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EFFECTS OF PRESERVATIVE SOLUTIONS ON THE POSTHARVEST LIFE OF *Heliconia psittacorum* CUT FLOWERS

BY

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DECLARATION

I hereby declare that except for references to other people's work which have been duly acknowledged, this dissertation is the result of my own effort, and that it has neither in wholly nor partially been submitted for another degree elsewhere.

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ABSTRACT

Heliconia (*Heliconia psittacorum*) cut flower has magnificent economic value in international cut flower industry. Due to high temperatures, sensitivity to ethylene and microbial growth in preservatives, it has a short vase life. In order to assess the effects of various levels of pulsing solutions (water, vinegar and sucrose) against dry treatment on quality and vase-life of cut flower of Heliconia, an experiment was conducted based on completely randomized design. The cut flowers of Heliconia were treated with water only (1000 ml), vinegar solution (5.0 ml of Vinegar + 1000 ml of Water), sucrose solution (10.0 grams of Sucrose + 1000 ml of Water), and vinegar and sucrose solution (5.0 ml of Vinegar +10.0 grams of Sucrose + 1000 ml of Water) along with control (no water/dry) treatment. Preservative solutions were applied as long-term treatment. All treated cut flowers were stored at room temperature. The results showed that all wet treatments significantly ($p < 0.05$) improved the keeping quality and vase life of the cut flowers compared to the control ones. Among all these treatments applied, 1000 ml of Water Only (WO) and (W + S) treatments showed best for water uptake, percentage of maximum fresh weight of cut flower stems, and vase life which was extended for 14 days. It was also noticed that preservative solutions with low pH values ($pH < 3.2$) had adverse effects on the vase life and keeping quality of the cut flowers. Therefore 1000 ml of Water Only or 10.0 grams of Sucrose + 1000 ml of Water has the potential to be used as a commercial cut-flower preservative solution to delay flower senescence. Improved post-harvest quality and prolonged vase life of *Heliconia psittacorum* cut flowers have been achieved.

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DEDICATION

I dedicate this project to my family.

TABLE OF CONTENTS

LIST OF TABLES

TABLE **PAGE**

LIST OF FIGURES

FIGURE **PAGE**

LIST OF PLATES

PLATES **PAGE**

LIST OF APPENDICES

APPENDIX **PAGE**

LIST OF ABBREVIATIONS

$	Dollar
ABA	Abscisic acid
ANOVA	Analysis of variance
cm	Centimetre
CRD	Completely randomized design
EU	European Union
GA	Gibberellic acid
GEPA	Ghana Export Promotion Authority
GIPC	Ghana Investment Promotion Centre
GMT	Greenwich Mean Time
kg	Kilogram
LSD	Least significance difference
ml	Millilitres
pH	Potential in Hydrogen
PPM	Parts per million
RH	Relative humidity
STS	Silver thiosulphate
USA	United States of America

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Cut flowers, perennial flowers, ornamental plants, landscape and gardening, floral arrangements, and specific decorations are among important business areas currently practiced under floriculture sub-sector (Dahal, 2013). One critical issue of concern for Ghanaian exporters is difficulty with breaking into the global competitive market (Osei-Assibey, 2015). Considering that trade is essential for spurring growth and that growth is a critical part of poverty reduction, the continuous decline of Africa in global trade is a major source of concern (Jaeger and Voisard, 2003).

Exporters need to know how to obtain information about overseas markets and how to explore opportunities that are identified. Producers and exporters also have to attain high performance standards in terms of product consistency, tight planning and logistics, quality assurance, food safety, and traceability (Osei-Assibey, 2015). However, while many producers and exporters claim to have obtained certification (such as Global Gap for horticultural products), many still have poor knowledge of markets, poor management, and weak marketing channels. Although the country is gradually diversifying its export destinations, particularly to West African markets, challenges remain in breaking into the Asian market, which offers great size and opportunity (Osei-Assibey, 2015). Jesus et al., (2014) reported that the factors that influenced the increase of supply of cut flowers were greater range of varieties to the consumer, increased durability of the flowers and greater efficiency in the productive chain. According to Peter Obeng, Director of Product Development at Ghana Export Promotion Authority (GEPA), Ghana is lagging behind its fellow flower exporting

nations such as Kenya and Ethiopia wasting potential millions of dollars in revenue and employment opportunities (Graphic, 2014). This he said was due to a lack of knowledge of the international floral market, limited production facilities, insufficient government support and low local consumption meant that huge revenue was being left on the table.

Marketing trends of Ghana flower exports over the past years have not been so impressive despite a rich supply of flora and the high demand for tropical cut flowers. Table 1 below shows the marketing trend of Ghana's export of flowers.

Table 1: Statistics on export and earnings in Ghana

YEAR	Quantity in kg	Revenue in Dollars(US$)
2010	422,914	1,786,898
2011	452,358	2,046,577
2012	811,814	2,025,099
2013	766,090	2,326,368

Source: (Graphic, 2014)

The high export value of cut flowers has led to dramatic increases in production in many countries, and particularly Colombia (Reid, 2009). Production of cut flowers and foliage can be highly profitable in countries with an ideal growing environment (particularly those close to the equator where the environment is uniform throughout the year), and low labour costs. The average Ghanaian has shown low appreciation for the value and importance of fresh floral products and as such hardly make room for them in their budget or substitutes them with artificial floral decorations which are imported (Graphic, 2014). "It is not surprising that farmers lack sufficient information about flowers that do well in Ghana and which are of high value on the international

market"(Graphic, 2014). Some tropical varieties such as all Orchid varieties, Strelitzia (Bird of Paradise), Heliconia, Anthurium, Ginger, Gloriosa, Lily, Poinsettia and Euphorbia grow naturally in tropical regions where the air temperature does not fall below 18°C (Jones, 2001). These flowers are mostly used as cut flowers but unfortunately do not maintain their freshness for long. Plants grown for cut flowers should have vigorous growth and be disease free. The stage of floral development at which the flower should be removed from the parent plant depends on the species. After flowers or foliage are detached from their parent plant, they must be properly cared for and handled to maintain their freshness and keep them longer (Arteca, 2006).

In conclusion, as an International Trade Centre report points out, the key policy issue is not whether to export, but how to do so in a way that provides for sustainable income growth and increase foreign exchange earnings (Osei-Assibey, 2015).

1.2 Problem Statement

Although many efforts have been made to improve on the vase-life of cut flowers, more efforts are required to find the most effective preservative solution that would give a maximum vase-life period of *Heliconia psittacorum* by comparing vase-life activity of commonly known preservatives under the same conditions.

According to Nair *et* al. (2003), vase life is an important parameter for evaluating the postharvest life of cut flower quality, for both domestic and export markets. Addition of chemical preservatives to the holding solution is recommended to prolong the vase life of cut flowers. Thus, using appropriate preservatives could help extend the vase life of the harvested produce for consumer satisfaction and exploitation of the business. The postharvest longevity of *Heliconia* cut flowers is an important factor to the success of commercialization. Adequate storage conditions decrease the postharvest

senescence process, increasing durability of the flowering stem (Leite et al., 2015). Earlier research had shown that it is economically viable to preserve the cut flower of *Heliconia psittacorum* with water only or 10g of sugar in one litre of water (Owusu, 2013). Jones (2001) also reported that, one has to follow certain rules when preparing preservatives for cut flowers. The first rule says: one should not add sugar to vase water without a germicide. Bacteria feed on sugar, and breed faster in a nice sugar solution than in any other thing. Placing flowers in a solution containing sugar without a germicide can kill them very quickly. The second rule also says: an acidifier such as citric acid or vinegar should always be used. Sugar solutions are sticky, and flowers cannot take up as much sugar solution as water alone. Adding an acidifier inhibits bacteria growth, helps the flower take up more of the solution and ensures the sugar gets into the flower to nourish it.

In view of this, the study was conducted to find a way to extend the vase life of *Heliconia psittacorum* cut flowers with varied levels of sucrose and vinegar solutions.

1.3 Objectives of the Study

The objectives of the research were:

1) To determine the effects of treatments on the relative fresh weight of flower stems.
2) determine the relationship between vase life and water uptake.

1.4 Significance of the Study

The study of the vase life of *Heliconia* cut flowers may lead to identification of strategies for prolonging the vase life of the flower. This would ultimately benefit the floricultural industry in Ghana as well as the consumer.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Introduction

This section gives a detailed description of the plant with emphasis on the origin and its distribution, taxonomy, botany, physiological characteristics and their types. In addition, the climatic and environmental requirements, and cultural practices during pre and postharvest have fully been discussed.

2.2 Origin and Distribution of *Heliconia*

Heliconias are native to Central and South America and islands of the South Pacific (McConnell and Cruz, 2001). According to Owusu (2013), *Heliconia psittacorum* is grown for the florist trade as a landscape plant for indoor and outdoor beautification as well as for cut flower production. There are many species and cultivars of *Heliconia psittacorum*. Heliconias are found throughout the Neotropics and are actually quite common in the rainforest. They are also often found as ornamental plants in gardens and landscaped areas. People enjoy their colorful, gravity-defying ornamentation.

2.3 Taxonomy of *Heliconia*

Heliconia cut flowers belong to the family *Heliconiaceae* formerly included in the family Musaceae where they were grouped with the bananas (Kress, 1990). Heliconia, a primarily neotropical genus is represented in the Old World tropics by six species and five varieties. These taxa are distributed throughout the South Pacific region from Samoa and Fiji in the east to the Indonesian Moluccas in the west, including New Guinea, the Solomon Islands, Vanuatu, and New Caledonia (Kress, 1990).

2.4 Botany of *Heliconia*

Heliconia leaves look more or less like banana leaves. They are generally green, but some are tinged slightly with colour (particularly when young) and sometimes the leaves and stems are coloured or patterned slightly. The true flowers are hidden inside these bracts. Heliconias are tropical plants related to bananas, cannas and gingers (Length, 2016). Many of these closely related plants are grown as ornamentals. Most have large leaves, often with long petioles and large showy flowers commonly with one or more colorful bracts (McConnell and Cruz, 2001). Most heliconias are well adapted to the humid lowland tropics. They are easy to grow and produce a brilliant show of color. It is a vigorous grower and prolific producer of flowers most of the year, and makes an excellent cut flower (Length, 2016). Most species of heliconias require lots of space and can spread across an area in all directions. The larger species such as *H. caribea* can grow to 25 feet in height. Many cultivars have long lasting flowers which make excellent cut flowers (McConnell and Cruz, 2001).

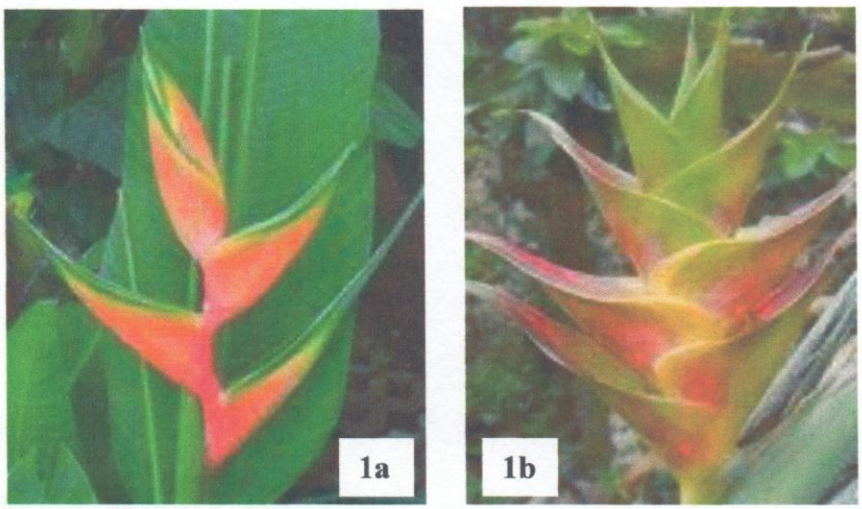
2.5 Physiological Characteristics of the Flower

The inflorescence of Heliconia (*Heliconia spp*), red ginger (*Alpinia purpurata*) and bird-of-paradise (*Strelitzia reginae*) have similar stem structures and postharvest handling regimes (Teeranuch and Paull, 2003). Heliconia shows considerable genetic differences in vase life and is used as a major criteria to elect promising lines (Criley and Broschat, 1991). For small heliconias, the vase life varies with cultivar, stage of flower development, and time of day when harvested. The postharvest vase life of the better selection of the psittacorum types ranges from 14 and 17 days (Criley and Broschat, 1991). Broschat and Donselman (1983) reported that storage temperatures for tropical cut flowers vary, as bird-of-paradise is less cold sensitive than heliconia and ginger. The minimum recommended storage temperature is greater than 10 °C for

heliconia (Broschat and Donselman, 1983). Studies have shown that hot water treatment can extend the vase life of tropical cut flowers, especially red ginger (Teeranuch and Paull, 2003). However, the ability of the hot water treatment to extend flower vase life is not consistent but varies with season of harvest (Chantrachit and Paull, 1998).

