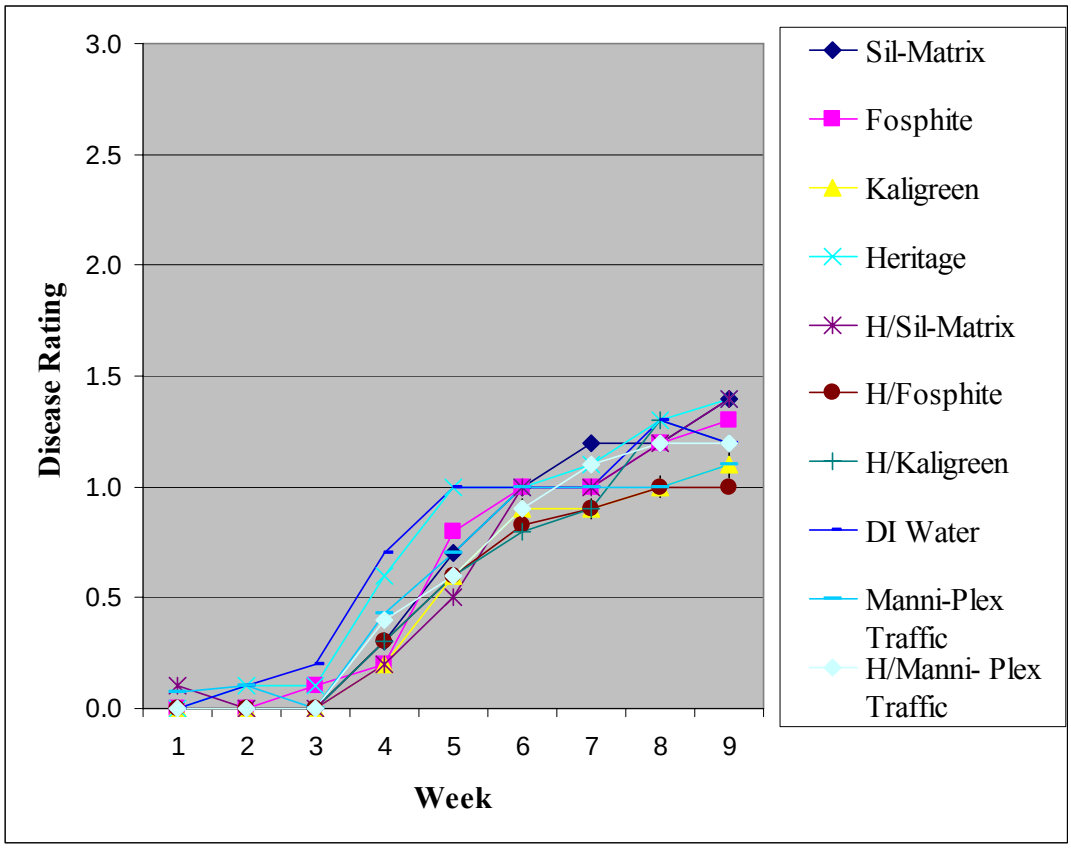


Figure 5.4 Effect of foliar application of treatments of *Rosa chinensis minima* cultivar 'Alto'. 0= no disease, 1= 25% infection, 2= 50% infection, 3= 75% infection, 4= 100% infection, and 5= dead plant.

## 5.4 DISCUSSION

The results of experiment 1 show that disease pressure was higher and spread quicker than in experiment 2 for both cultivars. This could be due to the fact that the plants grown in experiment 1 were grown during a warmer time during the year. Warmer climates can cause plants to be infected by powdery mildew more easily (Pemberton, 1908). The disease pressure was very low in the first few weeks of all experiments and most treatment separations were not seen until after the third week when disease pressure rose at a quicker rate.

There were no treatment effects for 'Alto' in experiment 2. This could be due to the low disease pressure seen throughout the experiment as compared to 'Sonja' in experiment 1 and 2. This indicated that if the disease pressure had been higher there might have been a significant

difference between treatments. Also, this indicated that 'Alto' was not as susceptible to powdery mildew as 'Sonja'. Overall, Kaligreen® had the better control of powdery mildew than other treatments for all experiments. However, Kaligreen® should be applied as a preventative fungicide not as a curative. It should be applied at the first sign of powdery mildew and remove the plants that show signs of powdery mildew.

## 5.5 LITERATURE CITED


Dole, J.M. and H.F. Wilkins. 2005. In: Floriculture: Principles and Species. 2nd ed. Pearson Education, Inc., Upper Saddle River, NJ. p331-347, 808-827.

Eken, C. 2005. A review of biological control of rose powdery mildew (*Spaerotheca pannosa* var. *rosae*) by Fungal Antagonists. Acta Hort. 690:193-196.

Pemberton, J.H. 1908. In: Roses. Longmans, Green, and Co., London. p294-302.

# CHAPTER 6. SUMMARY AND CONCLUSIONS

Poinsettias are the number one flowering potted plant in the U.S. and is the most popular Christmas plant sold (Jerardo, 2002). One of the problems with poinsettias is weak stem strength leading to stem breakage (Kuehny and Branch, 2000). The rose is one of the most popular flowers in the world (Jerardo, 2007). Even though roses are popular they can be susceptible to diseases such as leaf yellowing, powdery mildew, rust, and rose mosaic (Dole and Wilkins, 2005). Research in horticulture has indicated that calcium and silicon reduce fungus and other biotic stresses and increase stem strength. Calcium, also, is involved in membrane function and structure and cell wall structure, and reduces respiration and ethylene production (Poovaiah and Leopold, 1973). Also, research has indicated that silicon alleviates water stress by decreasing transpiration, decreases powdery mildew, alleviates salt stress, and others. This research was developed to determine the effects of supplemental calcium or silicon on growth and development of potted miniature roses and poinsettias. Poinsettia cultivar 'Orion Red' and miniature rose cultivars 'Alto' and 'Sonja' were used in the study; the sources of Ca were $Ca(NO_3)_2$, and Ca chelate. The sources of silicon were Si chelate and $KSiO_2$. There was also a chelate alone and the control was deionized water. Supplemental treatments were applied as a foliar spray to runoff and as a drench. Untreated plants were included in all the experiments, means and standard errors were calculated for comparison with treatments.

Supplemental Ca or Si applied by foliar spray for poinsettias increased plant width and stem strength average. Treatments applied as a drench for poinsettias increased flower dry weight. Supplemental Ca or Si by foliar spray for miniature roses had no significant effects on any of the growth parameters measured or for Ca concentration of tissue samples. In support of this result, miniature roses were unaffected by the spray treatment. Calcium chelate applied as a

drench ‘Sonja’ gave greater flower bud numbers, plant height, plant width, dry weight, and leaf area. For ‘Alto’, drench applied treatments also had the same trend with Ca chelate. Also, drench applied treatments had a significant effect on Ca concentration for both cultivars.

All of the poinsettia tissue samples were in the sufficiency range for Ca (1500-1575 μg/g) except for the stem tissue for the drench experiment. This could be the reason that there was not more significance with measuring stem strength. The leaf tissue contained the highest Ca concentration which concurs with other experiments conducted.

Biofungicide Kaligreen® proved to have a better control of powdery mildew during the visual weekly ratings as compared to other treatments applied. However, as the disease pressure increased so did the weekly ratings. This indicates that Kaligreen® should be applied as a preventative fungicide as it is labeled. And should not be used as a curative for powdery mildew.

## APPENDIX: NON SIGNIFICANT DATA

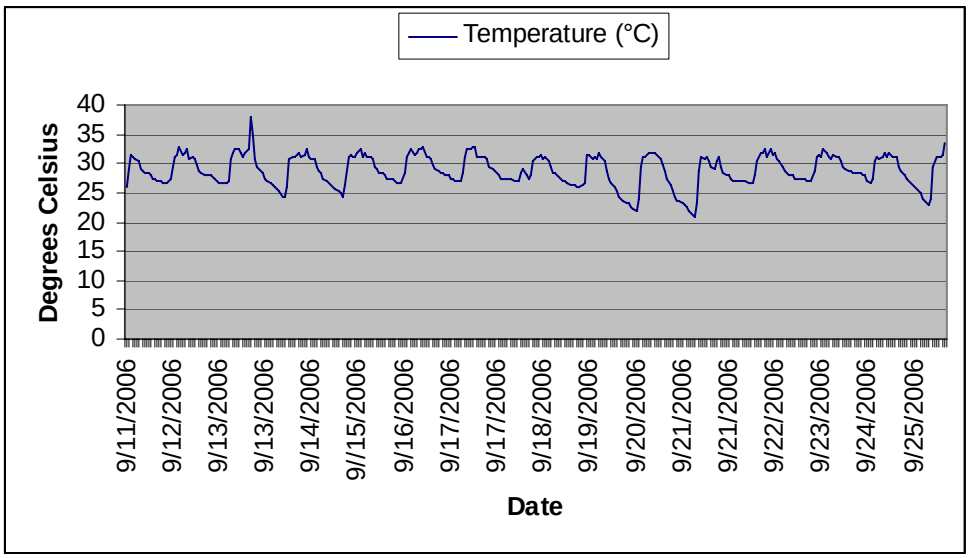


Figure 1. Average weekly greenhouse temperature ºC during 2006 Ca/Si foliar spray treatment experiment on poinsettias at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

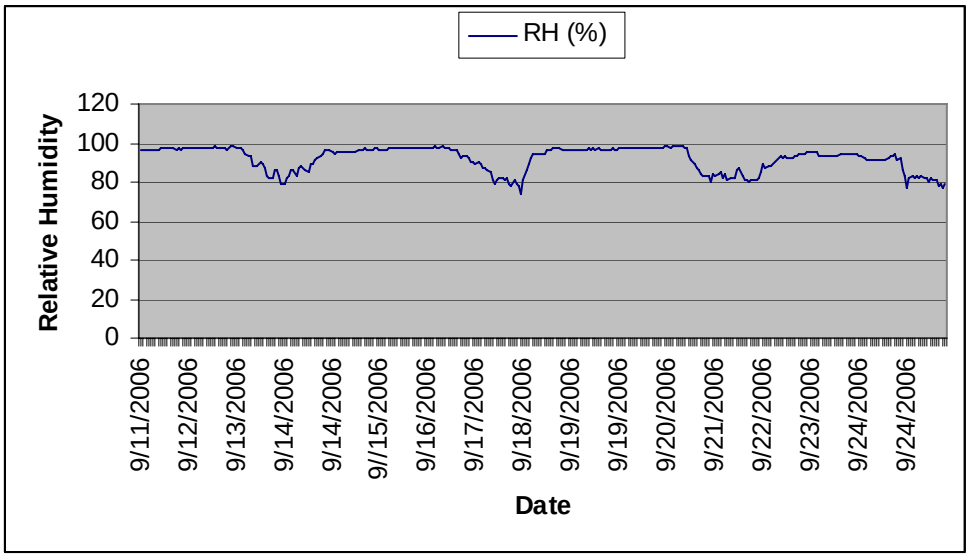


Figure 2. Average weekly % relative humidity during 2006 Ca/Si foliar spray experiment on poinsettias at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

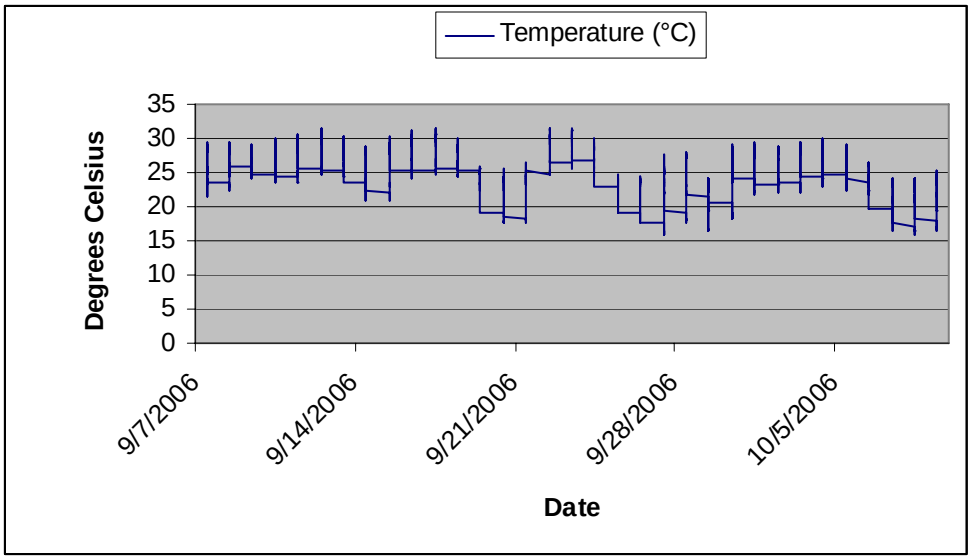


Figure 3. Average weekly greenhouse temperature ºC during 2006 Ca/Si drench treatment experiment on poinsettias at the Burden Center, Baton Rouge, Louisiana.

