DETERMINATION OF THE OPTIMAL PRESERVATIVES FOR PREVENTING POSTHARVEST STEM BENDING OF *Gebera jamesonii* "Black Diamond".

By

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DECLARATION

I, Mdungazi Knox Maluleke (Student no: 53376544), declare that this dissertation entitled “Determination of the optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond” is my own work and that all sources that I have used or quoted have been indicated and acknowledged by means of complete references. Prior to the commencement of the research project, both the researcher and the University of South Africa library conducted a literature review, and ascertained that no other similar research had been conducted in South Africa, prior to the registration of this project.

Signature Date

Student number 53376544

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ABSTRACT

Postharvest stem bending is one of the most detrimental factors that affect postharvest quality life of *Gerbera jamesonii* cutflower varieties. Stem bending is of economic importance in the cutflower industry in South Africa because it negatively affects the overall total sales. Growers and retailers want to improve the postharvest vaselife of this crop using suitable preservatives. The aim of this study was to determine suitable preservatives and optimal vaselife conditions that could prevent or minimise postharvest stem bending of *Gerbera jamesonii* “Black diamond”.

The variety “Black diamond was selected and treated with four different floral preservative solutions. The relationship between stem bending and absorption rate of the preservative solutions was established. The data gathered indicated that there was a significant difference to the solution absorption rate and stem bending. Stem bending differed from 0 to 38 degrees. Stems treated on control, preservative 3 and 4 recorded the highest degrees of bending, while preservative 1 and 2 recorded the lowest degrees of stem bending within 12 day period. The performance results of the preservatives and control repeated three times under the same experimental conditions showed that preservative 1 and 2 can be used to minimise postharvest stem bending of *Gerbera jamesonii* ‘Black diamond’.

Key words: Cutflowers, *Gerbera jamesonii*, Postharvest, Preservatives, stem bending.

ABBREVIATIONS AND ACRONYMS

ANOVA	Analysis of variance
ATPS	African Technological Policy Studies Network
CTA	Centre for Agricultural and Rural cooperation
Ml	Millilitres
EU	European Union
USA	United States of America
LD	Long day
REP	Repetition
SD	Short day

GLOSSARY

Additives	Substances added to water, with the aim to increase or prolong the quality of the cut flowers, once a flower stem has been harvested from the mother plant (Kikuchi, Mastro, & Wiendl, 1995).
Conditioning	The treatment of harvested cutflowers to prolong life span prior to treatment, storage and arrangement (Sisquella, Viñas, Teixidó, Picouet, & Usall, 2013).
Ethylene	A biological gas that cause ageing or fast maturation of flowers during postharvest storage (Scariot, Paradiso, Rogers, & De Pascale, 2014).
Evaporation	The movement or loss of water from the earth surface to the atmosphere in the form of water (Witte, Harkema, & Doorn, 2014).
Harvest	The process that involves the cutting, removing and gathering of ready crops from the field or place of growth after they have reached the maturity stage. The harvesting period indicates the end of the growing cycle of any crop. Harvesting is done through mechanisation or labour (Nations et al., 2012).
Flower scape	It is a botanical way of defining a leafless flower stalk growing directly from the base of the plant (Kara, Hata, Tenbrink, Hu, & Kaneko, 1996).
Postharvest	An action or practice that follows after the fresh produce has been harvested from the field (Darras, Akoumianaki-Ioannidou, & Pompodakis, 2010).

Preservative solutions	It can be defined as chemicals added to water or solution, which fresh produce such as cutflowers, fruits and vegetables are placed or dipped to prevent or minimise decay or growth of micro-organisms or occurrence of desirable chemical reaction such as oxidation that can end up spoiling the product (Soad, Lobna, & Rawia, 2011).
Senescence	The biological process of aging in plants, particular fruits, vegetables and cutflowers. It is the last stage characterised by natural degradation of the fresh produce which results in loss of texture, flavour, colour and shape. It ends in the death of the plant tissue (Pun & Ichimura, 2003).
Stem bending	Is the artificial turning of plant stems caused by lack of enough turgor pressure to keep it straight (Perik, Razé, Harkema, Zhong, & van Doorn, 2012).
Leaf-whorl	Form of leaf arrangement whereby a stem is surrounded by leaves, petals or sepals (Put, 1990).
Morphology	Involves the phenotypical or external form or structure of plants such as leaves, flowers and roots (Bradley & Hosier, 1999).
Necrosis	The death of plant tissue whereby leaves of plants turn brown and black (Javad, Ahmad, Mostafa, & Roya, 2011).
Percolation	Is the downwards movement of water from the earth surface into the soil (Wouter G,Van Doorn & Han, 2011).
Transpiration	The loss of water from the plant leaves via the stomatal pores in the form of vapour (van Meeteren, van Gelder, & van Ieperen, 2000).