2.6 Types of *Heliconia*

There are about 100 different individual species, and most species then have a large number of hybrids and cultivars, with flower styles varying significantly from the original. Heliconias (Family Heliconiaceae), along with Bird-of-Paradise (Family Strelitziaceae), Gingers (Family Zingiberaceae), Costus (Family Costaceae) and Cannas (Family *Cannaceae*) are relatives of Bananas (Family *Musaceae*) (McConnell and Cruz, 2001). Some species of heliconia have upright facing flowers, and in some called hanging heliconia, the flowers dangle down from the main stem. According to Hintze and Darwin (2014), flowering styles are roughly classified into two groups - 'erect' or 'pendant' (hanging flowers). Some people like to separate the psittacorums into a third group, as psittacorum flower on the end of stalks, rather than from the middle as do the 'erect' or 'pendant' types.

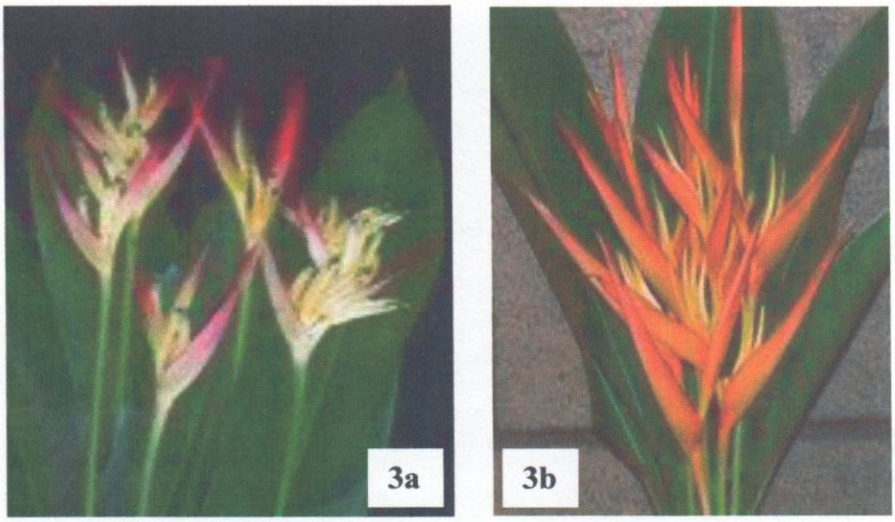


Source: Hintze and Darwin (n.d.).

Plate 1: Erect type of *Heliconia*

Source: Hintze & Darwin (n.d.).

Plate 2: Pendant type of *Heliconia*



Source: Hintze & Darwin (n.d.).

Plate 3: Psittacorum type of *Heliconia*

2.7 Senescence of Cut Flowers

Senescence of cut flower can be defined as the terminal phase of developmental process which leads to death of flower such as flower wilting, shedding of flower parts and fading of blossoms (Tripathi and Tuteja, 2007). According to Bowyer and Wills (2003), postharvest senescence is the major limitation to many species of cut flowers and so considerable effort has been devoted to developing postharvest treatments to

extend their marketing periods. Reid (2009) also reported that quality loss and reduced vase life of cut flowers can be caused by early flower senescence. In terms of senescence, flowers can be grouped into categories such as extremely long-lived which includes the daisy and orchid families. Many of the bulb crops like tulip, Iris and Narcissus are short-lived.

Flower senescence is also hastened by several biotic and abiotic stresses (Tripathi and Tuteja, 2007). The environmental factors such as insect-mediated pollination, seasonal changes, lack of water, and various stresses such as invasion by a pathogen or attack by a predator affect flowers since they are the most colorful and susceptible part of plants. Abiotic stresses, like drought, light quality, heat shock can also affect the senescence of flower. In these stresses, the senescence process is intervened by the evolution of ethylene in ethylene-sensitive flowers but in ethylene-insensitive flowers, the abscisic acid (ABA) levels are elevated which might be an important hormonal intermediate signal for responses.

2.7.1 Factors that Induce Senescence in Cut Flower

Reid (2009) explains that the early death (senescence) of flowers is a common cause of quality loss and reduced vase life for cut flowers and that maintaining quality in export cut flowers depends on an understanding the factors that lead to deterioration. Understanding these factors allows the grower and shipper to develop and implement optimum postharvest handling technologies. Several factors such as flower maturity, time and mode of harvest, temperature, relative humidity, food supply, light, water supply, water quality, ethylene and other growth hormones, growth tropisms, mechanical damage, and disease can hasten flower senescence (Reid, 2009).

2.7.1.1 Temperature

According to Jones (2001), it can be argued that the most critical factor in the care of cut flowers is temperature. Most flowers are made up of thin, delicate petals that lose water and wilt rapidly; and the warmer the weather, the faster flowers wilt. Saltveit (1998) also reported that temperature has a profound effect on the rate of biological reactions such as respiration and metabolism. For that matter increased temperature cause an exponential rise in respiration. Moreover, Van't Hoff rule states that the rate of a biological reaction increases 2 to 3-fold for every 10 °C rise in temperature. Furthermore, as the ambient temperature rises, the respiration rate increases. For example, a flower held at 30 °C is likely to respire (and therefore age) up to 45 times as fast as a flower held at 2 °C. The rate of aging can be reduced dramatically by cooling the flowers. Rapid cooling and maintenance of the cool chain are essential for maintaining quality and satisfactory vase life of cut flowers (Reid, 2009).

According to Saltveit (1998), although respiration is normally reduced at low temperatures, certain flowers, chiefly those originating in the tropics and subtropics, exhibit abnormal respiration when their temperature falls below 10 °C to 12 °C. Jones (2001) described these flowers as tropical cut flowers and are damaged by cool temperatures. Flowers in this category include all Orchid varieties, Strelitzia (Bird of Paradise), Heliconia, Anthurium, Ginger, Gloriosa Lily, Poinsettia and Euphorbia. These varieties must never be refrigerated, and should be kept above 12°C at all times.

2.7.1.2 Light

Light is not of great concern as other factors mentioned earlier; however, chronic darkness will cause foliar deterioration. Optimum light levels during production are important to ensure high quality cut flower (Dole and Schnelle, 2001). Reid (2009) reported that the leaves of certain cultivars of chrysanthemum, alstroemeria,

marguerite daisy and other crops can turn yellow if stored in darkness at warm temperatures and recommended that the blackening of leaves of cut Protea flowers can be prevented by maintaining the flowers in high light or by treating the harvested flowers with a sugar pulse (Reid, 2009). This suggests that the problem is induced by low carbohydrate status in the harvested inflorescence and its exposure to high light intensity improves photosynthesis and hence carbohydrate storage in plants.

2.7.1.3 Food Supply

Starch and sugars manufactured during photosynthesis which are stored in the stem, leaves and petals provide much of the food needed for cut-flower opening and maintenance. According to Reid (2009), carbohydrate levels are generally highest in the late afternoon after a full day of sunlight. However, flowers are preferably harvested in the early morning, because temperatures are low, plant water content is high, and a whole day is available for processing the cut flowers (Reid, 2009). Stevens (1995) suggested that cut stems should be placed into either water or a fresh flower food (floral preservative solution). The typical fresh flower food contains water, a simple sugar that serves as a food source and a chemical to prevent or retard the growth of microorganisms that can plug the conductive tissue; and an ingredient to acidify the water, typically citric acid (Stevens, 1995).

2.7.1.4 Role of Ethylene and other Plant Hormones in Senescence

Jones (2001) described ethylene as a natural ageing and ripening hormone released by ripening fruit, trimmed leaf and stems and burning wood and that it is physiologically active in trace amounts (0.1 ppm). Reid (2009) asserted that certain flowers, especially carnations, gypsophila and some rose cultivars, die rapidly if exposed to minute concentrations of ethylene gas. A number of cut flowers produce ethylene as they age. In carnations and sweet peas, this ethylene is involved in the death of the flower. In

other flowers, such as calceolaria, snapdragon, and delphinium, ethylene causes flower abscission (or shattering). Reid and Jiang (2012) stated that Gibberellins, auxins, and other plant hormones and regulators have also been shown to have positive and negative effects on floral longevity. However, the nature of the senescence signal in ethylene-insensitive flowers remains to be established, but there is evidence that ABA and GA may respectively play accelerating and retarding roles.

2.7.1.5 Stage of Maturity

Reid (2009) describes flower maturity as the stage at which harvested buds can be opened fully and have satisfactory display life after distribution. Many flowers are best cut in the bud stage and opened after storage, transport or distribution. According to Stevens (1995), the ideal stage of maturity will also vary with the intended use. That is, flowers for drying should be harvested when almost fully open, while for fresh use they should be less mature. The information provided in table 2 should be considered as a general guideline of harvest maturity for retail sales direct to final consumers.

Table 2: Guidelines for optimal harvest stage of maturity of specialty cut flowers for direct sale to the final consumer.

Common Name	Stage of Maturity
Aster	flowers fully open
Astilbe	one-half of the florets open
Bachelor's Button, Cornflower	flowers just beginning to open
Calendula	flowers fully open
Cockscomb	one-half of florets open
Coreopsis	flowers fully open
Dahlia	flowers fully open
Delphinium	one-half of florets open
Dutch Iris	when flower buds are colored
Freesia	when first bud is fully open
Gladiolus	one to two florets fully open
Globe Thistle	when flowers are half open
Goldenrod	one-half of florets open
Heather	one-half of florets open
Heliconia	one to three opened bracts
Hollyhock	one-third of florets open
Larkspur	two to five florets open
Lisianthus	three to five open flowers
Liatris, Gayfeather	one-half of florets open
Love-in-a-Mist, Nigella	when flowers are open
Marigold	when flowers are almost fully open
Peony	puffy, colored buds
Peruvian Lily, Alstroemeria	one to three florets open
Phlox	one-half of florets open
Pincushion Flower, Scabiosa	flowers half open
Purple Cone Flower open	flowers almost fully open
Sea Holly	flowers fully open
Snapdragon	one-third of florets open
Statice— annual	one-half of bracts open
Statice—Sea Lavender	when majority of flowers are open
Sunflower	flowers almost fully open
Sweet Pea	one-third of florets open
Tuberose	one-half of florets open
Yarrow	when flowers are almost fully open
Zinnia	when flowers are almost fully open

Source: (Stevens, 1995)

2.7.1.6 Growth Tropism

Reid (2009) explained that geotropic responses of cut flowers to environmental stimuli can result in quality loss. Most important are bending away from gravity (Geotropism) and bending towards light (Phototropism) which reduce quality in spike-flower crops like gladiolus, snapdragon, lisianthus, stock, roses, and gerbera, because the flower stems (pedicels) or the main stem bends upward when stored horizontally (Reid, 2009).

2.7.1.7 Mechanical Damage

According to Stevens (1995), after flowers have been transported from the field to the storage/packing facility, careful handling to prevent damage and rapid decline is important. Bruising and breaking flowers destroys their aesthetic and economic value as well as increasing the production of ethylene gas (Stevens, 1995). Jones (2001) described ethylene as a natural ageing and ripening hormone released by ripening fruit, leaf and stem trimming and burning wood. It is physiologically active in trace amounts (0.1 ppm) and often released when plant produce is bruised or broken (Jones, 2001). Reid (2009) advised that all efforts must be made to avoid bruising and breakage of cut flowers. Flowers with torn petals, broken stems or other obvious injuries are undesirable for aesthetic reasons and also serve as entry points for disease organisms which can easily infect plants through injured areas (Reid, 2009).

2.7.1.8 Diseases and Pests of Cut Flower

Owusu (2013) reported that plant vigour can directly be reduced by diseases and pests and indirectly reduce the vase life of cut-flowers by producing ethylene gas from injured plant tissues hastening senescence and deterioration of the flower. Flower petals are fragile and the secretions of their nectaries often provide an excellent nutrient supply for insects as well as pathogens, hence are very susceptible to diseases (Reid, 2009). Bogash et al. (2012) also explained that the major impact of cut-flower

plantings is fungal diseases and even though some diseases will not kill the flowers, their marketability can drastically be reduced. Moreover, powdery mildew can be a real problem in zinnias and many other flowers. Many seedlings are susceptible to damping off, and a number of leaf spot fungi can also reduce the value of certain species. According to Reid (2009), wherever free moisture is present, the most commonly disease organism encountered is gray mold (*Botrytis cinerea*) germination. Therefore, losses caused by this disease can be reduced by proper management of greenhouse hygiene, temperature control, and minimizing condensation. Some approved fungicides, such as Ronalin, Rovral (Iprodione), and the copper-based Phyton-27 are very effective and have been used on cut flowers against gray mold.

Based on their taxonomy, cut-flowers represent a wide group of plants and so there is a significant difference in pest problems among each genus, species, and cultivar. Bogash et al. (2012) explained that while a wide variety of insects will inhabit any flower planting, only a few are recognized as causing economic damage, including aphids and thrips.