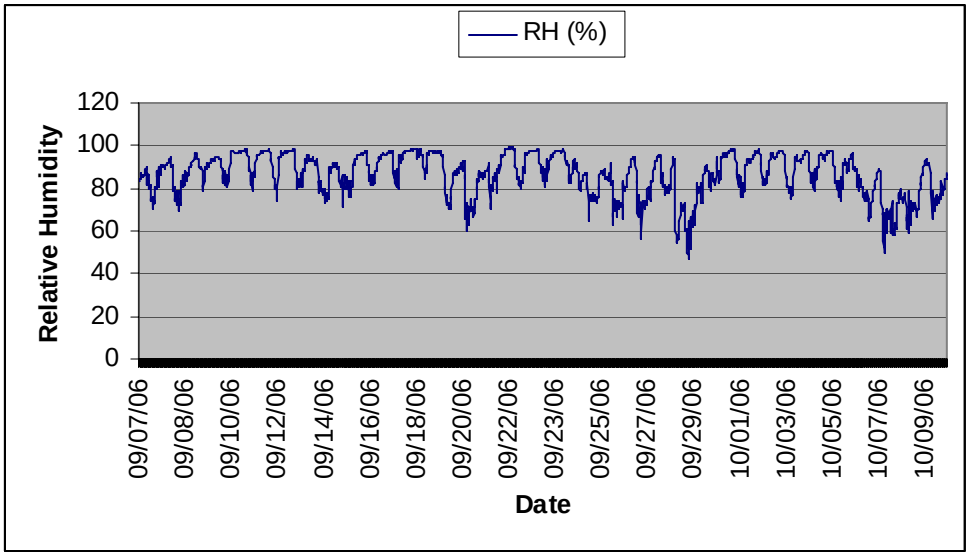


Figure 4. Average weekly % relative humidity during 2006 Ca/Si drench treatment experiment on poinsettias at the Burden Center, Baton Rouge, Louisiana.

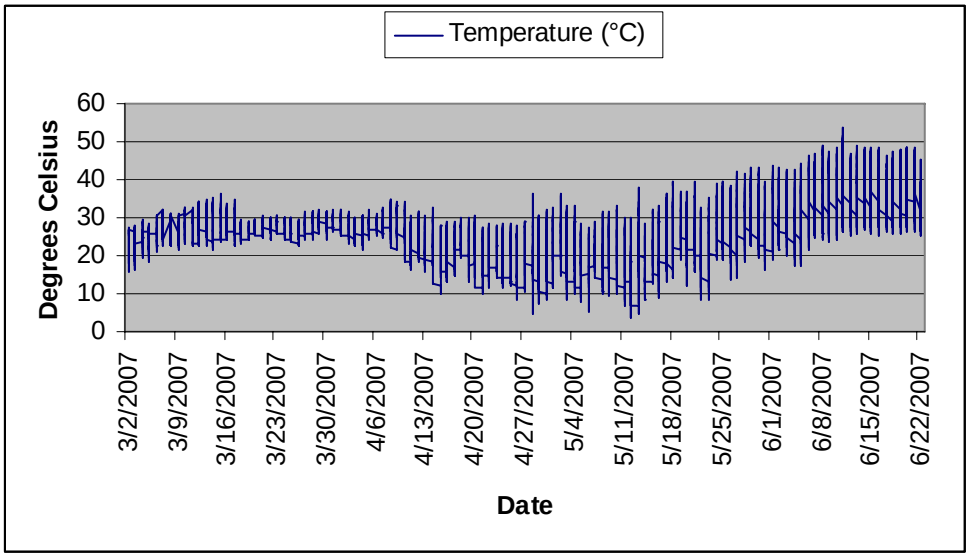


Figure 5. Average weekly greenhouse temperature $^{o}$C during 2007 Ca/Si foliar spray treatment experiment on miniature roses at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

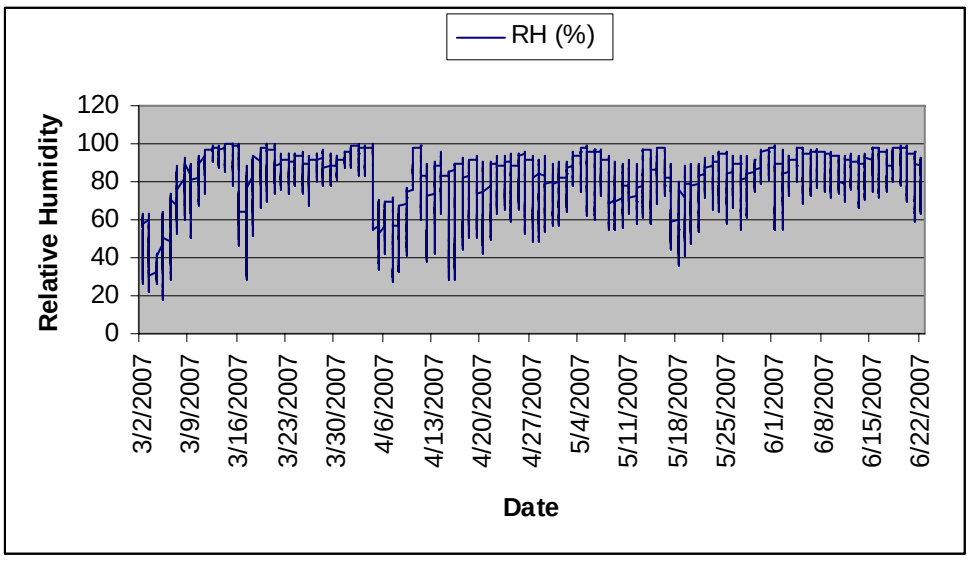


Figure 6. Average weekly % relative humidity during 2007 Ca/Si foliar spray treatment experiment on miniature roses at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

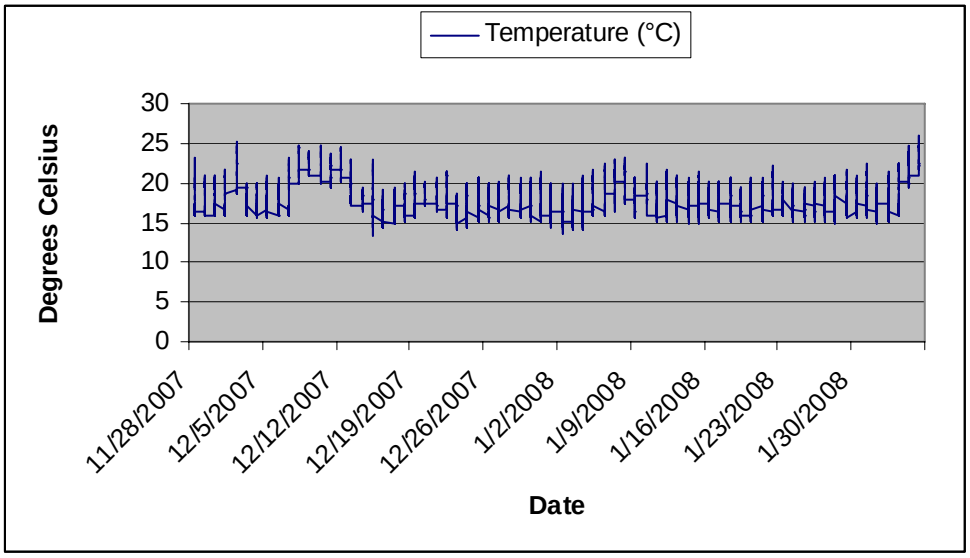


Figure 7. Average weekly greenhouse temperature $^{o}$C during 2007 Ca/Si drench treatment experiment on miniature roses at the Burden Center, Baton Rouge, Louisiana.

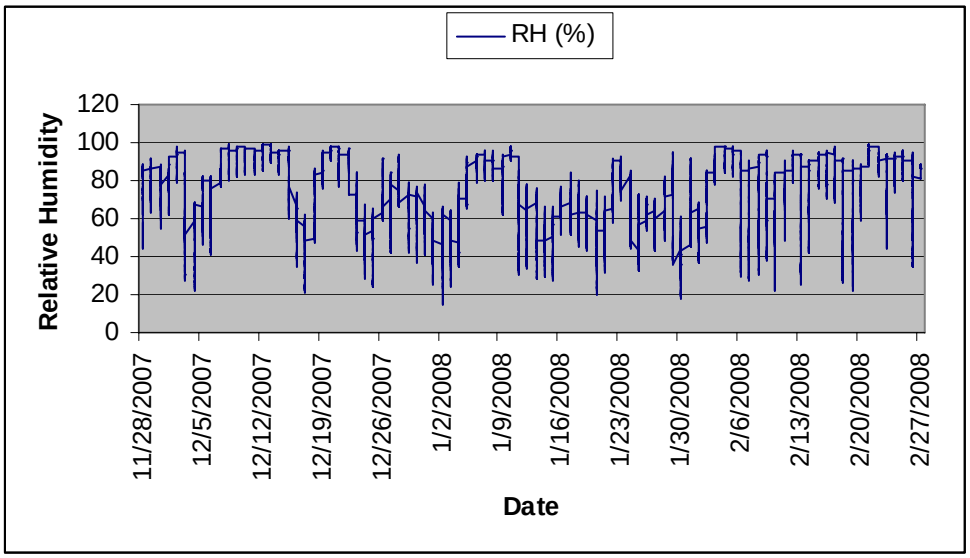


Figure 8. Average weekly greenhouse % relative humidity during 2007 Ca/Si drench treatment experiment on miniature roses at the Burden Center, Baton Rouge, Louisiana.

