THESIS

ENHANCING HERBACEOUS PERENNIAL STOCK PRODUCTION THROUGH THE APPLICATION OF PLANT GROWTH REGULATORS FOR *HEUCHERA SANGUINEA* 'SNOW ANGEL' AND *ZAUSCHNERIA GARRETTII* 'PWWGO1S' ORANGE CARPET®

Submitted by

Sean Markovic

Department of Horticulture and Landscape Architecture

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Master's Committee:

Advisor: Jim Klett

Steven Newman
Elizabeth Pilon-Smits

ABSTRACT

ENHANCING HERBACEOUS PERENNIAL STOCK PRODUCTION THROUGH THE APPLICATION OF PLANT GROWTH REGULATORS FOR *HEUCHERA SANGUINEA* 'SNOW ANGEL' AND *ZAUSCHNERIA GARRETTII* 'PWWGO1S' ORANGE CARPET®

Commercial growers throughout the Rocky Mountain Region have an increased commercial demand for sustainable herbaceous perennial plants. Greenhouse production for these adaptable perennials has resulted in problems with stock plant management and propagation. The objective of this study was to determine the efficacy for increased vegetative growth of three dissimilar plant growth regulators applied as foliar sprays on the vegetative growth of *Heuchera sanguinea* 'Snow Angel' and *Zauschneria garrettii* 'PWWGO1S' ORANGE CARPET® propagation stock plants in number one (2.84L) containers. Three chemical plant growth regulators were applied at two different rates: 1) Ethephon (2-chloroethyl Phosphonic Acid) (200 and 400 $mg \cdot L^{-1}$ (ppm)) (Verve, Nufarm Americas, Inc., Alsip, IL), 2) 6-benzylaminopurine (250 and 500 $mg \cdot L^{-1}$) (Configure; Fine Agrochemicals Limited, Worcester, U.K.), and 3) Gibberellins A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine (50 and 100 $mg \cdot L^{-1}$) (Fascination; Valent USA Corp., Fresno, CS). Twelve replications of the two taxa were evaluated every month for a period of four months for plant height, width, number of cuttings, and fresh & dry weight of the cuttings. This study was replicated twice, the first experiment was performed from November 2016 to March 2017, and the second experiment was performed from August 2017 to December 2017. The two experiments conducted at different times of the year gave an indication of a better time of year for stock production of these two herbaceous perennials. *Heuchera* performed better in the first

experiment from November to March. The *Zauschneria* plants performed better during the second experiment from August to December. *Heuchera p*lants that received Fascination (A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine) treatments at 50 and 100 $mg \cdot L^{-1}$ and Configure (6-benzylaminopurine) at 400 $mg \cdot L^{-1}$ concentrations resulted in 17%, 22%, and 20% more cuttings taken than control plants. Both concentrations of Ethephon treated *Heuchera* plants were statistically similar to control plants. *Zauschneria* plants that received Fascination (A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine) treatments at 50 and 100 $mg \cdot L^{-1}$and Configure (6-benzylaminopurine) at 200 $mg \cdot L^{-1}$ concentrations resulted in 14%, 16%, and 10% more cuttings, respectively. However, *Zauschneria* plants that received Fascination (A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine) treatments at 50 and 100 $mg \cdot L^{-1}$ had a decrease of 13% and 14% for the fresh weight of cuttings taken when compared to the control. Configure (6-benzylaminopurine) treatments also resulted in a visual decrease in reproductive growth.

The different applications of the plant growth regulators resulted in a wide variety of cutting sizes and water content; this is based on the differences seen per treatment in the fresh and dry weights collected. A secondary rooting study was conducted after each stock plant experiment. Cuttings were harvested from each treatment combination after four weeks; May 16, June 13, and July 11, 2017 for the first experiment and January 11, February 8, and March 1, 2018 for the second experiment. Cuttings were taken at the same time of day, in the morning, and stuck in trays of 98 or 72 cells filled with Jiffy® Preforma media and placed under mist with bottom heat at a temperature of 18.3 or 23.9 degrees Celsius for *Heuchera* and *Zauschneria* respectively. Rooting percentages and number of visible roots were then collected every week for four weeks. Rooting of the two taxa resulted in no statistical differences observed between the treatments and the control. This gave the indication that the use of plant growth regulators during stock plant

production would not result in decrease rooting of the harvested cuttings. In conclusion, the use of plant growth regulators resulted in increases in propagation material produced by stock plants of both taxa. A Fascination (A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine) treatment between 50 and 100 $mg \cdot L^{-1}$is recommended in *Heuchera sanguinea* stock plant production for its increase in cuttings available at each harvest event. A Configure (6-benzylaminopurine) at 200 $mg \cdot L^{-1}$treatment is recommended for *Zauschneria garrettii* stock plant production due to the increase in quality vegetative propagation material.

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CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction

Ornamental herbaceous perennials are a major crop in the horticultural industry. The need for more landscape plants throughout the United States and Canada due to increased land development has amplified the demand for a larger market presence of herbaceous perennials. The United States Department of Agriculture's 2014 Census of Horticultural Specialties states that sales of potted herbaceous perennial plants were $945 million. This market showed an increase of 12% from the previous census taken in 2009, or a 2.25% annual increase in sales (USDA Census, 2014).

Ornamental herbaceous perennials are a major contributor to the landscape industry and have become popular with consumers and industry professionals because of their advantageous low-input cultural characteristics. Low-input cultural characteristics include their drought, cold, and salt tolerances. All these characteristics are important in the state of Colorado, which the USDA reported had a $16.1 million in potted herbaceous perennial revenue for 2014 (USDA Colorado Census, 2014). These characteristics have been linked to their increase in overall production in the state of Colorado. However, with this increase in production more propagation problems have evolved for many growers.

Herbaceous perennials are highly desirable for many homeowners throughout the arid western region. One program administered through Colorado State University, the Denver Botanic Garden, and the Colorado Green Industry is the Plant Select® brand. Plant Select® is the country's leading brand of plants designed to thrive in High Plains and Intermountain

Regions, offering plants that provide more beauty with less work. Gardeners of all levels utilizing these plants can achieve smart, stunning, and successful gardens using fewer resources and with a more positive environmental impact (Plant Select 2017). Two herbaceous perennials in the program are: *Heuchera L. 'Snow Angel' and Epilobium canum (Greene) P.H. Raven ssp.garrettii (A. Nelson) P.H. Raven 'PWWG01S' ORANGE CARPET®, referred to throughout this paper as Zauschneria garrettii 'PWWG01S'*.

Greenhouse and nursery operations propagating these Plant Select® plants indicated that there are production problems with *Heuchera sanguinea* 'Snow Angel' and *Zauschneria garrettii* 'PWWGO1S' ORANGE CARPET®. The main problems indicated were, the lack of vegetative propagation material from stock plants and/or low rooting percentage rates in propagation. Taking cuttings year-round is a challenging task, because perennials want to flower at different times of the year and harvesting cuttings before bloom time is not preferred (Walters 1982). These problems could have possible solutions by using plant growth regulators (PGR). Some green industry producers had performed some independent experiments, but not in a very scientific manner. This study conducted at Colorado State University involved the application of three commercially available plant growth regulators on the propagation stock plants of *Heuchera sanguinea* 'Snow Angel' and *Zauschneria garrettii* 'PWWGO1S' ORANGE CARPET®.

1.2 Background Information on *Heuchera sanguinea* 'Snow Angel'

Heuchera sanguinea is an herbaceous perennial in the family Saxifragaceae that thrives in well-drained soil and part shade with bright pink flowers in late spring to early summer (Plant Select). *Heuchera sanguinea* is viewed as the best and most popular species of *Heuchera*, and

has been extensively bred in America and England, resulting in superior garden plants (Giles et al. 1980). Also referred to as alum root or coral bells, there are between fifty and seventy species of the genus *Heuchera* (Smith 1977). *Heuchera* have few serious pests or diseases in the landscape and can be incorporated in border plantings or a shade garden specimen plant (Hodgson 2000).

Heuchera sanguinea is native from New Mexico to Arizona, into northern Mexico. It is mainly found in areas with moist, shady rocky terrain in the mountains. This cultivar 'Snow Angel' was originally discovered by Bluebird Nursery in Clarkson, NE and has attractive white and green variegated foliage that makes it an excellent plant for a shade garden and has striking foliage when not in bloom (Plant Select 2017). Due to the shallow roots of the *Heuchera sanguinea* a rich, well-drained soil is required, to help prevent plant heaving during winter freezes (Crockett 1977). *Heuchera sanguinea* is hardy throughout most regions of the United States, but prefers the cooler and temperate regions of the northern hemisphere (Smith 1977).

Little research has been done specifically on *Heuchera sanguinea*. It is known is to be a day-neutral plant that must have a period of vernalization with subsequent long days to flower. The specific photoperiod and critical day length for vegetative growth is around 12 hours and between 12 and 15 hours for reproductive growth (Albrecht et al. 1994). *Heuchera sanguinea* therefore can be kept in the juvenile, vegetative state of development with proper lighting and temperature control in a controlled greenhouse environment. In a separate study by Yuan et al. (1998), results indicated that the juvenile phase of *Heuchera sanguinea* lasts until the plant has approximately 19 nodes. Without a vernalization period, plants with more than 19 nodes should not produce any reproductive tissue.

A study performed by Twardowski et al. (2012) identified the best nitrogen rate, electrical conductivity (EC) and pH level for ten herbaceous perennials, including *Heuchera* x 'Mt St. Helens'. Based on shoot dry weight, the most successful plants were given 150 mg x L-1 nitrogen, with soil pH of 5.9 and EC measured to be 2.0. *Heuchera* can display differences between species and their cultivars, but these findings can be used to develop stock plant protocols for *Heuchera sanguinea*.

Propagation of *Heuchera* can be by: division of the plant in the spring, cuttings taken when the plant is not in a flowering state or grown from seed (Coates 1976). Cultivars of *Heuchera* are often propagated commercially by tissue culture to keep the chosen characteristic traits across generations. However, *Heuchera sanguinea* 'Snow Angel' has shown a tendency for reversion in tissue culture. Propagators have found basal stem cuttings able to hold the desired leaf variegation well. There are differing recommendations for best time to take cuttings. Giles (1980) recommends midsummer basal stem cuttings, while Steven Still (1980) proclaims late fall is the optimum time.

Heuchera sanguinea due to the plant's basal growth habit does not yield propagation material quickly enough for large propagators to meet production numbers. Commercial growers would need to keep large numbers of these stock plants to obtain enough cuttings which is often not economically feasible. The purpose of this study is to develop protocols for improving the number of *Heuchera sanguinea* cuttings produced per plant. Meeting the high demand for this variety could be accomplished through increased propagation stock material. However, that may not be the best economic alternative. Optimal growth from stock plants can aid in keeping the plant profitable to produce.

1.3 Background Information on *Zauschneria garrettii* 'PWWGO1S' ORANGE CARPET®

Zauschneria garrettii, also known as *Epilobium canum subspecies garrettii* is a low growing subshrub or partially woody perennial in the Onagraceae family, which is native to Northwestern Arizona, Utah, Western Wyoming, and Southeastern Idaho (USDA, Plant Database). The evening primrose family contains temperate to subtropical genera and *Zauschneria*, also known as California fuchsia, has shown more temperate climate adaptability (Smith 1977). The subspecies *garrettii* is found only north and east of the Great Basin, and the closest related plants *Epilobium canum subspecies canum* and *subspecies latifolium* are found in the Southwestern region of Oregon and the Sierra Nevada mountains of California (Bowman 1980).

Zauschneria garrettii has a height of 7-10 centimeters (cm) tall in a spreading habit that can be up to 45-60 cm wide. It prefers aerated, well-drained soil and full sun, but will tolerate light shade. It flowers in mid to late summer with numerous red-orange tubular shaped flowers. *Zauschneria garrettii* has deer resistant and drought tolerant attributes and has been shown to be a hummingbird attractant because of it is an excellent source of nectar. The hummingbird attraction is how it received another common name of hummingbird trumpet (Plant Select 2017). Due to its low growing growth habit, *Zauschneria garrettii* is a drought tolerant option as a colorful ground cover.

Zauschneria garrettii is thought to be short day plant, but no scientific research on this subject has been reported. The lack of photoperiod information means that *Zauschneria garrettii* flowers after the summer solstice, which is used to determine the critical photoperiod for the species. The lack of research has led to difficulties in the propagation of this species. Further

studies into *Zauschneria garrettii* will allow for development of more practical steps in production protocols.

It has been found that stock plants of *Zauschneria garrettii* were improved by holding greenhouse temperatures between 39 and 50 degrees Fahrenheit (4-10 degrees Celsius) (Anderson). Internode lengths were found to be shorter and the plants had thicker stems under the lower temperatures in the greenhouse. It was found that cooler temperatures seemed to provide a longer window for taking cuttings. Cuttings taken from these stock plants were rooted at very high percentages near 100% and their roots developed more quickly (Anderson et al. 2012). This information is useful to growers, and they should place *Zauschneria garrettii* in the coolest parts of their stock greenhouses.

Seed propagation is the preferred method, but to maintain the characteristics of ORANGE CARPET®, vegetative propagation must be performed because this selection is self-infertile as thus not true to type when grown from seeds (Plant Select). Tissue culture is another propagation technique, and one protocol has been developed and proven to be successful. That protocol utilized Benzyladenine, a cytokinin, to induce shoot formation on *Zauschneria garrettii*. Utilizing this protocol would allow thousands of plants to be produced quickly without using any phytohormones to initiate rooting (Alosaimia et al. 2018). Most Plant Select® growers are not able to propagate by tissue culture and depend on vegetative cuttings for the propagation of *Zauschneria garrettii.*

1.4 Vegetative Herbaceous Perennial Propagation

The selection and propagation of plants is one of the oldest works of mankind (Wells 1971). The Royal Horticultural Society *Dictionary of Gardening* defines a cutting as "… any

portion of a plant, root, stem, leaf, or bud which is separated from the plant and has been induced to form roots of its own." (Royal Horticultural Society 1999). Asexual plant propagation is used throughout the green industry for mass production of genetically identical plant crops through vegetative cuttings. The reasons for vegetative over seed propagation include: inability to produce viable or true to type seeds, perpetuate a certain form of the plant, modification of habit, adaptability to habitat, and develop pest resistance (Mahlstede et al. 1966). Hartmann et al. (2002) states that commercial propagators have developed technologies that successfully manipulate environmental conditions to maximize rooting and what has lagged is the knowledge of the biochemistry, the genetic, and molecular manipulation of rooting.

The determination of the best time to take cuttings has always been a critical step in the propagation process. As has the skills to discern the state of development of the cutting and its condition during removal from the stock plant (Wells 1971). It is important to know the plant to be propagated, its specific biology, and cultural needs. Herbaceous perennials are very diverse, and it can be difficult to determine a lot of the specifics for the propagation of an individual plant. The type of cutting to be taken is also an important determination for a propagator. Some different cuttings are determined by area on the plant, apical (tip) or lateral and specific plant organ, leaf, stem, and root (Wells 1971). In this study, *Heuchera sanguinea* required a basal stem cutting, in contrast to an apical stem cutting preferred for *Zauschneria garrettii.*

Once the specific type of cutting is determined the propagator then must decide on the use of plant hormone (growth regulator). Most commercial propagators use some form of auxin, either Indolebutryic acid (IBA) or 1-Naphthaleneacetic acid (NAA) (Fretz et al. 1979). After speaking with Plant Select® propagators, it was determined *Heuchera sanguinea* at a rate of 500 $mg \cdot L^{-1}$ (ppm) IBA is enough to aid in consistently high rooting percentage. The addition of no

hormone was determined to be the preferred method for propagating *Zauschneria garrettii* cuttings by Plant Select® propagators.

Each operation is unique in their overall propagation protocols, the media chosen for propagation is an area where propagators have many choices. One common propagation media is perlite, vermiculite, sand, peat moss, and pine bark; or some combination of several of them. The preference of the propagator is usually determined through trialing different media in different combinations on various plant species to determine the optimal selection. Propagation media should be readily available and inexpensive. Also, media should possess certain characteristics; uniform, long-lasting, good drainage, disease, insect, and weed-free (Fretz et al. 1979).

The use of additional heat in the root zone can be beneficial during the propagation process. Bottom heat for a propagation bench has been shown to increase rooting rates (Wells 1971). The exact conditions a propagator prefers are based on their own growing environment and the production procedures in place.

Humidification and constant mist are important factors in the propagation process of vegetative cuttings. The use of greenhouse systems to keep humidity levels high has shown to be of vital importance for commercial propagation facilities (Wells 1971). Determining the correct amount of moisture to be added to the propagation environment is a critical task for the propagator. Fog, direct mist, or the use of plant cloth material are all aspects of humidifying a greenhouse space. Current greenhouse propagation areas can have the ability to monitor and adjust the level of humidity within the growing area very precisely (Hartmann et al. 2002). The ability of greenhouse environmental monitoring allows the propagator to consistently produce high rooting rates for a vast number of taxa.

Once the specifics of the plant, process, and the propagation environment to be used are determined, the original source of the propagation material plays the critical role in the overall propagation success. Stock plants, also known as mother plants, and their proper maintenance are needed to produce healthy propagation material (Dirr 2009). A motto used at some propagation facilities is, “Start clean, End clean.” This illustrates the desire for clean, healthy stock material for more successful propagation end results. When the knowledge of the ideal end results are provided to the grower, production facilities can select the preferred size, quality, and quantity of stock plants to be used to accomplish these results.

1.5 Herbaceous Perennial Stock Plant Management Research

Managing stock plant health is an important part of propagation, it has been studied for many herbaceous perennials being propagated throughout the United States. Like in many areas of horticulture, having healthy, disease free plants are desired. Procuring healthy starts to be planted and grown out into stock plants is a key practice that is not underestimated by propagators. The cultural practices a grower practices has a large impact on the overall health of the stock plants (Lamb et al. 1975). Introducing pests to the propagation area should be avoided and proper nutrition and plant care of stock plants are required cultural practices. Most growers start new stock plants from plugs will allow the plants to grow for 6 to 12 weeks before harvesting cuttings (Gibson et al. 2005).

Each grower has different procedures for harvesting cuttings, but they can be grouped into two general categories, selective or hedging harvests. Selective harvesting is when the grower removes only the ‘best’ available cuttings from the stock plants. While, hedging is done by taking all the available cuttings that meet a certain standard that was predetermined (Gibson

et al. 2005). The method of harvest that a grower has chosen is based on the genus of plant and the production schedule. What works for some growers for a specific genus, might not work for others, based on their production schedule and procedure. Some growers only need a small number of cuttings at one time of year, while others are trying to constantly propagate the same plant.

It is highly desirable to keep stock plants in a juvenile or vegetative state of development. Wells states, "The state of development of the cutting and its condition on removal from the parent are of the highest importance." He also states that the success of propagating the cutting is highly dependable on the judgement of the propagator (Wells 1971). It has been shown that reproductive tissue on cuttings can inhibit root and vegetative development (Gibson et al. 2005).

Plant nutrition is a cultural area that can have a large impact on the productivity of herbaceous perennial stock plants. A typical range of stock plant fertilizer concentrations for herbaceous perennials between 150 to 200 $mg \cdot L^{-1}$ (ppm) (Gibson et al. 2005). A constant feed injection unit, such as a Dosatron, helps maintain nutritional levels for a stock plant greenhouse. Proper nutrition of stock plants assists in maintaining healthy, vigorous plants that produce superior propagation material for the taking of cuttings.

Other cultural practices that growers have used to maintain a state of juvenility include lighting and temperature in the greenhouse space. The length of the photoperiod required for herbaceous perennials varies based on the type of plant; short day, long day, or day neutral. The knowledge of the specific stock plant can be used to determine if additional lighting is required. Also, temperature manipulation can be easily performed in many modern greenhouses. The flowering of *Heuchera sanguinea* is dependent on the vernalization period the stock plants have

received (Yuan et al. 1998). It has been shown lack of flowering of stock plants of *Zauschneria garrettii* was improved by holding greenhouse temperatures between 39 and 50 degrees Fahrenheit (4-10 degrees Celsius) (Anderson et al. 2012). The knowledge of how to keep stock plants in a juvenile state will aid in developing protocols for these herbaceous perennials.

1.6 Plant Growth Regulators

There are many chemicals found in plants that effect their functions and growth. Among the substances which influence the reactions and metabolism within plants are hormones that are internally synthesized (Meyer et al.1960). Plant hormones are involved in many plant growth and development processes, which allow plants to respond to introduced internal or external stimuli (Rademacher 2015). Phytohormones, another term for plant hormones, are naturally occurring organic chemicals that are synthesized at a given site and translocated to the site of action in the plant. The five major phytohormones are auxin, cytokinin, gibberellin, abscisic acid, and ethylene. Whereas plant growth regulators (PGR) are any synthetic and natural chemical that shows hormonal effects (Hartmann et al.2002).

Plant growth regulators (PGR) are used to propagate, to increase yield, to improve plant quality, to alter plant growth habit, or to aid in harvesting or postharvest storage (Preece et al.1993). The application of PGR in commercial operations is widely used, but there are areas of the industry where increased knowledge and research into the effects of plant growth regulators would be beneficial. Most PGR are typically applied via foliar sprays with water as the carrier. This application method can be easily incorporated into most commercial systems (Rademacher 2015). In this section the specific plant growth regulators used in the study will be discussed in further detail.

1.6.1 Gibberellic Acid

Gibberellins also known as Gibberellic Acid (GA) promotes growth primarily through cell enlargement that is uniform throughout the plant tissue. Plant growth in the most basic sense, cell division, involves the promotion of cell elongation, which gibberellins and auxins are two special growth-regulating chemicals. The plant stem growth resulting from GA treatments is due to the increased elongation of cells as well as an increase in cell division. Gibberellins influence plant metabolism in several ways, they are capable of stimulating cell division by the enhancement of DNA and RNA synthesis. Gibberellins also hydrolyze starch into sugar, which in turn provides energy and encourages uptake of water by cells. Cell wall elasticity is another product of gibberellin activity in the cell (Moore 1984). GAs used in plant growth regulation have been isolated from species of the fungus *Gibberella fujikuroi* and were first found in Japan in 1926 by E. Kurosawa (Salisbury et al.1969).

Gibberellins are diterpenoids, which means they contain four isoprene units. An isoprene unit is five carbon atoms bonded together to form a molecule shaped like a capital Y. Gibberellins all basically have the same four-ring molecular structure, as shown in Fig. 1.2; but they differ in the total number of carbons, some have 19 while others have 20 carbons, they also can possess different side chains (Preece et al.1993). GA is found in a wide range of plant parts including: meristem, roots, stem, and the seed embryo. Gibberellins are transported throughout the plant in the xylem and phloem and occur during numerous stages of growth. GA applied to one part of the plant can have effect on all other plant parts (Leopold et al.1975).

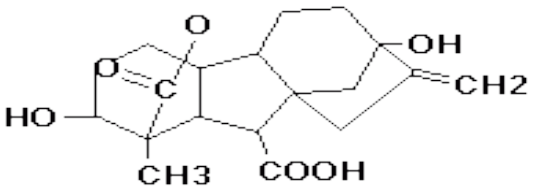

Figure 1.1 Molecular structure of Gibberellic Acid provided by www.planthormones.info

Gibberellin production is not done synthetically, but through the process of fermentation of *Gibberella* fungi. During the process gibberellins are separated out and concentrated into specific GAs. GA_3 is the most popular gibberellin used in the green industry for its cell elongation and ability to break seed dormancy. GA_4 has been shown to have beneficial plant growth as well and was used in this study (Preece et al.1993).

GA has been found to be involved in a variety of plant processes. Seed germination and dormancy are two areas that GA has been shown to effect plant growth and development. Barnes (2013) stated that gibberellins are found in high concentrations in immature seeds and can offset the need for cold moist stratification of seeds. GA terminates seed dormancy by changing the seed coat permeability and activating specific enzymes such as amalyses, which are enzymes that catalyze the hydrolysis of starch into sugars. Flower formation has also been observed with the use GA, Boyle, et al, cited an inverse relationship between vegetative growth and flowering was demonstrated by a highly significant negative correlation between the numbers of flower buds per plant and new apical phylloclades per plant in Easter cactus.

The product used in this study, Fascination produced by Valent U.S.A. Corporation (Walnut Creek, CA, www.valentpro.com), contains 1.8% GA_{4+7} which has shown to retard the aging process in plants (Nelson 2003). Keeping the stock plant in a juvenile development state

longer was one goal of this study. Increased stem elongation and juvenility are areas of enhancement that are necessary for stock plant management to meet the economic demands of the overall production operation. The reason GA_4 and GA_7 are in the product is they are difficult to separate (Preece et al.1993). GA_4 is less persistent than GA_3 or GA_7, which can be better suited for propagation where long lasting effects may be unwanted (Rademacher 2015). GA has been shown to inhibit adventitious root development and can affect lateral branching (Preece et al.1993). For this study, the ability to produce more cuttings and have them root at a higher rate is the goal and GA_4 which could have a lesser effect on rooting then GA_3.

1.6.2 Benzyladenine

In the early 1900's it was known that certain substances caused increased cell division (cytokinesis). In 1913 G. Haberlandt, an Austrian scientist discovered soluble substances that were present in the phloem that could cause cell division in potato parenchyma cells. In 1954, Carlos Miller found that aged or autoclaved DNA from herring sperm would stimulate cell division of tobacco in tissue culture, this substance was called kinetin (Salisbury et al.1969). The common name cytokinin is used for any chemical substance which stimulate cell division, or cytokinesis.

Cytokinins have been found to be involved in nearly all aspects of plant growth and development (Leopold et al.1975). Other cytokinins were discovered and many of them isolated from plant tissues, beginning with zeatin discovered in corn (*Zea mays*) which is a modified version of adenine (Moore 1984). Natural and synthetic cytokinins include: zeatin, zeatin riboside, kinetin, isopentenyladenine (2iP), and benzyladenine (BA or BAP).