2.7.1.9 Relative Humidity (R.H.)

Humidity refers to the amount of moisture content in the air. Humid days are those when the air contains high levels of moisture while on hot, dry days the humidity level can falls. R.H may be beneficial or harmful to cut flowers. According to Jones (2001), the air is quite dry in air-conditioned rooms and offices, usually about 65% R.H. Flowers lose water much faster when the air is dry (low humidity), compared to when the air is damp. The ideal humidity for flowers is between 90% to 95%. This is very helpful with some flowers, such as Hydrangeas, Boronia, Thryptomene and Violets, as they are able to absorb water through their petals and leaves. However, flowers such

as Roses, Gerberas and Chrysanthemums are very susceptible to fungal diseases such as Botrytis, and misting increases the likelihood of fungal attack.

2.8 Plant Material

2.8.1 Heliconia psittacorum

McConnell and Cruz (2001) described the plant as Parrot's Beak and belongs to the plant family *Heliconiaceae*. It is one of the many species of Heliconias which originates from Central and South America and islands of the South Pacific. There are many species and cultivars of *Heliconia psittacorum*. Some species include Giant Lobster Claw (*H. caribea*), Hanging Lobster Claw (*H. rostrate*), and Small Lobster Claw (*H. stricta*). Mostly they have large leaves, often with long petioles and large showy flowers commonly with one or more colorful bracts. Most Heliconias are well adapted to the humid lowland tropics. They are easy to grow and produce a brilliant show of color. Many cultivars have long lasting flowers which make excellent cut flowers (McConnell and Cruz, 2001).

According to Wolverton (1996), it is a herbaceous upright plant often cultivated as a tropical ornamental plant and can grow up to a height of 1.2meters. The leaves may be between 15-100cm long and 6-20cm wide, they are oblong in shape, dark green and leathery. They are exotic plants which bloom abundantly all year round. Their orange-red bracts arise from a central point on the stem and are also pollinated by humming birds. Their fruits are round, one centimetre wide and yellow to dark-blue at maturity with three seeds.

2.8.2 Plant Propagation

Heliconias are most easily propagated by dividing the rhizomes by cutting the stem behind a recent growth. After cutting, dig out the growth and cut off the stem, leaving

about 1 foot to ensure that there is a healthy bud on each division. After washing the rhizome, remove the roots and plant in a pot which contains moist soil/organic matter mix. Plant with the bud near the surface of the soil. Place in a shady location, keeping the soil moist after which they are transferred to the light condition after the first leaf has fully expanded (McConnell and Cruz, 2001).

2.8.3 Site selection

This has been described by McConnell and Cruz (2001) as plants that like lots of water, well-drained soils, rich in organic matter and sunlight. Heliconias do not grow well in standing water. A good growing medium can be made using equal parts soil, wood chip mulch, and peat moss. This mix can be used for starting heliconias in a pot and also can be added to the hole when planting in the ground. Heliconias grown in alkaline conditions will often produce yellow to white new leaves typical of iron deficiency. Most species of heliconias require lots of space and can spread across an area in all directions. The larger species such as *H. caribea* can grow to 7.5 metres in height. However, when planting, space the rhizomes at least 4.5 metres apart or it to spread during maturity. Smaller species such as *H. psittacorum* can be planted closer.

2.9 Treatments

2.9.1 Water and Water Quality

Water is an important part of fresh cut-flower handling process but unfortunately it is overlooked. Water makes up 80 to 90 percent of flowers, and keeps them turgid or firm hence its quality should often not be taken for granted. According to Reid (2009) cut flowers, especially those with leafy stems, have a large surface area, so they lose water and wilt very rapidly. They should be stored at relative humidity above 95% to minimize water loss, particularly during long-term storage. However for flowers to last long for consumers' satisfaction, it should be quality (Gast, 2000). Water is

expected to be pure and healthy for flowers. Ranwala (2010) asserted that there are several important quality parameters that one should know about water. The quality of water varies depending on the source, geographic location and any treatments by the local municipalities or in-house water purifiers. Chemicals commonly found in tap water are toxic to some cut flowers. Sodium (Na) present in high concentrations in softened water is for example toxic to carnations and roses. Fluoride (F) is very toxic to gerbera, gladiolus, roses and freesia; fluoridated drinking water contains enough F (about 1 ppm) to damage these cut flowers (Reid, 2009). For water to be considered quality, the following parameters should be assessed: pH, temperature, soluble salts, alkalinity, and total dissolved solids (Gast, 2000).

2.9.2 Pulsing Treatment

Reid (2009) describes the term "pulsing" as placing freshly harvested cut-flowers for a relatively short time (a few seconds to several hours) in a solution specially formulated to extend their storage and vase life. Sucrose or silver thiosulphate (STS) is the main ingredient of pulsing solutions and the proper concentration ranges from 2 to 20% depending on the crop. According to Jones (2001), it is used on flowers picked in tight bud to supply them with a high concentration of sugar to open the buds. This solution can be used on Gypsophila, Carnations, Chrysanthemum and Gladiolus or any flower that is in tight bud except for Rose, as high sugar solutions damage Roses. Further suggestion indicates that when one wants to make preservative for cut-flowers, germicide should be added to the sugar solution since bacteria feed and breed faster in sugar. Acidifier such as vinegar or citric acid should be added to the solution to help the flower take up more of the solution and ensure that the sugar gets into the flower to nourish it.

2.10 Vase Life

Vase life is the period during which a cut flower or foliage retains its appearance in a vase. This is a major consideration in plant species suitable for use in the floral industry. Plants with a long vase life is far more desirable than those with a short vase life. Chemical treatments that extend vase life are a major component of floricultural research. Asrar (2012) indicated that the vase life of cut-flowers was determined by counting from the day the cut-flower spikes were transferred to the keeping solutions and was assessed to be terminated when flowers lost their ornamental/ display value (underwent color change; wilted and lost turgidity). The vase life of the individual snapdragon cut flower stem used for that research work was terminated when all florets wilted or when they showed bent neck. Florets with unfolded petals on stems which had not bent were counted as an open floret. However, Gul and Tahir (2013) assessed the vase life of *Narcissus tazetta* cut flower by counting from the day the spikes were transferred to the holding solution and was assessed to be terminated when 50% of the flowers had senesced. This was characterized by loss of turgor followed by petal wilting.

Table 3 shows a data on the vase life of some tropical cut flowers and their sensitivity to ethylene.

Table 3: Data on the vase life and ethylene sensitivity of some tropical cut flowers

Cut Flower	Optimum Vase Life In Days	Ethylene Sensitive	Cut Flower	Optimum Vase Life In Days	Ethylene Sensitive
Agapanthus	6-12	Extremely	Montbretia	7-14	Moderately
Alstoemeria (Peruvian Lily)	6-14	Varies	Narcissus (Daffodil/Jonquil)	4-6	Moderately
Anthurium	10-45	Slightly	Narcissus (Paper-White)	5-8	Moderately
Baby's Breath (Gypsophillia)	5-10+	Extremely	Nerine	6-14	Slight/Mod
Bird of Paradise	7-14	No	Oncidium	10-14	No-Slightly
Bouvardia	7-14	Extremely	Peony	5-10	Unknown
Calla Lily	4-8	Slightly	Phalaenopsis (Orchid)	20-30	Mod/Ext
Carnation /Mini Carnation	6-14+	Extremely	Pincushion	8-16	No
Chrysanthemum / Sprays	7-14+	No	Poppy	5-7	No
Cymbidium (Orchid)	7-28	Mod/Extreme	Pro tea	8-16	No/Mod
Dahlia	4-10	Extremely	Queen Anne's Lace	3-5	Extremely
Delphinium	4-12	Extremely	Ranunculus	3-7	Moderately
Dendrobium	10-16+	Slightly	Rose	4-12	Moderately
Freesia	4-12	Moderately	Rose (Garden)	4-12	Moderately
Gardenia	1-3	Moderately	Rose (Spray)	4-12	Moderately
Gerbera	4-14	No	Rose (Sweetheart)	4-12	Moderately
Gladiolus	6-10	No	Snapdragon	5-8	Extremely
Heliconia	7-14	No	Solidago / Solidaster	7-10	No
Hyacinth	3-7	Slightly	Statice	4-8+	Moderately
Hydrangea	5-10	Moderately	Stock	5-8	Moderately

Hypericum	10-21	No	Sunflower	5-12+	Slight/Mod
Iris	2-6	No/Mod	Sweet Pea	3-7	Extremely
Kangaroo Paws	8-25	No	Tuberose	4-10	Slightly
Larkspur	4-12	Extremely	Tulip	3-7	Slight/Mod
Leptosperum	3-5	Moderately	Waxflower	5-9	Extremely
Liatris	6-14	No	Yarrow	5-10+	
Lily (Hybrids)	4-11	Moderately			
Lisianthus	10-14	Slight/Mod			
Marguerite (Daisy)	4-7	No			

Source: growerdirect.com (n.d).

2.11 Harvesting of Cut Flowers

2.11.1 Time and Mode of Harvesting of Flowers

The ideal stage of maturity varies with the intended use. Flowers for direct sale to final consumers, such as in farmer's markets, should be harvested slightly more mature than flowers sold to retailers for resale. Selling to wholesalers requires a slightly less mature flower than a retailer would require. Flowers for drying should be harvested when almost fully open (Stevens, 1995). Dole and Schnelle (2001) also explained that the optimum stage of harvesting cut-flowers varies with the species grown and the time of the year. Some species may be harvested at a less mature stage during the summer, when warmer temperatures may induce rapid development. Moreover, morning harvest is often advantageous over afternoon harvests, because the temperature is lowest during the morning, plant water content is high, and the rest of the day is available for packing and flower distribution. According to Reid (2009), the minimum harvest maturity for a cut-flower crop is the stage at which harvested buds can be opened fully and have satisfactory display life after distribution. Many flowers are best cut in the bud stage and opened after storage, transport or distribution. This technique has many advantages, including reduced growing time for single-harvest crops,

increased product packing density, simplified temperature management, reduced susceptibility to mechanical damage and reduced desiccation. Many flowers are presently harvested when the buds are starting to open (rose, gladiolus), although others are normally fully open or nearly so (chrysanthemum, carnation). Flowers for local markets are generally harvested much more open than those intended for storage and/or long-distance transport (Reid, 2009).

2.11.2 Harvest Containers

Due to the danger of contaminating flowers with disease organisms, it is advisable that harvested flowers are not placed on the ground. Stevens (1995) suggested that when choosing containers to keep harvested flowers, plastic containers should be considered over their metal counterparts for the following reasons:

1. Metal containers have the possibility of rust formation and blocking the stems' conductive tissue.
2. Chemicals in floral preservatives may also react with metal containers.

2.12 Packaging and Transportation of Cut Flowers

Cut-flowers are often packed in boxes made of cardboards during transportation. According to Reid (2009), there are many shapes of packing containers for cut flowers, but most are long and flat with the top completely overlapping the bottom. This design restricts the depth of the flowers in the box, which may in turn reduce physical damage of the flowers. In addition, flower heads can be placed at both ends of the container for better use of space. With this kind of flower placement, whole layers of newspaper are often used to prevent the layers of flowers from injuring each other. The use of small pieces of newspaper to protect only the flower heads, however, is a better practice, since it allows for more efficient cooling of flowers after packing. It is

critically important that containers be packed in such a way that transport damage is minimized (Reid, 2009). Stevens (1995) reported that flowering stems to be sold as a fresh product must be transported from the plant; to the harvester's arms; to the aisle between production beds; to a roadway; to a holding/storage facility; to a grading/packing area; to refrigerated storage; and finally to the delivery truck. Stems which will be marketed as preserved materials must also be transported in and out of processing areas and each of these product movement activities require a cooling chain system to be developed (Stevens, 1995).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Introduction

This chapter gives a vivid description of the location of the experiment, the procedure followed in the preparation of materials and solutions for the experiment and how the various treatments were laid out in the design. It also indicated how each data was collected and parameters obtained indicating appropriate formulae used where necessary. The statistical tool for the analysis of data was also indicated.

3.2 Experimental Site

The study was conducted at the Spanish laboratory of the Faculty of Agriculture, Nyankpala campus of the University for Development Studies, from July to August, 2016. Nyankpala is situated at Tolon. Geographically, the campus lies within latitudes 9° 25'N and longitude 0° 58' W. Nyankpala is 16 km (10 miles) away from Tamale, the capital of the region with an altitude of 183 m above sea level.

3.3 Pulsing treatments

Treatments used to condition the cut flowers ranged from the individual and combined concentrations of water, vinegar and sucrose solutions with one that was kept dry with no solution at all as the control. Water used in the experiment was obtained from tap water from the University's Spanish laboratory and slightly warmed to a temperature of about 33 °C (Arteca, 2006).

3.4 Flower Vases

Vases were washed with hot soapy water to remove debris and eliminate the bacteria and fungi that contribute to deterioration of flower stems (Geisel and Unruh, 2004).