Treatment	This involves the use of chemicals or additives in order to improve the cut flower vaselife or improve the specific cutflower products (Shimizu-Yumoto & Ichimura, 2010).
Trials	Involves the use of tests, experiments and controls in order to accomplish or prove how things function or work in a scientific manner and the primary purpose for doing trials is to gather results (Heinz, Nunney, & Parrella, 1993).
Vaselife	The industry and consumers tend to measure the quality of cut flowers primarily by how long they will last once harvested and sold or brought and arranged (Asrar, 2012).

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CHAPTER 1: INTRODUCTION

This chapter aims to introduce the research topic with a detailed outline of the industrial importance of cutflowers and background information on the postharvest challenges. It also includes reasons for the research study, gaps in the research, and the purpose of the research and objectives of the study.

1.1 BACKGROUND

Cutflowers flowers can be defined as flowers that have been harvested from the field or the greenhouse for various purposes that include decoration for events, meetings and funerals (Maree, 2010). It is called a cutflower because the flower including the flower stalk has been removed from the original plant. This plant was grown in soil or in a growth medium which was supplying it with water and nutrients up to now. Because the flower has been removed from the plant it is now reliant on water and nutrients that is absorbed by the flower stalk. To prolong the life of the flower, it is advised that the water provided with additives which will replace nutrients that they used to get from the growth media (Alaey, Babalar, Naderi, & Kafi, 2011).

According to Amini & Golparvar (2013), consumer patterns and preferences differ greatly since flowers have different meaning to different people. Consumers buy flowers to express their affection to their partners, for wedding decoration, at the funerals to pay their last tribute to their loved ones as well as for office decoration. The market is characterised by preferences for high quality, a high degree of freshness and long shelf life of a specific crop (Costa, Millan Montano, Carrión, Rolny, & Guiamet, 2013).

Soad et al (2011) indicated that most cutflowers are popular choices as gifts on special occasions, either as a single flower or a bunch of flowers. Roses are the most popular of all the cutflowers in the world because of their high demand as compared to carnations. Chrysanthemums are second highest in terms of market demand worldwide. Gerberas are the third highest cutflowers followed by tulips, gladiolus, lilies, and anthuriums (Hoogerwerf et al., 1994).

1.2 HISTORY OF CUTFLOWERS

According to Maree (2010), the year in which cutflower industry began and was established is not known but there are some outlines that indicate that cutflowers have been in use for decades and evidence can be noticed on ancient pottery, rock art, Egyptians tomb walls and Roman frescoes. This shows that the beauty of flowers has been acknowledged by people throughout the years. Most civilised countries like Egypt grew bulbs for their medicinal properties. Meanwhile by the 3rd century BC, countries like Greece were already cultivating cutflower species such as hyacinths and ranunculi because of their pleasant physical characteristics. They also used them for decorations and floral designs.

Most flowering crops were introduced in Western Europe by the pharmacist known as Carolus Clusius who was in charge of the Imperial Medicinal Gardens of Emperor Maximilian II in Vienna in the 1573. He collected a number of bulbs species from a friend who was a consul at the court of the sultan. When Maximilian died, Carolus was dismissed and he relocated to Holland, where he took some of the species with him. Most of these cutflowers were bulbous species (Bachmann, 2006).

In the 17th century, tulips became the most popular product in Holland and several varieties were sold over and over again. In the 1720s, almost 2000 cultivars were traded with higher prices than other flowers such as lilies, and consumers would buy since specialist had not discovered a way to propagate bulbs on a large scale in a very short period of time as is done today (Maree, 2010).

At Greek marriage ceremonies around 1800, brides would wear a crown of lilies and wheat which symbolised purity and abundance. To show that flowers have a strong associated significance, the Greeks normally placed beautiful flowers on children graves as a symbol of love (Dole, 2005). In Greek culture, winners of specific sport competitions such as the marathon, swimming and high jump would be rewarded with a wreath of flower as a merit to their accomplishment. This practice was witnessed during the 2004 Olympics games in Athens and that signified peace and merit (Benschop & Kamenetsky, 2010)

1.3 REGION OF ORIGIN

According to Dole (2005), well-known cutflower species originated in different regions of the world. During the period of their discovery, most people were interested in exotic and beautiful flowers from different regions. The biological diversity of the world has contributed the large number of species known as commercial cutflowers to date. Since people have been cultivating, breeding and trading for many years, it is very difficult to point the place of origin for specific cutflower specie, but it is much easier to point their general geographic region. That is the exact reason why some countries fight for plants because their natural habitat cannot be traced (Reinten, Coetzee, & Van Wyk, 2011).