Hormonal cytokinins are usually made up of adenine with a five-carbon isoprene as a side chain. The isoprene unit comes from the mevalonate pathway which is also where gibberellins come from, therefore, to a certain extent, gibberellins and cytokinins share a portion of the same biosynthetic pathway in the cell (Preece et al.1993). The biosynthesis of cytokinins of the purine type occur via the substitution of the side chain onto the common plant constituent adenine (Leopold et al.1975). Cytokinins are known for cell enlargement, not cell elongation like with auxins and gibberellins. They promote cell growth in all directions (Preece et al.1993). The promotion of cell division can result in the decrease of apical dominance if cytokinin levels in the plant are elevated (Hartmann et al.2002).

The ratio of cytokinin to auxin has been studied and has been found to have a major effect on plant growth development. Higher auxin to cytokinin ratios result in better rooting, while higher cytokinin to auxin rations result in better vegetative growth (Preece et al.1993). There are exceptions to this, but the increase in cytokinins in the plant through additional applications could have detrimental effects on the rooting percentages of herbaceous perennials (Grossman 2012). Increasing branching and providing more propagation material per stock plant is important; however, having quality cuttings that produce roots at a high percentage is also important.

N-6-Benzyladenine (6-BA), Figure 1.3, is a synthetic cytokinin and was used in this study to see the plants' response for lateral branching. Cytokinins are used in a variety of horticultural practices. In commercial greenhouse production, cytokinins are applied to increase branching and help decrease crop times by increasing the ability of the plant to fill out in a container in a shorter time period. In micropropagation (tissue culture), cytokinins are incorporated in the auger for increased branching of plantlets for division (Barnes 2013). The use

of cytokinins in micropropagation is widely used and has been used as an indicator for whole plant application success possibilities.

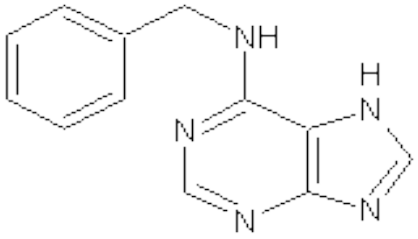

Figure 1.2 Molecular structure of N-6-Benzyladenine provided by www.sigmaaldrich.com.

1.6.3 Ethephon

Ethylene is a gaseous plant hormone that has the ability to affect a wide range of plant growth and development processes (Simons 1984). In its pure form ethylene is a gas and at normal temperatures dissipates into the atmosphere too quickly to be effective if it is applied to horticultural crops (Preece et al.1993). One of the main plant responses to ethylene is the enhancement of maturation. Dependent on the growth stage of the plant, several responses are capable of being induced with using ethylene: seed germination, root hair development, flowering, increased branching, growth regulation, fruit maturation, and leaf drop (Nelson 2003). All these desirable responses to ethylene have led to the need for a nongaseous, liquid form of ethylene.

The movement in the plant of ethylene is by diffusive processes, due to the relatively small size of the molecule. The small size and the solubility in water and other lipophilic systems allows for easy movement of ethylene throughout the plant tissues. The easy movement through cell membranes because of the solubility in lipophilic systems and the movement through air spaces suggests porosity of the tissue allows for movement similar to carbon dioxide in the plant

(Leopold et al.1975). The easy movement of ethylene in the plant is the reason that ethylene affects many different growth and development processes in the plant.

The biosynthetic pathway of ethylene was studied by Lieberman and Mapson, in 1964, they first proposed that the amino acid methionine is the precursor of ethylene. Adams and Yang, in 1979, worked to establish the exact sequence for the ethylene biosynthesis pathway in ripening apples, which follows the pathway; Methionine to SAM (S-adenosylmethionine) to ACC (1 -aminocyclopropane-1 -carboxylic acid) to ethylene. Methionine is first converted to S-adenosylmethionine (SAM) through reaction with available ATP. The next step in the pathway is the conversion of SAM to ACC and MTA (methylthioadenosine). ACC synthase, which catalyzes the conversion of SAM to ACC and MTA has a key role in the regulation ethylene biosynthesis (Adams 1979). Through this process ethylene is made available to the plant cells.

The liquid form of ethylene, ethephon is a liquid form that is widely used as an alternative to the gaseous form and allows for better efficacy on plant crops. The chemical name for Ethephon is 2-chloroethyl phosphonic acid and is written as CEPHA in some instances. The structure of ethephon is a phosphonic acid compound having a 2-chloroethyl substituent attached to the phosphate atom, as in Figure 1.4.

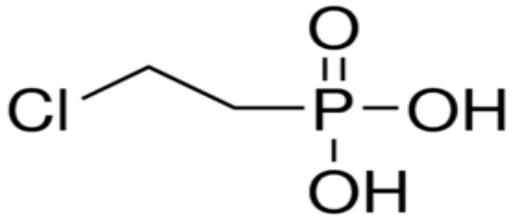

Figure 1.3 Molecular Structure of Ethephon provided by www.sigmaaldrich.com.

Ethephon enters the plant and begins to breakdown into three molecules phosphate, chloride, and ethylene, these are released into the plant systems and effect plant growth and development (Preece et al. 1993). The production of ethylene in a plant has been observed to occur slightly before the ripening process of fruit (Salisbury et al.1969). Ethephon has been used on food crops since the middle of the twentieth century. The release of ethylene has been used to promote the maturation and ripening of apples, bananas, tomatoes, and coffee for example. It aids in the loosening of certain fruit to increase production efficiency, cherries and walnuts are two major food crops that are treated with ethephon prior to harvest (Preece et al.1993). The fruit industry uses Florel, a commercially available PGR that contains 3.9% ethephon, to increase efficiency in harvests through the release of ethylene (Nelson 2003).

Ethephon is widely used to promote axillary shoot development and not damage the apical meristem (Hayashi et al.2001). There are other pinching PGR that have more of a damaging effect on the plant growth than ethephon, which makes it a preferred chemical for most herbaceous horticultural crops. The main response examined in this study, the inhibition of flowering initiation and abortion of young flowers was written about in some detail by Dole and Wilkins (2005). The increase of branching and decrease of flower development could result in herbaceous perennial stock plants with significantly more vegetative cutting material.

1.7 Herbaceous Perennial Response to Plant Growth Regulators Research

Research pertaining to the application of PGR on herbaceous perennial crops has been an area of increased interest in the past twenty years. Commercial operations are interested in any product that may allow them to lower their input costs or decrease the growing time required for herbaceous perennial crops. Research specifically involving GA, 6-BA, and Ethephon on

herbaceous perennials has been conducted on more of the commercially produced taxa. *Heuchera* has been studied in conjunction with GA and 6-BA, while *Zauschneria* has not been studied for its response to any of the three PGR in this study. Parallels can be drawn between similarly growing herbaceous perennials and the two examined in this study.

Bluebird Nursery in Clarkson, Nebraska has used GA_3 since the early 1990's and found that applying a product named GibbPro (Abbot Laboratories, Chem & Ag Products, North Chicago, IL) at a rate of 25 mL per 10 L on 4-inch pots of *Heuchera sanguinea* 'Snow Angel' produced an increase cutting numbers. They noticed a two to three times rate increase in vegetative growth as well as increased axillary bud development (Ackerman et al.1994). This study was done at the nursery and did not involve a control group, so findings are not statistically valid. However, the continued use of GA on *Heuchera* 'Snow Angel' by the nursery and the improved vegetative growth results are encouraging for further research of GA on this herbaceous perennial.

The addition of the synthetic cytokinin BA was shown to increase the cytokinin to auxin ratio in the plant and increase lateral branching by disrupting apical dominance (Cline 1991). The use of 6-BA on herbaceous perennials has a proven history of efficacy and improved branching. In the past two decades, 6-BA has been researched thoroughly for many herbaceous perennials. In a study that involved herbaceous perennial liners with applications of 300, 600, 900, 1200 $mg \cdot L^{-1}$ 6-BA showed increased branching on *Echinacea* at rates as low as 300 m $mg \cdot L^{-1}$ (Latimer et al. 2011).

The use of 6-BA on *Dianthus caryophyllus* was done in Poland on mother plant production and resulted in more cuttings with a 6-BA treatment, except for the highest

application rate of 800 $mg \cdot L^{-1}$ (Mynett 1977). The application of 6-BA on *Sedum* 'Autumn Joy' was shown to be very effective with treated liners having four times as many lateral branches when compared to untreated control liners (Latimer et al. 2013). Having an application schedule for stock plants or longer-term production plants is important. It has been shown that over time treated and untreated liners eventually resulted in the same amount of lateral branching after only one treatment (Grossman et al.2012). Faster results can be achieved through an intensive application schedule at a shorter interval.

Latimer et al. (2015) found that *Heuchera* 'Silver Lode' had little response to an application of 600 $mg \cdot L^{-1}$ 6-BA for plant height and width. It is the compactness of the crown of the *Heuchera* that makes it difficult to accurately count lateral branching. An increase in branching was observed after destructive harvests. The use of 6-BA showed increased branching resulting in more propagation material, but it has also showed a uniformity effect on herbaceous perennials. Martin and Singletary (1999) noticed an increase in lateral offshoots was accompanied by more uniform offshoot growth, which could result in less production time and ultimately more uniform cuttings for propagation flats.

The PGR ethephon breaks down and releases ethylene, which influences internode elongation, increases branching, and abort reproductive buds (Lopez et al.2017). Some of the first research on an ethylene controlling substance was performed by Warner and Leopold in 1967. They determined that the Amchem Products compound 66-329 controlled the release of ethylene better than any other plant regulator used, which were mainly auxins (Warner et al.1967). The wide array of plant activities that ethephon influences resulted in an increase of PGR research on herbaceous perennials. The commercially available product Florel has been researched for its efficacy on herbaceous perennials. Ethephon applications increased vegetative

growth and controlled the timing of flowering. Ethephon treatments on herbaceous perennials resulted in increased number of cuttings while also reducing the size (Brown et al.2000).

Konjoian (1994) performed different studies with Florel and its effect on greenhouse crops including annuals and perennials. These studies were partly responsible for the increased desire to find greenhouse crops and production processes that could benefit from ethephon applications. Konjoian (1994) estimated an 80% reduction in labor with the application of ethephon by eliminating the need for hand removal of flowers and the promotion of vegetative growth. Also, Whipker (2015) found that using Ethephon on vegetative annuals improved plant structure, prevented early flowering, and controlled excessive plant growth.

Roger C. Styer (2002) found the proper application rate, timing, and crop susceptibility for Florel. Florel can be a tool for both the control of plant height and the promotion of branching. He stated that Florel was cheaper then most other PGR and more cost effective than pinching or cutting by hand. Styer (2002) found utilizing Florel on stock plants to increase branching instead of hand pinching or in coordination with could result in increased production efficiency. A study at Texas A&M University found that out of 27 vegetative annuals only three displayed no response to 500 and 1000 $mg \cdot L^{-1}$ ethephon applications (Starman et al.2004). Ethephon effected the growth and development of a wide range of herbaceous annual plants. Further trials and research on ethephon should be conducted on new herbaceous perennials.

Environmental factors could influence the efficacy of ethephon in the plant. Air temperature and water alkalinity are two factors studied and it was determined that air temperature at the time of application should be below 79 °F and high alkalinity water should be buffered before tank mixing (Lopez 2017). The application of ethephon is usually done through

foliar spray, but recent research suggested drenching can have a more uniform effect on the greenhouse crops (Aiken et al.2015). Reduction in stem elongation as well as a flowering delay was observed on research performed on a broad range of annual floriculture crops, although biomass accumulation was reduced (Miller et al.2012). When a drench is performed the substrate pH can have an impact of the efficacy of ethephon on herbaceous perennials. Aiken found that Verbena and Veronica both had responses to an ethephon drench performed a week after transplanted into number one containers. As the substrate pH increased the ethephon drench showed less effect on the plant growth (Aiken et al.2015).

Michigan State University has researched PGR on the production of herbaceous perennials. Erik Runkle maintains a website dedicated to PGR information on herbaceous perennials and annuals (http://www.flor.hrt.msu.edu/PGRs/). One study conducted at Michigan State University performed by Glady et al. (2007) showed the effects of ethephon on three herbaceous perennials. The inability of growers to control the plant growth and development through environmental signals has lead to the attempts to control these processes through chemical control. It was found that the effect of ethephon was species dependent. Weekly and biweekly treatments of 400, 600, and 800 $mg \cdot L^{-1}$ Ethephon resulted in markedly different responses on *Veronica, Coreopsis,* and *Dianthus.* Other herbaceous crops have also shown the species-specific sensitivity to ethephon application. The timing and repetition of application also effected cutting quality and stock plant growth (Glady et al. 2007). Additional research on new herbaceous perennials is required before ethephon should be incorporated into crop production plans.

1.8 Study Objectives

The objectives of the stock plant study for *Heuchera sanguinea* and *Zauschneria garretti* were to determine if plant growth regulator treatment(s) resulted in more vegetative propagation material with high propagation qualities. Also, developing stock plant protocols for growers to improve their propagation rates to be more economically acceptable. The rooting study objective was to determine whether the stock plant protocol resulted in any effects on the rooting percentages for the cuttings produced.

CHAPTER 2. MATERIALS & METHODS

2.1 Herbaceous Perennial Stock Plant PGR Study

This study was conducted at Colorado State University Horticulture Center which is located at 1707 Centre Avenue, Fort Collins, CO. The first experiment was performed starting in October 2016 with data collected through March 2017. The second experiment was performed starting in July 2017 with data collected through November 2017.

This research was designed to examine three herbaceous perennial varieties in the Plant Select® program: *Heuchera L. 'Snow Angel' and Epilobium canum (Greene) P.H. Raven ssp.garrettii (A. Nelson) P.H. Raven 'PWWG01S' ORANGE CARPET®*. Plants of uniform size (72 plug tray) were purchased from a local greenhouse (Gulley Greenhouse, Fort Collins, CO). A total of 84 plants per variety were selected, so that four replicates of three plants (twelve total) were placed in a randomized complete design and placed throughout the greenhouse bench for each of the six treatment and control group (Fig 2.1).

The plants were transplanted from the 72 plug size into black #1 (2.84L) containers. All containers were prepared by being soaked in a disinfecting anti-fungal, anti-bacterial, and anti-algae solution for ten minutes prior to use to prevent contamination from previous use. The media used for this study was Berger BM-7, which is a bark mix of intermediate particle size that includes coarse peat moss, perlite, dolomitic and calcitic lime, and a non-ionic wetting agent, see analysis in appendix Table A1.2 & A1.3. In the analysis of the media, there was a large discrepancy in pH between the first experiment batch and the second experiment batch of media,

6.1 and 3.8 respectively. This may have attributed to the decline in overall plant growth and propagation material collected in the second experiment when compared to the first experiment.

Groups of twelve plants were randomly selected for a specific plant growth regulator treatment. Three chemical plant growth regulators were applied at two different rates: 1) Ethephon [250 and 500 $mg \cdot L^{-1}$ (ppm)] (Verve, Nufarm Americas, Inc., Alsip, IL), 2) 6-benzylaminopurine (200 and 400 $mg \cdot L^{-1}$) (Configure; Fine Agrochemicals Limited, Worcester, U.K.), and 3) Gibberellins A4A7 (GA) & N-(phenylmethyl)-1H-purine 6-amine (50 and 100 $mg \cdot L^{-1}$) (Fascination; Valent USA Corp., Fresno, CS), and a control group was maintained. The treatments were applied using a 3.79-liter hand pump sprayer starting two weeks before the first data collection and then monthly throughout the duration of the two experiments. The first experiment treatments were applied on November 13, 2016, December 13, 2016, January 12, 2017, and February 14, 2017. The second experiment treatments were applied on August 12, 2017, September 12, 2017, October 14, 2017, and November 12, 2017. The harvest of cuttings was performed monthly, approximately two weeks after the PGR treatment applications. These treatments were based on the recommendations on the product label and from interviews of nine Colorado greenhouse growers, who have previously or are currently growing these taxa.

Each individual taxon (*Heuchera and* Zauschneria) were placed on a single rolling greenhouse bench with dimensions approximately 1.54 m by 12.19 m. The four groups of 3 plants for each treatment were randomly assigned a location on the greenhouse bench using random number generation in Microsoft Excel, making the layout as a complete randomized design. Groups of three were space approximately 30 cm apart. The plants were individually numbered using an ID of 1 to 84 and data was collected separately for each plant.

Figure 2.1 Photograph of herbaceous perennial plant growth regulator study at the Horticulture Center, 1707 Center Ave., Ft. Collins, Colorado in July, 2017.

The greenhouse used for this study was run by a Wadsworth control system. The greenhouse, number 118, was heated by a natural gas, forced air heater, and cooled passively by automatic ridge vents and automatic pulled shade cloths, and actively by a pad and fan system. Initially, daytime temperatures were maintained between 16.7 and 21.1 degrees Celsius, while night time temperatures were held between 14.4 and 21.1 degrees Celsius. The temperature ranges were adjusted in late December of 2016 to help combat powdery mildew on the *Heuchera* plants. For the rest of the study daytime temperatures were held between 18.3 and 22.8 degrees Celsius with nighttime temperatures between 16.1 and 22.8 degrees Celsius. Before starting the second experiment, greenhouse temperature set points were moved to between 16.7 and 20 degrees Celsius during the day with a night time range of between 12.8 and 16.7 degrees Celsius, to suppress flowering on the *Zauschneria* plants. For the second experiment *Zauschneria* stock

plants were moved closer to the pad wall in the greenhouse. This resulted in cooler temperatures and larger, more vegetative *Zauschneria* stock plants.

In the first experiment, supplemental lighting was provided in two ways. Four strips of Light Emitting Diode (LED) fixtures provided approximately 90% Red and 10% Blue light from sunrise to sunset every day throughout the greenhouse. A secondary set of lights was only used on the *Zauschneria* subjects to help control short-day blooms. These lights were used each day for night interruption and provided red light only from 10:00 pm to 2:00 am. Light readings were performed using a light sensor to ensure there was not enough red light bleeding across the greenhouse to disrupt the other taxa in the study. During the second experiment, no secondary lighting for night interruption was implemented, as it did not show any positive results for reducing flowering in the *Zauschneria*.

During the initial establishment period, plants were watered by hand as needed with a 14-4-14 fertilizer at 200 parts per million (PPM) nitrogen every watering. Fertilizer was constantly injected using a Dosatron® model D14MZ2. Once the majority of all plants had roots striking the sides on the #1 containers, drip irrigation was installed, and the fertilizer regimen was switched to a 20-10-20 fertilizer at 200 PPM nitrogen continual feed. Using 1.9 liters per hour emitters, the irrigation initially ran twice weekly for 30 minutes, for a total of 1.9 liters of fertilized water per week per plant. In January, the weekly water times were increased to every other day for an average of 2.8 liters of fertilized water per week per plant. The second experiment was conducted in the same manner, with the exception of the irrigation initially ran three times weekly for 30 minutes, for a total of 2.8 liters of fertilized water per week per plant.

Some pesticide treatments were required during this study. Powdery mildew and aphids were a problem for the *Heuchera* and spider mites were a problem for the *Zauschneria*. Pageant and Heritage were used in rotation for suppression of powdery mildew. Mantra, Bifenthrin, and Safari were used in rotation for suppression of aphids, with some effect on spider mites. Kontos and Floramite were used in rotation for suppression of spider mites.

2.2 Cutting Protocols

Separate protocols were written for harvesting cuttings from each taxon. Protocols were determined based on information provided by industry partners.

Protocol for *Heuchera* 'Snow Angel' cutting harvest:

Superior cuttings will have a standard pencil width at base (1.27 to 2.54-cm stems) with no lateral shoots. Clean the cutting by removal of dead leaves and lateral buds.

Step by Step Protocol:

1. Start by taking the most ideal cuttings first, being careful not to remove more than 1/3 of foliage
2. If you have removed 1/3 of foliage at this point, move to next plant; if you have not removed 1/3 of foliage yet, continue by taking slightly less ideal cuttings until you have removed 1/3 of foliage or no acceptable cuttings remain
3. Remove any dead foliage from the stock plant at this time (minimize powdery mildew spores)

4. Cut meristem off any shoots that are too large to take as a cutting (increase lateral growth for next round of cuttings)

Figure 2.2 Photograph of *Heuchera* cutting protocol provided by Gulley Greenhouse, Fort Collins, CO

Protocol for *Zauschneria garrettii 'PWWG01S' ORANGE CARPET*® cutting harvest:

Superior cuttings will have soft, non-woody growth with at least 2 nodes below the terminal bud and have fully expanded leaves. The presence of expanded flower buds is highly undesirable. A 1.27 to 1.9 centimeters stem at the base is needed for anchoring the cutting into the plug tray cell.

Step by step protocol:

1. Start by taking the most ideal cuttings first
2. Start with soft new growth at the tips of the stems
3. Feel for stem flexibility below second node
4. Take cutting and remove any expanding buds
5. Remove stalks that have open flowers or flower buds on rest of plant
6. Remove all large woody branches while keeping a third of the original foliage

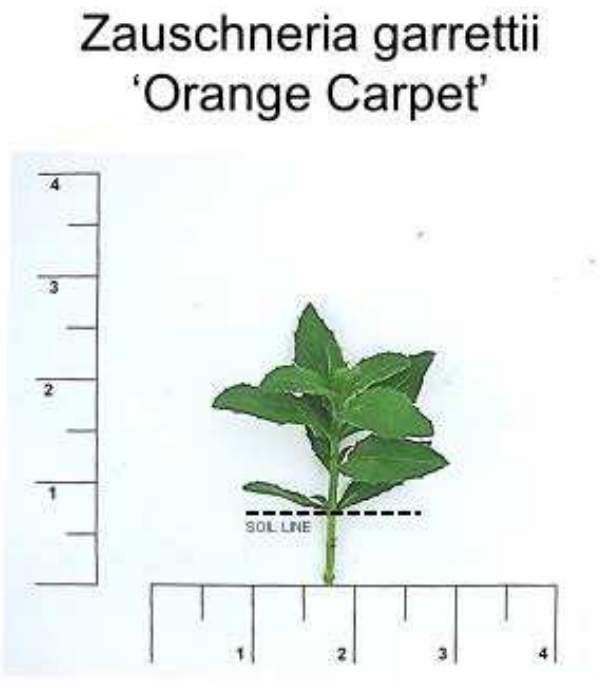

Figure 2.3 Photograph of *Zauschneria* cutting protocol provided by Gulley Greenhouse, Fort Collins, CO

2.3 Data Collection

Initial measurements of height, width, and number of breaks (branching) were taken before the first application of PGR treatments for all 84 plants. Parameters measured monthly were plant height, width, number of cuttings, total fresh weight of cuttings, and total dry weight of cuttings. Plants were measured in centimeters at their highest point from the base of the plant and at two perpendicular widths. Photographs were taken at each sampling date to help document the differences between the treatment groups, before cuttings were removed from the individual plants. Figure 2.4 illustrates the photographs taken and the visual differences between treatments.

Figure 2.4 Photograph of the 7 treatment groups of *Heuchera* stock plants March 2017, treatment from left to right; Control, Verve 200 ppm, Verve 400 ppm, Configure 250 ppm, Configure 500 ppm, Fascination 50 ppm, Fascination 100 ppm.

The cuttings from each individual stock plant were counted, placed in a paper bag and weighed to determine the fresh weight, then placed in a drying oven at 70 degrees Celsius for a minimum of 48 hours. After the cuttings were completely dried, the bags were weighed again to obtain the dry weights. After harvest, stock plants were allowed to grow for four weeks before taking another set of cuttings. The only maintenance done between rounds of cuttings was removing flowering stalks in an attempt to keep stock plants vegetative.

In the first experiment, the first round of cuttings was taken from *Heuchera* individuals on December 1st, 2016, the second round of cuttings one month later on January 3rd, 2017, the third round on February 9th, 2017, and the last round on March 7th, 2017 for a total of four harvests. During the first round of cuttings the apical meristem was removed from each plant at that time to stimulate branching, this is a common practice with all new *Heuchera* stock plants and a recommendation from Gulley Greenhouse from Fort Collins, Colorado.

The first round of cuttings was taken from *Zauschneria* individuals on December 7th, 2016, the second round of cuttings one month later on January 11th, 2017, the third round on February 15th, 2017, and the last round on March 16th, 2017 for a total of four harvests. Removal of all reproductive structures (flowering) was performed at each harvest to encourage juvenility and new vegetative growth.

In the second experiment, the first round of cuttings was taken from *Heuchera* individuals on September 5th, 2017, the second round of cuttings one month later on October 3rd, 2017, the third round on November 6th, 2017, and the last round on December 7th, 2017 for a total of four harvests. During the first round of cuttings the apical meristem was removed from each plant at that time to stimulate branching, this is a common practice with all new *Heuchera* stock plants and a recommendation from Gulley Greenhouse from Fort Collins, Colorado.

The first round of cuttings was taken from *Zauschneria* individuals on September 5th, 2017, the second round of cuttings one month later on October 3rd, 2017, the third round on November 6th, 2017, and the last round on December 7th, 2017 for a total of four harvests. Removal of all reproductive structures (flowering) was performed at each harvest to encourage juvenility and new vegetative growth.

One month after the last cutting harvest for each experiment, nine out of the twelve stock plants from each treatment had all the vegetative growth removed, dried, and weighed. This was done to simulate the average growth of the plant between harvest events. The root balls were removed from the pots and based on a determined rating scale of zero to five (zero being no roots and five being fibrous root system), given a visual rating. A visual reference was photographed and displayed as root ratings were taken for the individual plants for consistency.

Figure 2.5 Photograph of the root rating scale of *Heuchera* stock plants March 2017. Left to right is rating of 5, 4, 3, 2, and 1 of the control treatment group.