3.5 Plant Material

On the basis of value and usage, *Heliconia psittacorum* was selected for the study. This plant is cultivated by flower producers as a cut flower and also for export to the EU markets on a very small scale (Ghana Investment Promotion Centre - GIPC, 2002). The flower was obtained from the Department of Horticulture, Faculty of Agriculture, Kwame Nkrumah University of Science and Technology in Kumasi.

3.6 Methodology

Thirty plant materials of *Heliconia psittacorum* were collected and sent to the Spanish laboratory around 17:00 hours Greenwich Mean Time (G.M.T.). The plants were harvested at the stage when the buds were tight and the sepals enclosed in the flower bud (Souza et al., 2015). Twenty of the plant materials were carefully selected with all diseased parts removed to prevent the possibility of having diseases affecting the results of the study. Also to avoid any form of crushing of the xylem cells which can lead to vascular blockage of water pathway into the stalk, flower stems were cut diagonally using a sharp knife. The fresh weight of each cut flower was immediately weighed using the electronic scale and immersed into the vase solution to facilitate absorption. To ensure that cut flowers stood well in the vases without causing the vases to topple over due to an unbalanced weight, they were cut to lengths a little longer than the 30 cm while the vases had a height of 22.0 cm (Owusu, 2013). On the 7^{th} day, stems of cut-flowers were recut to a length of 30.0 cm. Black tapes were used to hold the base of the vases that had no solutions in them to keep them firm preventing them from falling. The cut ends were slanted to allow room for water infiltration into the stalk when it stood in the vase. Methylated spirit was used to sanitize the blade of the knife each time they were used on a different plant to avoid contamination or pathogen transfer. The prevailing room temperature was also noted and recorded daily whiles

the solution was changed on the 7th day (Owusu, 2013). The vases containing the treatments and the individual cut-flowers were finally arranged in a Completely Randomized Design (CRD) and kept at room temperature with 12 hours of photoperiod under cool-white fluorescent light. Evaluations were made and the postharvest physiological characteristics of the flower stems were studied throughout the vase life period (Gebremedhin et al., 2013).

3.7 Experimental Design

The Completely Randomized Design (CRD) was used with five treatments and four replications. The layout is as shown below.

Table 4: Experimental Layout

$R_4 T_4$	$R_3 T_1$	$R_4 T_5$	$R_3 T_2$	$R_3 T_4$
$R_1 T_1$	$R_2 T_1$	$R_4 T_1$	$R_1 T_3$	$R_2 T_4$
$R_1 T_5$	$R_2 T_3$	$R_2 T_5$	$R_4 T_3$	$R_2 T_2$
$R_3 T_3$	$R_1 T_4$	$R_1 T_2$	$R_3 T_5$	$R_4 T_2$

"R" represents replication; "T" represents the various treatments used in the experiment.

Treatments

Treatment one (T1) – No Water (NW)

Treatment two (T2) – 1.0 litre (l) of Water Only (WO)

Treatment three (T3) – 5.0 ml of Vinegar + 1.0 litre of Water (Vs)

Treatment four (T4) – 10.0 grams of Sucrose + 1.0 litre of Water (Ss)

Treatment five (T5) –5.0 ml of Vinegar +10.0 grams of Sucrose + 1.0 litre of Water (Vs + Ss)

3.8 Treatments and pH of Solutions

The pH meter was used to measure the pH of all the treatments and their replicates with the exception of the control treatment which had no solution (stored dry). This

was repeated anytime the solutions were renewed and the average pH for each treatment was calculated.

3.9 Vase Life of *Heliconia psittacorum*

The vase life of the cut-flower was determined by counting from the day the cut-flower stems were transferred to the keeping solutions and was assessed to be terminated when flowers lost their ornamental/ aesthetic value (underwent color change; wilted and lost turgidity) (Asrar, 2012).

3.10 Parameters Measured

3.10.1 Relative Fresh Weight (RFW)

The flower stems were assessed for fresh mass change (%). The electronic balance was used to take the fresh weights of cut-flower stems just before the immersion of the flowers into the keeping solutions and repeated daily after the third day by taking them out of solutions for such a short time as possible and placed on the scale (20 to 30 s) interval. This was done periodically until the vase life of the flowers were terminated. The RFWs of flowers were obtained using Joyce and Jones (1992) formula.

$$\text{Relative Fresh Weight} = \frac{\text{Final Weight}}{\text{Initial Weight}} \times 100$$

3.10.2 Loss in Weight (%)

Percentage loss in fresh weight of cut flowers was calculated at the end of each week when the vase solutions were renewed. The difference in weight of cut flowers for each week was expressed over the initial weight of cut flowers at the beginning of the week as a percentage.

$$\text{Loss in Weight} = \frac{(\mathbf{Wt} - \mathbf{Wt^{-7}})}{\mathbf{Wt}} \times 100$$

where **Wt** is the weight of cut flower (g) at the beginning of each week and $\mathbf{Wt^{-7}}$ is the weight of cut flower (g) at the end of every 7^{th} day.

3.10.3 Solution Uptake in Millilitres (ml)

Water consumption was quantified from the third storage day and estimated by the average difference between the initial volume already established in a measuring cylinder (1000 ml) and the volume of water obtained at the end of each assessment. The volume of solution in each vase was measured daily from the third day throughout the vase life period. The difference between the initial (W_1) and the final solution (W_2) levels in the vase was determined by subtracting the initial volume from the final volume (Owusu, 2013).

That is = Amount of solution taken up by cut flowers = W_1-W_2

where W_1 = Initial volume of solution in the vase (1000ml) and W_2 = Final volume of solution in the vase after every third day.

3.10.4 Flower Longevity

Flower longevity was determined by counting from the day the cut-flower stems with foliage were transferred to the keeping solutions and was terminated on the day it was observed that flowers have lost their ornamental/ display value (underwent color change; wilted and lost turgidity) (Asrar, 2012). Longevity was estimated as the percentage of inflorescences rates higher than or equal to 2 for the visual appearance (unsatisfactory marketable rate) during the period from harvest up to 14 days.

Visual appearance was evaluated using a subjective rating scale from 5 to 1, proposed by Souza (2008a), in which 5 was for turgid flower stem and/ or the bract; 4, when the stem or the bract was at the onset of colour changing; 3, was the loss of turgor of the stem and dried at the tips of the bracts; 2, the presence of small spots on the stem and/or on the bract; 1, necrosis and prominent spots on the stem and/or on the bracts.

3.10.5 Flower Opening

Inflorescences were harvested a few days earlier than the commercial stage since sugar pulsing treatment was used to enhance flower bud opening (Halevy et al., 1978). A subjective rating scale (1 to 5) in flower opening, of 'Golden Touch' heliconias proposed by the formation of a new pointer and the expansion of the third formed bract (Souza, 2008a) (Appendix 1).

3.10.6 Statistical Analysis

Data were subjected to Analysis of Variance (ANOVA) using Genstat software version 4.10.4 (Genstat, 2014). Verification of significant differences was done using LSD test at 5% probability level.

CHAPTER FOUR

4.0 RESULTS

4.1 Introduction

This chapter displays figures, tables and plates with explanation on the outcomes of the experiment carried out. Confidence level and least significant differences where necessary were stated to substantiate the outcomes.

4.2 pH of Preservative Solutions

It was observed from (Table 5) that preservative solutions such as (1000ml WO and 1000ml W + 10g S) with high pH values or slightly acidic showed longer vase life than those stored in solutions such as (1000ml W + 5ml V) and (1000ml W + 5ml V + 10g S) of lower pH values or highly acidic.

Table 5: Effects of preservative solutions on the pH

Treatment	**pH**	
	week 1	**week 2**
NW (Control)	-	-
1000ml WO	4.45	5.615
1000ml W + 5ml V	3.26	2.860
1000ml W + 10g S	5.21	5.250
1000ml W + 5ml V + 10g S	3.26	2.945
LSD	**0.667**	**0.3027**
P-VALUE	**<0.001**	**<0.001**

4.3 Analysis of Mean Water Uptake (ml)

Data collected on water uptake rate and water loss rate change of cut flowers stored in different solutions showed that, the flowers in the vase containing WO experienced the highest volume of water uptake or loss followed by W + S as compared to the other treatments. The flowers in the W + V solution absorbed the least water during the vase life period. A similar result was earlier reported by Owusu (2013) using various levels of sucrose and sodium benzoate solutions on *H. psittacorum* cut flowers. Seyf et al. (2012) found that because of more water absorption, aluminum treated flowers of cut rose 'Boeing' had more RFW than control. A general increase in water loss or uptake was observed in week 2 for all treatments after re-cutting of flower stems (Table 6). Uptake was adequate to maintain stems for 11.50-14 days but was inadequate to fully open the flower.

Table 6: The effects of preservative solutions on the Water uptake rate of *Heliconia psittacorum* cut flowers at the end of week 1 and 2.

Treatment	Mean water uptake in millilitres (ml)		
	week 1	week 2	Total
NW	-	-	-
WO	83.00	86.25	169.25
W + V	70.25	78.75	149.00
W + S	71.5	82.00	153.50
W + V + S	68.25	79.00	147.25

Values are means of four replicates of each treatment

4.4 Relationship between RFW and Vase Life of Cut Flowers

Graphical representations of the Relative Fresh Weight in Figures 1 and 2 below bring out marked differences in the behaviour of *Heliconia psittacorum* cut-flowers stored *dry* and those stored with the stems in water, vinegar, and sucrose solutions used either

singly or in combination. The cut-flower stems were kept in the solutions after which the stems were re-cut on the 7th day with the solutions also renewed.

Fresh weights of flowers kept in different solutions at the end of week 1 showed a marginal decline with senescence within the first five days irrespective of the treatment. The *dry* treatment showed a sharp decline just after the 4th day. After the 3 and 4 days of vase life, the fresh weights of flowers receiving water, sucrose and vinegar either singly or in combination were significantly different from that of the control (Figure 1).

Week 2 showed marginal fluctuations in the relative fresh weights of flowers stored in water only and sucrose solution respectively within day 8 to 10 after which a marginal decline in these two treatments was observed from day 10 to 14 of vase life of cut flowers. Flowers stored in combined concentrations of vinegar and sucrose solution and vinegar solution respectively showed a gradual decline in their relative fresh weights from day 8 to 14 (Figure 2). The declined RFW during prolonged storage time might be due to high water loss and the declining solution uptake (Bayleyegn et al. 2012). Cut flowers stored dry again showed a sharp decline in their fresh weights which indicated a significant difference between those stored in pulsing solutions.

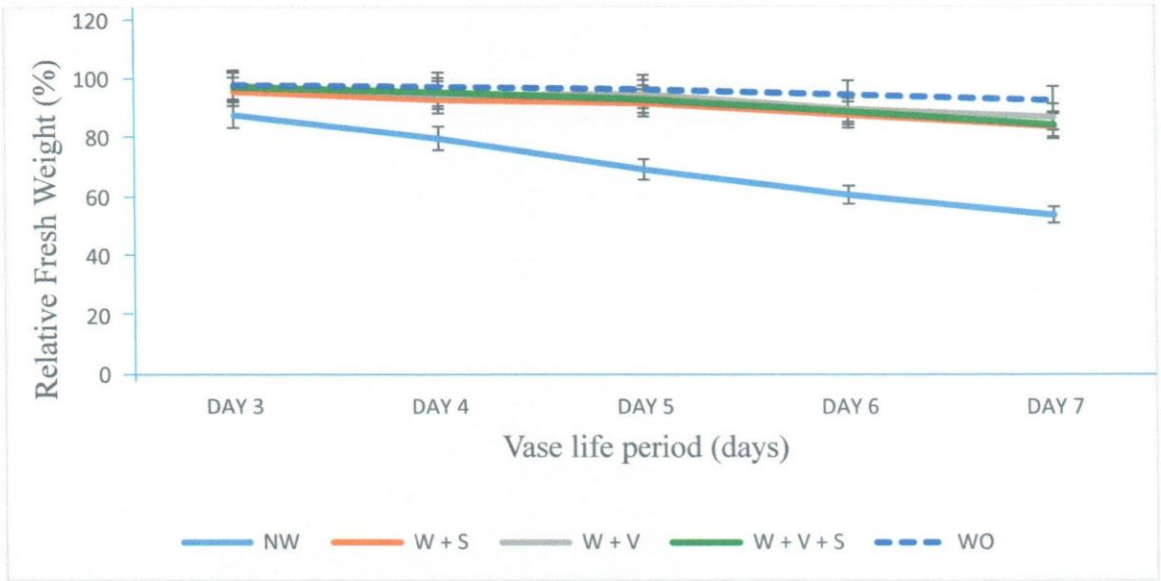


Figure 1: Variation in relative fresh weight of cut flowers at the end of week 1.