1.3.1 China and Japan

Bachmann (2006) indicated that these two countries may be the original regions of many cutflowers species because they are known for their history of successful cultivation of different cutflower species for many centuries. Most cutflower species were cultivated for various purposes such as beauty, pleasure and some for their medicinal properties. Examples of species known to be grown in these regions are orchids, roses and chrysanthemums. The Chinese had been cultivating chrysanthemums species for more than 2000 years before they were first introduced in England in 1795 (Maree, 2010).

1.3.2 Mediterranean and Near East regions

The Mediterranean region is well known for being the natural habitat for popular cutflowers species such as tulips, carnations and hyacinths. Other well-known perennial cutflower species originated from these regions include delphiniums, ranunculi and veronicas (Benschop & Kamenetsky, 2010).

1.3.3 South Africa

South Africa is known for its unique biodiversity such as the Fynbos biome found in the Western Cape region. When explorers and collectors came to Southern Africa in the 1700s and 1800s, they were pleased by the wealth of bulbs and several plant species found in the Cape region. Most of them were exported to the Netherlands and are still amongst the favourites at the floral markets. Examples of species which come from the Southern African region include calla lilies also known as arum lily, gladiolus, freesia, sparaxis, gerbera and ornithogalum (Maree, 2010).

1.4 BACKGROUND OF THE RESERCH PROJECT

Gerbera jamesonii commonly known as Barberton daisy in South Africa is a perennial flowering plant belonging to the Asteraceae family. They are mainly grown for ornamental purposes and have a diverse range of flowering colours. It is these diverse and vibrant flowering colours which gives them an advantage in the cutflower production market. Most of the present day *Gerbera jamesonii* crops are hybrids (Dole, 2005).

Although *Gerbera jamesonii* is generally a healthy cutflower with few problems, it is prone to bent-neck or stem bending in its vaselife, which refers to the number of days a flower stem can last after harvest. The insufficient flower hardening or maturation of the stem tissue bellow the flower head which can result in stem collapse remains one of the major problems of *Gerbera jamesonii* cutflower. This problem has a negative effect on gerberas as cutflower products because it shorten its postharvest shelf-life and consumer prefer to buy flowers with long postharvest shelf-life (Shvarts at al., 1997). According to Ali et al., (2013), preservatives can be used effectively to prevent stem bending.

Nowak & Rudnicki (1990) wrote that stem bending is normally caused by gravity and can be minimised if cutflowers are treated with preservatives that will continually supply carbohydrates as a source of energy during vaselife. The method of handling of cutflowers, vaselife treatment and the use of suitable floral preservatives can greatly minimise the stem bending. The stage at which flowers are harvested also play a very significant role on the degree of bendiness of the flowers because if the flower is harvested early, it will not be sufficiently hardened to handle the weight of the flower head (Javad et al., 2011).

According to Dole (2005), microbes are one of the major causes of stem bending which then prevent the cutflowers from absorbing water which can result in wilting. Buckets and glass vases must always be sanitised to discourage microbial activities. Some cultivars have lower levels of bending and it is advisable to always select cultivars which are slow to bend. Consumer preference can make the postharvest practice difficult because they only want to buy what they want rather than what is on the market (Ansari, Hadavi, Salehi, & Moradi, 2011).

Dole (2005) also indicated that Gerbera cutflowers are harvested when the outer rows of flowers are open and pollen is visible. The harvesting method involves pulling rather than cutting of the stem and then cutting the base of the stem to allow maximum hydration.

Several commercial floral preservatives have been developed to address the stem bending of *Gerbera jamesonii* cutflowers. A variety of hydration solutions such as short-term pulses and long term holding solutions have been used for such a long time to help prevent stem bending, but is it still not clear which one is more suitable to address the stem bending problem of *Gerbera jamesonii* cutflowers (Javad et al., 2011).