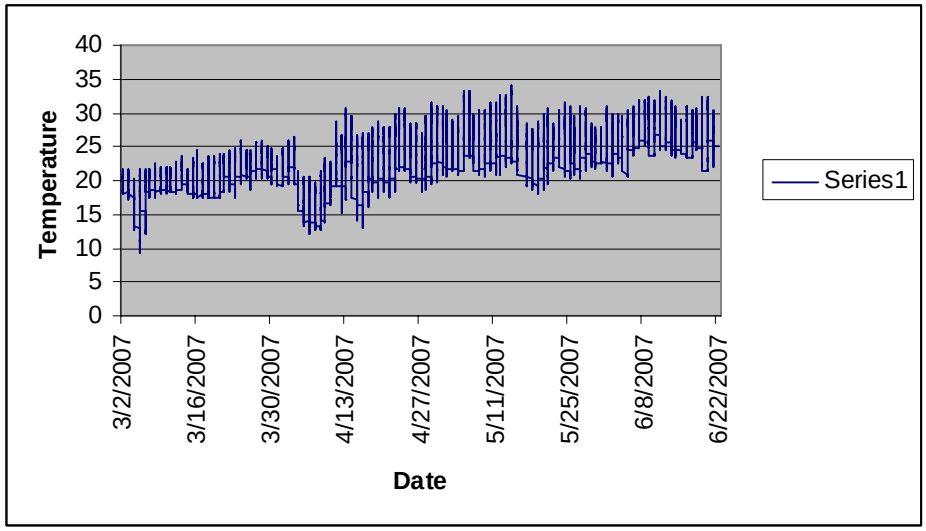


Figure 9. Average weekly greenhouse temperature $^{o}$C during 2007 powdery mildew experiment on miniature roses at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

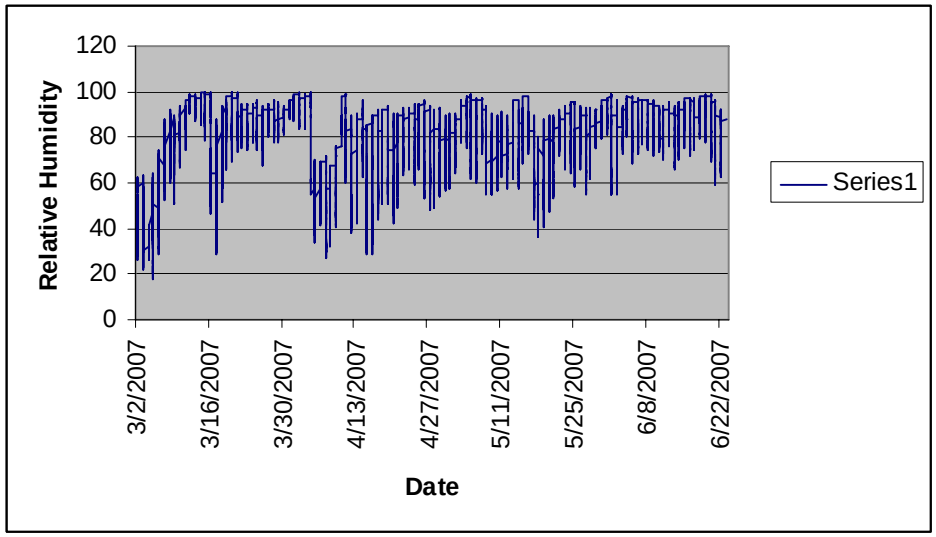


Figure 10. Average weekly greenhouse % relative humidity during 2007 powdery mildew experiment on miniature roses experiment at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

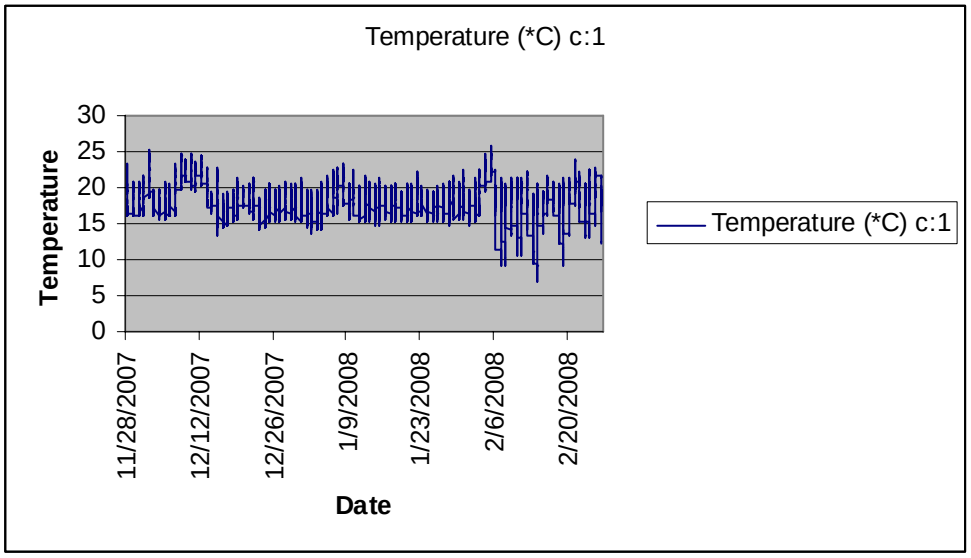


Figure 11. Average weekly greenhouse temperature ºC during 2007 powdery mildew experiment 2 on miniature roses at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

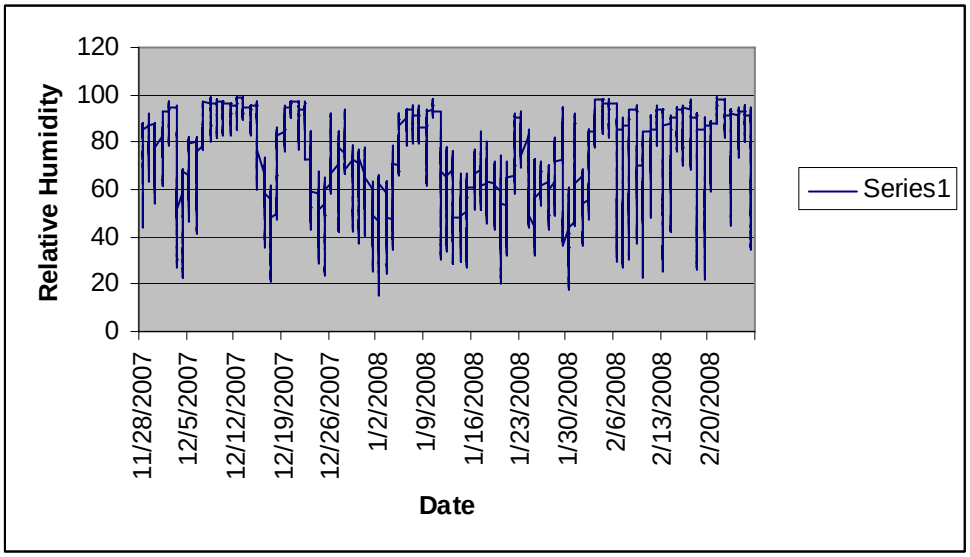


Figure 12. Average weekly greenhouse % relative humidity during 2007 powdery mildew experiment 2 on miniature roses at the LSU Campus Greenhouses, Baton Rouge, Louisiana.

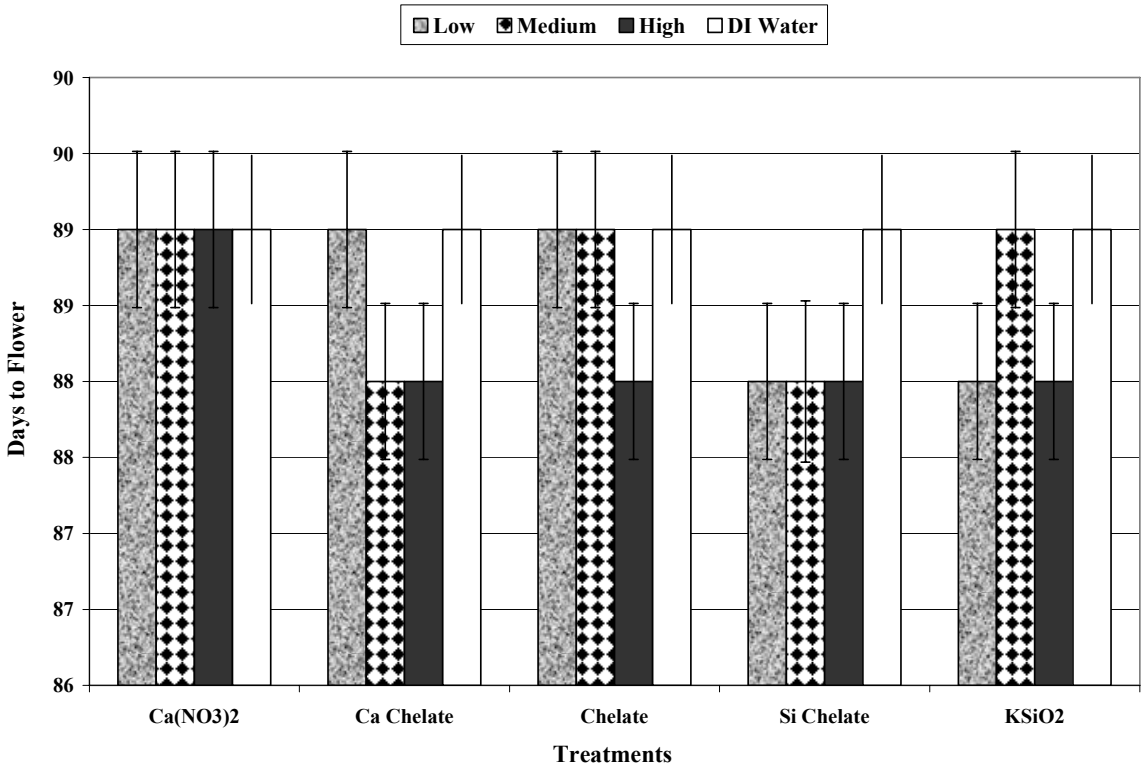


Figure 13. Effect of supplemental spray applications of treatments on days to flower of *Euphorbia pulcherrima* 'Orion Red'.

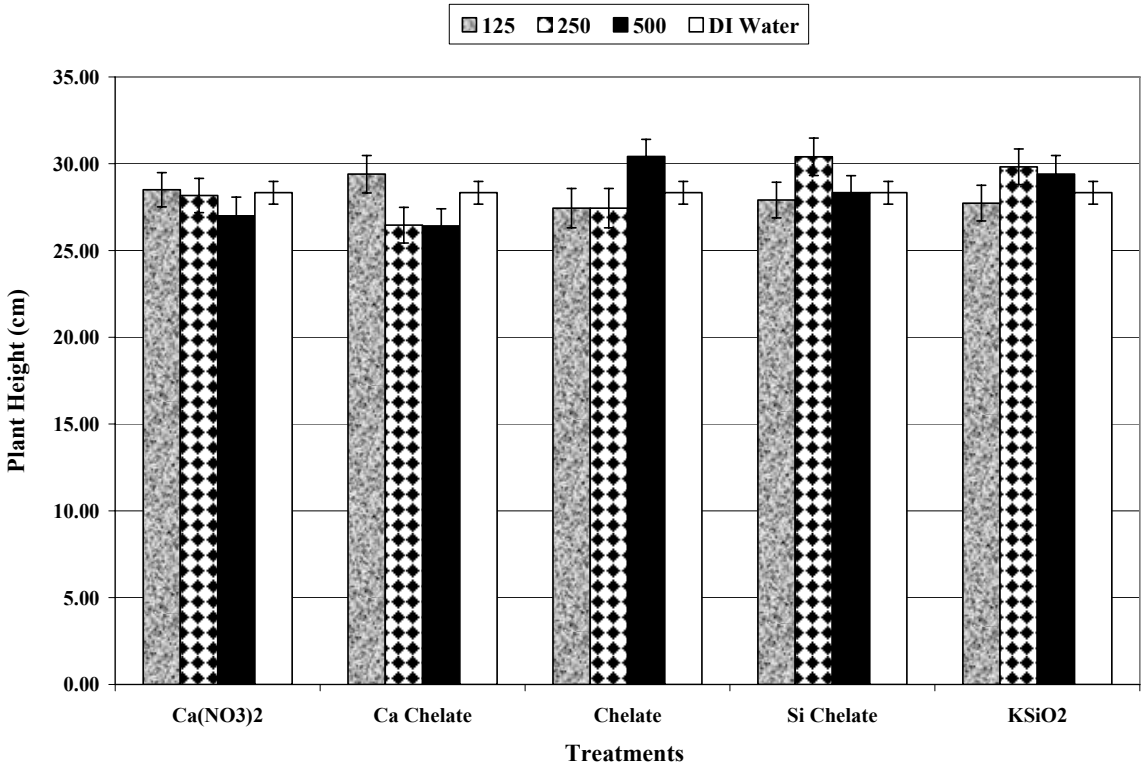


Figure 14. Effect of supplemental spray applications of treatments on plant height of *Euphorbia pulcherrima* 'Orion Red'.