Prior to planting for each experiment, samples of the Berger BM7 media used in this study were submitted to Colorado State University's Soil, Water and Plant Testing Laboratory for analysis. Analysis included the percent lime, soluble salts, pH, Electric Conductivity (EC) and Cation Exchange Capacity (CEC) for the media. The analysis also determined the following: levels of nitrogen as ammonium, nitrate, and organic nitrogen, ratio of Ammonium: Nitrate, the Carbon: Nitrogen ratio and total carbon in the media. Phosphorus content was measured as P and P_2O_5, while potassium content was measured as K and K_2O. Analysis included percent lime, soluble salts, pH, Electric Conductivity (EC) and Cation Exchange Capacity (CEC). Media test results are presented in appendix 2.1

2.4 Rooting Study

Three of the stock plants from each treatment combination were randomly selected and continued to be grown under the same conditions for a rooting study. The only variables of the rooting experiment were the stock plant treatments. Cuttings were harvested from each treatment combination after four weeks; May 16, June 13, and July 11, 2017 for the first experiment and January 11, February 8, and March 1, 2018 for the second experiment. Cuttings were taken at the same time of day, in the morning, and stuck in trays of 98 or 72 cells filled with Jiffy® Preforma media and placed under mist with bottom heat at a temperature of 18.3 or 23.9 degrees Celsius for *Heuchera* and *Zauschneria* respectively. Rooting data was then collected every week for four weeks before removing top growth and determining the weight of the dry rooted cell with roots and media.

The *Heuchera* rooting study had three stock plants from each treatment saved and the treatments were continued with the six plant growth regulator treatments being applied monthly and cuttings taken every two weeks after the applications, the control was untreated. The four best cuttings were taken from each plant for a total of twelve. Ten randomly selected cuttings were chosen and then stuck in 72 cell trays. The plug trays were placed on heating mats that maintained a soil temperature of 18.3 degrees Celsius. The mist times on the bench were adjusted weekly, for week one, ten seconds every 15 minutes, for the second week every 30 minutes and for the third and fourth weeks every 60 minutes. This was active for the total 24 hour period each day, there were no differences between mist intervals for day or night.

The *Zauschneria* rooting study had three stock plants from each treatment saved and the treatments were continued with the six plant growth regulator treatments being applied monthly

and cuttings taken two weeks after the applications, the control was untreated. The four best cuttings were taken from each plant for a total of twelve. Ten randomly selected cuttings were chosen and then dipped for five seconds in 500 parts per million IBA/NAA (Dip-n-Gro concentration was diluted), and stuck in 98 cell trays. The plug trays were placed on heating mats that maintained a soil temperature of 23.9 degrees Celsius. The mist times on the bench were adjusted weekly, for week one, ten seconds every 15 minutes, for the second and third weeks every 30 minutes and for the fourth week every 60 minutes. This was active for the total 24 hour period each day.

2.5 Data Analysis

Data analysis was done using R version 3.3.1 with packages car, LSMeans, and ggplot**.** A One-Way ANOVA run separately for the response variables. Response variables include: average number of cuttings per plant, average number of cuttings per square foot, average fresh weight per cutting, average dry weight per cutting, and the final dry weight of top growth. Terms included in the model were predictor variables matching to the plant growth regulator treatments (6 levels). Pairwise comparisons and least squares means were calculated using the lsmeans package for each response variable. Significant differences were noted using $\alpha=0.05$ and 95% confidence intervals.

Response variables for the rooting study include: average rooting percentage per treatment and average number of visible roots per plant per treatment. These were analyzed using a One-Way ANOVA and pairwise comparisons and least squares means were calculated using the lsmeans package for each response variable. Significant differences were noted using $\alpha=0.05$ and 95% confidence intervals.

CHAPTER 3. RESULTS AND DISCUSSION

3.1. *Heuchera sanguinea* 'Snow Angel'

3.1.1 Plant Size

A single parameter for size was calculated to represent overall plant size by averaging the measured height and two widths of each plant. Statistical analysis of size index was done for each time point beginning with initial measurements and occurring before each data collection period. Subsequent analyses contain all treatments averaged over the five time points.

3.1.1.1 Size Index

Analysis of variance of *Heuchera* Experiment #1 revealed a significant effect of treatment for the average size index and all pairwise comparisons were significantly different at the significance level of 0.05 (Figure 3.1.1). The smallest plants were treated with Configure 500 ppm and the largest plants were treated with Fascination 50 ppm (Table 3.1.1, Figures 3.1.2 and 3.1.3). These results suggest that the difference in size and growth of the plants is affected by the specific PGR that is being applied. The Fascination treatment of 50 ppm generating the most growth agrees with the study done by Ackerman at Bluebird Nursery in Nebraska, that two to three times the growth was observed with the application of GA (Ackerman et al. 1994). The Configure 500 ppm would be thought of to have influenced apical growth dominance, but it should increase the lateral growth with increased branching (Latimer et al. 2011). The increased basal branching of the *Heuchera* appeared to have not allowed for the individual internodes to expand as fast and increase the plant height or width in comparison to the other treatments.

```
## Response: GI
##           Sum Sq Df F value   Pr(>F)
## Treatment 20.924  6  3.2792 0.006322 **
## Residuals 81.888 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.1 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for initial size index with Treatment as the predictor.

Table 3.1.1 *Heuchera sanguinea* 'Snow Angel' Experiment #1 initial size index ((height + width 1 + width 2)/3), and 95% confidence intervals for each PGR treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Size Index	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	26.0068	25.4140	26.5996	1
Configure 250 ppm	25.9927	25.3999	26.5855	1
Configure 500 ppm	25.7316	25.1388	26.3244	1
Fascination 50 ppm	26.6065	26.0137	27.1993	12
Fascination 100 ppm	27.2909	26.6981	27.8837	2
Verve 200 ppm	26.1126	25.5198	26.7054	12
Verve 400 ppm	25.9009	25.3082	26.4937	1

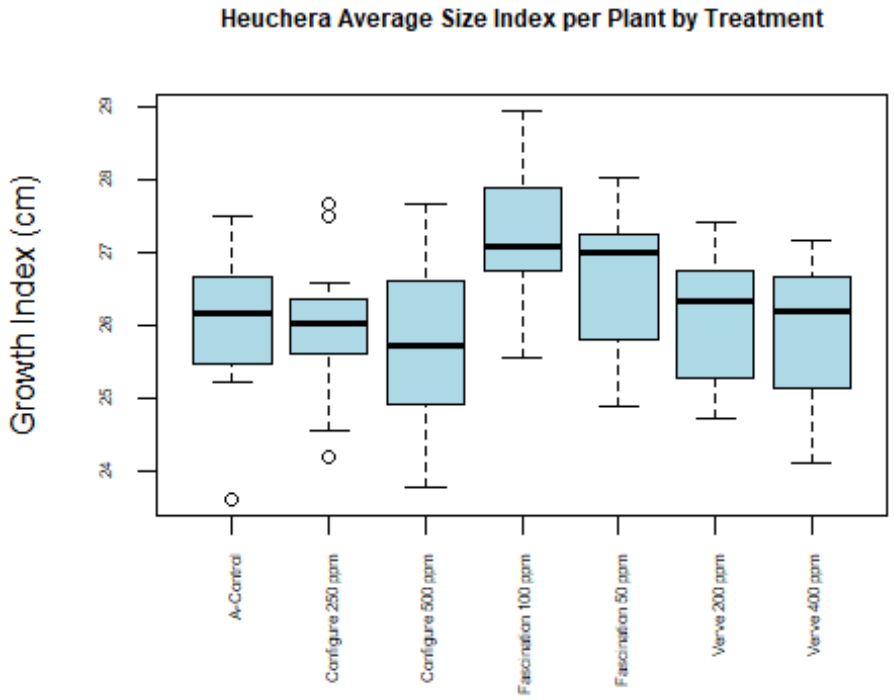

Figure 3.1.2 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average size index per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Figure 3.1.3 *Heuchera sanguinea* 'Snow Angel' Experiment #1 photograph, left to right, Control, Fascination 50 ppm, and Fascination 100 ppm average plant size.

Analysis of variance for *Heuchera* Experiment #2 revealed to not have significant differences of treatments for the average size index at the significance level of 0.05 (Figure 3.1.3). The smallest plants were treated with Configure 250 ppm and the largest plants were treated with Fascination 100 ppm (Table 3.1.2, Figure 3.1.4). These treatments did not produce

statistically different results for plant size index. These results do follow the same trends as the first experiment with the only difference being the PGR concentration rates were inverse. Fascination was again the treatment with the largest plants and Configure the treatment with the least amount of growth. Barnes (2013) discussed these trends in their research and this has shown to be true for many herbaceous perennials.

```
## Anova Table (Type II tests)
##
## Response: GI
##           Sum Sq Df F value Pr(>F)
## Treatment  32.997  6  1.5056 0.1875
## Residuals 281.258 77
```

Figure 3.1.4 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for initial size index with Treatment as the predictor.

Table 3.1.2 *Heuchera sanguinea* 'Snow Angel' Experiment #2 initial size index ((height + width 1 + width 2)/3), and 95% confidence intervals for each PGR treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Size Index	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	26.3278	25.2292	27.4264	1
Configure 250 ppm	25.4776	24.3790	26.5762	1
Configure 500 ppm	25.8798	24.7812	26.9784	1
Fascination 50 ppm	26.5712	25.4726	27.6698	1
Fascination 100 ppm	27.5625	26.4639	28.6611	1
Verve 200 ppm	25.8339	24.7353	26.9325	1
Verve 400 ppm	26.4074	25.3088	27.5060	1

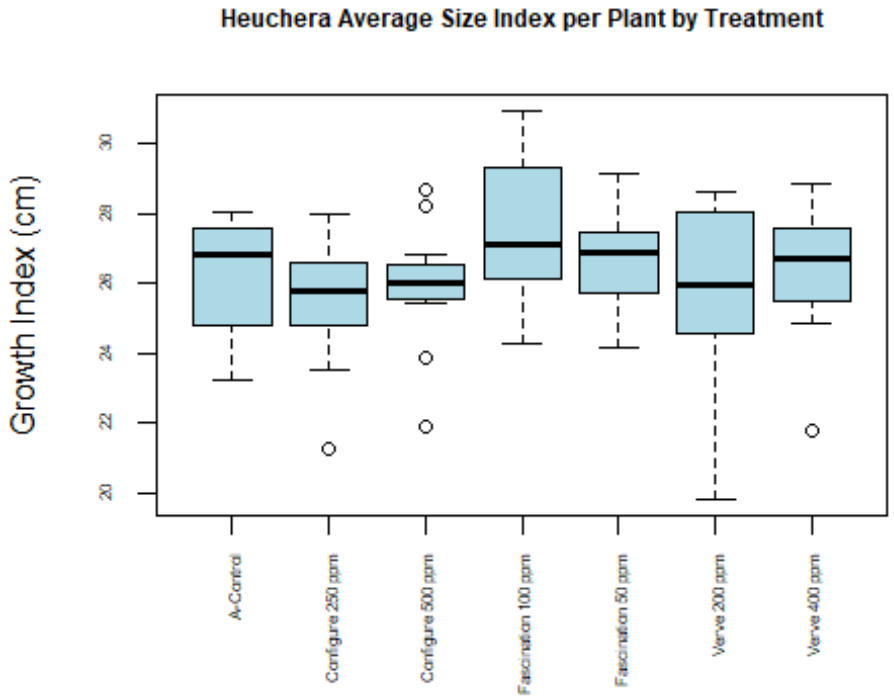

Figure 3.1.5 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average size index per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.2 Final Dry Weight

Final Dry weight of stock plants was determined by cutting off all top growth at the crown of the plant and drying at 70 °C for at least 4 days in paper bags before weighing. This was performed one month after the fourth and final round of cuttings. This duration was meant to simulate the amount of growth the plants were putting on in-between cutting events.

Analysis of variance of *Heuchera* Experiment #1 revealed significant differences for treatment for the average final dry weight at the significance level of 0.05 (Figure 3.1.5). The smallest plants were treated with Fascination 50 ppm and the largest plants were treated with Fascination 100 ppm (Table 3.1.3, Figure 3.1.6 and 3.1.7). These results were unexpected, since Fascination should have shown some consistency in plant growth at the two rates after five

months of growth in the greenhouse. No research was found that could explain this inconsistency. One factor could be that one Fascination 50 ppm plant was an extreme low outlier in the data (Figure 3.1.6).

```
## Anova Table (Type II tests)
##
## Response: FDW
##           Sum Sq Df F value Pr(>F)
## Treatment  97.84  6  2.2272 0.0492 *
## Residuals 563.77 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.6 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for final dry weight of top growth with Treatment as the predictor.

Table 3.1.3 *Heuchera sanguinea* 'Snow Angel' Experiment #1 mean final dry weight of top growth. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Final Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Signficance Group
Control	10.8083	9.252931	12.36374	12
Configure 250 ppm	11.8333	10.277931	13.38874	12
Configure 500 ppm	12.7333	11.177931	14.28874	12
Fascination 50 ppm	9.6417	8.086264	11.19707	1
Fascination 100 ppm	13.1250	11.569598	14.6804	2
Verve 200 ppm	11.6917	10.136264	13.24707	12
Verve 400 ppm	11.4583	9.902931	13.01374	12

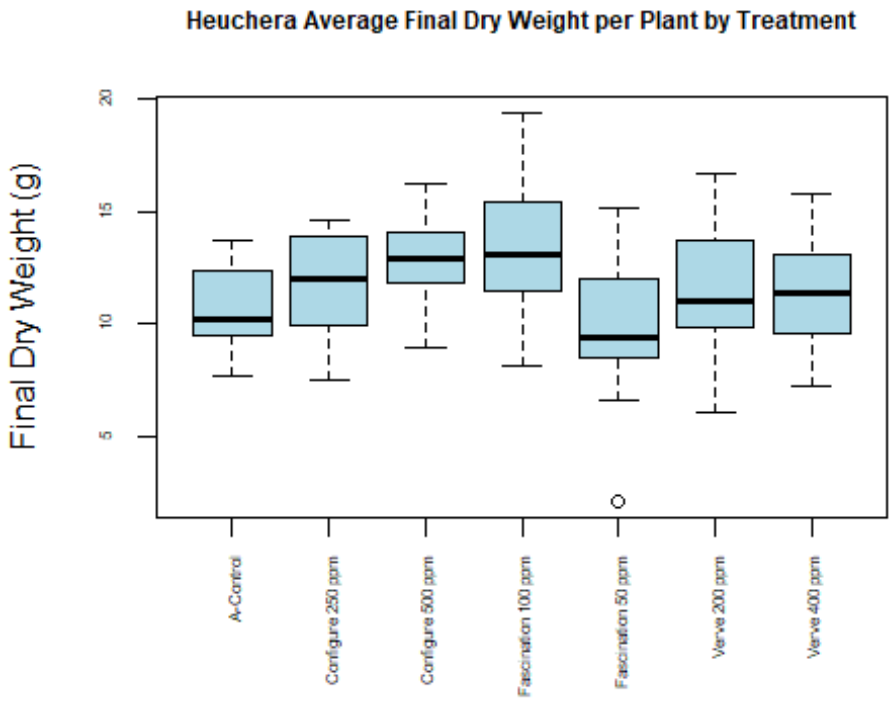

Figure 3.1.7 *Heuchera sanguinea* 'Snow Angel' Experiment #1 box plots of mean final dry weight of top growth. Standard error bars indicate a 95% confidence interval for the mean.

Figure 3.1.8 *Heuchera sanguinea* 'Snow Angel' Experiment #1 photograph of average size of plant by Treatment, left to right, Control, Verve 200 ppm, Verve 400 ppm, Configure 250 ppm, Configure 500 ppm, Fascination 50 ppm, and Fascination 100 ppm.

Analysis of variance of *Heuchera* Experiment #2 did not follow the same trends as the first *Heuchera* experiment, there was no significant effect of treatment for the final average dry weight, but two treatments had significant differences in least squared means pairwise comparisons at the significance level of 0.05 (Figure 3.1.7 and 3.1.8). The smallest plants were treated with Verve 400 ppm and the largest plants were treated with Configure 500 ppm (Table

3.1.4, Figure 3.1.8). *Heuchera* did not have flowering issues for the stock plants in the second experiment, the Verve treatments showed little effect on the plants. Styer (2002) did find that Ethephon effected increased branching and plant height control, which coincides with these results. The Configure 500 ppm treatment was thought to result in more plant growth through the increase in lateral branching, which was observed in this research. Latimer (2011) found that *Heuchera* 'Silver Lode' increased branching from 13 to 23 branches when treated with Configure 500 ppm.

```
## Anova Table (Type II tests)
##
## Response: FDW
##           Sum Sq Df F value  Pr(>F)
## Treatment  336.59  6  2.0356 0.07591 .
## Residuals 1543.29 56
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.9 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for final dry weight of top growth with Treatment as the predictor.

Table 3.1.4 *Heuchera sanguinea* 'Snow Angel' Experiment #2 mean final dry weight of top growth. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Final Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Signficance Group
Control	16.1667	12.6612	19.6721	12
Configure 250 ppm	16.9778	13.4723	20.4832	12
Configure 500 ppm	19.0000	15.4946	22.5054	2
Fascination 50 ppm	15.8556	12.3501	19.3610	12
Fascination 100 ppm	16.0200	12.6945	19.3455	12
Verve 200 ppm	13.1778	9.6723	16.6832	12
Verve 400 ppm	11.1625	7.4444	14.8806	1

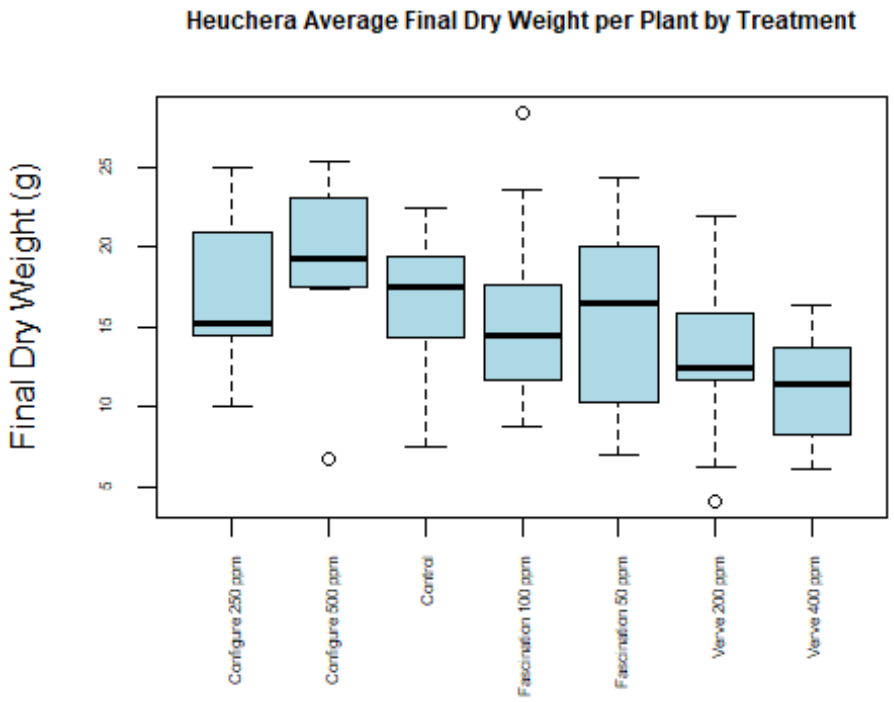

Figure 3.1.10 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of final dry weight of top growth per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.3 Average Number of Cuttings Per Plant

The average number of harvested cuttings was averaged over the four harvest dates for analysis. Analysis of variance for *Heuchera* Experiment #1 resulted in very high significant differences for treatments for the average number of cuttings harvested with a p-value of less than .0001, at the significance level of 0.05 (Figure 3.1.9). The smallest number of cuttings were from the untreated Control group and the largest number of cuttings were from the Fascination 50 ppm treatment (Table 3.1.5, Figure 3.1.10). These results were not exactly what was predicted during the experimental design process. Fascination at 50 ppm was expected to produce more internode elongation and produce more cuttings every month between data collection dates (Ackerman et al. 1994). Although, the higher application rate of 100 ppm Fascination was thought to produce more internode elongation and more available cutting material at the harvest

times. The Control group was thought to be the lowest cutting producer, Ethephon was a surprise for *Heuchera* due to the lack of research with Ethephon and its effect on vegetative growth. Ethephon has shown to have a negative effect on plant height and this could have led to the diminished number of cuttings (Styer 2002). Lack of flowering was observed in the overall *Heuchera* stock plants. Ethephon and its effect on plant physiological functions for flower abortion would then not benefit *Heuchera* stock plant production in this research.

```
## Anova Table (Type II tests)
##
## Response: Cuttings
##           Sum Sq Df F value    Pr(>F)
## Treatment  57.039  6  6.4093 1.655e-05 ***
## Residuals 114.208 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.11 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for the average number of cuttings harvested with Treatment as the predictor.

Table 3.1.5 *Heuchera sanguinea* 'Snow Angel' Experiment #1 mean average cuttings harvested per treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cuttings per Plant	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	10.6667	9.9666	11.3667	1
Configure 250 ppm	11.9792	11.2791	12.6792	1234
Configure 500 ppm	12.7500	12.0499	13.4501	34
Fascination 50 ppm	13.0625	12.3624	13.7626	4
Fascination 100 ppm	12.4792	11.7791	13.1792	234
Verve 200 ppm	11.2292	10.5291	11.9292	12
Verve 400 ppm	11.2917	10.5916	11.9917	123

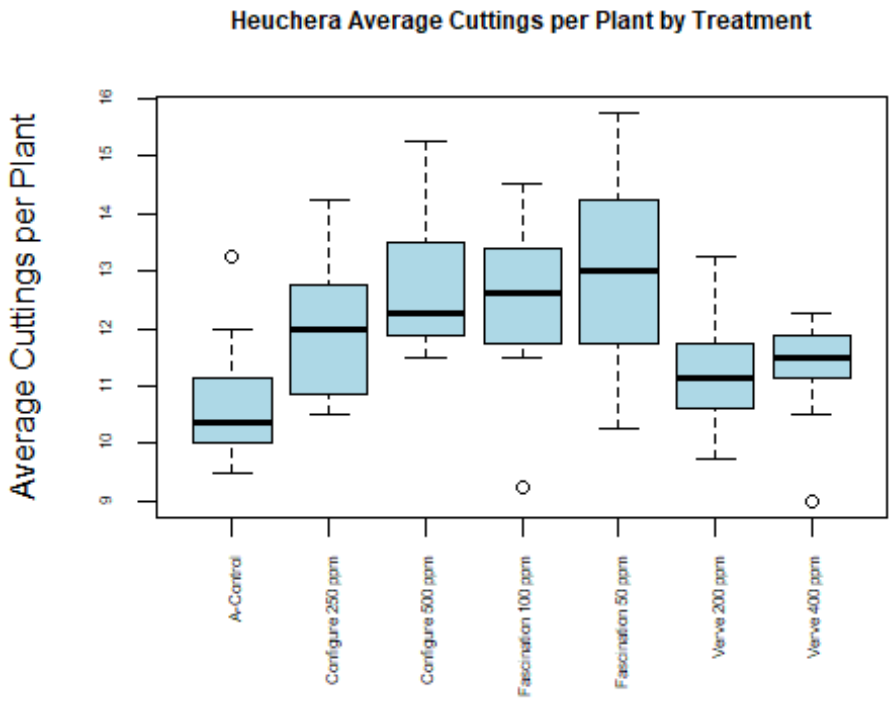

Figure 3.1.12 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average number of cuttings per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance of *Heuchera* Experiment #2 followed the same trends as the first experiment, there were significant differences for the effect of Treatment on the average number of cuttings harvested, at the significance level of 0.05 (Figure 3.1.11). The smallest plants were the untreated Control group and the largest plants were treated with Fascination 50 ppm (Table 3.1.6, Figure 3.1.12). This experiment had data that was grouped tighter together then in experiment #1 and did not show the same drastic effects of Fascination or any of the other treatments. Difference in the time of year of the two experiments could be responsible for this discrepancy. The first experiment started in November, while the second experiment started in August, this led to light levels and temperatures that were different in each experiment. Having the different times of the year for the starting of the two experiments gave the added information about a possible better time to grow stock plants for the two genera.

```
## Anova Table (Type II tests)
##
## Response: Cuttings
##           Sum Sq Df F value  Pr(>F)
## Treatment  21.103  6  2.3573 0.03831 *
## Residuals 114.885 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.13 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average number of cuttings harvested.

Table 3.1.6 *Heuchera sanguinea* 'Snow Angel' Experiment #2 mean number of cuttings harvested. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cuttings per Plant	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	6.5000	5.7979	7.2021	1
Configure 250 ppm	7.0833	6.3812	7.7855	12
Configure 500 ppm	7.5000	6.7979	8.2021	12
Fascination 50 ppm	8.1250	7.4229	8.8271	2
Fascination 100 ppm	7.6458	6.9437	8.3480	12
Verve 200 ppm	7.1458	6.4437	7.8480	12
Verve 400 ppm	6.8333	6.1312	7.5355	12

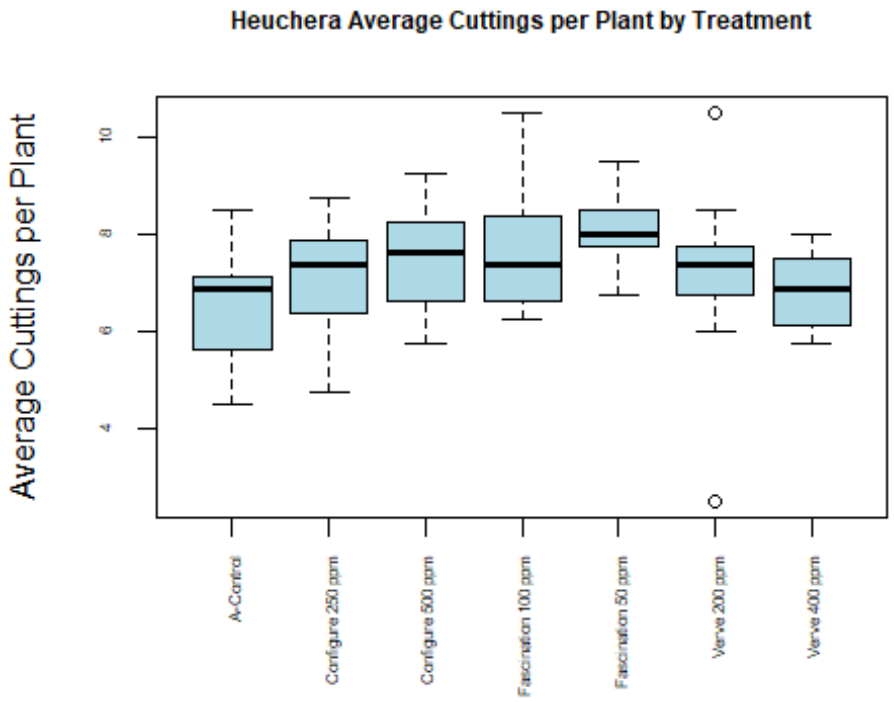

Figure 3.1.14 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.4 Fresh Weight Per Cutting

Average fresh weights per cutting were calculated by dividing the total fresh weight of cuttings (grams) by the total number of cuttings harvested for each plant averaged over the four harvest dates.

Analysis of variance of *Heuchera* Experiment #1 resulted in no significant differences for the effect of treatment for the average individual fresh weight of cuttings harvested, at the significance level of 0.05 (Figure 3.1.13). These statistical results were expected from the time cuttings were harvested due to the lack of different sizes of *Heuchera* cuttings observed. The *Heuchera* cutting protocol used from Gulley greenhouse limited the variation of cutting size taken during harvest. All *Heuchera* plants, regardless of treatment, grew to about the same size

and had numerous cuttings that fell within the protocol parameters. The untreated Control had the highest fresh weight per cutting, which would suggest that all the PGR treatments had some effect on growth. All of the PGR used in this experiment have been proven to have certain effects on the plant physiological functions and overall growth discussed in chapter 1, these traits have been identified since the early 1950's (Leopold et al. 1975).