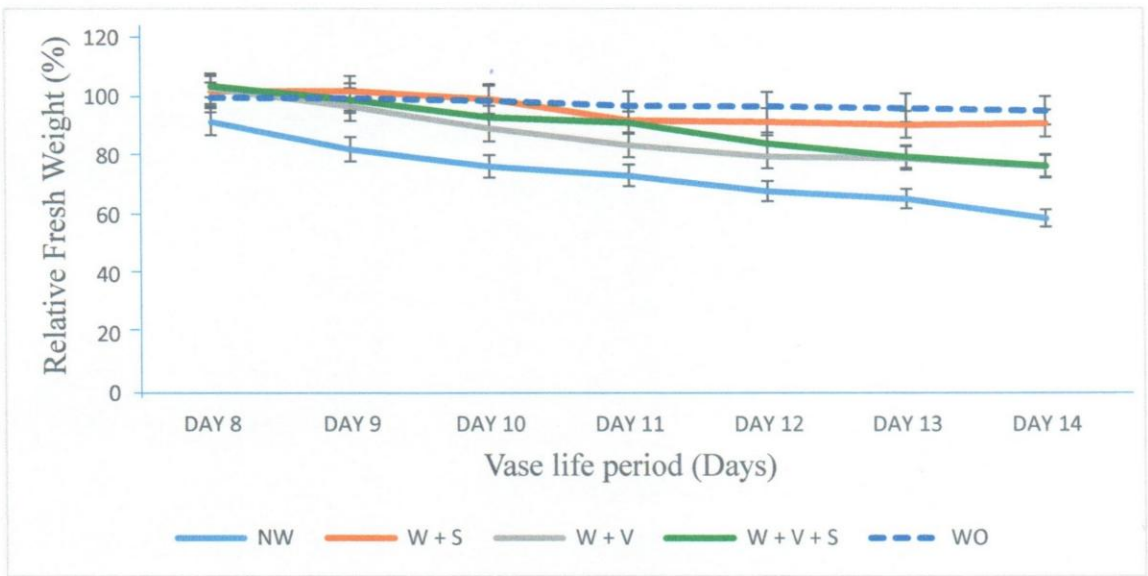


Figure 2: Variation in relative fresh weight of cut flowers at the end of week 2.

4.5 Analysis of Percentage Loss in Weight

There has been a significant difference ($p < 0.001$) in percentage weight loss among treatments applied on cut flowers. The control (NW) treatment which has cut flowers stored dry recorded the highest percentage weight loss with treatment (W + V + S) recording the least in both week 1 and week 2 (Table 7).

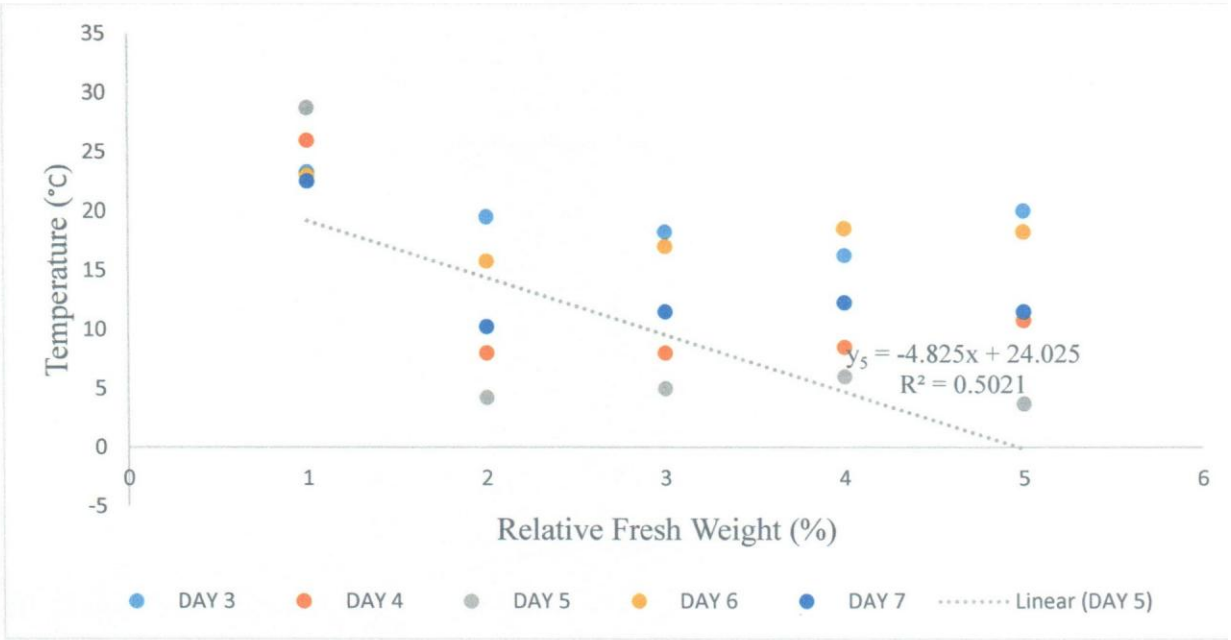


Figure 3: Generalized linear regression model for temperature and RFW.

Figure 3 above was also used to show the linear relationship between temperature and relative fresh weight. From the graph, there is an indication of an inverse relationship between temperature and relative fresh weight of cut flowers on day five. This means that an increase in temperature brings about a reduction in the weight of fresh *Heliconia* cut flowers.

Table 7: Comparison of percentage weight losses between week 1 and week 2.

Treatment	Weight loss (%)	
	week 1	week 2
NW	45.6	41
WO	15.9	9
W + V	12.7	23.6
W + S	15.3	23.3
W + V + S	7.1	4.7
LSD	**8.81**	**12.49**
P-VALUE	**<0.001**	**<0.001**

4.6 Effect of Ambient Temperature on Water Uptake

Figure 4 below showed a sharp rise in ambient temperature from day 3 to day 5 after which a sharp decline was observed on day 6. From day 8, there has been a low steady temperature through to the end of the vase life period (day 14).

Figure 5 also showed an initial rise in water uptake from day 3 to day 4 after which a fall in uptake was observed on day 6. There was an increase and a decrease in water uptake from day 6 to day 8 after which a low steady uptake was observed up to the last day.

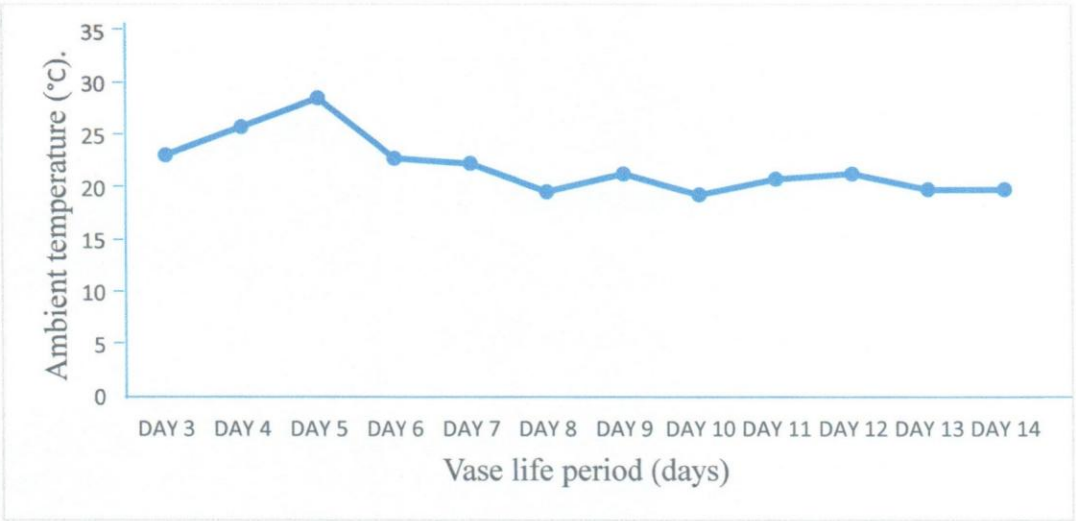


Figure 4: Variation in daily ambient temperature.

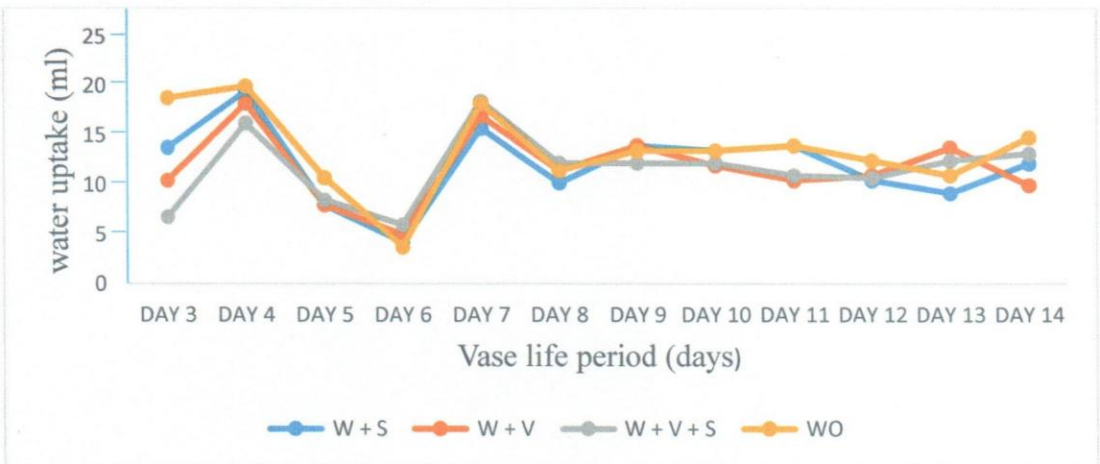


Figure 5: Variation in daily water uptake.

There was a direct relationship between ambient temperature and daily water uptake. This means that a decline in ambient temperature resulted in a corresponding decrease in water uptake by the cut flowers and vice versa. This was seen in the simultaneous increase and decrease in ambient temperature and daily water uptake respectively from day 3 to day 8 after which a relatively lower and steady daily variable temperature with corresponding mean water uptake was observed from day 8 to day 14 (Figures 4 and 5). The water uptake rate of the psittacorum types 'Lady Di' and Sassy' declines after harvest (Paull and Chantrachit, 2001). For 'Parakeet', the average water uptake rate is 3ml per inflorescence with no leaves during the first 15 days after harvest. The greater the number of leaves left attached to the stem, the greater the water uptake rate (Ka-ipo, *et al.*, 1989). However , since there are no above ground vascular connections between the flower peduncle and the leaves (Criley and Broschat, 1991), the higher rate of water uptake when the leaves are attached has no effect on flower vase life (Ka-ipo et al., 1989).

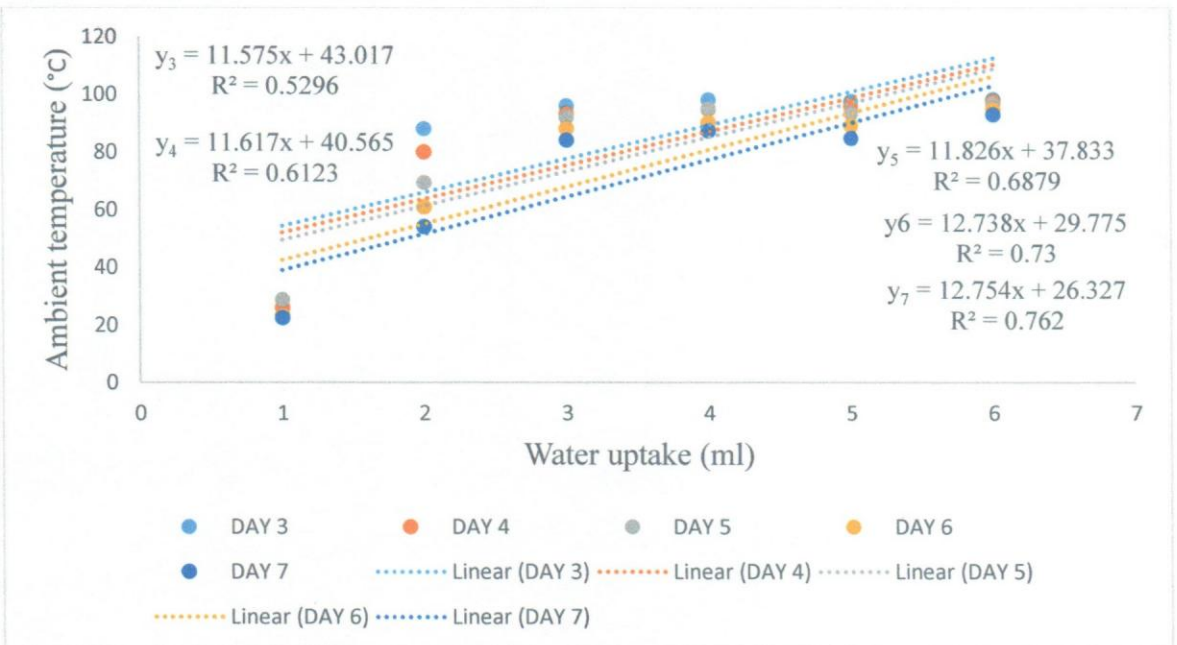


Figure 6: Generalized linear regression model for ambient temperature and water uptake.