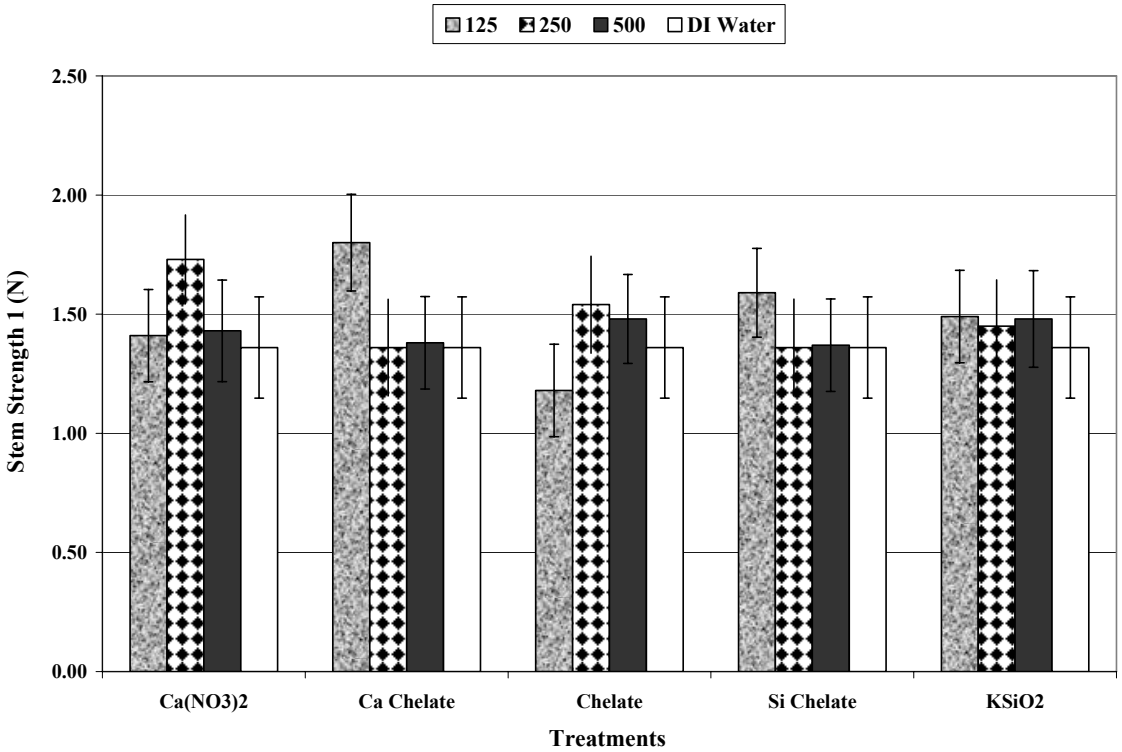


Figure 15. Effect of supplemental spray applications of treatments on stem strength 1 of *Euphorbia pulcherrima* 'Orion Red'.

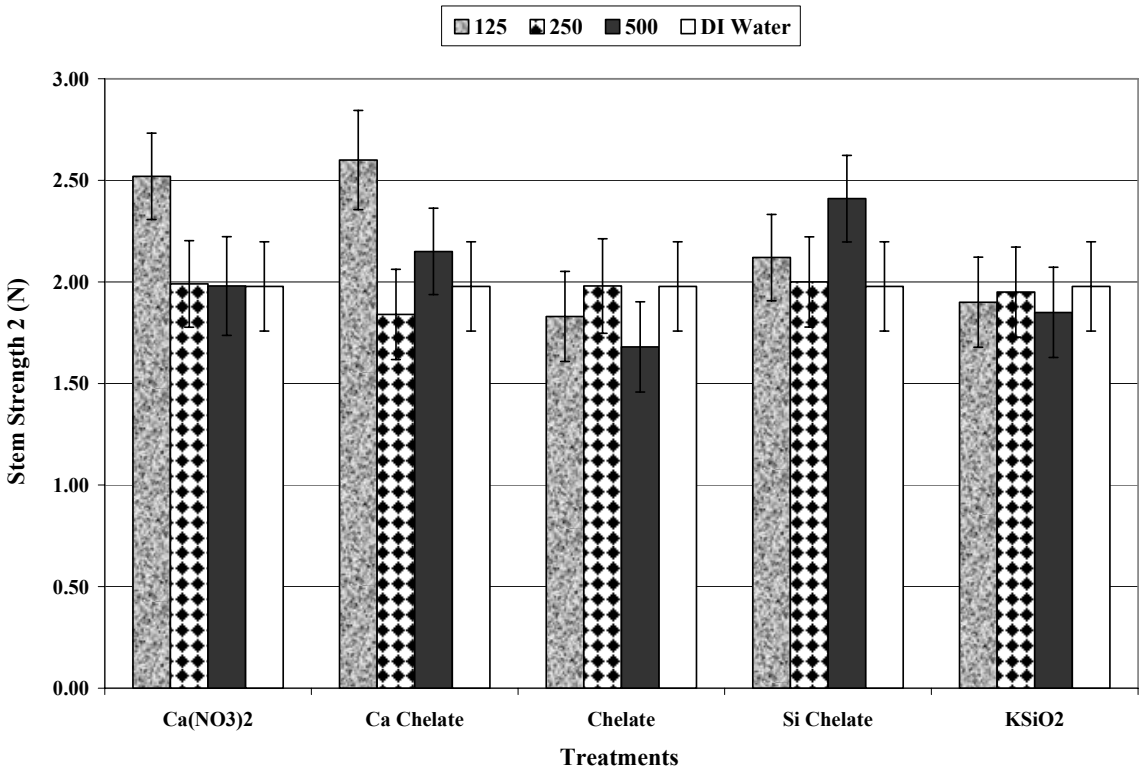


Figure 16. Effect of supplemental spray applications of treatments on stem strength 2 of *Euphorbia pulcherrima* 'Orion Red'.

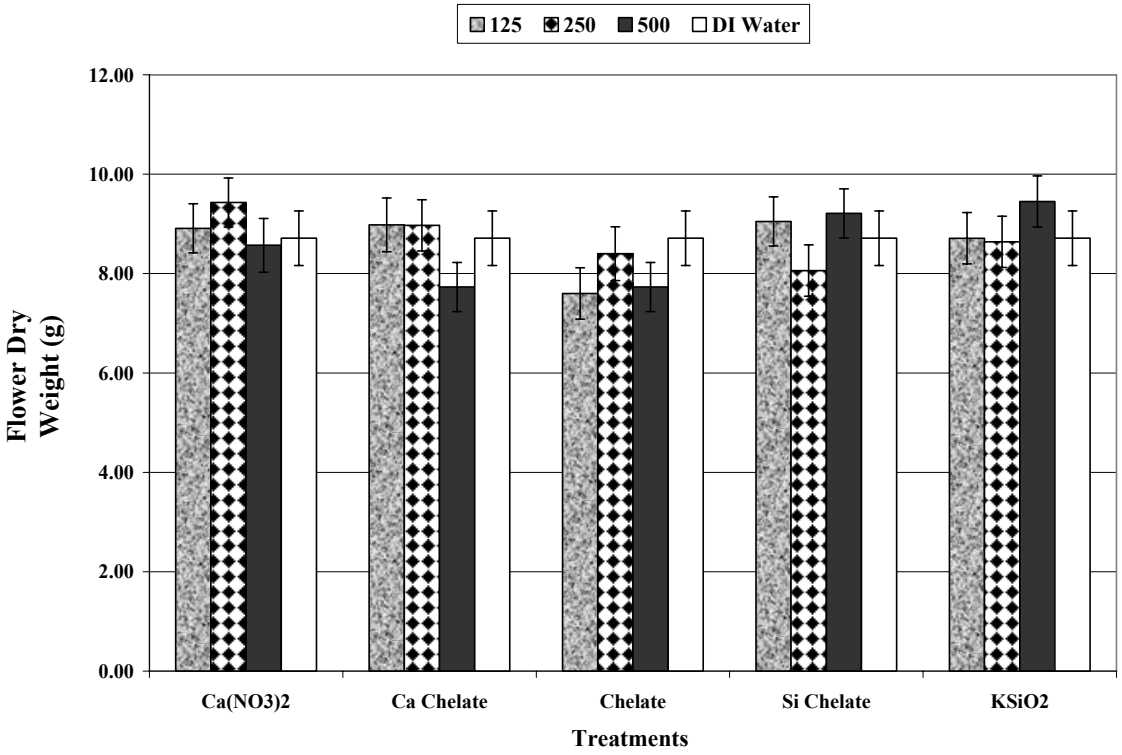


Figure 17. Effect of supplemental spray applications of treatments on flower dry weight of *Euphorbia pulcherrima* 'Orion Red'.

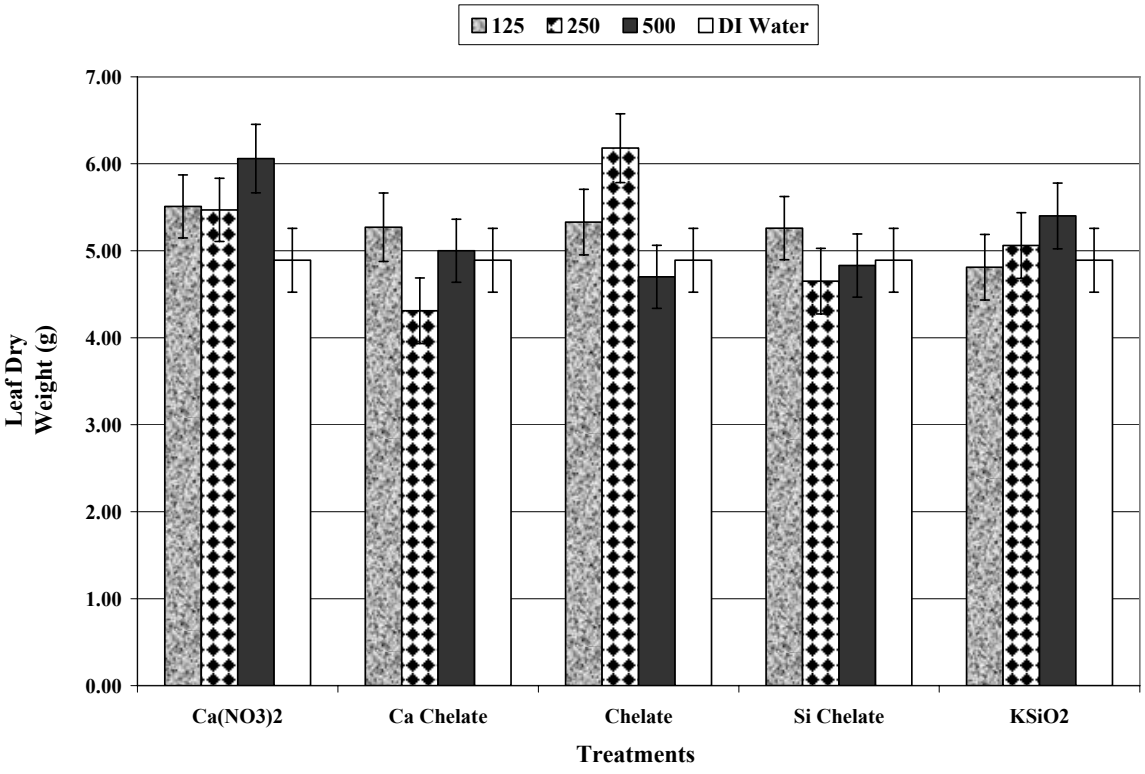


Figure 18. Effect of supplemental spray applications of treatments on leaf dry weight of *Euphorbia pulcherrima* 'Orion Red'.