```
## Anova Table (Type II tests)
##
## Response: CFW
##           Sum Sq Df F value  Pr(>F)
## Treatment  2.6734  6  1.9017 0.09117 .
## Residuals 18.0409 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.15 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for average individual cutting fresh weight with Treatment as the predictor.

Table 3.1.7 *Heuchera sanguinea* 'Snow Angel' Experiment #1 average individual cutting fresh weight per treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cutting Fresh Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	4.8642	4.5859	5.1424	1
Configure 250 ppm	4.3342	4.0559	4.6124	1
Configure 500 ppm	4.3500	4.0718	4.6282	1
Fascination 50 ppm	4.6392	4.3609	4.9174	1
Fascination 100 ppm	4.5067	4.2284	4.7849	1
Verve 200 ppm	4.7175	4.4393	4.9957	1
Verve 400 ppm	4.5242	4.2459	4.8024	1

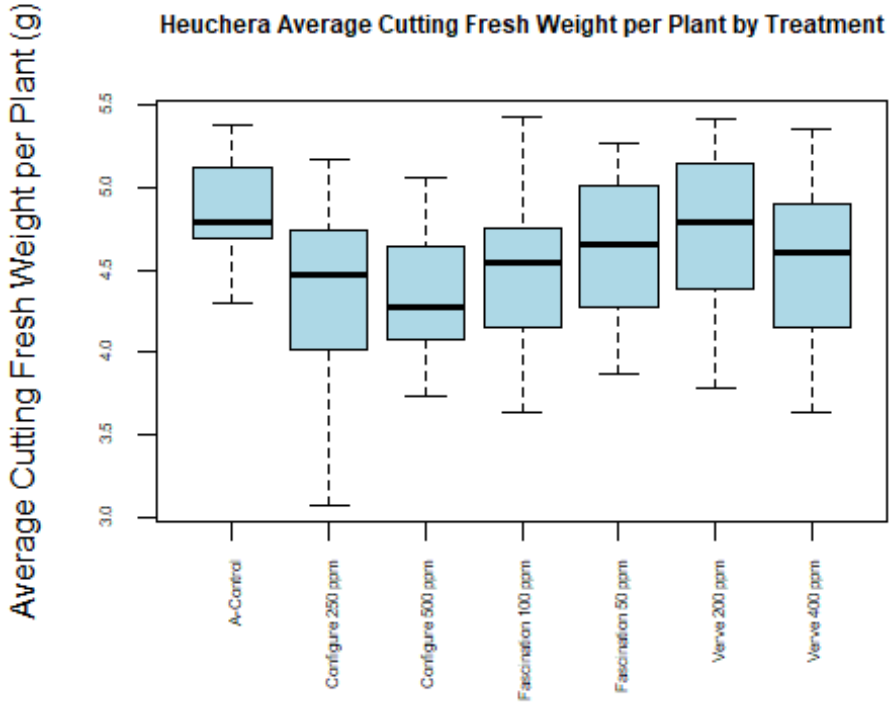

Figure 3.1.16 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average fresh weight of individual cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Heuchera* Experiment #2 did not follow the same trends as the first experiment, there was significant differences for treatment effects on the average fresh weight of individual cuttings harvested, at the significance level of 0.05 (Figure 3.1.15). The smallest plants were treated with Fascination 50 ppm and the largest plants were treated with Fascination 100 ppm and Verve 400 ppm (Table 3.1.8, Figure 3.1.16). The Fascination treatments resulting in both the lowest fresh weight and highest fresh weight was not predicted since the plants looked similar and the number of cuttings harvested from both treatments were higher than other treatment groups. However, this does correlate to the final dry weights discussed from *Heuchera* Experiment #1, although there is no extreme outlier to explain the results in this case. The Verve 400 ppm treatment resulted in significantly higher dry weights

than all but one other treatment. Research on Ethephon has shown decreases herbaceous perennial plant height, but little research has been reported on the fresh or dry weight of cuttings (Hayashi et al. 2001). Ethephon having this response could be attributed to the decrease in internode elongation and the increase in energy available to grow stouter stems (Miller et al. 2012).

```
## Anova Table (Type II tests)
##
## Response: CFW
##           Sum Sq Df F value   Pr(>F)
## Treatment 17.149  6  3.3552 0.005446 **
## Residuals 65.593 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.17 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average fresh weight of cuttings harvested with Treatment as the predictor.

Table 3.1.8 *Heuchera sanguinea* 'Snow Angel' Experiment #2 average fresh weight of cuttings harvested by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cutting Fresh Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	7.5214	6.9909	8.0519	12
Configure 250 ppm	7.1729	6.6423	7.7034	12
Configure 500 ppm	7.1231	6.5926	7.6537	12
Fascination 50 ppm	6.8477	6.3172	7.3783	1
Fascination 100 ppm	8.1777	7.6472	8.7082	2
Verve 200 ppm	7.4293	6.8987	7.9598	12
Verve 400 ppm	8.0429	7.5124	8.5734	2

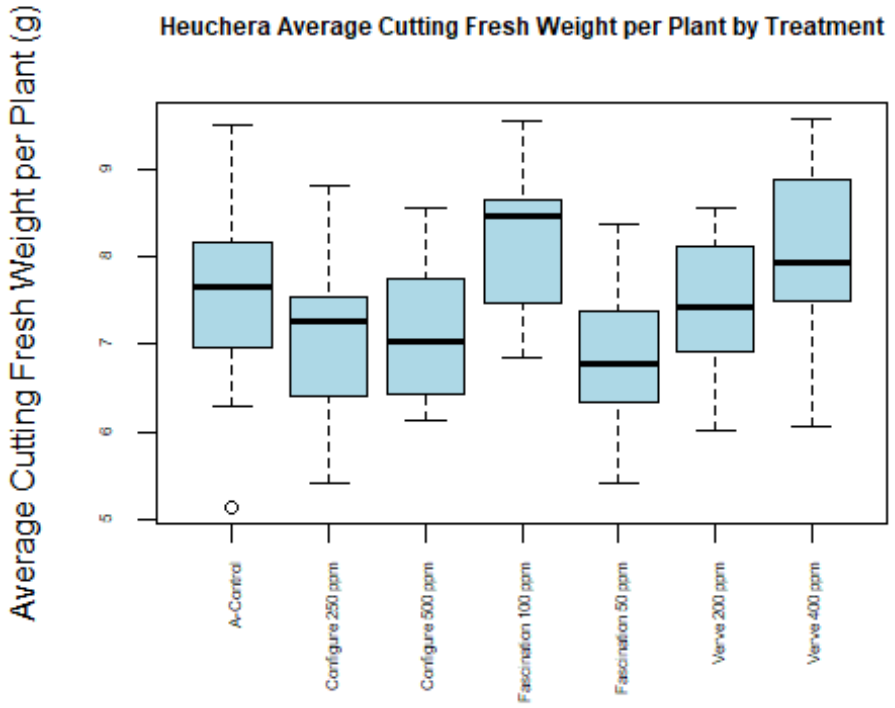

Figure 3.1.18 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average fresh weight of individual cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.5 Dry Weight Per Cutting

Average dry weights per cutting were calculated by dividing the total dry weight of cuttings by the total number of cuttings harvested for each plant during each harvest date and averaged over the four harvest dates.

Analysis of variance of *Heuchera* Experiment #1 revealed no significant differences with the average individual dry weight of cuttings harvested, at the significance level of 0.05 (Figure 3.1.17). These results were not expected, the fresh weights of the Configure and Fascination treatments were the inverse of the dry weights for *Heuchera* Experiment #1. This indicates more water per cutting for the Fascination treated cuttings. This goes along with the known effects of GA on the plant, mainly elongation of the cell/internode (Salisbury et al. 1969). How this

observed effect on the rooting of GA treated vegetative cuttings has not been reported in researched data. One inference to be made from this is GA treated vegetative materials may need a larger amount of moisture added during the rooting process to combat the loss of the extra water from the cutting. Dirr (2009) discusses different humidity may be required dependent on the specific species being propagated and its unique physical condition.

```
## Anova Table (Type II tests)
##
## Response: CDW
##           Sum Sq Df F value Pr(>F)
## Treatment 0.05518  6   0.775  0.592
## Residuals 0.91380 77
```

Figure 3.1.19 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for the average dry weight of individual cuttings harvested with Treatment as the predictor.

Table 3.1.9 *Heuchera sanguinea* 'Snow Angel' Experiment #1 average dry weight of individual cuttings harvested by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cutting Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.8008	0.7382	0.8635	1
Configure 250 ppm	0.7642	0.7015	0.8268	1
Configure 500 ppm	0.7550	0.6924	0.8176	1
Fascination 50 ppm	0.7442	0.6815	0.8068	1
Fascination 100 ppm	0.7358	0.6732	0.7985	1
Verve 200 ppm	0.8033	0.7407	0.8660	1
Verve 400 ppm	0.7433	0.6807	0.8060	1

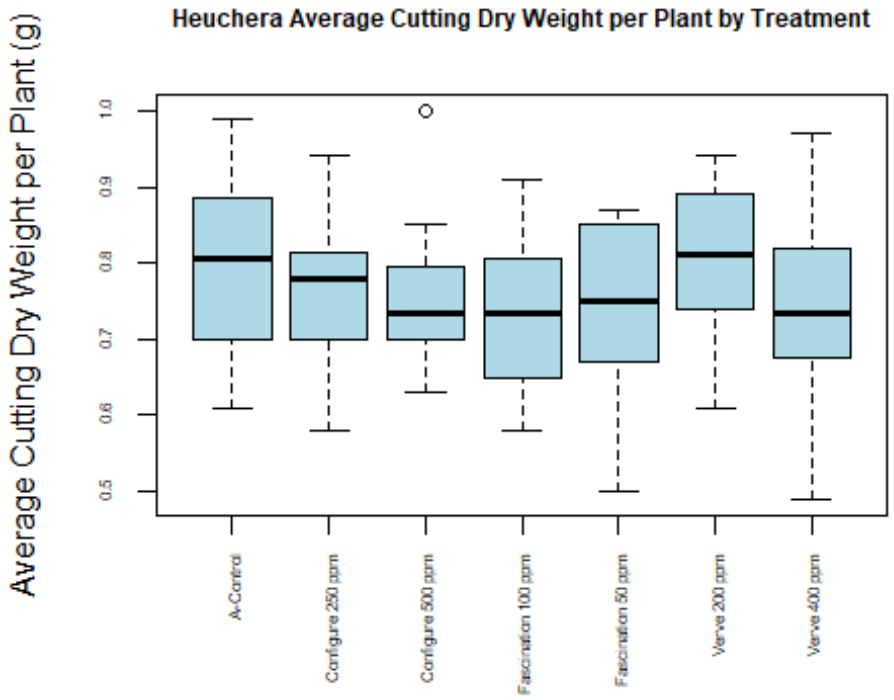

Figure 3.1.20 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average dry weight of individual cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance of *Heuchera* Experiment #2 did not follow the same trends as the first experiment, there were significant differences in the average dry weight of individual cuttings harvested, at the significance level of 0.05 (Figure 3.1.19). The smallest plants were treated with Fascination 50 ppm and the largest dry weight of cuttings were treated with Fascination 100 ppm and Verve 400 ppm (Table 3.1.10, Figure 3.1.20). The Verve 400 ppm treatment resulted in significantly greater dry weight of cuttings than all other treatments. This was also reflected in the fresh weight of the individual cuttings for *Heuchera* Experiment #2. Glady et al. (2007) found that *Veronica longifolia* 'Sunny Border Blue' when first vernalized (8 weeks at 5°C) showed an increase in cutting dry weight when Ethephon was applied at rates of

400, 600 and 800 ppm weekly or bi-weekly. This suggests that Ethephon also promotes shorter, stouter growth with *Heuchera sanguinea.*

```
## Anova Table (Type II tests)
##
## Response: CDW
##           Sum Sq Df F value  Pr(>F)
## Treatment 0.7567  6  3.0351 0.01021 *
## Residuals 3.1994 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.1.21 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average dry weight of individual cuttings harvested by treatment.

Table 3.1.10 *Heuchera sanguinea* 'Snow Angel' Experiment #2 average dry weight of individual cuttings harvested by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Cutting Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	1.6350	1.5178	1.7522	12
Configure 250 ppm	1.5052	1.3881	1.6224	12
Configure 500 ppm	1.4769	1.3597	1.5941	12
Fascination 50 ppm	1.4257	1.3086	1.5429	1
Fascination 100 ppm	1.6523	1.5351	1.7695	12
Verve 200 ppm	1.5142	1.3970	1.6314	12
Verve 400 ppm	1.6975	1.5803	1.8147	2

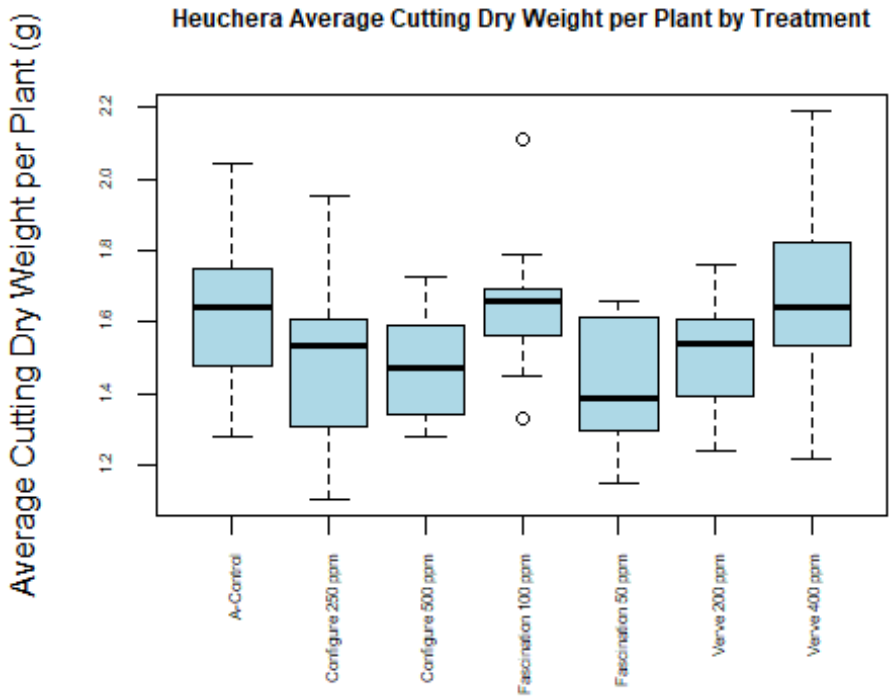

Figure 3.1.22 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average dry weight of individual cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.6 Root Ratings

Root ratings were conducted at the end of the experiment after the top growth was harvested for the final dry weight. The ratings were done using a scale of 1-5 with 1 being very lightly rooted to 5 being fully rooted out throughout the container.

Analysis of variance of *Heuchera* Experiment #1 did not reveal any significant differences for the various treatments on average root ratings taken, at the significance level of 0.05 (Figure 3.1.21). These statistical results were a little surprising because of reported researched effects on rooting by the different PGR treatments. Such as the application of Configure (BA), which contains cytokinins, should inhibit rooting to a certain degree because it is making the auxin to cytokinin ratio unequal (Preece et al. 1993). Also, Ethephon, in the Verve

applications, has shown to increase root growth in some propagation studies. Glady et al. (2007) found that on a subjective performance scale of 1 to 6 (6 being excellent), cuttings from control plants were often rated between 1 and 3 and averaged 1.8, whereas cuttings from ethephon-treated plants averaged 3.2 to 4.2. Past research indicates a relationship between PGR applications and increased or decreased rooting by the plant, however in this experiment no significant difference appeared to be a result.

```
## Anova Table (Type II tests)
##
## Response: RR
##           Sum Sq Df F value Pr(>F)
## Treatment  8.224  6  1.6739 0.1479
## Residuals 39.304 48
```

Figure 3.1.23 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for the average root ratings by treatment taken at the end of the experiment with Treatment as the predictor.

Table 3.1.11 *Heuchera sanguinea* 'Snow Angel' Experiment #1 average root ratings by treatment taken at the end of the experiment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Root Rating	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	4.1250	3.4817	4.7683	1
Configure 250 ppm	3.6250	2.9817	4.2683	1
Configure 500 ppm	3.6250	2.9817	4.2683	1
Fascination 50 ppm	3.2500	2.6067	3.8933	1
Fascination 100 ppm	4.2857	3.5980	4.9734	1
Verve 200 ppm	3.6250	2.9817	4.2683	1
Verve 400 ppm	4.3750	3.7317	5.0183	1

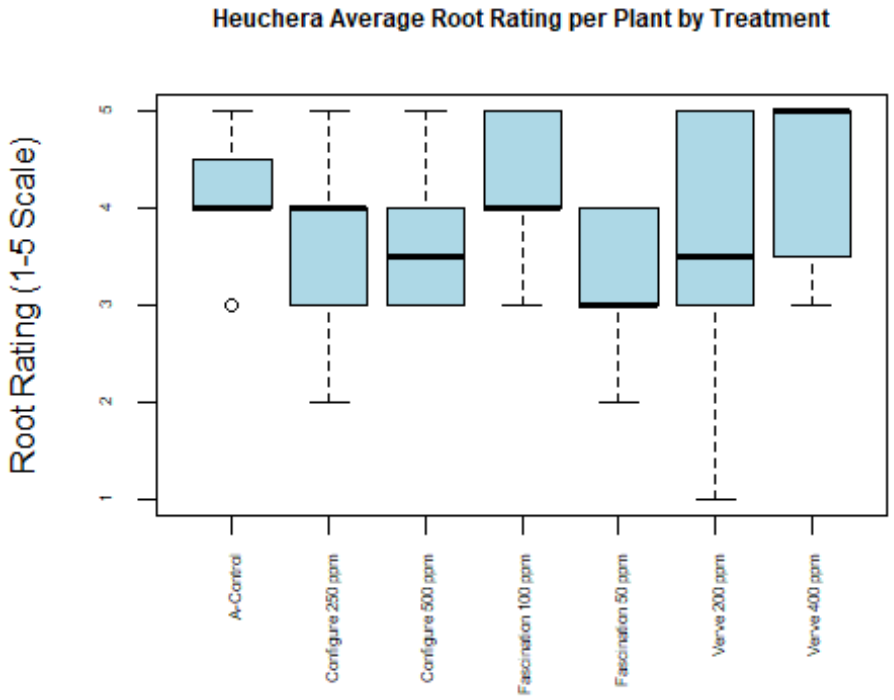

Figure 3.1.24 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average root ratings by treatment taken at the end of the experiment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance of *Heuchera* Experiment #2 followed the same trends as the first experiment, there were no significant differences with average root ratings taken at the end of the experiment, at the significance level of 0.05 (Figure 3.1.23). The results in table 3.1.12, while not significantly different, indicated better root systems for plants treated with Configure then those treated with Fascination or the untreated Control.

```
## Anova Table (Type II tests)
##
## Response: RR
##           Sum Sq Df F value Pr(>F)
## Treatment 10.114  6  1.1826 0.3288
## Residuals 79.822 56
```

Figure 3.1.25 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average root ratings by treatment taken at the end of the experiment.

Table 3.1.12 *Heuchera sanguinea* 'Snow Angel' Experiment #2 average root ratings by treatment taken at the end of the experiment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Root Rating	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	3.3333	2.5361	4.1306	1
Configure 250 ppm	3.6667	2.8694	4.4639	1
Configure 500 ppm	3.4444	2.6472	4.2417	1
Fascination 50 ppm	2.6667	1.8694	3.4639	1
Fascination 100 ppm	3.3000	2.5437	4.0563	1
Verve 200 ppm	2.6667	1.8694	3.4639	1
Verve 400 ppm	3.7500	2.9044	4.5956	1

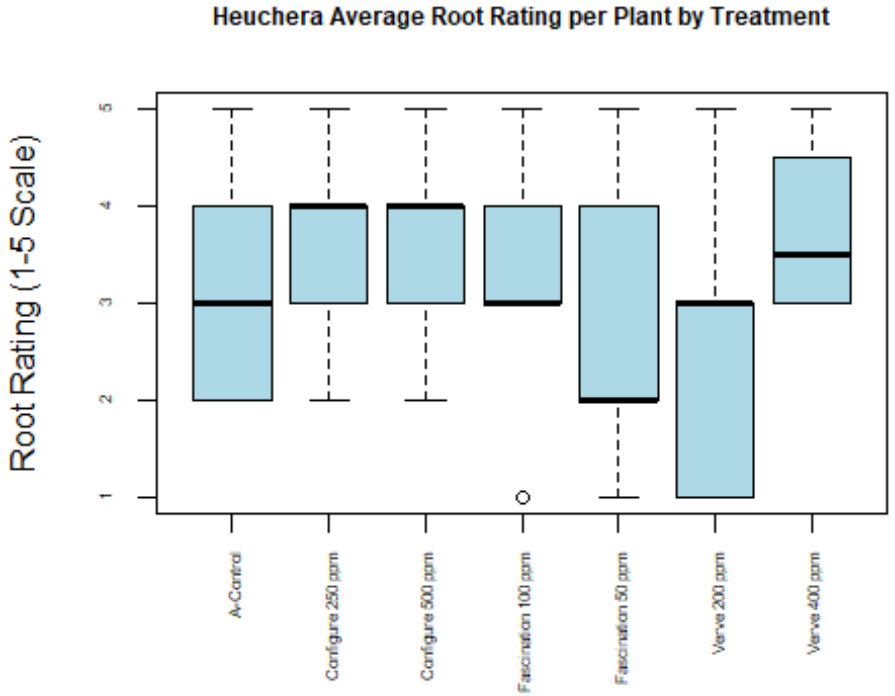

Figure 3.1.26 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average root ratings by treatment taken at the end of the experiment. Standard error bars indicate a 95% confidence interval for the mean.

3.1.7 Differences Between *Heuchera* Experiment 1 and Experiment 2

Differences in mean response between *Heuchera* Experiment #1 and #2 are partially due to the time of year the experiment was carried out. The first experiment was initiated in October 2016, while the second was initiated in July 2017. It is possible that fewer cuttings were produced per plant in the second study because of lower temperatures in the greenhouse which were adjusted for the second study and the natural difference in photoperiod.

3.1.8 Rooting Experiment Results

Rooting percentages were taken weekly for a period of four weeks on the mist bench, as well as counting the number of visible roots to a total of 50 visible roots. Statistical analysis was performed using the final rooting percentages and visible number of roots averaged over the three-month time points for each experiment. There were some correlations between treatments applied and the rooting of those vegetative cuttings.

Analysis of variance of *Heuchera* Experiment #1 revealed no significant differences in average rooting percentage, at the significance level of 0.05 (Figure 3.1.25). There were also no significant differences for the effect of treatment for the average number of visible roots, at the significance level of 0.05 (Figure 3.1.27). These statistical results were a little surprising because various other research showed effects on rooting by the different PGR treatments. Grossman et al. (2012) found that Configure (BA) treated herbaceous perennial liners had less root growth. The physiological relationship between cytokinins and auxins is apparent in the lower rooting percentages of the Configure treatments (Preece et al. 1993). Also, Ethephon has shown to increase rooting in perennials (Glady et al. 2007). These statistics show that if a grower uses any of these three PGR treatments, rooting of those cuttings will not be statistically different.

```
## Anova Table (Type II tests)
##
## Response: RP
##           Sum Sq Df F value Pr(>F)
## Treatment 0.18667  6  1.1667 0.3772
## Residuals 0.37333 14
```

Figure 3.1.27 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for the average rooting percentage with Treatment as the predictor.