A linear regression was used to find the linearity between temperature and water uptake. It was observed that a strong linear relationship existed between temperature and water uptake during the first seven days of vase life period. This implies that an increase in temperature resulted in an increase in water uptake or loss and vice versa (Figure 6).

4.7 Relationship between Mean Water Uptake and Average Vase Life

The graph in Figure 3 showed a direct correlation between water uptake and average vase life (flower longevity). The highest average vase life of 14 days was recorded by cut flowers stored in WO which also recorded a maximum water uptake or loss of 169.25 ml whiles those stored in W + V + S recorded the least water loss or uptake (Table 6) with a corresponding average vase life of 11.50 days among those stored under wet conditions. In the current study, the best relative fresh weight maintained on cut flowers treated with *WO* could be related to reduced microbial load in the vase solution and hence, solution usage as confirmed by (Gebremedhin et al., 2013). Cut flowers stored under dry conditions (control) lasted for 6.75 days.

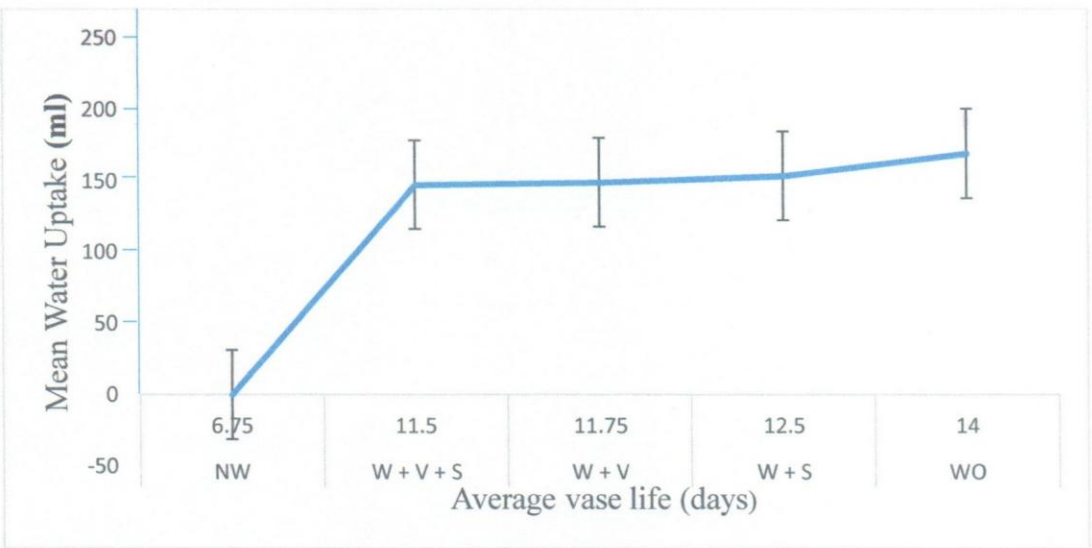


Figure 7: Relationship between mean water uptake and average vase life.

4.8 Visual Appearance

Visual appearance was evaluated using a subjective rating scale from 5 to 1, proposed by (Souza, 2008b), in which 5 was for turgid flower stem and/or the bract; 4, when the stem or the bract was at the onset of colour changing; 3, was at the loss of turgor of the stem and dried at the tips of the bracts; 2, the presence of small spots on the stem and/or on the bract; 1, necrosis and prominent spots on the spots on the stem and/or on the bracts. At the beginning of the experiment, all the cut flowers selected and used appeared to be in the rating scale 5. At the end of the vase life period, the Control (NW) treatment which recorded the least average vase life of 6.75 days appeared to have all the visual ratings signs except scale 5 for turgid flower stem and/or the bract. The cut flowers in 1000mls WO which recorded the highest average vase life of 14 days still recorded scale 5 on the last day. Cut flowers in (1000ml W + 5ml V), (1000ml W + 10g S) and (1000ml W + 5ml V + 10g S) treatments which recorded average vase lives of 11.75, 12.5 and 11.50 respectively also had visual appearance ratings of 4, 3 and 2 at the end of their vase period.

A score of 1 – 3 as proposed by Tshwenyane and Bishop (2011) for disease incidence of the petals of 'Duett' was used to score the incidence of disease of the petals of *Heliconia psittacorum*. Disease as indicated by tissue browning in the inner whorl was scored 1; the disease has spread into the second inner whorl was scored 2; the disease has spread in all the whorls with severe petal infection causing the outer petals to fall off was scored 3. At the end of the vase life period, disease incidence rating beginning from 1, disease as indicated by tissue browning in the inner whorl on day 3 with its severity increasing to 3, when the disease has spread in all the whorls with severe petal infection causing the outer petals to fall off on the cut flowers used in the Control

(NW) treatment was recorded. No sign of disease incidence was observed on the cut flowers in the other treatments.

The flower opening was estimated on a subjective rating scale of (1 to 5) proposed by Souza (2008a) for 'Golden Touch' Heliconia considering the formation of a new pointer and the expansion of the third formed bract (Appendix A). Flowers were rated 1- when inflorescences presented two opened bracts and the pointer; 2- when inflorescences presented two opened bracts and onset of the pointer opening, from which a third bract was formed; 3- inflorescence with the third bract partially expanded towards the pointer; 4- the third quite expanded bract, forming an angle perpendicular to the pointer; and 5- for inflorescence with three completely expanded bracts and with the pointer. At the end of 14 days of evaluation, only the cut flowers in 1000ml WO and 1000ml W + 10g S treatments showed inflorescences which presented two opened bracts and onset of the pointer opening, from which a third bract was formed.

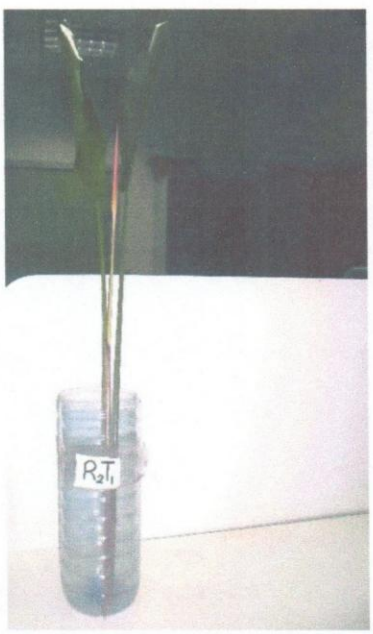


Plate 4: NW appearance at day

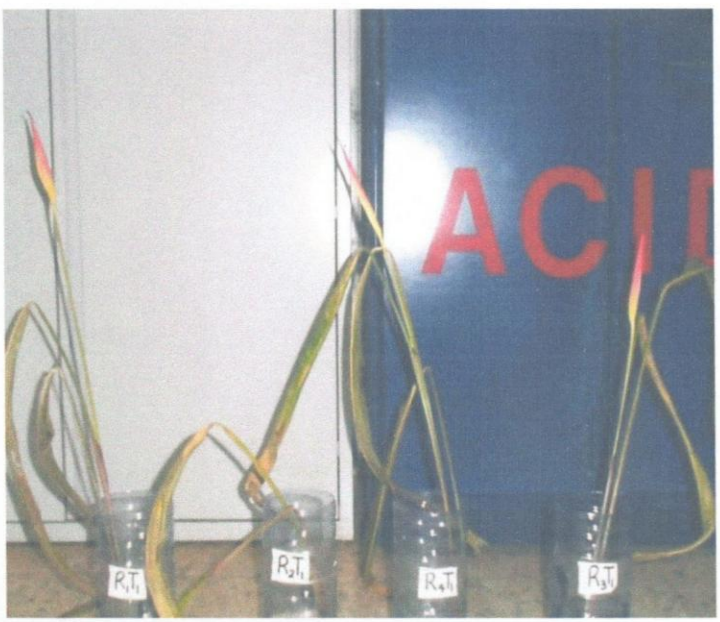


Plate 5: NW appearance at day 7

Plate 6: WO appearance at day 1

Plate7: WO appearance at day 14

Plate 8: W+V appearance at day 1

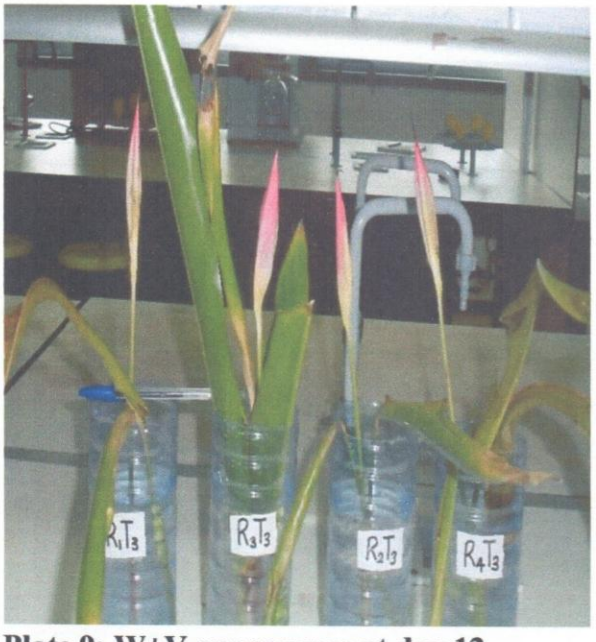


Plate 9: W+V appearance at day 12

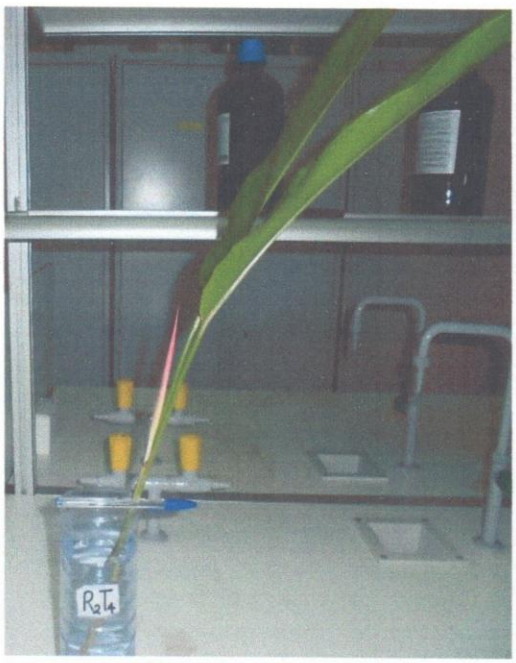


Plate 10: W+S appearance at day 1

Plate 11: W+S appearance day 12

Plate 12: W+V+S appearance day 1

Plate 13: W+V+S appearance day 12

4.9 Vase Life

The results given in Table 8 depicted an average vase life of *Heliconia psittacorum* cut flowers held under dry and wet conditions. Significant effects ($p < 0.05$) were found on the longevity of the storage of the cut flowers for all pulsing treatments as compared to those stored dry (control). There was as a gradual decline of flowers and foliage appearance in function of the storage length. Flower stems treated with pulsing solutions kept a satisfying commercial quality until the twelve day of storage, and thereafter they were unfit for marketing (Table 4). The vase life was longer in flowers treated with (1000ml W + 5ml V + 10g S) and (1000ml W + 5ml V) which resulted in 11.50 and 11.75 days respectively in comparison with 6.75 days of the control ones (Table 4). Although, (1000ml W + 10*g* S) resulted in longer vase life of 12.5 days compared to the latter two treatments, the longest vase life was attained when 1000ml WO was applied, where it gave 14 days in comparison with the other treatments. This result conforms with earlier works of Owusu (2013) using different levels of sucrose and sodium benzoate solutions to extend the vase life of *Heliconia psittacorum* cut-flowers.

Table 8: Effects of preservative solutions on the vase life of *H. psittacorum* cut flowers

Treatment	Vase life (Days)
NW (Control)	6.75
1000ml WO	14
1000ml W + 5ml V	11.75
1000ml W + 10g S	12.5
1000ml W + 5ml V + 10g S	11.50
L.S.D 5%	**0.728**
P-VALUE	**<0.001**

The values of each treatment are means of four replicates obtained from *H. psittacorum* cut flower.

CHAPTER FIVE

5.0 DISCUSSIONS

5.1 Discussion of Results

Cut flowers in the control treatment experienced a sharp decrease in fresh weight throughout the vase period that recorded the lowest vase life of 6.75 days as against 14 days of those stored in *WO*. The rapid decrease in weight can be attributed to lack of keeping quality since cut flowers were deprived of water and nutrients which they needed to carry out metabolic and physiological activities to promote longevity. Since the cut portion is exposed to air, there is the likelihood of air embolism and vascular blockage. Hardenburg (1968) reported that one of the greatest problems in postharvest flower physiology is the blockage of vascular system, due to air or bacterial growth, which reduces water uptake and this blocks xylem vessels leading to water stress. That was expressed in the form of early wilting of leaves or flowers Henriette and Clerkx (2001), as a result of premature loss of cell turgidity and might appear when water uptake and transpiration are out of balance during a lasting period of time. This finally leads to an unrecoverable situation and the premature end of flower vase life (Van Meetern et al. 2001).