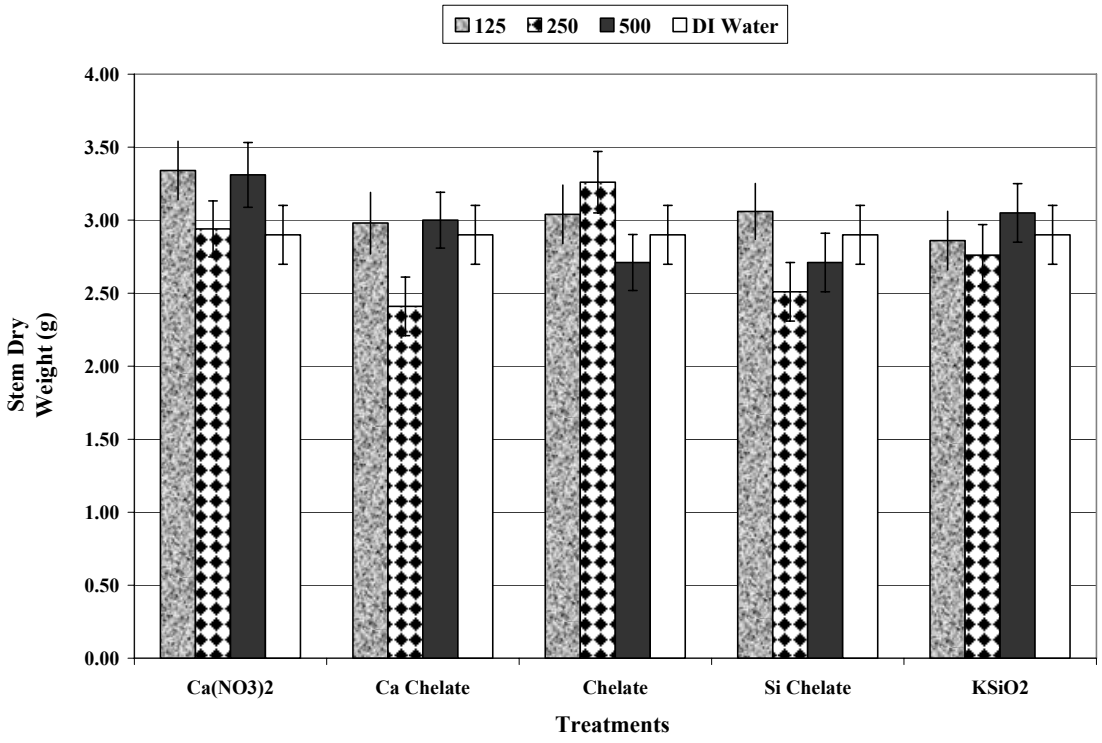


Figure 19. Effect of supplemental spray applications of treatments on stem dry weight of *Euphorbia pulcherrima* 'Orion Red'.

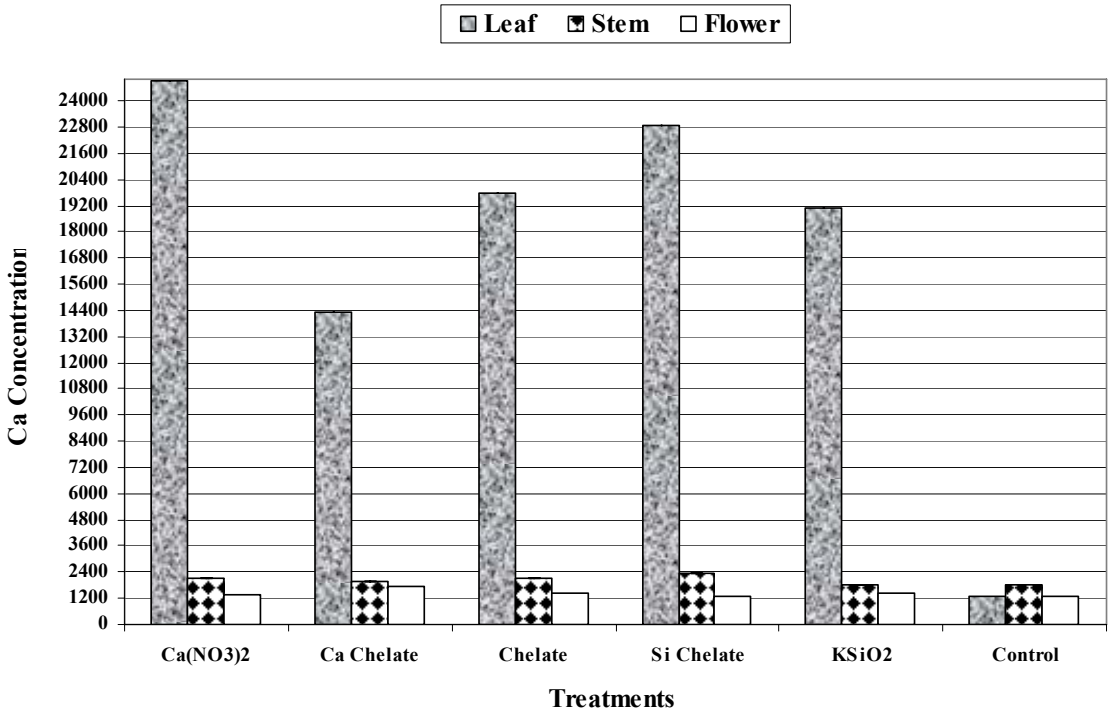


Figure 20. Effect of supplemental spray applications of treatments on Ca concentration of *Euphorbia pulcherrima* 'Orion Red'.

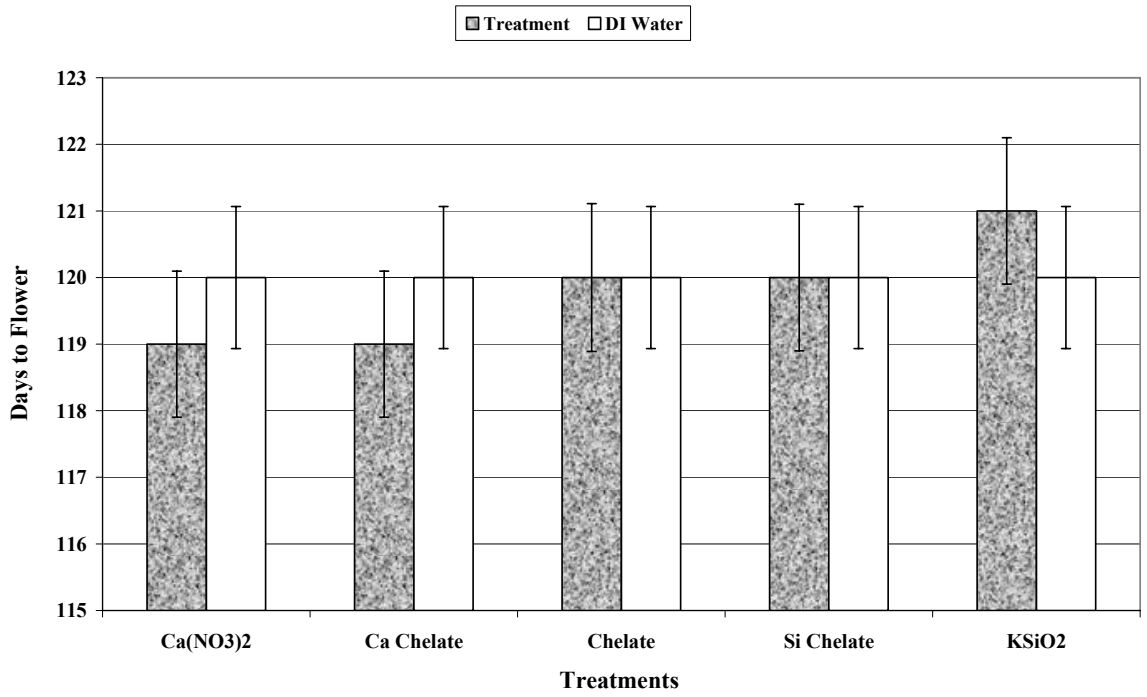


Figure 21. Effect of supplemental drench applications of treatments on days to flower of *Euphorbia pulcherrima* 'Orion Red'.

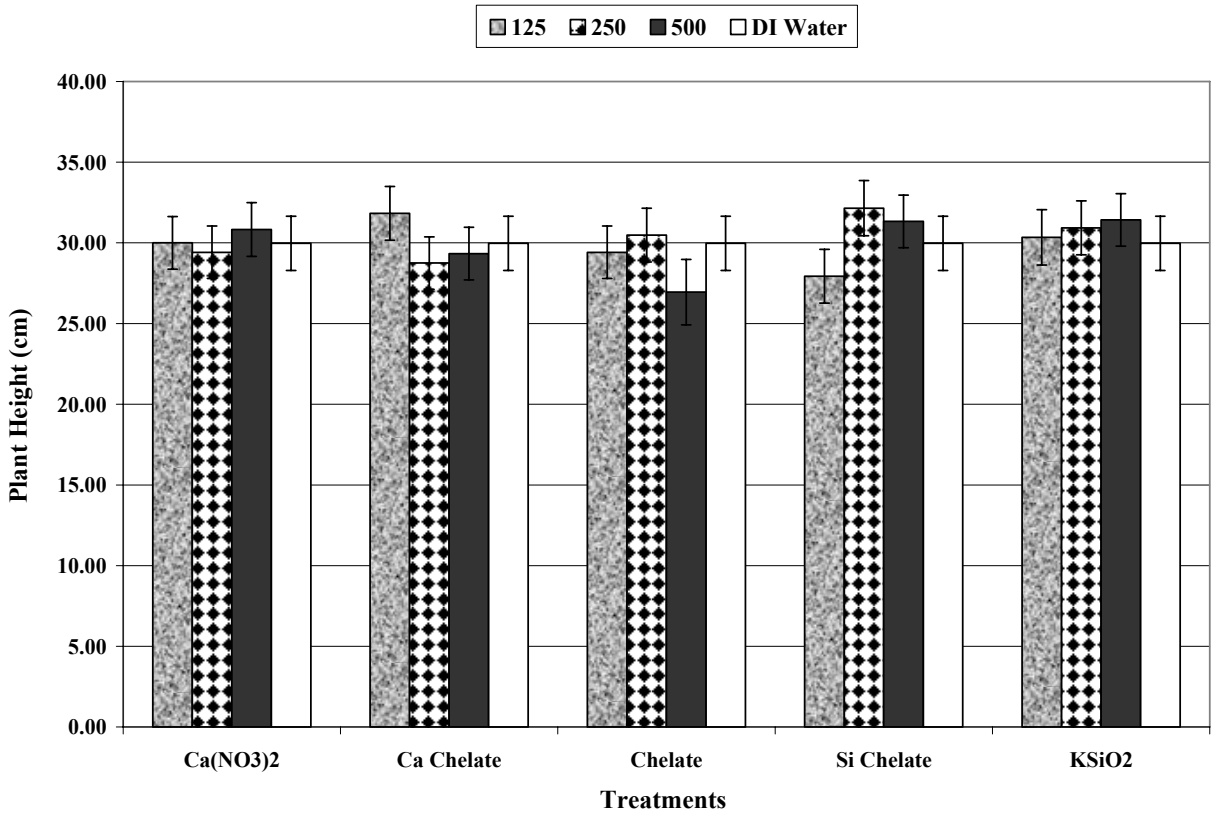


Figure 22. Effect of supplemental drench applications of treatments on plant height of *Euphorbia pulcherrima* 'Orion Red'.