Table 3.1.13 *Heuchera sanguinea* 'Snow Angel' Experiment #1 average rooting percentage by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Rooting Percentage	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.9333	0.7311	1.1355	1
Configure 250 ppm	0.7667	0.5645	0.9689	1
Configure 500 ppm	0.6333	0.4311	0.8355	1
Fascination 50 ppm	0.8000	0.5978	1.0022	1
Fascination 100 ppm	0.7333	0.5311	0.9355	1
Verve 200 ppm	0.9000	0.6978	1.1022	1
Verve 400 ppm	0.8333	0.6311	1.0355	1

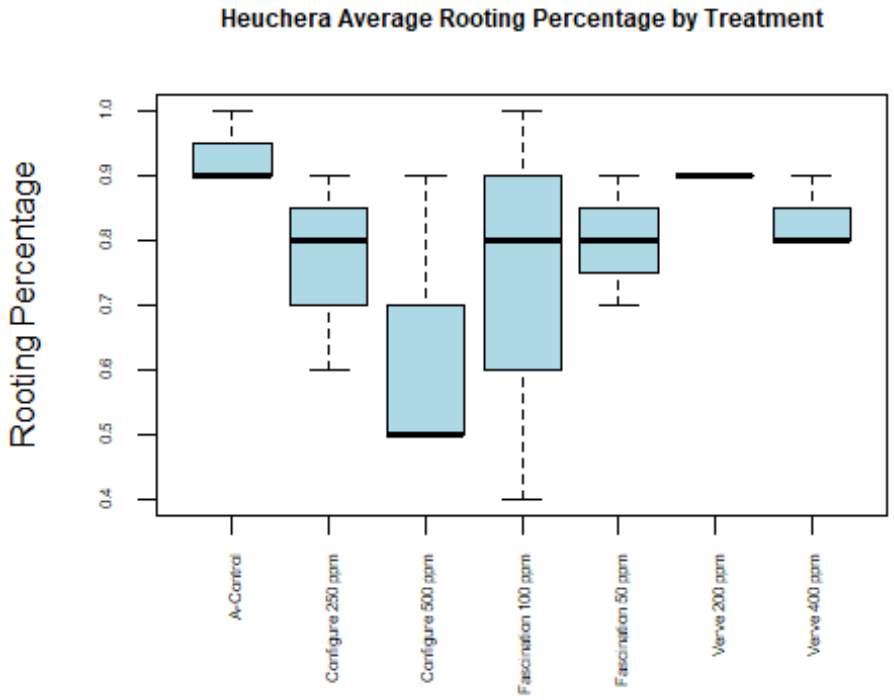

Figure 3.1.28 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average rooting percentage by treatment. Standard error bars indicate a 95% confidence interval for the mean.

```
## Anova Table (Type II tests)
##
## Response: NR
##           Sum Sq Df F value Pr(>F)
## Treatment 2183.8  6  1.2948 0.3214
## Residuals 3935.3 14
```

Figure 3.1.29 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for the average number of visible roots per rooted cutting with Treatment as the predictor.

Table 3.1.14 *Heuchera sanguinea* 'Snow Angel' Experiment #1 average number of visible roots per rooted cutting by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	30.6667	9.9056	51.4278	1
Configure 250 ppm	20.6667	-0.0944	41.4278	1
Configure 500 ppm	14.0000	-6.7611	34.7611	1
Fascination 50 ppm	29.0000	8.2389	49.7611	1
Facination 100 ppm	25.6667	4.9056	46.4278	1
Verve 200 ppm	42.6667	21.9056	63.4278	1
Verve 400 ppm	44.3333	23.5722	65.0944	1

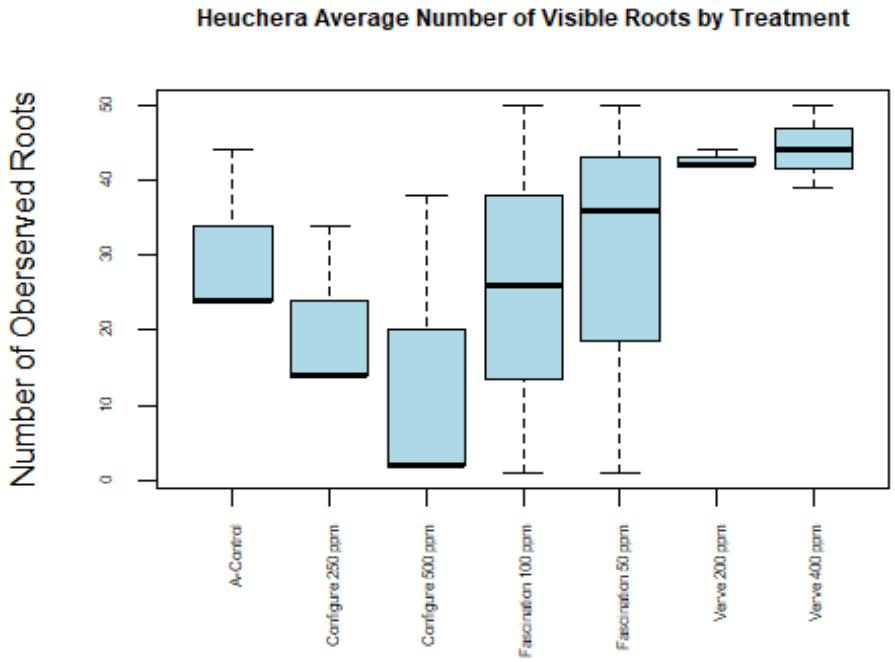

Figure 3.1.30 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average number of visible roots per rooted cutting by treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance of *Heuchera* Experiment #2 followed the same trends as the first experiment, there were no significant on the average rooting percentages or the number of visible roots, at the significance level of 0.05 (Figure 3.1.29 and 3.1.31). Overall rooting was higher in rooting percentage for the second experiment. The number of roots were also greater than the

first experiment. This is an indication of a better time of the year to propagate *Heuchera sanguinea.* The earlier start date for the second experiment, July as compared to October displays a positive effect on the overall growth.

```
## Anova Table (Type II tests)
##
## Response: RP
##           Sum Sq Df F value Pr(>F)
## Treatment 0.06476  6  0.4048 0.8638
## Residuals 0.37333 14
```

Figure 3.1.31 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average rooting percentage with Treatment as the predictor.

Table 3.1.15 *Heuchera sanguinea* 'Snow Angel' Experiment #2 average rooting percentage by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Rooting Percentage	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	0.8667	0.6645	1.0689	1
Configure 250 ppm	0.9667	0.7645	1.1689	1
Configure 500 ppm	0.9000	0.6978	1.1022	1
Fascination 50 ppm	0.8667	0.6645	1.0689	1
Fascination 100 ppm	0.8667	0.6645	1.0689	1
Verve 200 ppm	0.9000	0.6978	1.1022	1
Verve 400 ppm	0.7667	0.5645	0.9689	1

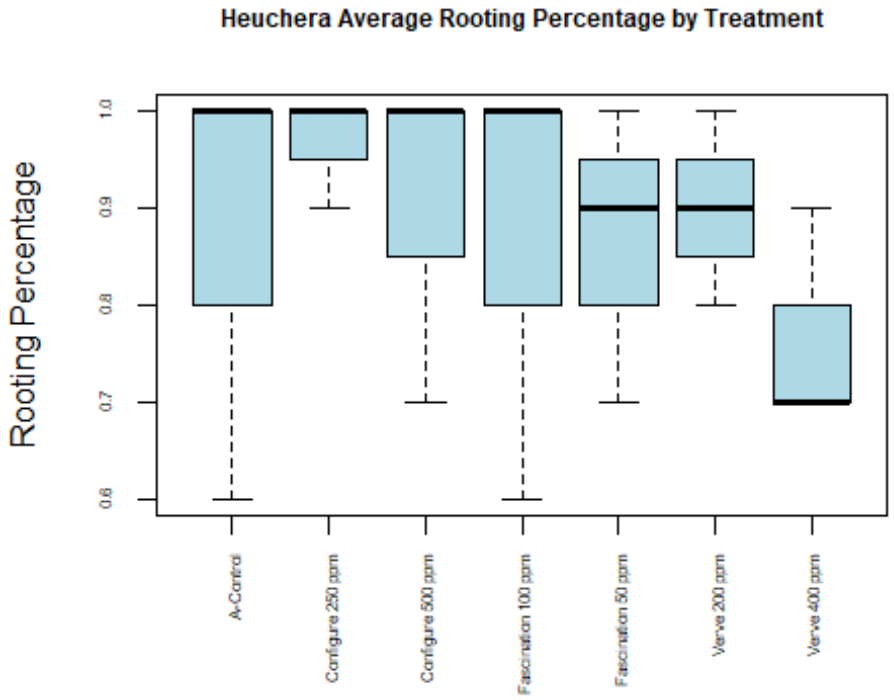

Figure 3.1.32 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average rooting percentage by treatment. Standard error bars indicate a 95% confidence interval for the mean.

```
## Anova Table (Type II tests)
##
## Response: NR
##           Sum Sq Df F value Pr(>F)
## Treatment 1163.8  6  1.3018 0.3187
## Residuals 2086.0 14
```

Figure 3.1.33 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for the average number of visible roots per rooted cutting with Treatment as the predictor.

Table 3.1.16 *Heuchera sanguinea* 'Snow Angel' Experiment #2 average number of visible roots per rooted cutting by treatment. Means with different significance groups are statistically different at the significance level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	44.3333	29.2180	59.4486	1
Configure 250 ppm	36.3333	21.2180	51.4486	1
Configure 500 ppm	21.6667	6.5514	36.7820	1
Fascination 50 ppm	27.0000	11.8847	42.1153	1
Fascination 100 ppm	27.6667	12.5514	42.7820	1
Verve 200 ppm	34.3333	19.2180	49.4486	1
Verve 400 ppm	40.3333	25.2180	55.4486	1

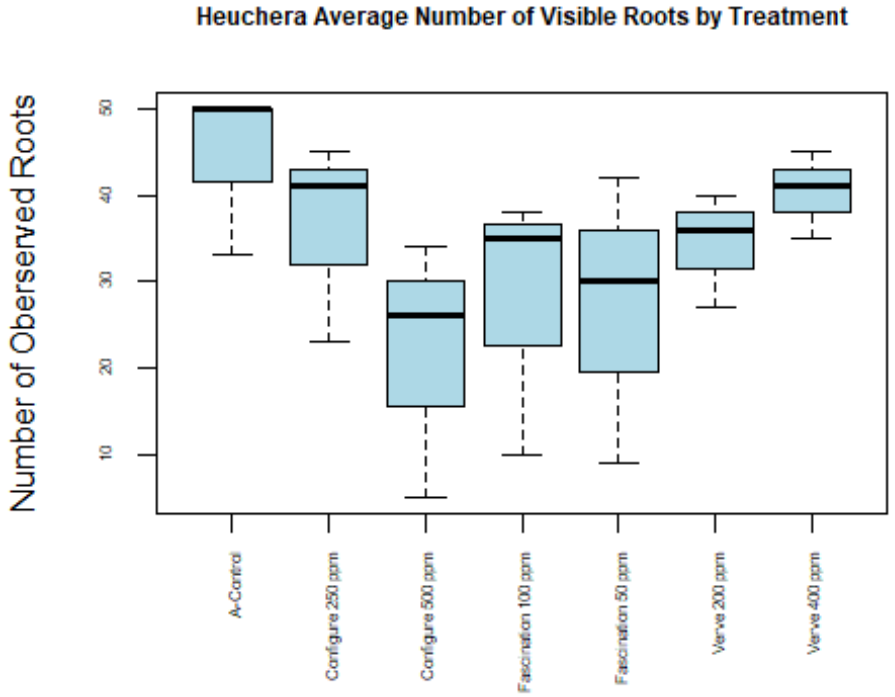

Figure 3.1.34 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average number of visible roots per rooted cutting by treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET®

3.2.1 Plant Size

A single parameter for size was calculated to represent overall plant size by averaging the measured height and two widths of each plant. Statistical analysis of size index was done for each time point beginning with initial measurements and occurring before each data collection period. Subsequent analyses contain all treatments averaged over the five time points.

3.2.1.1 Size Index

Analysis of variance for *Zauschneria* Experiment #1 revealed no significant statistical difference of treatment for the average size index (Figure 3.2.1). The largest plants were treated with Verve 200 ppm and the smallest plants were treated with Verve 400 ppm, but these were not significantly different then the other treatments (Table 3.2.1, Figure 3.2.2). These results suggest that the difference in size and growth of the plants is not affected by the specific PGR that is being applied. The results do not coincide with previous research performed on herbaceous perennials. Fascination, which contains GA, has been shown to increase plant growth through internode elongation (Barnes 2013). Configure increases lateral branching and should have increased the plant widths being recorded (Martin et al. 1999). However, in this experiment the lateral offshoots treated with Configure were not statistically larger than the other treatments.

```
## Anova Table (Type II tests)
##
## Response: GI
##           Sum Sq Df F value Pr(>F)
## Treatment  60.78  6  1.3958 0.2271
## Residuals 558.76 77
```

Figure 3.2.1 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for initial size index with Treatment as the predictor.

Table 3.2.1 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 initial size index ((height + width 1 + width 2)/3), and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Size Index	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	34.4149	32.8664	35.9634	1
Configure 250 ppm	33.4292	31.8807	34.9777	1
Configure 500 ppm	32.8542	31.3057	34.4027	1
Fascination 50 ppm	34.2194	32.6710	35.7679	1
Fascination 100 ppm	34.1171	32.5687	35.6656	1
Verve 200 ppm	35.3382	33.7897	36.8867	1
Verve 400 ppm	32.7731	31.2246	34.3215	1

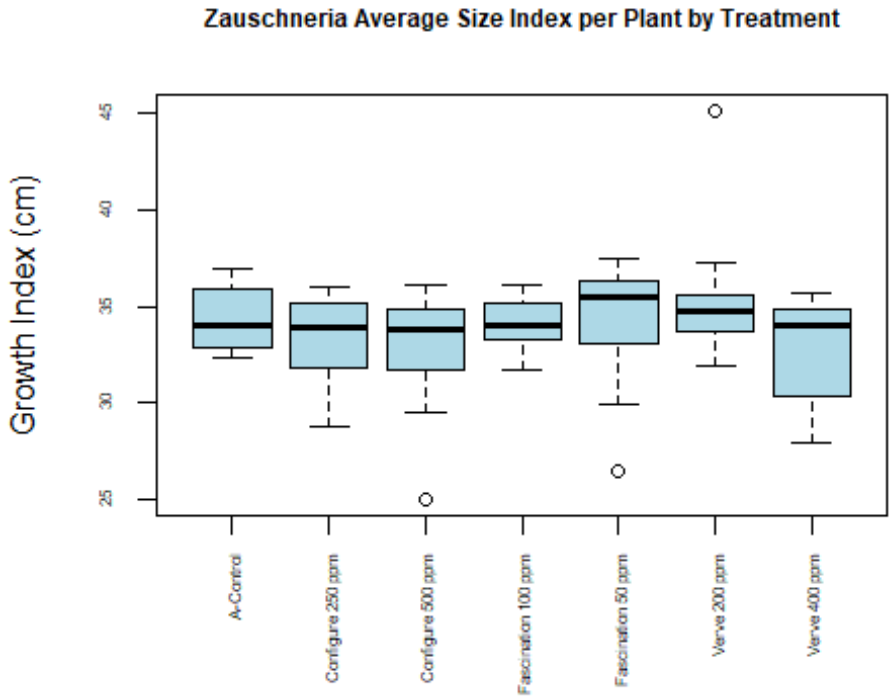

Figure 3.2.2 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average size index per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 revealed very high significant differences of treatment for the average size index and all pairwise comparisons were

significantly different at the significance level of 0.05 (Figure 3.2.3). The smallest plants were treated with Configure 500 ppm which is similar to the first *Zauschneria* experiment, but the largest plants were treated with Fascination 50 ppm (Table 3.2.2, Figure 3.2.4). The results did not follow the same trends seen in the first experiment. Fascination 50 and 100 ppm, Control and Verve 200 ppm were the treatments with the largest plants and Configure was the treatment with the least amount of growth. Previous research has shown similarities to these results for Fascination (GA) growing the tallest and longest plants (Preece et al. 1993). The Configure treatments resulting in the smallest plants does not agree with results from other herbaceous perennials where more branching was observed four to six weeks after treatments were applied (Latimer et al. 2015). There was no observed outside influence, such as greenhouse environment anomalies, that would have affected the plant growth habits in the way observed as compared to the *Zauschneria* Experiment #1.

```
## Anova Table (Type II tests)
##
## Response: GI
##           Sum Sq Df F value    Pr(>F)
## Treatment 288.50  6   15.17 2.201e-11 ***
## Residuals 244.06 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.3 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for initial size index with Treatment as the predictor.

Table 3.2.2 Experiment #2 initial size index ((height + width 1 + width 2)/3), and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Size Index	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	29.4534	28.4300	30.4768	34
Configure 250 ppm	26.8993	25.8759	27.9227	2
Configure 500 ppm	24.4969	23.4735	25.5203	1
Fascination 50 ppm	30.4871	29.4637	31.5105	4
Fascination 100 ppm	27.4849	26.4615	28.5083	23
Verve 200 ppm	29.4146	28.3912	30.4380	34
Verve 400 ppm	27.9753	26.9519	28.9987	23

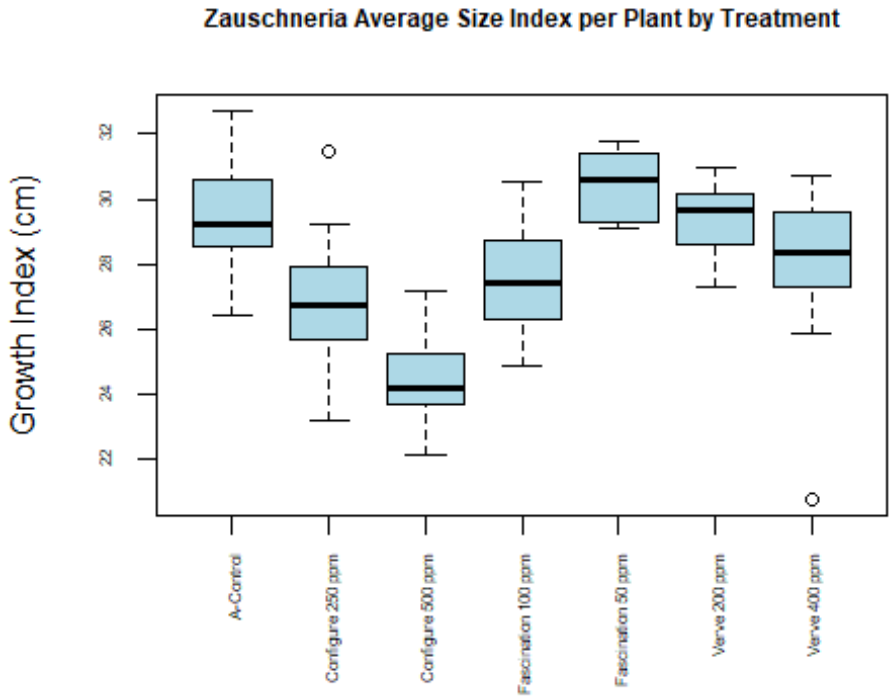

Figure 3.2.4 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average size index per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.2 Final Dry Weight

Final Dry weights of stock plants were determined by cutting off all top growth at the crown and drying at 70 °C for at least 4 days in paper bags before weighing. This was performed one month after the final fourth harvest of cuttings. This was meant to simulate the amount of growth the plants were putting on in-between cutting harvest events for the experiments.

Analysis of variance for *Zauschneria* Experiment #1 revealed significant treatment differences for the average final dry weight, at the significance level of 0.05 (Figure 3.2.5). The largest average final dry weights were treated with Configure 250 ppm and the smallest were the untreated Control group (Table 3.2.3, Figure 3.2.6). These results were expected, since the Configure would be predicted to produce more lateral growth and have more branching after five months of growth in the greenhouse as seen in other research on containerized herbaceous perennial (Latimer et al. 2015).

```
## Anova Table (Type II tests)
##
## Response: FDW
##           Sum Sq Df F value   Pr(>F)
## Treatment  97.22  6   3.092 0.009323 **
## Residuals 387.80 74
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.5 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average final dry weight with Treatment as the predictor.

Table 3.2.3 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean final dry weight and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Final Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	4.1667	2.8499	5.4834	1
Configure 250 ppm	7.0333	5.7166	8.3501	2
Configure 500 ppm	6.8636	5.4883	8.2389	12
Fascination 50 ppm	5.0273	3.6520	6.4026	12
Fascination 100 ppm	6.5500	5.2332	7.8668	12
Verve 200 ppm	5.4500	4.1332	6.7668	12
Verve 400 ppm	4.4000	3.0247	5.7753	12

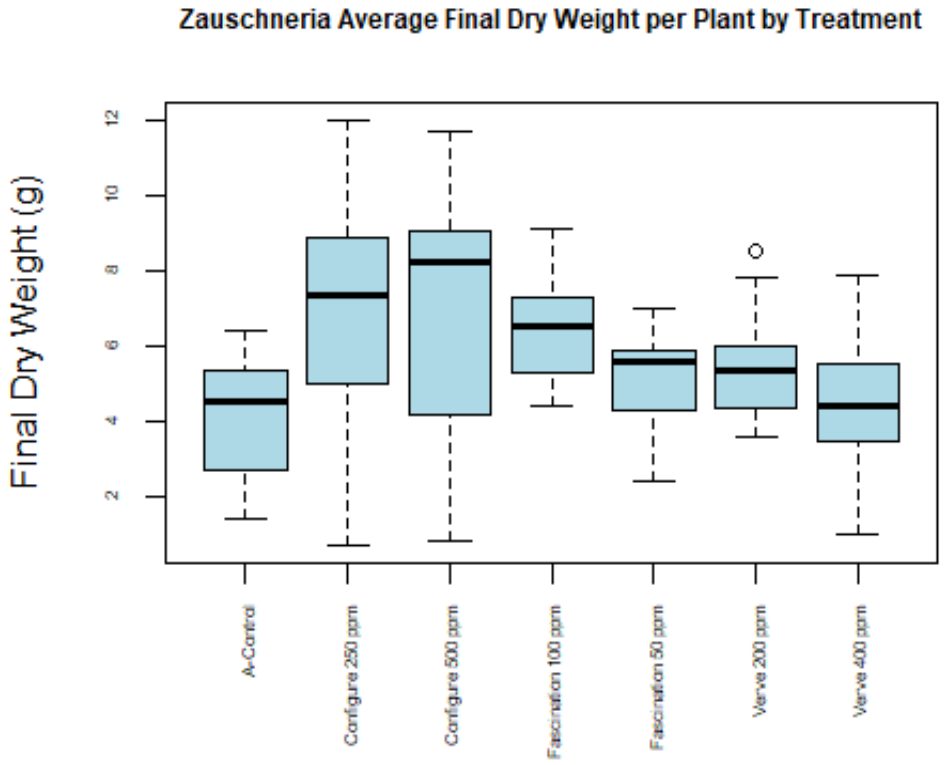

Figure 3.2.6 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average final dry weight per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 followed a similar trend as the first experiment, the untreated Control group had the smallest final dry weight, but Configure 250 ppm did not have the largest final dry weight (Figure 3.2.7). The largest plants were treated with Fascination 50 ppm and Verve 400 ppm (Table 3.2.4, Figure 3.2.8). This discrepancy between the two experiments may indicate the difference in growth depending on different times of the year. As has been shown in previously cited research, Fascination should have been one of the better growth stimulating PGR for final dry weight (Leopold et al. 1975). The Ethephon in Verve has been found to increase plant size and these results can be linked to other research findings. Cuttings of *Coreopsis* were found to have thicker stems and fewer flower buds with Ethephon treated plants (Glady et al. 2007). One question these results raised was why are the two concentration rates of both Fascination and Verve not resulting in similar plant growth? Fascination 100 ppm treated plants looked extremely spindly and did not appear to contain much thickness of the stem. Verve 400 ppm plants appeared to be growing similar to the Verve 200 ppm plants, but had a couple outliers (poor quality plants) which affected the statistics (Figure 3.2.8).

```
## Anova Table (Type II tests)
##
## Response: FDW
##           Sum Sq Df F value    Pr(>F)
## Treatment 162.31  6  6.8615 1.705e-05 ***
## Residuals 220.78 56
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.7 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average final dry weight with Treatment as the predictor.

Table 3.2.4 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean final dry weight and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Final Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	7.8667	6.5408	9.1925	1
Configure 250 ppm	8.2667	6.9408	9.5925	12
Configure 500 ppm	8.1000	6.7741	9.4259	1
Fascination 50 ppm	12.3000	10.9741	13.6259	3
Fascination 100 ppm	9.5000	8.1741	10.8259	123
Verve 200 ppm	11.0222	9.6963	12.3481	23
Verve 400 ppm	8.0889	6.7630	9.4148	1

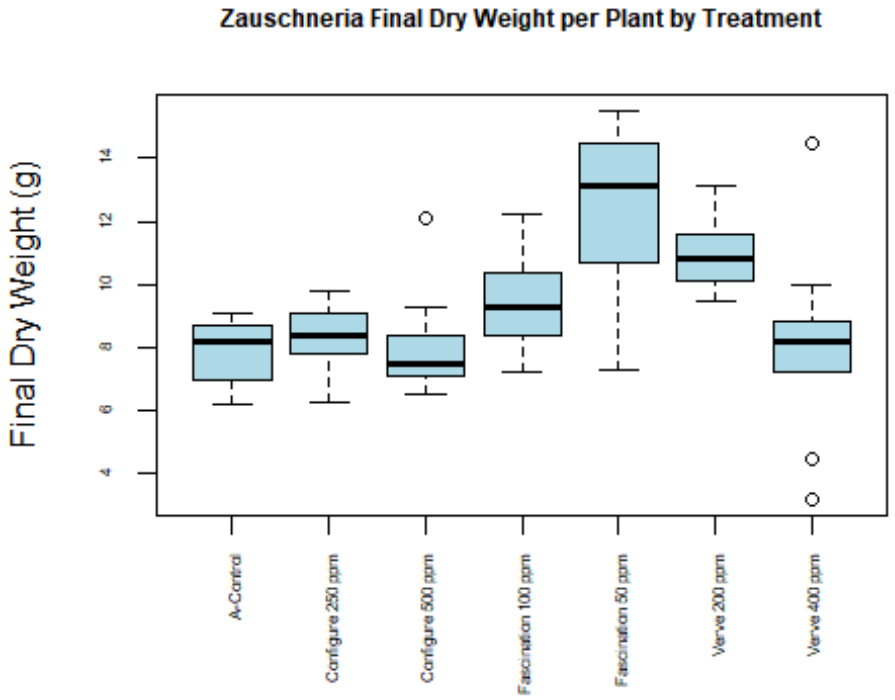

Figure 3.2.8 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average final dry weight per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.3 Average Cuttings Per Plant

Analysis of variance for *Zauschneria* Experiment #1 resulted in low significant differences for the effect of Treatment for the average number of cuttings, at the significance level of 0.05 (Figure 3.2.9). The smallest plants were the untreated Control group and the largest plants were treated with Fascination 50 ppm (Table 3.2.5, Figure 3.2.10). The data for this experiment indicates a large Treatment standard error and wide confidence interval. This may be attributed to the loss of some of the stock plants during the second half of the experiment. Fascination treatment at 50 ppm would be expected to produce more internode elongation and produce more cuttings every month between data collection dates (Burk et al. 1958). The untreated Control group being the lowest cutting producer which suggests that all the PGR treatments had some positive effect on plant growth for *Zauschneria*. Configure not being statistically different than the Control was unexpected. Branching in *Euphorbia pulcherrima* stock plants increased terminal stem cutting production by66% after 5 repeated applications (Kuminek et al. 1987). The same effects were thought to be likely within these experiments.