Flowers stored with the stems in either single or combined concentrations of water, vinegar, and sucrose solution(s) recorded a slight gain in weight and immediately had moisture available in unlimited quantities for any chemical or physical reactions. This might have accounted for the marginal fluctuations in the relative fresh weights of flowers within day 8 to 10 after which a marginal decrease was observed from day 10 to 14 of vase life (Figures 1 and 2). Gebremedhin et al. (2013) also reported that the increment in RFW of cut rose flowers at initial vase life days could be due to the higher solution uptake during the early storage time.

The general increase in water uptake or loss for all treatments in week 2 could be due to the re-cutting of flower stems preventing vascular blockage. One of the greatest problems in postharvest flower physiology is the blockage of the vascular system due to air or bacterial growth which reduces water uptake and this blocks xylem vessels leading to water stress (Hardenburg, 1968). According to Jones (2001), when flower stems are cut in air, bubbles of air (emboli) are drawn up (about 2 cm to 3 cm up flower stems) the xylem vessels causing vascular blockage hence re-cutting the flower stems can facilitate water and nutrient uptake. Water uptake was also facilitated when stems were cut with a sharp knife at an angle so that they will not sit flat in the bottom of the vase solution preventing water uptake (Jones, 2001).

With the exception of few cut flowers in WO and W + S treatments that were observed open, most of the cut flowers used for the experiment failed to open at the end of the vase life period. According to Broschat and Donselman (1984) in studies carried out in Florida, USA, Heliconias showed no additional opening of bracts after harvest therefore recommended that Heliconias should be harvested when they reach an appropriate commercial level.

The stress that flowers went through by exposing them to temperature fluctuation had an impact on the disease incidence which was manifested in some of the florets in the control treatment. *Botrytis cinerea* has been identified as a cause of floret browning and bract lesions (Halevy et al., 1978) and dipping flowers in 200 $mg \cdot l^{-1}$ benomyl is recommended (Halevy et al., 1978; Criley and Paull, 1993). This treatment is also recommended as postharvest treatment to control saprophytic mold on heliconia (Paull, 1991). These molds may reflect a carry-over of spores to postharvest storage stage from the field treatments used to control diseases and nematode (Criley, 1996).

This pattern has also been reported in strawberry (Nunes and Edmon, 1999) and mushrooms exposed to fluctuating temperatures (Tano et al., 2007).

When Heliconia flowers were stored with their basal parts in water, the effect of temperature on vase life were same as those stored dry. The vase life of those stored wet was significantly better than that of the dry-stored comparison flowers. The impact of fluctuating temperatures had a negative effect on the weight loss which is then related to the shorter vase life of the flowers

It was observed that, the four wet treatments which were applied to the cut-flowers under the same temperature conditions had significant effects (was beneficial) on vase life compared to those stored dry. Two of the preservative solutions stood outstanding W + S and WO with the latter preservative solution leading. This could have been owing to the fact that, the cut flowers that were used for the research were harvested in the evening and might have accumulated enough food or energy in the stems for development during the day and therefore did not depend on exogenous sugars to keep them alive. Dickey (1950) reported that the factor that usually limits the length of life of cut flowers is lack of water for the stem, foliage and flowers. Cut-flowers loose water at low humidity, high temperatures, and air circulation or when the end of the stem becomes plugged preventing enough water from being taken up by the stem to supply to the top.

The other two preservative solutions W + V and W + V + S even though had significant effects on vase life compared to those stored dry, had a lower vase life compared to W + S and WO. Jones (2001) reported that bacterial infection is one of the contributing factors to cut-flower deterioration are inactive in acidic conditions. It was proposed that when one intends to prepare a flower preservative which includes

an acidifier, the pH must be around 3.5. The pH of W + V and W + V + S treatments were observed to be lower than the 3.5 proposed by Jones (2001), (pH < 3.2).

The low pH was as a result of the addition of vinegar (an acidifier) which might have been slightly injurious to the cut-flowers which resulted in the severe foliage burn. The visual sign of deterioration was noticed in the form of wilting or browning of foliage and stem. Hitchcock and Zimmerman (1929) found that none of the compounds including acetic acid (vinegar) used was noticeably effective in prolonging the life of cut flowers used in their experiment. Geisel and Unruh (2004) also advised that aspirin, vinegar, or diet sodas should not be used in the vase solution when preparing flower preservatives since they will not contribute to the longevity of floral arrangement and may, in fact, decrease it. It was also obvious that the cut flowers that were kept under dry conditions (NW/control) recorded the lowest vase life because they were deprived of water and food which are the main ingredients in prolonging vase life of cut flowers.

CHAPTER SIX

6.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

6.1 Summary

Research over the years has been made to understand the factors that affect the life of cut flowers and also to find the most successful preservative to decrease the normal development of cut flowers without initiating undesirable physiological reactions. The main aim of this research was to develop the most effective postharvest treatment to reduce the senescence of *Heliconia psittacorum* cut flowers, extend the vase life and maintain the freshness. Comparisons were made between flowers stored under wet conditions and those stored under dry conditions (no preservative). The Completely Randomized Design (CRD) was used with five treatments and four replications. The treatments were: 1000 ml of water only (WO), 1000 ml of water + 5 ml of vinegar (W + V), 1000 ml of water + 10 g of sucrose (W + S), 1000 ml of water + 5 ml of vinegar + 10 g of sucrose (W + V + S), and a control with no preservative (NW). The result indicated that maximum increase in fresh weight and water loss or uptake has a positive correlation with vase life of *Heliconia psittacorum*. Preservative solutions with very low pH (pH < 3.2) were also suspected to have a detrimental effect on the longevity of the cut flowers at the expense of bacteria inhibition. WO treatment applied to the cut-flowers was found to be outstanding. *H. psittacorum* cut-flowers stored in WO wilted slightly but were many times better and more turgid than NW, W + V, W + S, and W + V + S treatments at the end of the 14 days vase period.

6.2 Conclusion

The longest vase life, maximum fresh weight and highest vase solution absorbance was maintained due to the treatment of *(WO)* preservative solution and the lowest vase life, fresh weight and vase solution absorbance was recorded from cut-flowers treated

with (*W + V + S*). Treatment of the cut flowers using (*W + V + S*), (*W + V*), (*W + S*), and (*WO*) extended the vase life of the cut flowers by 11.50, 11.75, 12.50 and 14 days, respectively than the control which lasted for 6.75 days. Generally, it can be concluded that the use of (*WO*) as a preservative solution for flower longevity and maintaining post-harvest characteristics of cut flowers is important for *Heliconia psittacorum*.

6.3 Recommendations

Based on the results of the experiment, consumers and commercial cut flower users could use *water only* or (*W + S*) to prolong the vase life and keeping quality of *Heliconia psittacorum* cut flowers. Clean and treated water with pH not less than 3.5 should be used as a preservative since contaminated water can cause microbial infection and high acidity could also be injurious to the cut flower.

Where a pulsing solution which includes sucrose must be prepared and used as a preservative, it is advisable to use (1% sucrose dissolved in water, W/V) or 10 g of sucrose dissolved in 1 litre of water.

A major problem for most tropical cut flower is chilling injury. Recommended temperature varies with commodity, and may also vary with cultivars. Little is known about relationship between exposure time and temperature for most tropical cut flowers.

It is recommended that further studies be carried out to ascertain the suitable postharvest storage temperature required to give a longer vase life during floral display or air freighting.

REFERENCES

Arteca, R. N. (2006). *Introduction to Horticultural Science*. Cengage Learning Costumer and Sales Support, 1-256.

Asrar, A. A. (2012). Effects of some preservative solutions on vase life and keeping quality of snapdragon (Antirrhinum majus L .) cut flowers. *Journal of the Saudi Society of Agricultural Sciences*, *11*(1), 29–35. http://doi.org/10.1016/j.jssas.2011.06.002

Bayleyegn, A., Tesfaye, B., and Workneh, T. S. (2012). Effects of pulsing solution, packaging material and passive refrigeration storage system on vase life and quality of cut rose flowers. *Afr. J. Biotechnol.*, *11*(16), 3800–3809.

Bogash, S. M., County, F., Ford, T. G., County, B., Kime, L. F., and Harper, J. K. (2012). Cut-Flower Production. *Agricultural Alternatives*, 1–8.

Bowyer, M. C., and Wills, R. B. H. (2003). Delaying postharvest senescence of cut flowers using nitric oxide. *A Report for the Rural Industries Research and Development Corporation.*, *03*(51), 11.

Broschat, T. K., and Donselman, H. M. (1983). Production and Postharvet culture of Heliconia psittacorum flowers in South Florida. *Proc. Fla. State Hort. Soc.*, *96*, 272–273.

Broschat, T. K., and Donselman, H. M. (1984). Andromeda, a red and orange heliconia for cut-flower use. *Circular S-Florida, Agricultural Experiment Station*, *309*, 309.

Chantrachit, T., and Paull, R. E. (1998). Effect of hot water on red ginger (Alpinia purpurata) inflorescence vaslife. *Postharvest Biol. Technol.*, *14*, 77–86.

Criley, R. A. (1996). Techniques of cultivation in the ornamental Zingiberaceae. *Bul. Heliconia Soc. Intl.*, *8*, 7–11.

Criley, R. A., and Broschat, T. K. (1991). Heliconia: Botany and horticulture of a new floral crop. *Hort. Rev.(Accepted for Publication)*.

Criley, R. A., and Paull, R. E. (1993). Review: Postharvest handling of bold tropical cut flowers Anthurium, Alpinia purpurata, Heliconia, and Strelitzia. *Acta Hort.*, *337*, 201–211.

Dahal, S. (2013). Post Harvest Handling of Cut-Flower Rose (pp. 1–19).

Dickey, R. D. (1950). Factors affecting the Keeping Quality of Cut Flowers. *Keeping Cut-Flowers-Florida Agricultural Experiment Station, Gainesville*, 203–206.

Dole, J. M., and Schnelle, M. A. (2001). The Care and Handling of Cut Flowers. *Division of Agricultural Sciences and Natural Resources*, *2*, 1–4.

Gast, K. L. B. (2000). Water Quality-Why it is so important for Florists. *Horticulture, Forestry and Recreation Resources*, *2*, 1–4.

Gebremedhin, H., Tesfaye, B., Mohammed, A., and Tsegay, D. (2013). Influence of preservative solutions on vase life and postharvest characteristics of rose (Rosa hybrid) cut flowers. *International Journal for Biotechnology and Molecular Biology Research*, *4*(December), 111–118. http://doi.org/10.5897/IJBMBR2013.0171

Geisel, P. M., and Unruh, C. L. (2004). Extending the Freshness of Cut Flowers at Home. *Division of Agriculture and Natural Resources. University of California*, 1–3.

GENSTAT®, 11th Ed (2014). A microcomputer software program for the design, management and analysis of agronomic experiments. *Crop and Soil Science Dept., Michigan State Univ. East Lansing, MI*.

Ghana Investment Promotion Centre - GIPC. (2002). Ghana Investment Profile: Floriculture. *A Publication of the Ghana Investment Promotion Centre (GIPC)*, 2.

Graphic (2014). Ghana wasting huge potential in horticulture - Export Authority. *Daily Graphic*. Accra. Retrieved from Graphic.com.gh, 2016, August 29, 13:43 hours GMT.

Growerdirect. (n.d.). Flowers -Vase Life in Your Home. http://www.growerdirect.com/flower-vase-life, 2017, August 7, 11:22 hours GMT

Gul, F., and Tahir, I. (2013). An effective protocol for improving vaselife and postharvest performance of cut Narcissus tazetta flowers. *Journal of the Saudi Society of Agricultural Sciences*, *12*(1), 39–46. http://doi.org/10.1016/j.jssas.2012.06.001

Halevy, A. H., Kofranek, A. M., and Besemer, S. T. (1978). Postharvest handling meth- ods for bird of paradise flowers (Strelitzia reginae Ait.). *American Society of Horticultural Science*, *103*, 165–169.

Hardenburg, R. . (1968). The commercial storage of fruits, vegetables and florist and nursery stock. *In: Lutz, J.M. (Ed.), Agricultural Handbook . United State. Department of Agriculture. Agricultural Research Service.*, (66), 130.

Henriette, M. C., and Clerkx, A. C. M. (2001). Anatomy of cut rose xylem observed by scanning electron microscope. *Acta Hortic*, *547*, 329–339.

Hintze, J., and Darwin, N. (2014). An identification picture book for heliconias and gingers for cut flower growers. *Jungle Plant & Flower Service*, 1–60.