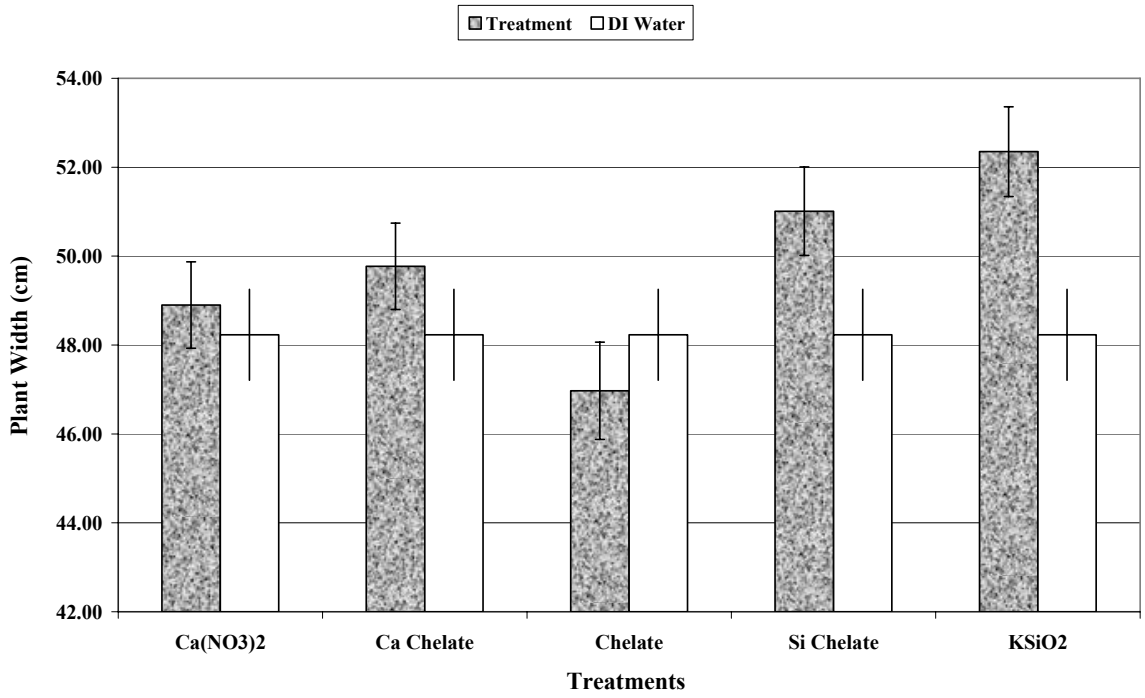


Figure 23. Effect of supplemental drench applications of treatments on plant width of *Euphorbia pulcherrima* 'Orion Red'.

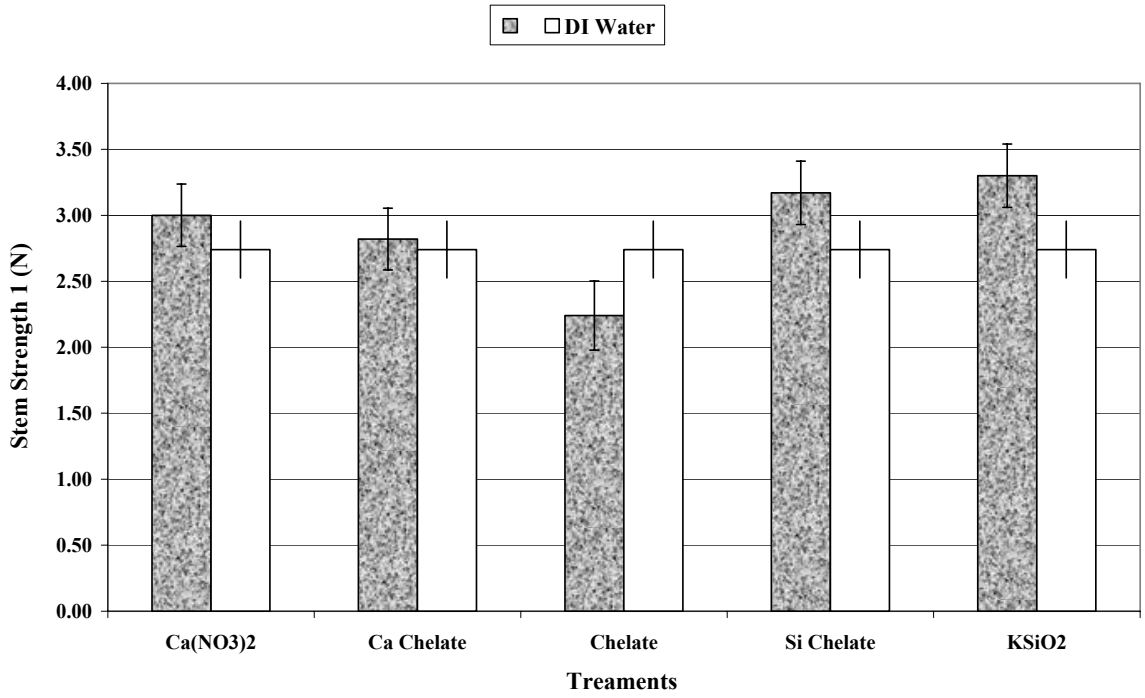


Figure 24. Effect of supplemental drench applications of treatments on stem strength 1 of *Euphorbia pulcherrima* 'Orion Red'.

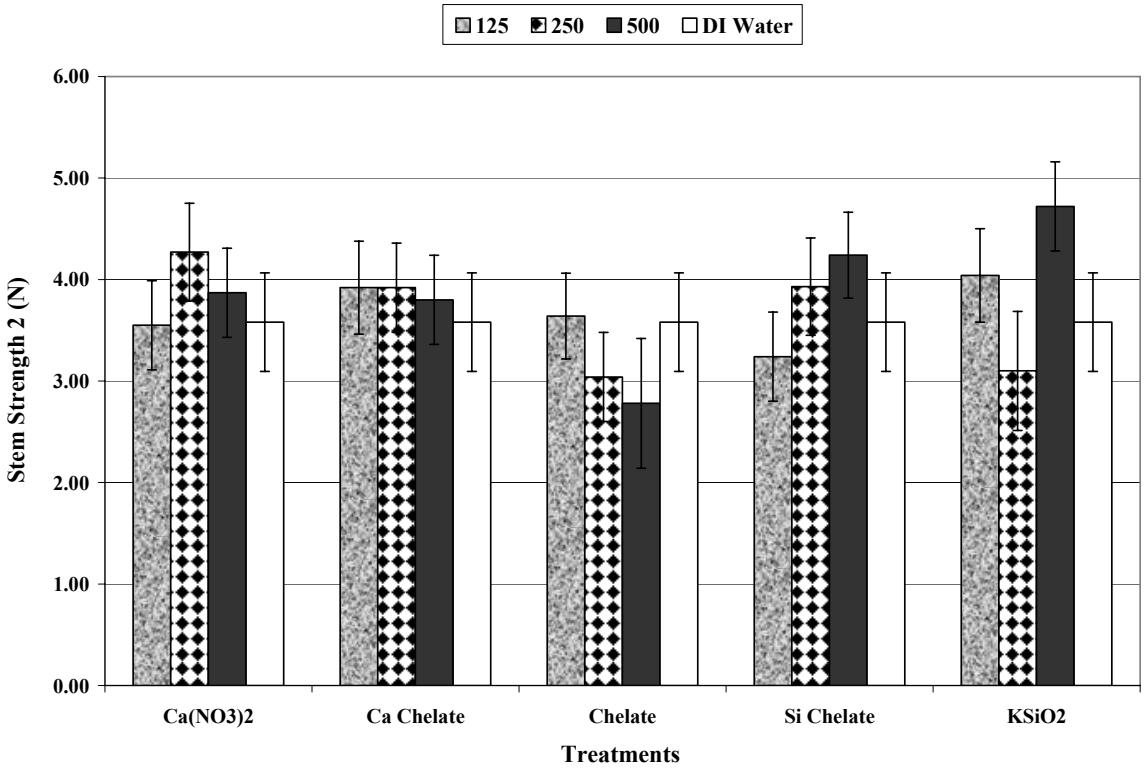


Figure 25. Effect of supplemental drench applications of treatments on stem strength 2 of *Euphorbia pulcherrima* 'Orion Red'.

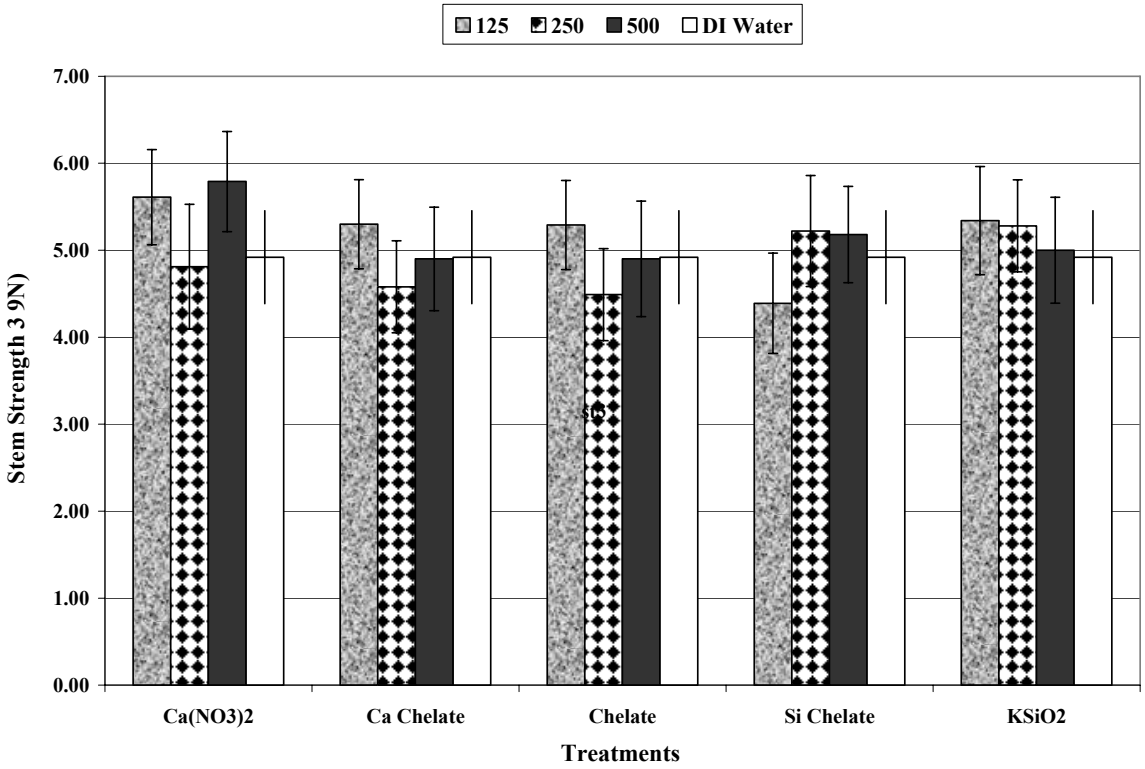


Figure 26. Effect of supplemental drench applications of treatments on stem strength 3 of *Euphorbia pulcherrima* 'Orion Red'.