```
## Anova Table (Type II tests)
##
## Response: Cuttings
##           Sum Sq Df F value Pr(>F)
## Treatment   653.8  6  0.5531 0.7661
## Residuals 15169.5 77
```

Figure 3.2.9 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average number of cuttings harvested with Treatment as the predictor.

Table 3.2.5 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean average number of cuttings harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cuttings per Plant	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	51.7083	43.6402	59.7765	1
Configure 250 ppm	57.0208	48.9527	65.0890	1
Configure 500 ppm	53.1042	45.0360	61.1724	1
Fascination 50 ppm	59.7292	51.6610	67.7974	1
Fascination 100 ppm	58.9792	50.9110	67.0474	1
Verve 200 ppm	56.2500	48.1818	64.3182	1
Verve 400 ppm	54.0000	45.9318	62.0682	1

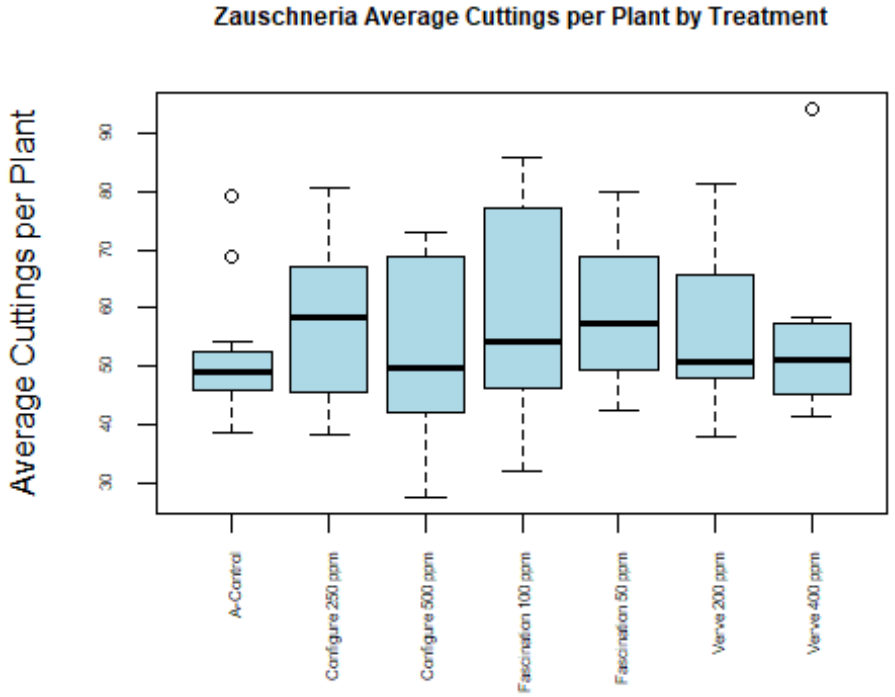

Figure 3.2.10 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average number of cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 followed the same trends as the first experiment, but there were significant differences for the effect of Treatment for the average

number of cuttings harvested, at the significance level of 0.05 (Figure 3.2.11). The smallest plants were the untreated Control group and the largest plants were treated with Fascination 50 ppm (Table 3.2.6, Figure 3.2.12). The Fascination treatments were thought to have more stem elongation and more cuttings material available, and this resulted from the experiment (Lang, 1956). Configure was also thought to have more branching and cutting material available, but the results showed its effect was less significant than Fascination, but still resulted in having produced more cuttings per plant then the Control.

```
## Anova Table (Type II tests)
##
## Response: Cuttings
##           Sum Sq Df F value    Pr(>F)
## Treatment 8112.4  6  20.402 3.825e-14 ***
## Residuals 5103.0 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.11 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average number of cuttings harvested with Treatment as the predictor.

Table 3.2.6 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean average number of cuttings harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cuttings per Plant	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	36.7292	32.0496	41.4087	1
Configure 250 ppm	52.0625	47.3830	56.7420	23
Configure 500 ppm	45.5208	40.8413	50.2004	12
Fascination 50 ppm	69.1458	64.4663	73.8254	4
Fascination 100 ppm	61.4375	56.7580	66.1170	34
Verve 200 ppm	55.3333	50.6538	60.0129	23
Verve 400 ppm	48.7917	44.1121	53.4712	2

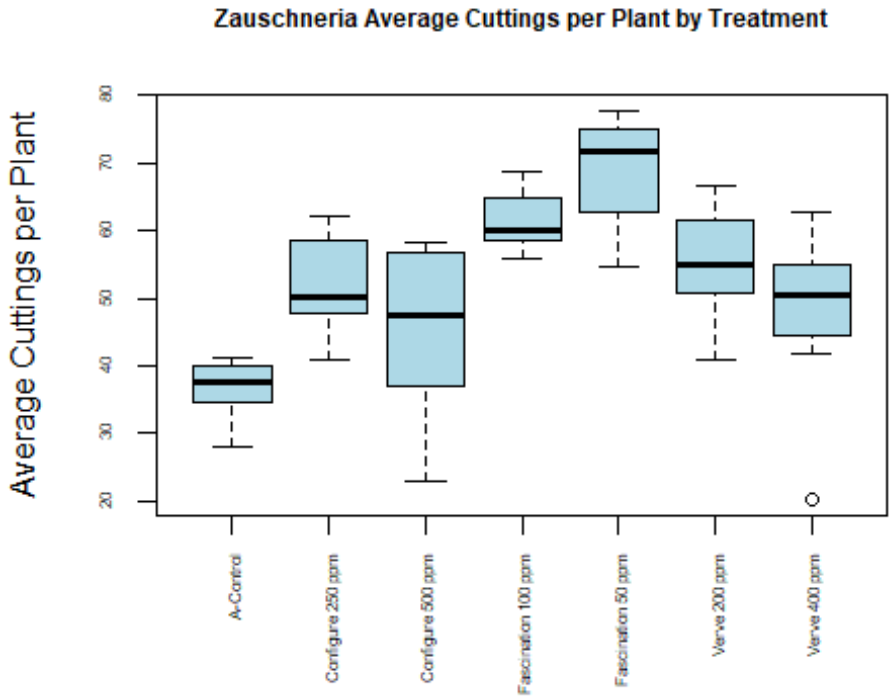

Figure 3.2.12 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average number of cuttings harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.4 Fresh Weight Per Cutting

Analysis of variance for *Zauschneria* Experiment #1 resulted in significant differences in the average individual fresh weight of cuttings harvested, at the significance level of 0.05 (Figure 3.2.13). The average cutting fresh weight was calculated by taking the total fresh weight of all the cuttings harvested from a single plant and dividing that by the number of cuttings harvested. Both Fascination 50 and 100 ppm had the smallest fresh weight per cutting. The Control group had the largest, but it was not significantly greater than the other treatments. These results were expected from the time cuttings were harvested due to the different sizes of *Zauschneria* cuttings visibly observed. Other conducted research on plant sizes produced from PGR applications have

mainly been conducted with Configure (BA) and Ethephon. Both have been observed in manipulating plant growth to produce thicker stems in herbaceous perennials (Hayashi et al. 2001; Martin et al. 1999).

```
## Anova Table (Type II tests)
##
## Response: CFW
##            Sum Sq Df F value    Pr(>F)
## Treatment 0.102595  6  13.434 2.318e-10 ***
## Residuals 0.098008 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.13 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average fresh weight per individual cutting harvested with Treatment as the predictor.

Table 3.2.7 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean average fresh weight per individual cutting harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cutting Fresh Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.3567	0.3362	0.3772	2
Configure 250 ppm	0.3300	0.3095	0.3505	2
Configure 500 ppm	0.3442	0.3237	0.3647	2
Fascination 50 ppm	0.2650	0.2445	0.2855	1
Fascination 100 ppm	0.2692	0.2487	0.2897	1
Verve 200 ppm	0.3383	0.3178	0.3588	2
Verve 400 ppm	0.3442	0.3237	0.3647	2

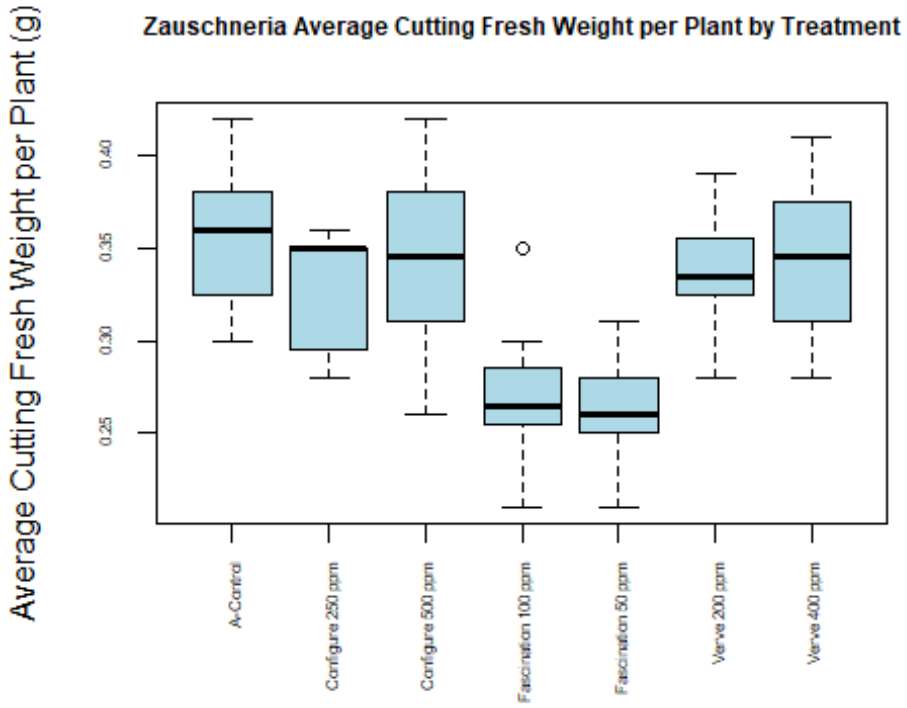

Figure 3.2.14 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average fresh weight per individual cutting harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 followed the same trends as the first experiment, since there were significant differences among PGR treatments with fresh weights of individual cuttings harvested, at the significance level of 0.05 (Figure 3.2.15). The smallest plants were treated with Fascination 50 and 100 ppm and the largest plants were the untreated Control which was significantly greater than all the other treatments in this experiment (Table 3.2.8, Figure 3.2.16). The Fascination treatments resulted in the lowest fresh weights which were again predicted at the time of harvest based on visible differences observed between the different treatments. The fresh weights for the second experiment were all higher in comparison to the first experiment. This could be attributed to the movement of the stock plants closer to the pad

wall in the greenhouse. This resulted in cooler temperatures and larger, more vegetative *Zauschneria* stock plants.

```
## Anova Table (Type II tests)
##
## Response: CFW
##           Sum Sq Df F value    Pr(>F)
## Treatment 0.31295  6  18.771 2.491e-13 ***
## Residuals 0.21396 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.15 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average fresh weight per individual cutting harvested with Treatment as the predictor.

Table 3.2.8 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean average fresh weight per individual cutting harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cutting Fresh Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.5332	0.5029	0.5635	4
Configure 250 ppm	0.4641	0.4338	0.4944	3
Configure 500 ppm	0.4196	0.3893	0.4499	23
Fascination 50 ppm	0.3704	0.3401	0.4007	12
Fascination 100 ppm	0.3275	0.2972	0.3578	1
Verve 200 ppm	0.4399	0.4096	0.4702	3
Verve 400 ppm	0.4142	0.3839	0.4445	23

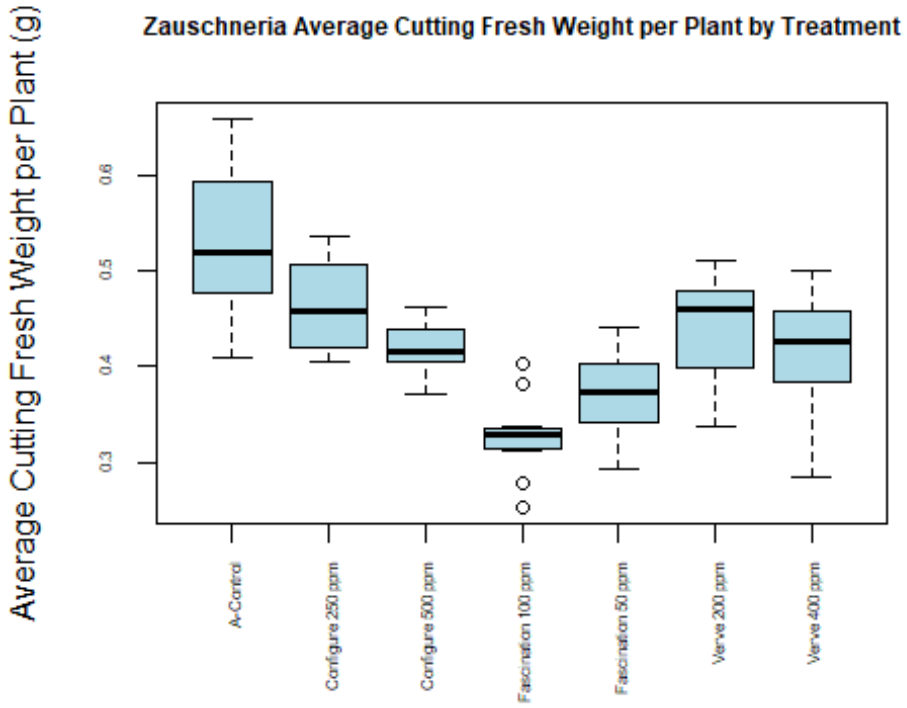

Figure 3.2.16 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average fresh weight per individual cutting harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.5 Dry Weight Per Cutting

Analysis of variance for *Zauschneria* Experiment #1 resulted in significant differences on the average individual dry weight of cuttings harvested, at the significance level of 0.05 (Figure 3.2.17). The average cutting dry weight was calculated by taking the total dry weight, after 48 hours in the drying oven at a temperature of 70 degrees Celsius, of all the cuttings harvested from a single plant and dividing that by the number of cuttings harvested. These statistical results followed the same pattern as the fresh weight per cutting with Fascination being the smallest and all others statistically similar (Figure 3.2.18, Table 3.2.9). This indicates that all the plants had relatively similar water contents in their leaves and stems, which could suggest that the PGR treatments did not have an effect on water retention within the apical plant area. Having water

contents that are similar showed that the propagation material will be similar in keeping the turgidity of the cutting during rooting (Loach 1977).

```
## Anova Table (Type II tests)
##
## Response: CDW
##           Sum Sq Df F value    Pr(>F)
## Treatment 0.003931  6  5.7654 5.376e-05 ***
## Residuals 0.008750 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.17 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average dry weight per individual cutting harvested with Treatment as the predictor.

Table 3.2.9 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean average dry weight per individual cutting harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cutting Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.0933	0.0872	0.0995	3
Configure 250 ppm	0.0892	0.0830	0.0953	3
Configure 500 ppm	0.0892	0.0830	0.0953	3
Fascination 50 ppm	0.0742	0.0680	0.0803	1
Fascination 100 ppm	0.0758	0.0697	0.0820	12
Verve 200 ppm	0.0892	0.0830	0.0953	3
Verve 400 ppm	0.0875	0.0814	0.0936	23

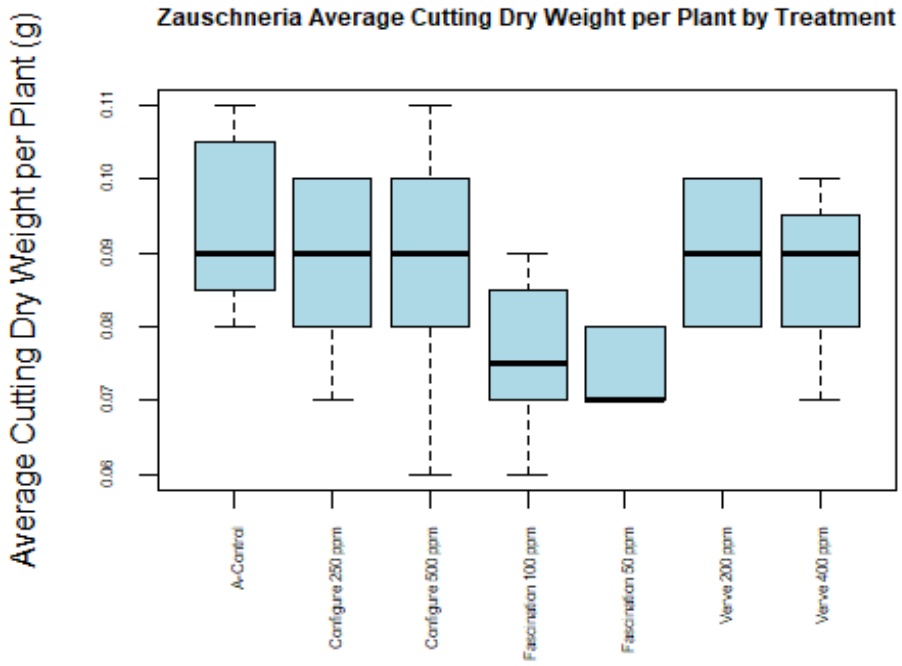

Figure 3.2.18 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average dry weight per individual cutting harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 followed the same trends as the first experiment, there were significant differences with the average dry weight of individual cuttings harvested, at the significance level of 0.05 (Figure 3.2.19). The smallest plants were treated with Fascination 50 and 100 ppm ppm and the largest plants were the untreated Control which was statically different from the other treatment groups (Table 3.2.10, Figure 3.2.20). These results were similar to the fresh weight per cutting results and indicated that all treatments had plants with comparable water contents in their leaves and stems. These results showed the similarity in water potential during propagation of the different treatments which is important to keeping turgidity in the cutting (Loach 1977).

```
## Anova Table (Type II tests)
##
## Response: CDW
##            Sum Sq Df F value    Pr(>F)
## Treatment 0.031984  6  27.243 < 2.2e-16 ***
## Residuals 0.015067 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.19 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average dry weight per individual cutting harvested with Treatment as the predictor.

Table 3.2.10 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean average dry weight per individual cutting harvested and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Cutting Dry Weight	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	0.1737	0.1656	0.1817	3
Configure 250 ppm	0.1501	0.1420	0.1581	2
Configure 500 ppm	0.1437	0.1356	0.1517	2
Fascination 50 ppm	0.1165	0.1084	0.1245	1
Fascination 100 ppm	0.1111	0.1030	0.1191	1
Verve 200 ppm	0.1438	0.1357	0.1518	2
Verve 400 ppm	0.1362	0.1281	0.1442	2

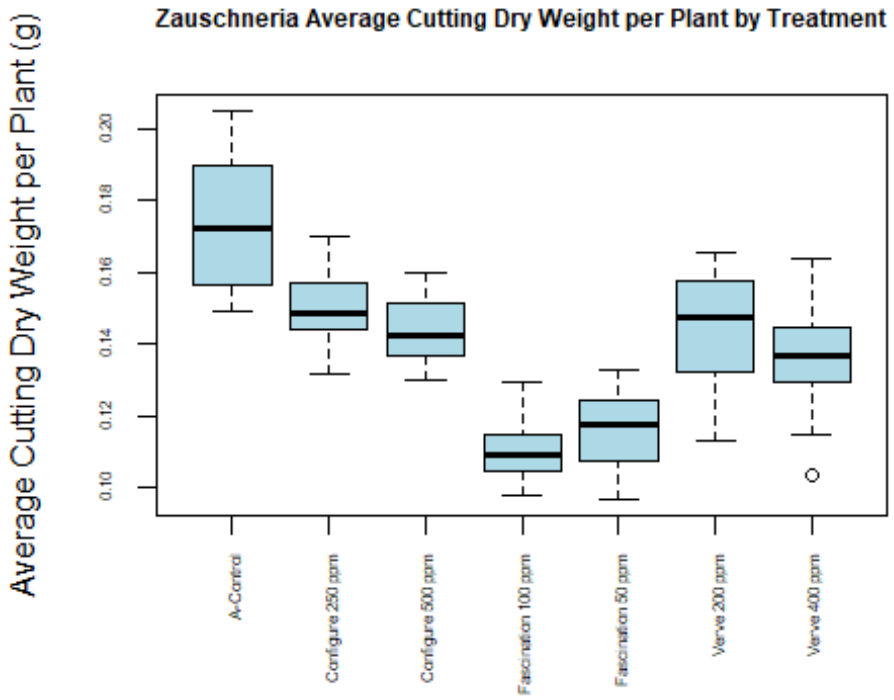

Figure 3.2.20 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average dry weight per individual cutting harvested per treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.6 Root Ratings

Root ratings were conducted at the end of the experiment after the top growth was harvested and weighed. The ratings were done using a scale of 1-5 with 1 being very lightly rooted to 5 being fully rooted out throughout the container.

Analysis of variance of *Zauschneria* Experiment #1 revealed no significant differences in the average root ratings, at the significance level of 0.05 (Figure 3.2.21). These statistical results were a little surprising because of the researched effects on rooting by the different PGR treatments, especially Configure (BA) which has been shown to negatively affect rooting (Leopold et al. 1975).

```
## Anova Table (Type II tests)
##
## Response: RR
##           Sum Sq Df F value Pr(>F)
## Treatment  2.714  6  0.4512 0.8406
## Residuals 49.125 49
```

Figure 3.2.21 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average root rating with Treatment as the predictor.