Hitchcock, A. E., and Zimmerman, P. W. (1929). Effect of Chemicals , Temperature , and Humidity on the Lasting Qualities of Cut Flowers. *American Journal of Botany*, *16*(6), 433–440.

Jaeger, P., and Voisard, J.-M. (2003). Ghana Horticulture Sector Development Study. *Regional Study on Agricultural Trade Facilitation/Export Promotion in SSA Ghana*, 108.

Jesus, I. De, Viégas, M., Rodrigues, É. F., Almeida, D., Silva, S., Poliana, S., and Okumura, R. S. (2014). Growth and visual symptoms of macronutrient deficiency and zinc in Heliconia psittacorum cv . Golden Torch, 169–173.

Jones, R. (2001). Cut Flowers. In *Caring for cut Flowers* (2nd ed., p. 11). Collingwood: Landlinks press 150 Oxford Street (P.O. Box 1139) Collingwood VIC 3066 Australia.

Joyce, D. C., and Jones, P. N. (1992). Water balance of the foliage of cut Geraldton wax flower. *Postharvest Biol. Technol.*, *2*, 31–39.

Ka-ipo, R., Sakai, W. S., Furutani, S. C., and Collins, M. (1989). Effect of postharvest treatments with antitranspirant on the shelf-life of Heliconia psittacorum cv. Parakeet cutflowers. *Bul. Heliconia Soc. Intl.*, *4*, 13–14. 2017, August 7, 11:30 hours GMT.

Kress, W. J. (1990). The taxonomy of old world heliconia (heliconiaceae). *National Tropical Botanical Garden*, *6*(1), 1–58. Retrieved from http://www.jstor.org/stable/23188167, 2017, August 7, 11:33 hours GMT.

Leite, K. P., Costa, A. S., Pinheiro, P. G. L., Gomes, R. J., Loges, V. (2015). Postharvest of cut flower Heliconia stricta 'Bucky' stored under different conditions. Actya Hortic., 235-241.

Length, F. (2016). Growth responses of two varieties of Heliconia flowers to selected growth media in Port Harcourt , *10*(March), 68–76. http://doi.org/10.5897/AJPS2016.1401

McConnell, J., and Cruz, F. J. (2001). Heliconias. *Ornamental Notes*, 1–2.

Nair, S. A., Singh, V., and Sharma, T. V. R. S. (2003). Effect of chemical preservatives on enhancing vase-life of gerbera flowers Gerbera. *Journal of Tropical Agriculture*, *41*, 56–58.

Nunes, N. C., and Edmon, J. P. (1999). Quality of strawberries after storage in constant or fluctuatng temperature. *International Congress of Refrigeration*, *4*, 205.

Osei-Assibey, E. (2015). Export Promotion in Ghana. *African Center for Economic Transformation*, 1–21. Retrieved from www.acetforafrica.org., 2017, August 7, 14:30 hours GMT.

Owusu, S. K. (2013). The effects of different levels of sugar and benzoate on the extension of *Heliconia psittacorum* cut flowers. *College of Agriculture and Natural Resources, Kwame Nkrumah University of Science And Technology Kumasi*, 41.

Paull, R. E. (1991). Postharvest handling of Hawaii cut flowers for export,. *In: Proceedings: The Hawaii Tropical Cut Flower Industry Conference. HITAHR, Univ. Hawaii Res. Ext. Serv.*, *134*, 40–48.

Paull, R. E., and Chantrachit, T. (2001). Benzyladenine and the vaselife of tropical ornamentals. *Postharvest Biol. Technol.*, *21*, 303–310.

Ranwala, A. (2010). Effects of Water Quality on Cut Flower Hydration and Flower Food Solutions. *Floralife-The Care and Handling Experts*, *12*, 2.

Reid, M. S. (2009). Handling of Cut Flowers for Export. *Proflora Bulletin*, 1–26. Retrieved from http://ucanr.edu/datastoreFiles/234-1906.pdf, 2016, August 23, 14:23 hours GMT.

Reid, M. S., and Jiang, C. (2012). Postharvest Biology and Technology of Cut Flowers and Potted Plants. *Horticultural Reviews*, *40*, 1–54.

Saltveit, M. E. (1998). Respiratory Metabolism, 1–12.

Seyf, M., Khalighi, A., Mostofi, Y., and Naderi, R. (2012). Study on the effect of aluminum sulfate treatment on postharvest life of the cut rose "Boeing" (Rosa hybrid cv. Boeing). *Hortic. For. Biotechnol.*, *16*(3), 128–132.

Souza, S. O. (2008a). Longevidade de Heliconia psittacorum x H. spathocircinata "Golden Torch" e H. bihai em resposta ao uso de reguladores de crescimento. *Tese (Doutorado Em Fitotecnia) – Universidade Federal de Viçosa, Viçosa, MG.*, 158.

Souza, S. O. (2008b). Longevidade de Heliconia psittacorum x H. spathocircinata "Golden Touch" e H. bihai em resposta ao uso de reguladores de crescimento. *Universidade Federal de Vicosa, Vicosa, MG.*

Souza, S. O., Finger, F. L., Miqueloto, A., Lima, M. A. C., Amariz, A., and Oliviera, A. H. (2015). Pulsing Treatment with Gibberellic Acid in Heliconia psittacorum x H. spathocircinata "Golden Touch" Inflorescences. *Postharvest Quality of Oramental Plants*, Acta Hort. 1060, 126.

Stevens, A. B. (1995). *Harvest Systems. Commercial Specialty Cut Flower Production HARV*. Kansas State University. Retrieved from http://www.oznet.ksu.edu, 2016, August 23, 14:30 hours GMT.

Tano, K., Oule, M. K., Doyon, G., Lencki, R. W., and Arul, J. (2007). Comparative evaluation of the effect of storage temperature fluctuation on modified atmosphere packages of selected fruit and vegetables. *Postharvest Biology and Technology.*, (46), 212 – 221.

Teeranuch, J., and Paull, R. E. (2003). Reviews: Postharvest Handling of Heliconia, Red Ginger, and Bird-of-Paradise. *HortTechnology*, *13*(2), 259–266.

Tripathi, S. K., and Tuteja, N. (2007). Integrated Signaling in Flower Senescence. *Plant signaling and behaviour*, *2*(6), 437–445.

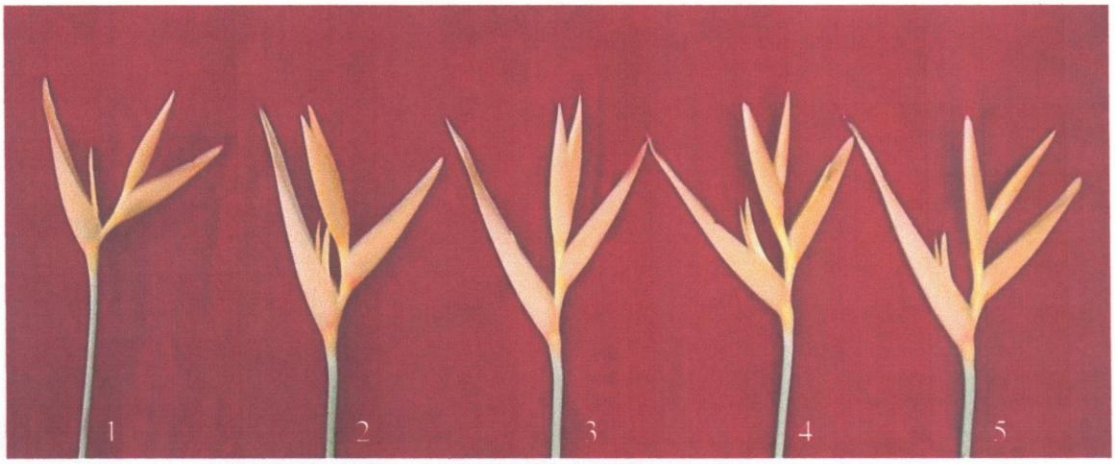
Tshwenyane, S., and Bishop, C. (2011). The Effect of Storage Temperature Fluctuations on the Post-Harvest Performance of Rosa hybrida L. "Duett." *Acta Hort. 911-International Society for Horticultural Science*, 531–536.

Van Meetern, U., Van Iberen, W., Nijsse, J., and Keijzer, K. (2001). Processes and xylem antimicrobial properties involved in dehydration dynamics of cut flowers. *Acta Hortic.*, *543*, 207–211.

Wolverton, B.C. (1996).Co. friendly House plants Weidenfied and Nicolson, Ltd,London.

APPENDICES

Appendix 1: a subjective rating scale in flower opening



Flowers were rated 1, when inflorescences presented two opened bracts and the pointer; 2, when inflorescences presented two opened bracts and onset of the pointer opening, from which a third bract was formed; 3, inflorescences third bract partially expanded towards thee pointer; 4, when the third quite expanded bract, forming an angle perpendicular to the pointer; and 5, for inflorescences with three completely expanded bracts and with the pointer (Souza, 2008a).

Appendix 2: ANOVA for RFW (%) for day 3.

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	0.721	0.24	0.06	
Treatment	4	296.36	74.09	17.47	<.001
Residual	12	50.896	4.241		
Total	19	347.978			

L.s.d. = 3.173

Appendix 3: ANOVA for RFW (%) for day 4

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	2.810	0.937	0.11	
Treatment	4	788.973	197.243	23.49	<.001
Residual	12	100.783	8.399		
Total	19	892.566			

L.s.d. = 4.465

Appendix 4: ANOVA for RFW (%) for day 5

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	28.63	9.54	0.91	
Treatment	4	2002.61	500.65	47.92	<.001
Residual	12	125.38	10.45		
Total	19	2156.63			

L.s.d. = 4.980

Appendix 5: ANOVA for RFW (%) for day 6

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	70.09	23.36	1.37	
Treatment	4	2899.01	724.75	42.34	<.001
Residual	12	205.39	17.12		
Total	19	3174.48			

L.s.d. = 6.374

Appendix 6: ANOVA for RFW (%) for day 7

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	156.42	52.14	1.59	
Treatment	4	3655.79	913.95	27.82	<.001
Residual	12	394.18	32.85		
Total	19	4206.39			

L.s.d. = 8.83

Appendix 7: ANOVA for RFW (%) for day 8

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	16.94	5.65	0.45	
Treatment	4	382.77	95.69	7.5	0.003
Residual	12	151.62	12.63		
Total	19	551.33			

L.s.d. = 5.476

Appendix 8: ANOVA for RFW (%) for day 9

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	62.60	20.87	0.64	
Treatment	4	984.07	246.02	7.55	0.003
Residual	12	390.81	32.57		
Total	19	1437.48			

L.s.d. = 8.79

Appendix 9: ANOVA for RFW (%) for day 10

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	32.20	10.73	0.31	
Treatment	4	1381.09	345.27	10.13	<.001
Residual	12	409.03	34.09		
Total	19	1822.33			

L.s.d. = 8.99

Appendix 10: ANOVA for RFW (%) for day 11

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	48.11	16.04	0.28	
Treatment	4	1350.77	337.69	5.86	0.007
Residual	12	691.74	57.65		
Total	19	2090.62			

L.s.d. = 11.70

Appendix 11: ANOVA for RFW (%) for day 12

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	4.29	1.43	0.02	
Treatment	4	1958.58	489.64	6.35	0.006
Residual	12	925.09	77.09		
Total	19	2887.96			

L.s.d. =13.53

Appendix 12: ANOVA for RFW (%) for day 13

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	9.71	3.24	0.05	
Treatment	4	2235.99	559.00	8.91	0.001
Residual	12	753.26	62.77		
Total	19	2998.95			

L.s.d. = 12.21

Appendix 13: ANOVA for RFW (%) for day 14

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	58.34	19.45	0.30	
Treatment	4	3292.91	823.23	12.52	<.001
Residual	12	788.85	65.74		
Total	19	4140.10			

L.s.d. = 12.49

Appendix 14: ANOVA for Vase Life (days)

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	8.600	2.867	1.50	
Treatment	4	118.700	29.675	15.55	<.001
Residual	12	22.900	1.908		
Total	19	150.200			

L.s.d. = 2.128

Appendix 15: ANOVA for percentage loss in weight (week 1)

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	155.94	51.98	1.59	
Treatment	4	3653.59	913.40	27.92	<.001
Residual	12	392.54	32.71		
Total	19	4202.08			

L.s.d. = 8.81

Appendix 16: ANOVA for pH

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Treatment	3	10.9602	3.6534	19.52	<.001
Residual	12	2.2459	0.1872		
Total	15	13.2061			

L.s.d. = 0.667

Appendix 17: ANOVA for percentage loss in weight (week 2)

Source of variation	d.f.	s.s.	m.s.	v.r.	Fpr.
Rep stratum	3	58.21	19.40	0.30	
Treatment	4	3289.95	822.49	12.52	<.001
Residual	12	788.57	65.71		
Total	19	4136.73			

L.s.d. = 12.49