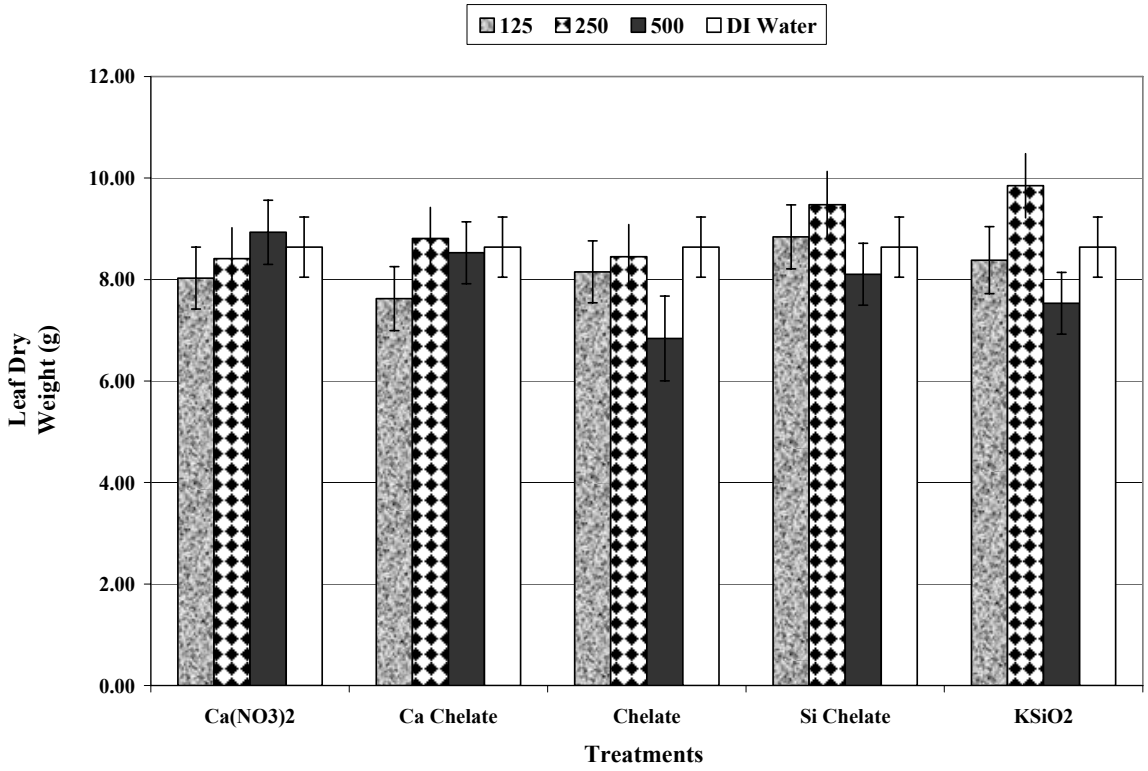


Figure 27. Effect of supplemental drench applications of treatments on leaf dry weight of *Euphorbia pulcherrima* 'Orion Red'.

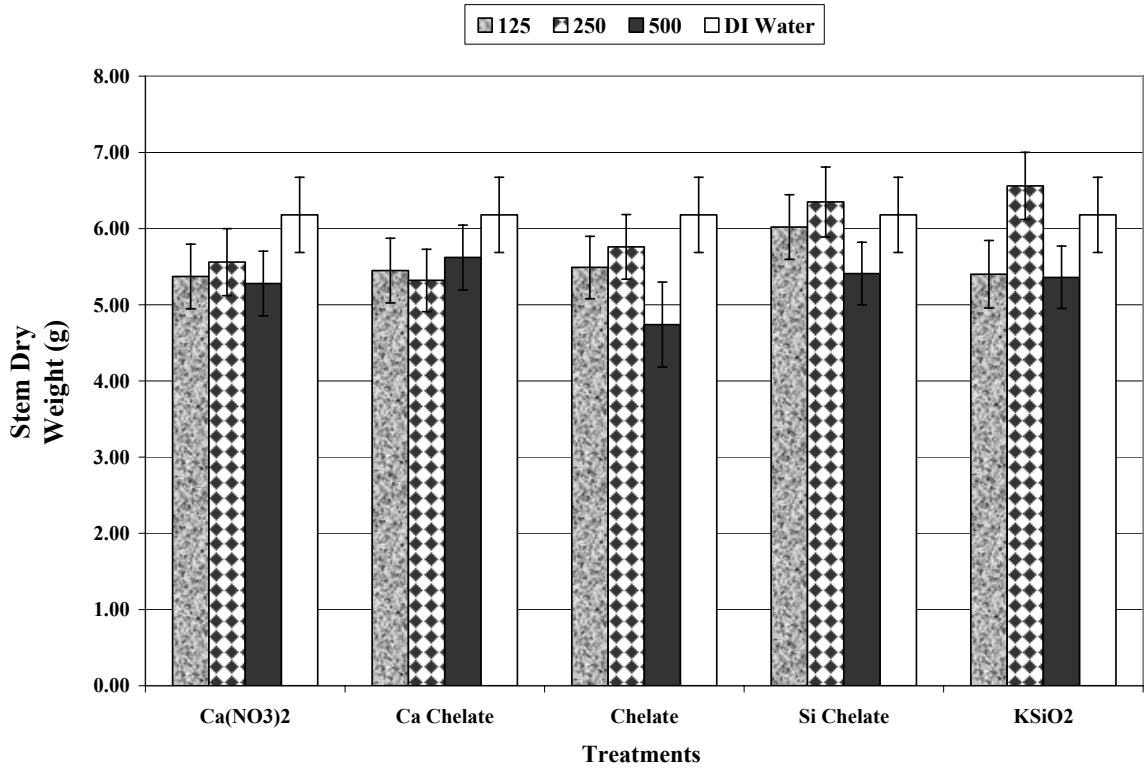


Figure 28. Effect of supplemental drench applications of treatments on stem dry weight of *Euphorbia pulcherrima* 'Orion Red'.

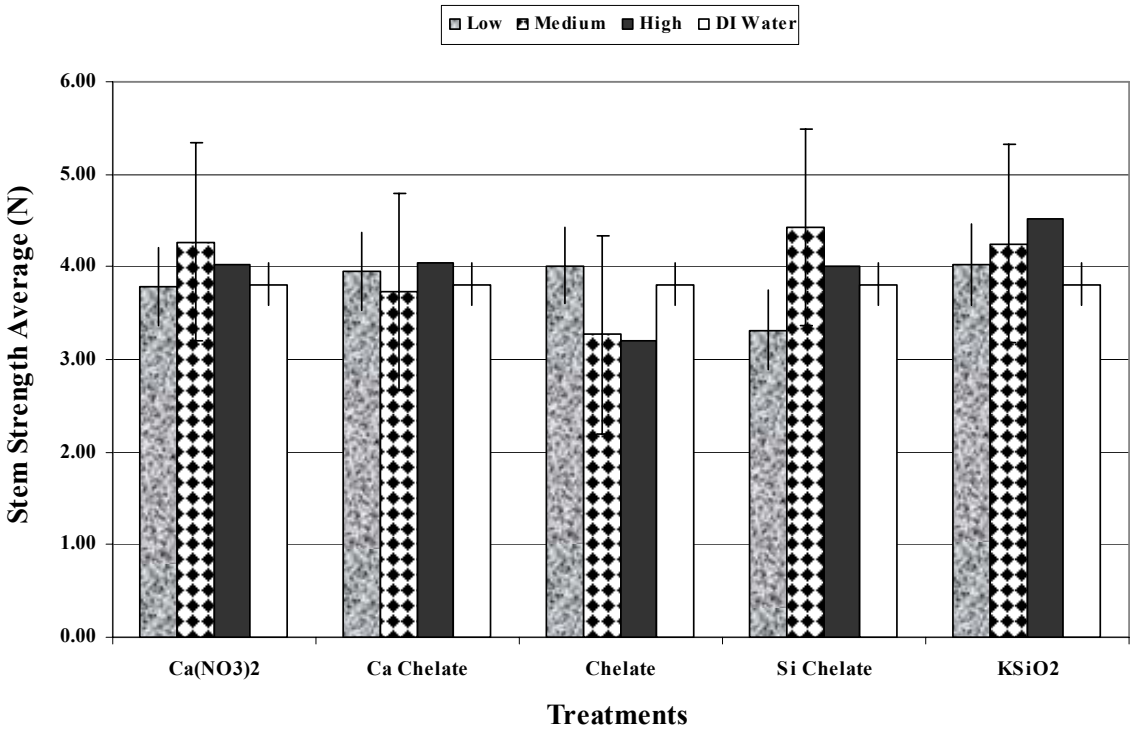


Figure 29. Effect of supplemental drench applications of treatments on stem strength average of *Euphorbia pulcherrima* 'Orion Red'.

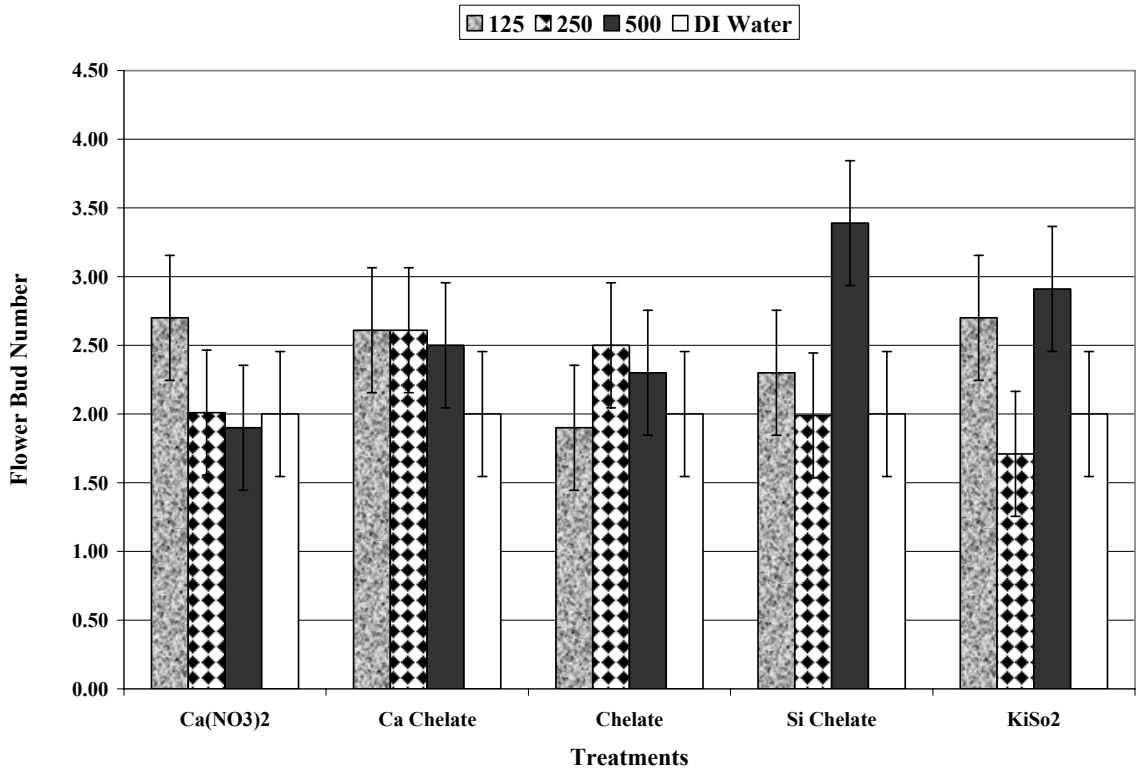


Figure 30. Effect of supplemental spray applications of treatments on flower bud number of *Rosa chinensis minima* 'Sonja'.