Table 3.2.11 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean root rating and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Root Rating	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	2.7500	2.0386	3.4614	1
Configure 250 ppm	2.2500	1.5386	2.9614	1
Configure 500 ppm	2.1250	1.4136	2.8364	1
Fascination 50 ppm	2.1250	1.4136	2.8364	1
Fascination 100 ppm	2.2500	1.5386	2.9614	1
Verve 200 ppm	2.1250	1.4136	2.8364	1
Verve 400 ppm	2.5000	1.7886	3.2114	1

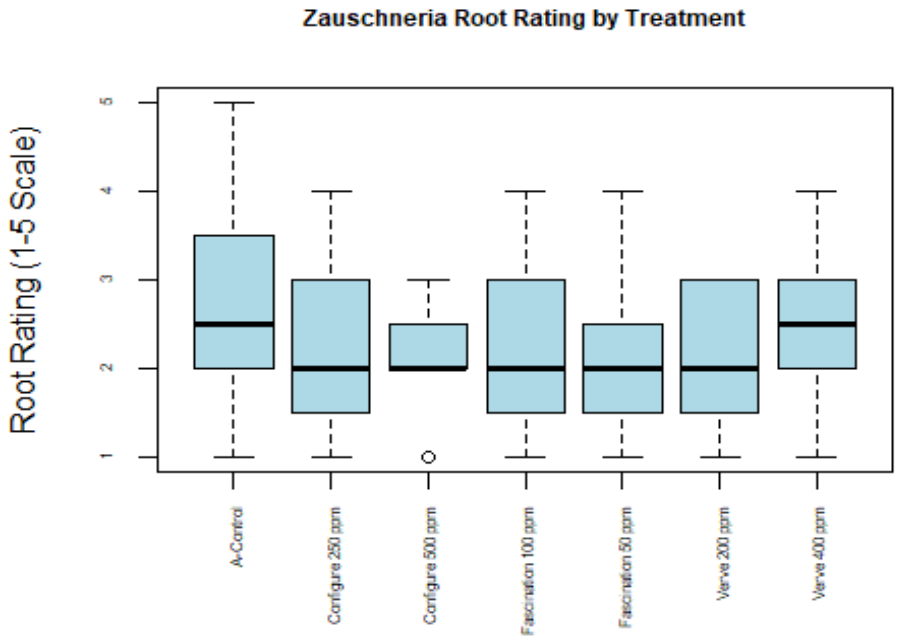

Figure 3.2.22 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average root rating by treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance for *Zauschneria* Experiment #2 did not have the same trends as the first experiment, since there were significant differences with average root ratings taken at the end of the experiment, at the significance level of 0.05 (Figure 3.2.23). Configure 500 ppm had the lowest ratings, which is explained by the inverse relationship between cytokinins and auxins and their specific roles in plant growth processes. Increasing the amount of cytokinins will decrease the efficacy of auxins, which will inhibit root development in the plant (Preece et al. 1993). The untreated Control had the highest rating, and this could indicate that all the PGR treatment groups effected the top growth in a positive way at the expense of the root system development.

```
## Anova Table (Type II tests)
##
## Response: RR
##           Sum Sq Df F value    Pr(>F)
## Treatment 29.873  6  5.2497 0.0002385 ***
## Residuals 53.111 56
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure 3.2.23 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average root rating with Treatment as the predictor.

Table 3.2.12 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean root rating and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Root Rating	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	2.8889	2.2386	3.5392	3
Configure 250 ppm	1.2222	0.5719	1.8725	12
Configure 500 ppm	1.0000	0.3497	1.6503	1
Fascination 50 ppm	1.6667	1.0164	2.3170	123
Fascination 100 ppm	1.8889	1.2386	2.5392	123
Verve 200 ppm	2.4444	1.7941	3.0947	23
Verve 400 ppm	2.7778	2.1275	3.4281	3

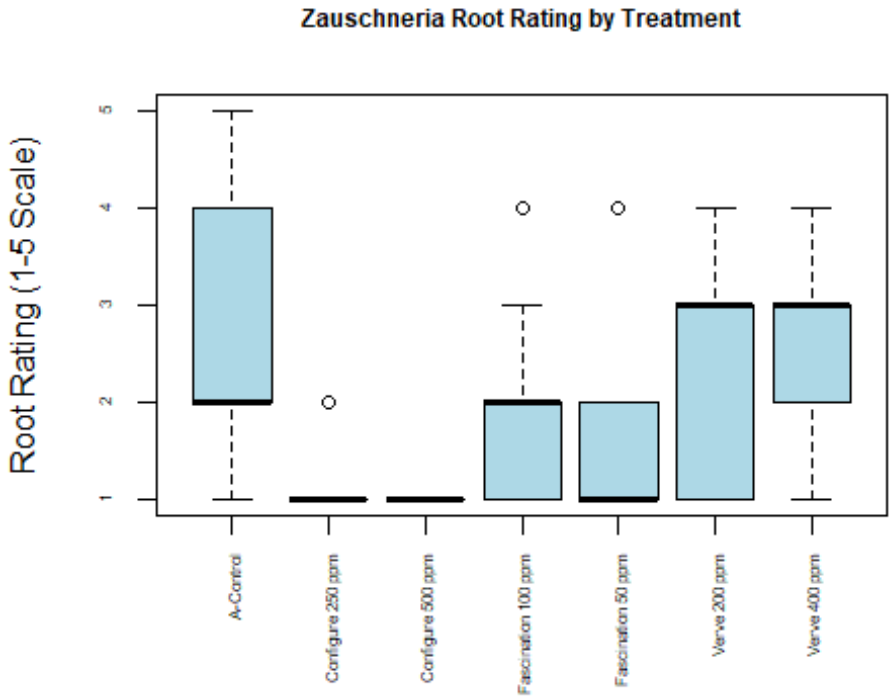

Figure 3.2.24 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average root rating by treatment. Standard error bars indicate a 95% confidence interval for the mean.

3.2.7 Differences Between Experiment 1 and Experiment 2

Differences in mean response between *Zauschneria* Experiment #1 and #2 are partially due to the time of year the experiment was carried out. The first experiment was initiated in October 2016, while the second was initiated in July 2017. It is possible that the number of cuttings produced per plant in the second study varied more than the first experiment because of lower temperatures in the greenhouse which were adjusted for the second study and the natural difference in photoperiod.

3.2.8 Rooting Experiment Results

Rooting percentages were taken after 4 weeks on the mist bench and the number of visible roots was counted to a total of 50 visible roots. This was sufficient to see any correlations between treatments and rooting of cuttings.

Analysis of variance for *Zauschneria* Experiment #1 revealed no significant differences from the PGR treatments on average rooting percentage, at the significance level of 0.05 (Figure 3.2.25). There were also no significant differences on the average of visible roots, at the significance level of 0.05 (Figure 3.2.27). These statistical results were surprising due to the researched effects on rooting by the different PGR treatments. The physiological relationship between cytokinins and auxins is apparent in the lower rooting percentages of the Configure treatments (Preece eta l. 1993). Also, Ethephon has been shown to increase adventitious rooting in perennials (Rapaka et al. 2005). The major result from these statistics is that if a grower uses any of the PGR treatments, rooting of those cuttings will not be negatively affected when compared to untreated *Zauschneria* stock plants.

```
## Anova Table (Type II tests)
##
## Response: RP
##           Sum Sq Df F value Pr(>F)
## Treatment 0.15619  6  0.4754 0.8157
## Residuals 0.76667 14
```

Figure 3.2.25 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average rooting percentage with Treatment as the predictor.

Table 3.2.13 Experiment #1 mean rooting percentage and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Rooting Percentage	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	0.4333	0.1436	0.7231	1
Configure 250 ppm	0.3333	0.0436	0.6231	1
Configure 500 ppm	0.3667	0.0769	0.6564	1
Fascination 50 ppm	0.3667	0.0769	0.6564	1
Fascination 100 ppm	0.4000	0.1102	0.6898	1
Verve 200 ppm	0.5000	0.2102	0.7898	1
Verve 400 ppm	0.6000	0.3102	0.8898	1

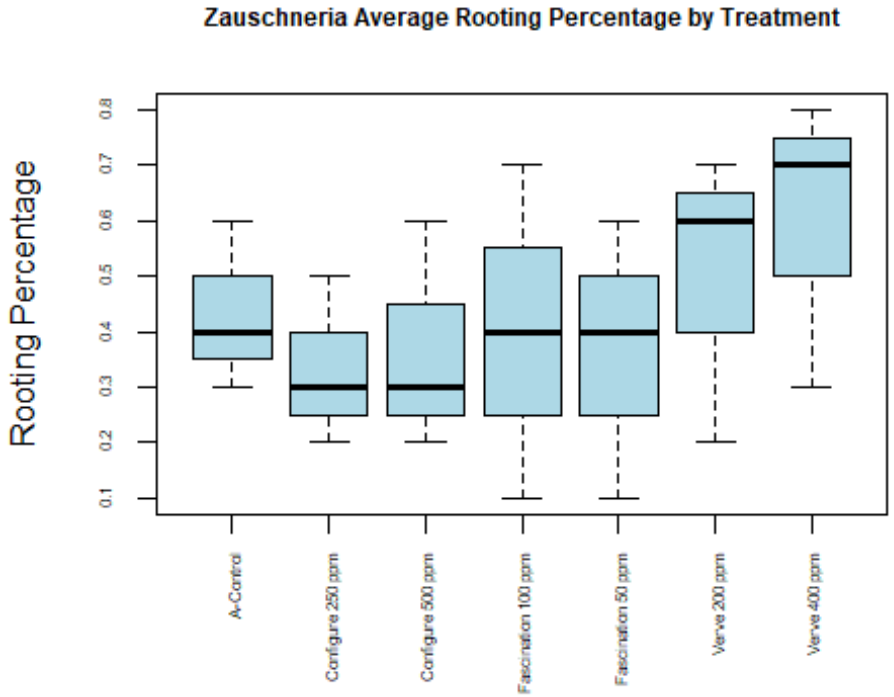

Figure 3.2.26 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average rooting percentage by treatment. Standard error bars indicate a 95% confidence interval for the mean.

```
## Anova Table (Type II tests)
##
## Response: NR
##           Sum Sq Df F value Pr(>F)
## Treatment 1107.8  6  0.9102 0.5154
## Residuals 2840.0 14
```

Figure 3.2.27 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average number of visible roots per cutting with Treatment as the predictor.

Table 3.2.14 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean average number of visible roots per cutting and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	8.3333	-9.3034	25.9701	1
Configure 250 ppm	23.6667	6.0299	41.3034	1
Configure 500 ppm	27.0000	9.3632	44.6368	1
Fascination 50 ppm	7.3333	-10.3034	24.9701	1
Fascination 100 ppm	20.6667	3.0299	38.3034	1
Verve 200 ppm	10.6667	-6.9701	28.3034	1
Verve 400 ppm	13.6667	-3.9701	31.3034	1

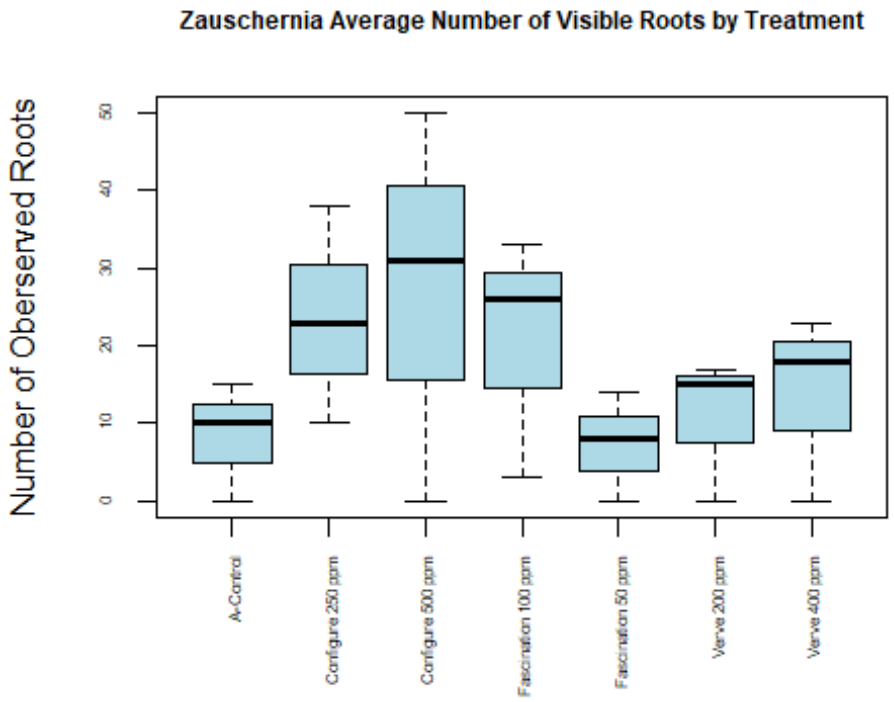

Figure 3.2.28 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average number of visible roots per cutting by treatment. Standard error bars indicate a 95% confidence interval for the mean.

Analysis of variance of *Zauschneria* Experiment #2 followed the same trends as the first experiment, there were no significant differences from the PGR treatments on average rooting percentages, at the significance level of 0.05 (Figure 3.1.29). Overall rooting was greater for the second experiment. However, the numbers of roots were lower than the first experiment. This could be an indication of this being a better time to propagate *Zauschneria sanguinea.* Photoperiod may have played a role in the difference between the two experiments, but the trends were consistent with only Fascination 100 ppm having showed low rooting percentages. The overall message for growers utilizing PGR treatments for the rooting of cuttings is there does not appear to be any negative correlation between treating stock plants and rooting of

cuttings. On the other hand, there also is no evidence of it being beneficial to increasing rooting in *Zauschneria.*

```
## Anova Table (Type II tests)
##
## Response: RP
##           Sum Sq Df F value Pr(>F)
## Treatment 0.34952  6  0.7694 0.6064
## Residuals 1.06000 14
```

Figure 3.2.29 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average rooting percentage with Treatment as the predictor.

Table 3.2.15 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean rooting percentage and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Rooting Percentage	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	0.7000	0.3593	1.0407	1
Configure 250 ppm	0.6667	0.3259	1.0074	1
Configure 500 ppm	0.6333	0.2926	0.9741	1
Fascination 50 ppm	0.5667	0.2259	0.9074	1
Fascination 100 ppm	0.3333	-0.0074	0.6741	1
Verve 200 ppm	0.5667	0.2259	0.9074	1
Verve 400 ppm	0.7667	0.4259	1.1074	1

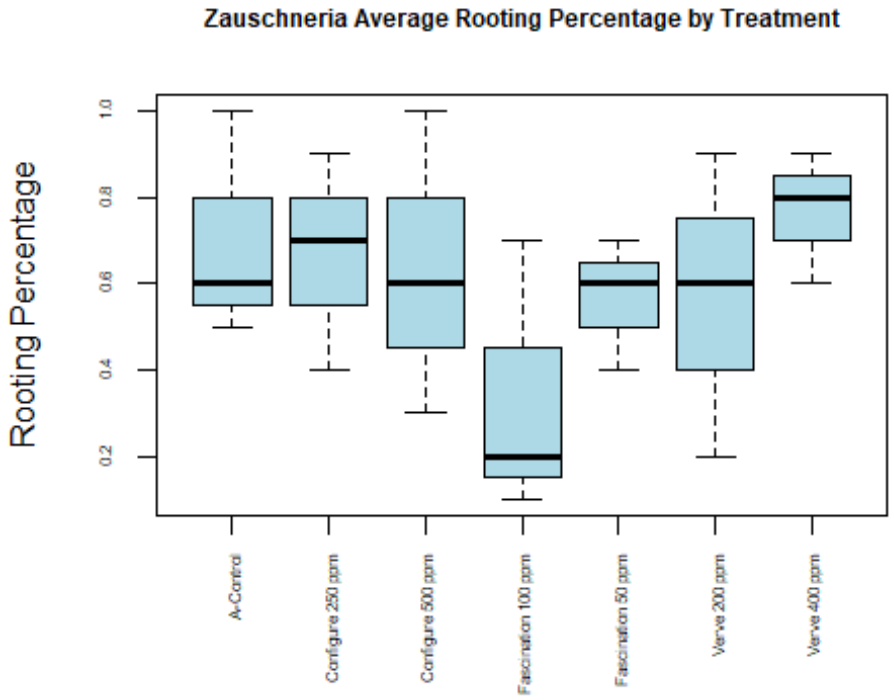

Figure 3.2.30 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average rooting percentage by treatment. Standard error bars indicate a 95% confidence interval for the mean.