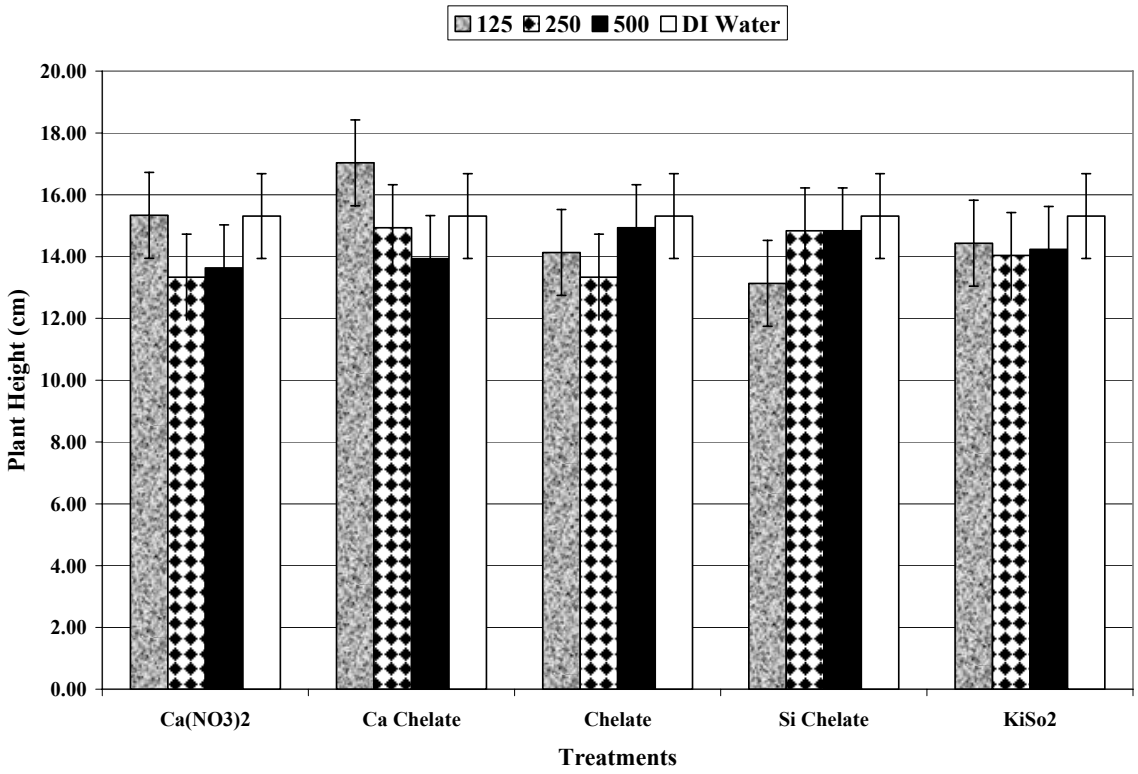


Figure 31. Effect of supplemental spray applications of treatments on plant height of *Rosa chinensis minima* 'Sonja'.

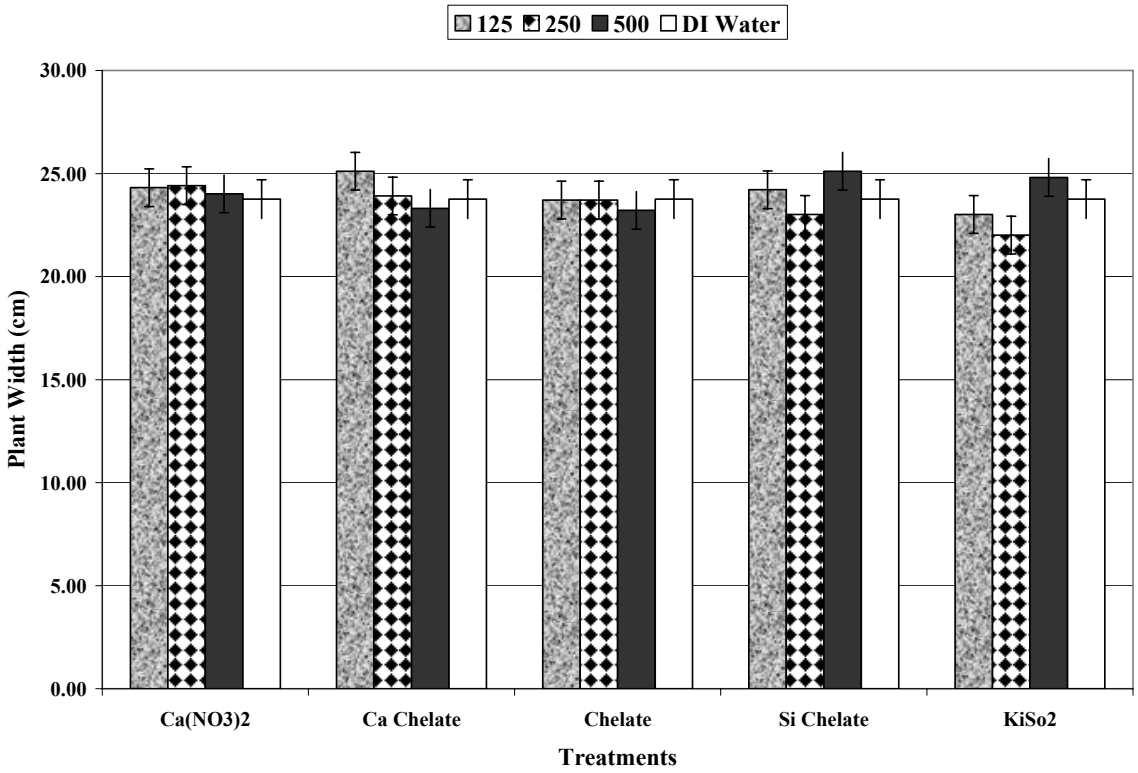


Figure 32. Effect of supplemental spray applications of treatments on plant width of *Rosa chinensis minima* 'Sonja'.

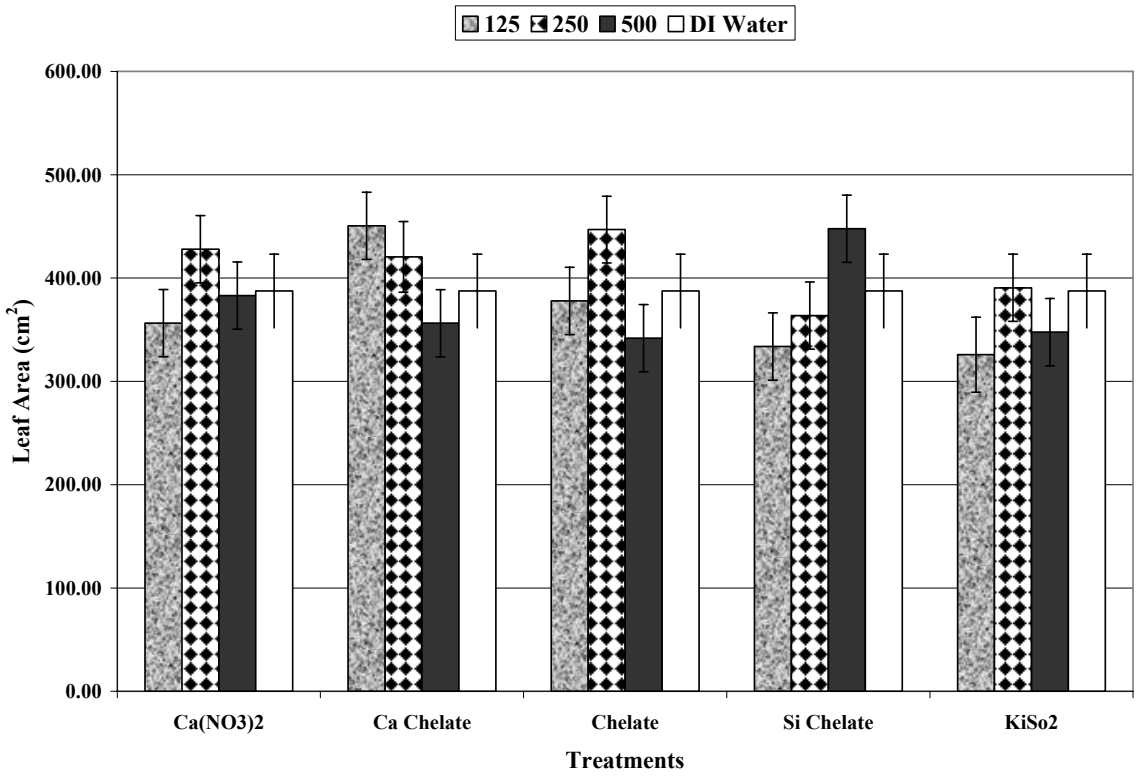


Figure 33. Effect of supplemental spray applications of treatments on leaf area of *Rosa chinensis minima* 'Sonja'.

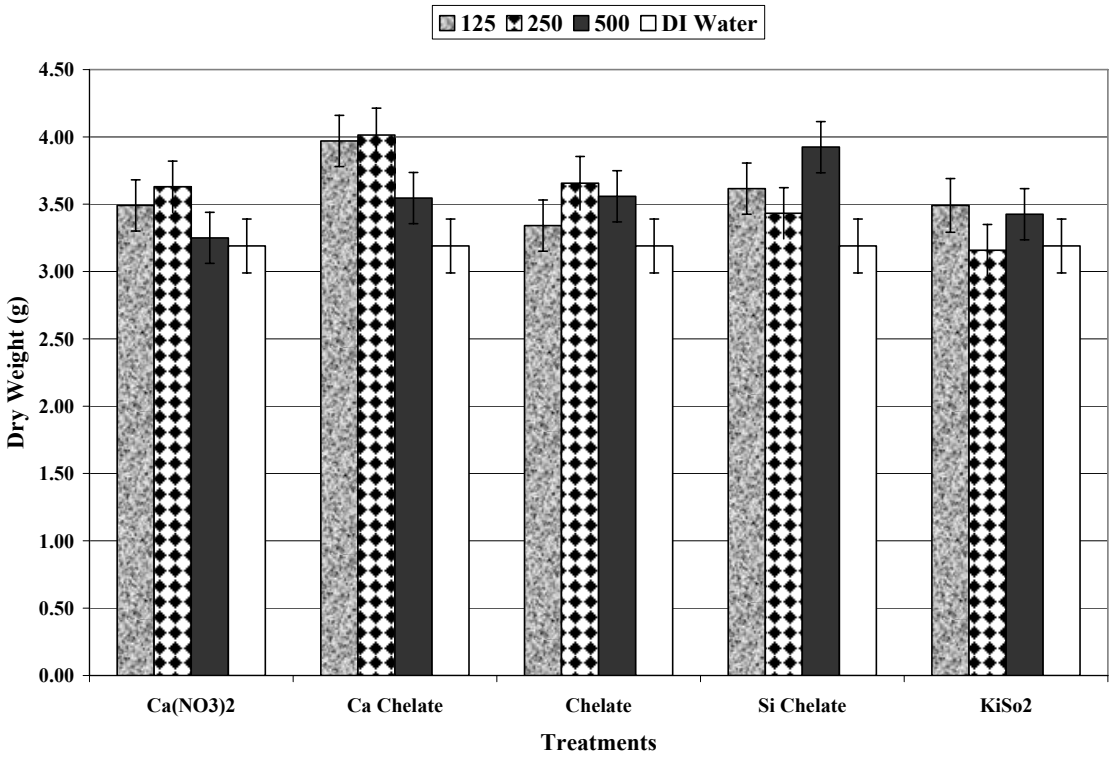


Figure 34. Effect of supplemental spray applications of treatments on dry weight of *Rosa chinensis minima* 'Sonja'.

## VITA

Mary Beth Robichaux was born on May 14, 1984, to Roland and Nancy Robichaux in St. Martinville, Louisiana. She obtained a Bachelor of Science degree in plant science from the University of Louisiana at Lafayette in December 2005. She entered the graduate school of Louisiana State University in January 2006 where she obtained her Master of Science degree in ornamental horticulture under Dr. Jeff Kuehny.