```
## Anova Table (Type II tests)
##
## Response: NR
##           Sum Sq Df F value Pr(>F)
## Treatment 171.00  6  0.7023 0.6528
## Residuals 568.17 14
```

Figure 3.2.31 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average number of visible roots per cutting with Treatment as the predictor.

Table 3.2.16 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean average number of visible roots per cutting and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
A-Control	5.5000	-2.3886	13.3886	1
Configure 250 ppm	11.8333	3.9448	19.7219	1
Configure 500 ppm	10.3333	2.4448	18.2219	1
Fascination 50 ppm	6.5000	-1.3886	14.3886	1
Fascination 100 ppm	8.8333	0.9448	16.7219	1
Verve 200 ppm	3.3333	-4.5552	11.2219	1
Verve 400 ppm	5.0000	-2.8886	12.8886	1

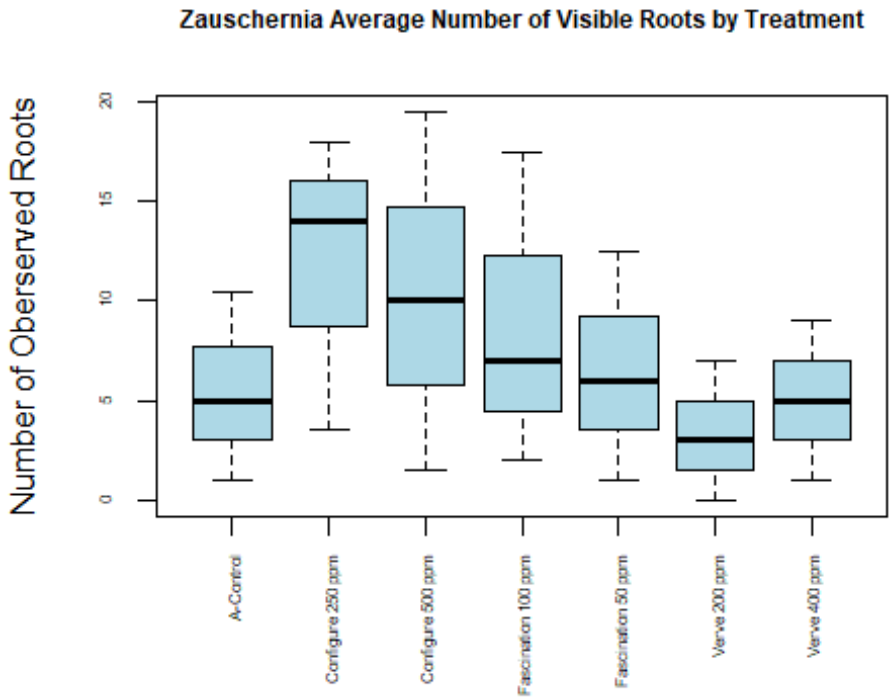

Figure 3.2.32 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average number of visible roots per cutting by treatment. Standard error bars indicate a 95% confidence interval for the mean.

CHAPTER 4. CONCLUSIONS

4.1 Conclusions Regarding Heuchera 'Snow Angel'

4.1.1 Response to Plant Growth Regulator Treatment

Stock plants of *Heuchera sanguinea* 'Snow Angel' responded to PGR treatments differently depending on the time of year it was grown. More in-depth research will need to be performed in order to determine which physiological traits are involved in that response. During the first experiment, Fascination treatments of 50 or 100 ppm resulted in initially larger plants and more cuttings per plant. The average fresh and dry weight per cutting for the Fascination treatments were close to the median and showed no signs of producing smaller, weaker cutting material. The increased success of more cuttings from stock plants grown in the first experiment can be attributed to the effects of GA on *Heuchera* growth. The elongated side shoots of the stock plants added to the overall plant size and propagation material available at each cutting harvest event.

During Experiment #2, the most successful stock plants were those again treated with Fascination 50 or 100 ppm. These treatments resulted in larger plants, more cuttings per plant, as well as average to higher fresh and dry weights of the cuttings when compared to the other treatments. The decreased plant growth and cutting materials of the second experiment was attributed to time of year. The same trends remained for both experiments which were interpreted as a strong correlation for determining the PGR treatment resulting in the most propagation material growth.

The application of Verve (Ethephon) resulted in similar results to that of the control group. Flowering was not an issue for any of the *Heuchera* stock plants in either experiment. Configure (BA) resulted in higher number of cuttings then the control group, but the difference between them was not statistically significant.

4.1.2 Propagator Recommendations

Despite some discrepancies between the first and second experiment, it is possible to make some recommendations to perennial propagators for future stock plant care and rooting of *Heuchera sanguinea* 'Snow Angel'. Based on the research conducted, stock plants would likely result in more cutting material with the addition of monthly applications of Fascination PGR at a rate between 50 and 100 ppm. Since our experiment did not last as long as most growers keep their stock plants, no claims can be made about the longevity of a stock plant in relation to additional treatments of PGR. Since more cuttings were produced during the first experiment, it may be advantageous to maintain daytime greenhouse temperatures between 18.3 and 22.8 °C and nighttime temperatures between 16.1 and 22.8 °C, although higher cutting production could also be due to seasonality of the plants or the higher pH of the media.

After completing the rooting study, it can be recommended that growers follow the propagation protocols described in Chapter 2 which resulted in very successful rooting during both experiments. There was no correlation between Fascination treated cuttings and higher or lower rooting percentages. This translates to the notion that applying this PGR will not decrease a propagator's rooting percentage of cuttings.

4.2 Conclusions Regarding *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET®

4.2.1 Response to Plant Growth Regulator Treatment

The response to PGR treatments found in *Zauschneria garrettii* 'PWWG01S' stock plants was not consistent across both experiments with the best results observed in different treatments for each experiment, although differences were more dramatic during experiment #2. Stock plants treated with Configure 250 ppm and Fascination 50 ppm produced more cuttings per plant in experiment #1 and #2 respectively. The Fascination treated cuttings were very thin and yellow, while the Configure treated cuttings were larger and darker green in color.

While the first experiment showed no significant correlation between treatment and plant size or number of cuttings produced, the second experiment had statistical significance by different PGR. This could be attributed to the dramatic increase in the number of cuttings and fresh and dry weights of the cuttings irrespective of treatment. The difference in response for the two experiments was mostly credited to greenhouse temperature differences between the two experiments. During Experiment #1, daytime greenhouse temperatures were between 18.3 and 22.8 °C and nighttime temperatures between 16.1 and 22.8 °C. For the second experiment, these set points were lowered to 16.7-20.0 °C (day) and 12.8-16.1 °C (night) in an attempt to discourage flowering on the *Zauschneria* plants which appeared to have aided in suppressing flowering. It is also possible that differences between treatments were smaller during the first experiment because all plants were experiencing temperature stress and therefore could not grow to the plant's full potential.

In order to determine if PGR treatments had any effect on the rooting of the cuttings, a propagation experiment followed the stock plant experiment. The greenhouse environment for the propagation of these cuttings was not ideal and resulted in numerous losses of cuttings on

the mist bench. Many contributing factors were observed: greenhouse fans, improper drainage, and irregular mist application. This experiment was the first of its kind to be done in the newly built greenhouse, so some problems were to be expected while learning the intricacies of this specific growing environment. While attempts were made to correct these issues between the two experiments, losses were also encountered during the second experiment as well, making it difficult to identify which treatments may offer an advantage during the rooting process. The overall increase in rooting percentage in the second experiment indicates some of the steps taken had a beneficial effect. Very few trends were identifiable and the only PGR that showed an increased rooting response was Verve 400 ppm during both experiments, which resulted in slightly higher rooting percentages, however these were not statistically significant.

4.2.2 Propagator Recommendations

The effect of PGR treatments on the rooting of *Zauschneria* cuttings resulted in recommendations that only can be made in terms of stock plant care for more production of propagation material. Based on the research conducted over the last two years, perennial propagators should grow *Zauschneria garrettii* 'PWWG01S' in a relatively cool greenhouse, maintaining temperatures below 20.0 °C if possible, to increase production of higher quality vegetative cuttings. For the best stock plants Configure treatments of 250 ppm it is recommended to increase their overall stock plant production of vegetative material. An increase in the amount of rooting hormone from 500 ppm IBA may be advisable to help increase the rooting percentages on the mist bench.

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APPENDIX

Table A1.1 Results of sieve tests for particle size distribution of four media samples from second batch of media.

	----------% Retained by Sieve Size----------				
Media	**0.5mm**	**2mm**	**4mm**	**6mm**	**8mm**
Berger BM-7	28.46	9.46	8.54	5.98	6.32

Table A1.2 Experiment #1 soil analyses of Berger BM-7 acquired for Experiment #1 conducted on fresh media before planting.

	Media
	BM-7
Organic Matter	65.5
pH (paste)	6.1
EC (paste, mmhos/cm)	1.3
CEC (meq/100g)	77
% $CaCO_3$ (Lime)	0.5
% Total N	1.1290
% Organic N	1.0807
NH_4-N (mg/kg)	7.4
NO_3-N (mg/kg)	475.7
NH_4:NO_3 Ratio	0.02
% Total C	34.85
C:N Ratio	30.9
% P	0.0142
% P_2O_5	0.0325
% K	0.1135

% K_2O	0.1362

Table A1.3 Experiment #2 soil analyses of Berger BM-7 acquired for Experiment #2 conducted on fresh media before planting.

	Media
	BM-7
Organic Matter	52.1
pH (paste)	3.8
EC (paste, mmhos/cm)	1.2
CEC (meq/100g)	3.60
% $CaCO_3$ (Lime)	0.329
% Total N	0.1517
% Organic N	0.10
NH_4-N (mg/kg)	293
NO_3-N (mg/kg)	193
NH_4:NO_3 Ratio	1.516
% Total C	12.43
C:N Ratio	81.94
% P	0.0082
% P_2O_5	0.0187
% K	0.0346
% K_2O	0.0415

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Active Ingredient: N-(phenylmethyl)-1H-purine-6-amine	2.0%
Other Ingredients:	98.0%
Total:	100.0%

KEEP OUT OF REACH OF CHILDREN
CAUTION

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NET CONTENTS: 0.5 gallon

FIRST AID

IF IN EYES:
- Hold eye open and rinse slowly and gently with water for 15-20 minutes.
- Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye.
- Call a poison control center or doctor for treatment advice.

IF SWALLOWED:
- Call a poison control center or doctor immediately for treatment advice.
- Have person sip a glass of water if able to swallow.
- Do not induce vomiting unless told to do so by a poison control center or doctor.
- Do not give anything by mouth to an unconscious person.

IF ON SKIN/CLOTHING:
- Take off contaminated clothing.
- Rinse skin immediately with plenty of water for 15-20 minutes.
- Call a poison control center or doctor for treatment advice.

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact 1-800-858-7378 (National Pesticide Information Center) for emergency medical treatment information.

FOR CHEMICAL EMERGENCY: spill, leak, fire, exposure, or accident call CHEMTREC 1-800-424-9300.

PRECAUTIONARY STATEMENTS

HAZARDS TO HUMANS AND DOMESTIC ANIMALS

CAUTION. Causes moderate eye irritation. Harmful if swallowed or absorbed through skin. Avoid contact with eyes, skin or clothing. Wash thoroughly with soap and water after handling.

PERSONAL PROTECTIVE EQUIPMENT (PPE)

Some materials that are chemical-resistant to this product are listed below. If you want more options, follow the instructions for Category C on an EPA chemical-resistance selection chart.

Applicators and other handlers must wear:
- Long-sleeved shirt and long pants.
- Chemical-resistant gloves such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, polyvinyl chloride or viton.
- Socks and shoes.

Follow the manufacturer's instructions for cleaning/maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE items separately from other laundry.

USER SAFETY RECOMMENDATIONS

Users should:
- Wash hands before eating, drinking, chewing gum, using tobacco or using the toilet.
- Remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.

ENVIRONMENTAL HAZARDS

For terrestrial uses: Do not apply directly to water, to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment wash waters or rinsate.

DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirement specific to your state or tribe, consult the agency responsible for pesticide regulation. Do not apply this product through any type of irrigation system.

AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labelling and with the Worker Protection Standard, 40 CFR Part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides. It contains requirements for training, decontamination, notification and emergency assistance. It also contains specific instructions and exceptions pertaining to the statements on the label about personal protective equipment (PPE) and restricted entry intervals. The requirements in this box only apply to uses of this product covered by the Worker Protection Standard.

Do not enter or allow entry into treated areas during the restricted entry interval (REI) of 12 hours.

PPE required for early entry to treated areas that is permitted under the Worker Protection Standard and that involves contact with anything that has been treated such as, plants, soil or water is:
- Coveralls
- Shoes plus socks
- Chemical-resistant gloves such as barrier laminate, butyl rubber, nitrile rubber, neoprene rubber, polyvinyl chloride or viton

GENERAL INFORMATION

Do not apply this product through any type of irrigation system.

FOR USE IN: COMMERCIAL GREENHOUSES, GLASSHOUSES (WHERE PLANTS ARE GROWN IN CONTAINERS), AND ON ACTIVELY GROWING STOCK PLANTS

CONFIGURE increases lateral branching and promotes flowering in certain ornamental crops. In addition, applications of CONFIGURE reduce the overall height of the plant resulting in more compact and marketable plants.

Plant response to CONFIGURE is strongly influenced by cultural and environmental variables. Growing media, water/fertilizer management, temperature, light, greenhouse composition, and other cultural practices may impact plant response. Plant size, container size and cultivar or variety can also influence treatment response. Although multiple cultivars have been tested for sensitivity to CONFIGURE and have demonstrated high levels of tolerance, it is impossible to insure an acceptable response in all cultivars. **First time users of CONFIGURE should first conduct trials on a limited number of plants to determine crop response.**

APPLICATION INFORMATION

Apply CONFIGURE as a foliar spray using standard foliar application spray equipment. Make sure that sufficient volumes are used to thoroughly wet foliage. Spray uniformity is equally important. Uniformly apply 1-2 quarts of finished spray solution to 100 sq. ft. of area. A high quality wetting agent or spray adjuvant, approved for use on your crop, may be added to spray solutions according to the manufacturer's use instructions.

DIRECTIONS FOR USE

Christmas Cactus (*Schlumbergera* spp.):

Apply CONFIGURE as a foliar spray to: 1) promote vegetative branching; or 2) increase the number of flower buds under reproductive conditions. Results vary with cultivar, therefore, trial a small group first.

To increase branching under vegetative conditions: Apply CONFIGURE at 100 ppm as a uniform foliar spray after planting when new vegetative growth begins.

To increase the number of flower buds under reproductive conditions: Apply CONFIGURE at 100 to 200 ppm as a uniform foliar spray after the start of short days following leveling, or when flower buds become visible. Below are specific guidelines based on lighted or natural season grown plants.

For floral initiation under short day conditions (i.e., lighting/black clothing): Wait 5 to 10 days after the start of short days to level by removing immature phylloclades. Make a single application of CONFIGURE immediately following or 1 day after leveling.

For floral initiation under natural environmental conditions: Make a single application of CONFIGURE after flower buds first become visible (i.e., pinpoint bud stage). First visible bud varies by cultivar. Avoid early applications which will result in phylloclade promotion and delayed flowering.

Plantain Lily (*Hosta* spp.):

Use CONFIGURE on *Hosta* to promote lateral growth of finished plants by inducing the outgrowth of axillary and rhizomic buds. Use CONFIGURE to increase offsets during propagation.

For the promotion of lateral growth on finished plants: Apply CONFIGURE at rates ranging from 1000 – 3000 ppm in a uniform spray volume. CONFIGURE is most effective when plants are fully established prior to application (i.e., at least 3 to 4 weeks after potting), when there is evidence of surface root development, but before flower initiation.

For increased production of offsets (propagation): Apply CONFIGURE at rates ranging from 1000 – 3000 ppm in a uniform spray volume to fully established, actively growing stock plants. Repeat the application at 30-day intervals during the growing season. Offsets may be harvested at any time.

Treatment effects may vary by *Hosta* cultivar, and may respond differently to a given rate of CONFIGURE. Multiple applications at 30-day intervals using lower rates may be more effective than a single application at higher rates. Conduct trials on a small number of plants under actual use conditions to establish the proper use rates and timings.

Purple Coneflower (*Echinacea* spp.):

Foliar applications of CONFIGURE have been shown to increase the number of branches when applied at rates of 300 to 900 ppm during active growth.

Apply CONFIGURE as a foliar spray after plant establishment and resumption of growth (i.e., approximately 2 weeks after potting). Apply in a uniform spray volume of 2 quarts per 100 square feet of area. Application timing and rate may vary with cultivar. First time users of CONFIGURE should determine the appropriate rate and application timing by conducting trials on a small number of plants on specific cultivars and under typical environmental growth conditions.

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APPLICATION INSTRUCTIONS FOR USE ON CONTAINERIZED ANNUAL AND PERENNIAL FLOWERING AND FOLIAGE CROPS AND TROPICAL PLANTS

- Apply CONFIGURE as a foliar spray when plants are fully established during active growth i.e., at least 3 to 4 weeks after potting.
- Apply CONFIGURE at rates ranging from 50 to 500 ppm.
- Apply in a uniform spray volume of 2 quarts per 100 square feet of area.
- FIRST TIME USERS OF CONFIGURE SHOULD TREAT A LIMITED NUMBER OF PLANTS STARTING WITH 50 PPM ON ANNUALS AND 100 PPM ON PERENNIALS AND TROPICAL PLANTS; OBSERVE FOR PLANT RESPONSES AND MAKE RATE ADJUSTMENTS ACCORDINGLY.
- Multiple applications of CONFIGURE at 7-10 day spray intervals may be necessary to achieve optimum results (i.e., increased lateral growth).

CONFIGURE DILUTION GUIDE

Desired Rate (ppm)	50	100	200	300	400	500	900	1000	2000	3000
1 oz CONFIGURE per gallon of water	0.3	0.6	1.2	1.8	2.4	3.0	5.4	6.0	12.0	18.0
ml CONFIGURE per gallon of water	9	18	36	54	72	90	162	180	360	540
ml CONFIGURE per liter of water	2.4	4.8	9.6	14.4	19.2	24.0	43.2	48.0	96.0	144

[Configure contains 39.35 grams active ingredient per 64 fluid ounces (one-half gallon).]

STORAGE AND DISPOSAL

Do not contaminate water, food or feed by storage or disposal.

Pesticide Storage: Keep container tightly closed when not in use. Store in cool, dry place. Protect from temperatures below 32°F. This product may freeze. If freezing should occur, thaw and shake gently to unify the product. Do not store diluted product.

Pesticide Disposal: Wastes resulting from the use of this product may be disposed of on site or at an approved waste disposal facility.

Container Disposal: Nonrefillable container. Do not reuse or refill this container. Triple rinse (or equivalent) promptly after emptying. Triple rinse as follows: Empty the remaining contents into the application equipment or a mix tank and drain for 10 seconds after the flow begins to drip. Fill the container 1/4 full with water and recap. Shake for 10 seconds. Pour rinsate into application equipment or a mix tank or store rinsate for later use or disposal. Drain for 10 seconds after the flow begins to drip. Repeat this procedure two more times. Then offer for recycling, if available, or puncture or dispose of in a sanitary landfill, or by incineration. Do not burn unless allowed by state and local ordinances.

CONDITIONS OF SALE AND LIMITED WARRANTY:

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Mar 09

Figure A1.1 Configure PGR Label

Fascination®

PLANT GROWTH REGULATOR (PGR) SOLUTION

For use on lilies.

ACTIVE INGREDIENTS:

N-(phenylmethyl)-1H-purine 6-amine	1.8% w/w
Gibberellins A_4A_7	1.8% w/w
Other Ingredients	96.4% w/w
Total	100.0% w/w

EPA Est. No. 33762-IA-001
EPA Reg. No. 73049-41 List No. 02571

INDEX:

KEEP OUT OF REACH OF CHILDREN
CAUTION
For MEDICAL and TRANSPORT Emergencies ONLY
Call 24 Hours A Day 1-800-892-0099.
For All Other Information Call 800-89-VALENT (898-2536).

1.0 FIRST AID

If in eyes	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.

HOT LINE NUMBER

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. For medical emergencies, you may also call toll-free 1-800-892-0099 for treatment information.

2.0 PRECAUTIONARY STATEMENTS

2.1 HAZARD TO HUMANS & DOMESTIC ANIMALS

CAUTION

Causes moderate eye irritation. Avoid contact with eyes or clothing. Wash thoroughly with soap and water after handling and before eating, drinking, chewing gum, or using tobaco.

2.2 Personal Protective Equipment (PPE)

Applicators and other handlers must wear:
- Long-sleeved shirt and long pants
- Waterproof gloves
- Shoes plus socks

2.3 User Safety Requirements

Follow manufacturer's instructions for cleaning and maintaining PPE. If no such instructions for washables, use detergent and hot water. Keep and wash PPE separately from other laundry.

2.4 User Safety Recommendations

User should:
- Wash hands before eating, drinking, chewing gum, using tobacco, or using the toilet.
- Remove PPE immediately after handling this product. Wash the outside of gloves before removing. As soon as possible, wash thoroughly and change into clean clothing.
- Remove clothing/PPE immediately if pesticide gets inside. Then wash thoroughly and put on clean clothing.

2.5 Environmental Hazards

For terrestrial uses: Do not apply directly to water, or to areas where surface water is present or to intertidal areas below the mean high water mark. Do not contaminate water when disposing of equipment washwaters or rinsate.

3.0 DIRECTIONS FOR USE

It is a violation of Federal law to use this product in a manner inconsistent with its labeling. Do not apply this product in a way that will contact workers or other persons, either directly or through drift. Only protected handlers may be in the area during application. For any requirements specific to your State or Tribe, consult the agency responsible for pesticide regulation.

4.0 AGRICULTURAL USE REQUIREMENTS

Use this product only in accordance with its labeling and with the Worker Protection Standard, 40 CFR Part 170. This Standard contains requirements for the protection of agricultural workers on farms, forests, nurseries, and greenhouses, and handlers of agricultural pesticides.

Figure A1.2 Fascination PGR Label

Verve™

Plant Growth Regulator

Intented for Commercial or Agricultural Use Only

For use on Apples, Blackberries, Blueberries, Cantaloupes, Cherries, Grapes, Peppers, Tobacco, Field and Greenhouse Tomatoes, Walnuts, and for Minimizing Lodging in Barley and Wheat.

For the Removal of Dwarf Mistletoe in Ornamental Conifers and Leafy Mistletoe in Ornamental Deciduous Trees, for the Elimination of Undesirable Fruit on Ornamental Trees and Shrubs, for Inducing Flowering of Ornamental Bromeliads, for Increased Lateral Branching in Ornamentals, for Reducing Plant Height of Potted Daffodils and Stem Topple of Potted Hyacinths, in the Production of Cucumber, Squash and Pumpkin Hybrid Seed, and for Use on Turf including Golf Courses and Sod Farms.

ACTIVE INGREDIENT:	
Ethephon: (2-Chloroethyl) phosphonic acid*	21.7%
OTHER INGREDIENTS:	78.3%
TOTAL:	100.0%

*1 Gallon contains 2 lb ethephon.

KEEP OUT OF REACH OF CHILDREN

DANGER / PELIGRO

Si usted no entiende la etiqueta, busque a alguien para que se la explique a usted en detalle.
(If you do not understand the label, find someone to explain it to you in detail.)

See Inside Label Booklet for PRECAUTIONARY STATEMENTS

For Chemical Spill, Leak, Fire, or Exposure, Call CHEMTREC (800) 424-9300.
For Medical Emergencies Only, Call (877) 325-1840.

FIRST AID	
IF IN EYES	• Hold eye open and rinse slowly and gently with water for 15-20 minutes. • Remove contact lenses, if present, after the first 5 minutes, then continue rinsing eye. • Call a poison control center or doctor for treatment advice.
IF SWALLOWED	• Call a poison control center or doctor immediately for treatment advice. • Have person sip a glass of water if able to swallow. • Do not induce vomiting unless told to do so by the poison control center or doctor. • Do not give anything to an unconscious person.
IF ON SKIN OR CLOTHING	• Take off contaminated clothing. • Rinse skin immediately with plenty of water for 15-20 minutes. • Call a poison control center or doctor for treatment advice.
IF INHALED	• Move person to fresh air. • If person is not breathing, call 911 or an ambulance, then give artificial respiration, preferably by mouth-to-mouth, if possible. • Call a poison control center or doctor for further treatment advice.

HOTLINE NUMBER

Have the product container or label with you when calling a poison control center or doctor, or going for treatment. You may also contact (877) 325-1840 for emergency medical treatment information.

NOTE TO PHYSICIAN

Probable mucosal damage may contraindicate the use of gastric lavage. No specific antidote is available. All treatments should be based on observed signs and symptoms of distress in the patient. Overexposure to materials other than this product may have occurred.

Victims of severe overexposure by inhalation should be kept under medical observation for up to 72 hours for delayed onset of pulmonary edema. In a victim of overexposure by ingestion, careful gastric lavage is required due to the possibility of stomach or esophageal perforation. This material is an acid but the use of alkaline substances to neutralize it is contraindicated.

EPA REG. NO. 228-660

Manufactured for
Nufarm Americas Inc.
11901 S. Austin Avenue
Alsip, IL 60803

Nufarm Grow a better tomorrow.

Figure A1.3 Verve PGR Label

A1.1 Additional Analyses for *Heuchera sanguinea* 'Snow Angel'

A1.1.1 *Heuchera* Experiment #1

```
## Anova Table (Type II tests)
##
## Response: Breaks
##            Sum Sq Df F value    Pr(>F)
## Treatment  89.791  6  6.7954 8.276e-06 ***
## Residuals 169.574 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure A1.4 *Heuchera sanguinea* 'Snow Angel' Experiment #1 one-way ANOVA table for average number of branches per plant with Treatment as the predictor.

Table A1.4 *Heuchera sanguinea* 'Snow Angel' Experiment #1 mean average number of branches per plant and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	12.88889	12.03585	13.74193	1
Configure 250 ppm	14.44444	13.5914	15.29749	123
Configure 500 ppm	15.61111	14.75807	16.46415	3
Fascination 100 ppm	15.05556	14.20251	15.9086	23
Fascination 50 ppm	13.38889	12.53585	14.24193	12
Verve 200 ppm	13.63889	12.78585	14.49193	12
Verve 400 ppm	12.63889	11.78585	13.49193	1

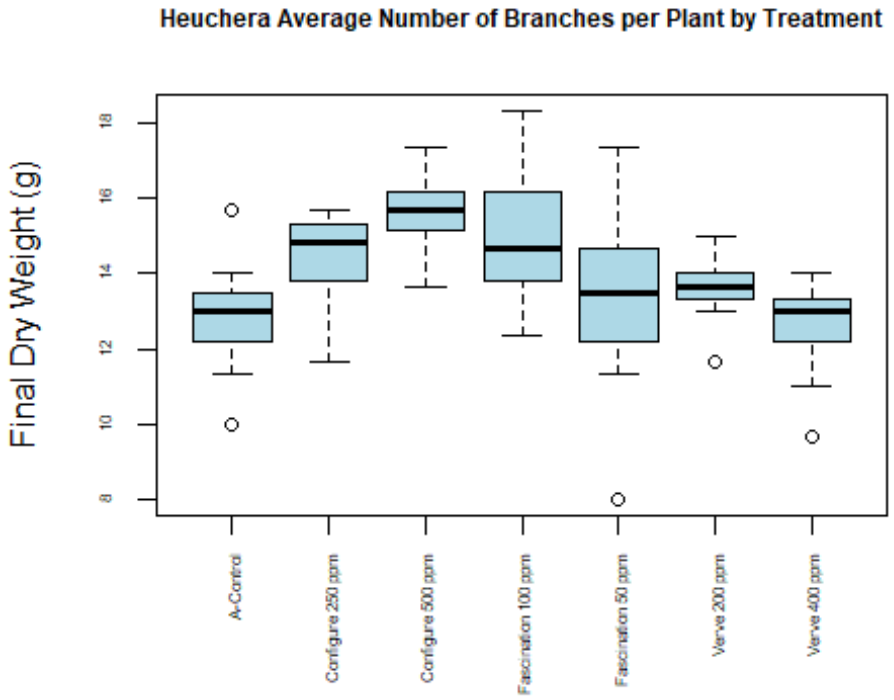

Figure A1.5 *Heuchera sanguinea* 'Snow Angel' Experiment #1 boxplots of average number of branches per plant by treatment. Standard error bars indicate a 95% confidence interval for the mean.

A1.1.2 *Heuchera* Experiment #2

```
## Anova Table (Type II tests)
##
## Response: Breaks
##           Sum Sq Df F value Pr(>F)
## Treatment  69.29  6  1.8075 0.1086
## Residuals 491.99 77
```

Figure A1.6 *Heuchera sanguinea* 'Snow Angel' Experiment #2 one-way ANOVA table for average number of branches per plant with Treatment as the predictor.

Table A1.5 *Heuchera sanguinea* 'Snow Angel' Experiment #2 mean average number of branches per plant and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	16.9167	15.4637	18.3697	1
Configure 250 ppm	18.8611	17.4081	20.3141	1
Configure 500 ppm	19.1389	17.6859	20.5919	1
Fascination 100 ppm	17.9444	16.4914	19.3975	1
Fascination 50 ppm	18.5833	17.1303	20.0364	1
Verve 200 ppm	16.9167	15.4637	18.3697	1
Verve 400 ppm	16.9444	15.4914	18.3975	1

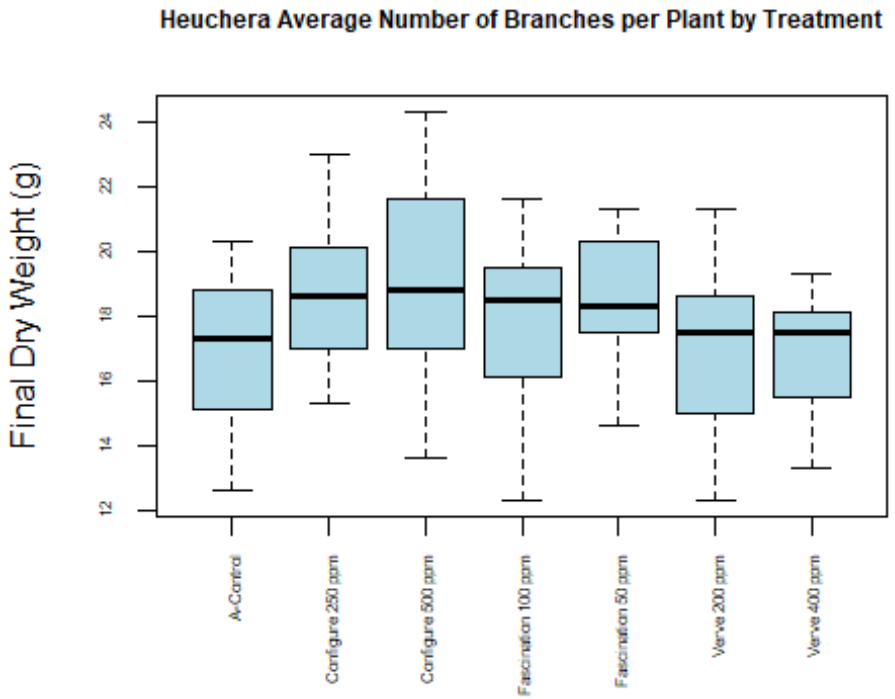

Figure A1.7 *Heuchera sanguinea* 'Snow Angel' Experiment #2 boxplots of average number of branches per plant by treatment. Standard error bars indicate a 95% confidence interval for the mean.

A1.2 Additional Analyses for *Zauschneria garrettii* 'PWGO1S'

A1.2.1 *Zauschneria* Experiment #1

```
## Anova Table (Type II tests)
##
## Response: Breaks
##           Sum Sq Df F value  Pr(>F)
## Treatment  653.5  6  1.8787 0.09516 .
## Residuals 4464.2 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure A1.8 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 one-way ANOVA table for average number of branches per plant with Treatment as the predictor.

Table A1.6 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 mean average number of branches per plant and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	24.8333	20.4565	29.2102	1
Configure 250 ppm	29.7500	25.3732	34.1268	1
Configure 500 ppm	25.6528	21.2759	30.0296	1
Fascination 100 ppm	27.9722	23.5954	32.3491	1
Fascination 50 ppm	28.1250	23.7482	32.5018	1
Verve 200 ppm	27.1389	22.7621	31.5157	1
Verve 400 ppm	20.5417	16.1648	24.9185	1

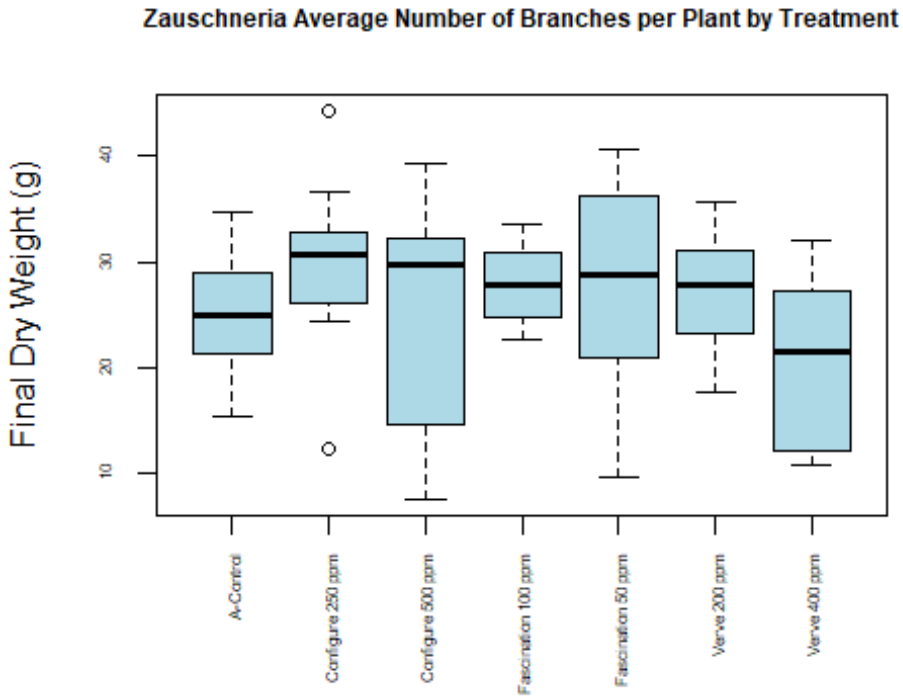

Figure A1.9 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #1 boxplots of average number of branches per plant by treatment. Standard error bars indicate a 95% confidence interval for the mean.

A.1.2.2 *Zauschneria* Experiment #2

```
## Anova Table (Type II tests)
##
## Response: Breaks
##           Sum Sq Df F value    Pr(>F)
## Treatment  10366  6  9.1823 1.413e-07 ***
## Residuals  14487 77
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Figure A1.10 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 one-way ANOVA table for average number of branches per plant with Treatment as the predictor.

Table A1.7 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 mean average number of branches per plant and 95% confidence intervals for each PGR treatment. Means with different significance groups are significantly different at the level of P<0.05.

Treatment	Mean Number of Visible Roots	Lower CI 2.5%	Upper CI 97.5%	Significance Group
Control	51.3056	43.4210	59.1901	1
Configure 250 ppm	63.6944	55.8099	71.5790	123
Configure 500 ppm	53.7222	45.8377	61.6068	12
Fascination 100 ppm	83.3611	75.4765	91.2457	4
Fascination 50 ppm	76.0000	68.1154	83.8846	34
Verve 200 ppm	68.7778	60.8932	76.6624	234
Verve 400 ppm	75.9722	68.0877	83.8568	34

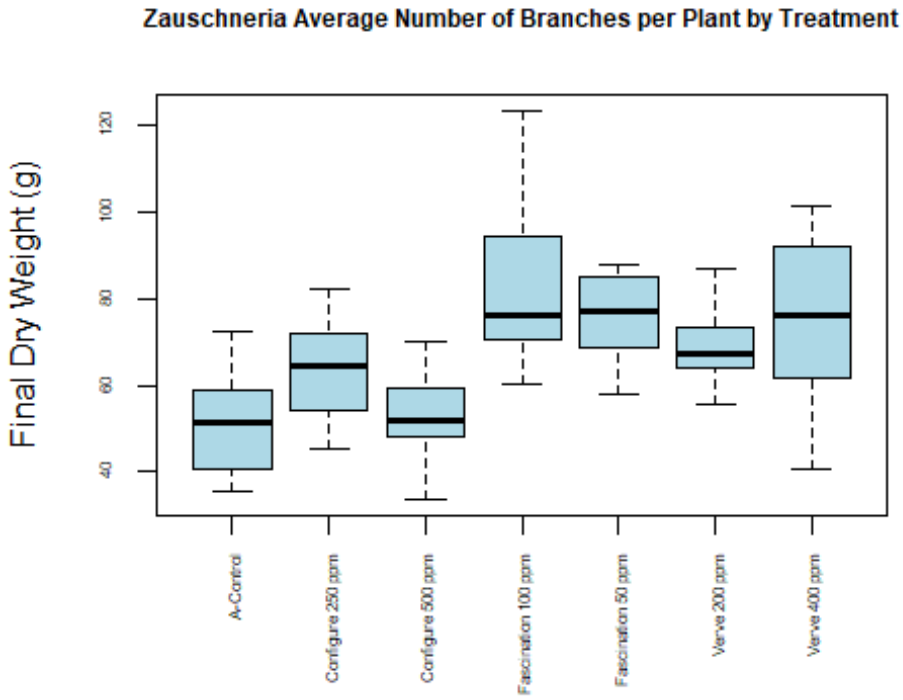

Figure A1.11 *Zauschneria garrettii* 'PWWG01S' ORANGE CARPET® Experiment #2 boxplots of average number of branches per plant by treatment. Standard error bars indicate a 95% confidence interval for the mean.