1.5 STEM BENDING

Mercurio (2002) defined stem bending as the unnatural turning of the stem to the right or left angle as a result of the inability of the flower stem to remain upright and still be able to handle the flower head weight. Several factors such as cellular turgidity and carbohydrate content are the primary cause of stem bending in *Gerbera jamesonii* cutflower varieties. The problem usually occurs along the first six to eight cm below the flower head where the stem tends to loose strength and eventually collapse due to lack of sufficient nutrients that provide energy for the stem to remain upright.

Dole (2005) reported that the imbalance between the amount of water absorbed by cutflower stems and the water lost through transpiration negatively contributes towards stem bending of *Gerbera jamesonii* cutflower varieties. These variables can cause serious problem in the postharvest period of the crop if not checked properly. To prevent this problem, it is important to ensure that large volumes of water are relative to the number of stems being stored in a glass vase or container so that the water demand of the cutflower stems can be met (Perik et al., 2012).

Mercurio (2002) indicated that the stem bending problem should be minimised straight from the harvesting stage by harvesting flowers when the two outer rows of floret disc have opened and clearly visible. If correct procedures such as harvesting at the right stage, time and temperature are followed, *Garbera jamesonii* cutflowers can stay fresh for two to three weeks. Different cultivars have different vase life period and they also require a specific postharvest treatment that will help prolong their postharvest shelf-life.

Gerasopoulos and Chebli (1998) stated factors such as bacterial contamination, anatomical characteristics, presence of ethylene and the type of cultivar greatly contribute to the stem bending problem for *Gerbera jamesonii* cutflowers and it is very important to ensure that maximum hygiene is maintained when working with cutflowers specifically *Gerbera jamesonii* varieties.

Most floral preservatives contain a specific formulation which has been developed to help minimise bacterial contamination when working with cut gerberas during the postharvest process. It is very important to follow the instruction of the dosage to ensure accurate application is practised in order to achieve the maximum effect of the particular floral preservative.

1.6 REASON FOR/PURPOSE OF THE RESEARCH

The import and export market of cutflowers between South Africa and various countries has been in existence for decades and fresh quality flowers seems to be acceptable by countries. Various wholesale growers in South Africa are currently facing the challenge to keep on producing, maintaining and exporting top quality cutflowers. Top quality cutflowers of *Gerbera jamesonii* varieties should be straight, free from pest and diseases (Maree, 2010).

Gerbera jamesonii is one of the most valuable cutflower crops currently occupying position number five on the list of top performing crops worldwide, it is very important that the quality is maintained. This will have a positive impact on the South African economy since growers will able to export quality products that will be accepted by the international markets. Therefore, it is crucial that suitable preservatives are identified based on scientific research, to prove the best possible way of preventing stem bending of *Gerbera jamesonii* cutflowers.

A gap in research has been identified and these includes but not limited to:

1. Very little research has been done on the topic of postharvest stem bending of cutflowers as it leaves a serious gap in postharvest quality of several cutflowers specie including *Gerbera jamesonii* (Dole, 2005).

2. Very little research has been done on different preservatives that can be used to prevent postharvest stem bending of *Gerbera jamesonii* cutflower varieties.

3. Very little research has been done in South Africa where *Gerbera jamesonii* originates from.

4. Dole (2005) presented the basic postharvest treatment of *Gerbera jamesonii* cutflower varieties and has defined a need for research of preservatives that can minimise the stem bending problem in order to improve the postharvest quality of the crop.

1.7 PROBLEM

The postharvest quality of South African cutflower industry and additional pressures by the European Union (EU) and other export market specifications demand high-quality cutflowers. Stem bending has become a negative factor for *Gerbera jamesonii* cutflower growers and the cutflower market industry. As more flowers are continuously exported everyday, there will be a need to increase the cutflower quality, specifically exporting *Gerbera jamesonii* that are free from stem bending because consumers are only interested in cutflowers that have straight upright stems.

The postharvest challenge and particularly stem bending significantly influences cutflower quality in the industry. If stem bending can be prevented, it can improve sales as less flower stems will be damaged which will make the flowers more marketable and accepted by consumers. Postharvest stem bending is a common problem that seems to be affecting *Gerbera jamesonii* cutflower crop and the utilisation of the correct floral preservatives can help minimise postharvest stem bending, which will in turn reduce the damage caused by this problem.

Commercial floral preservatives are available and have been used to improve flower vaselife by various growers and retailers in South Africa. The question is if these floral preservatives can be used to prevent stem bending of *Gerbera jamesonii* cutflowers or whether they are able to minimise stem bending of these cutflowers.

This study therefore, aims to determine the optimal preservative for preventing postharvest stem bending of *Gerbera jamesonii* cutflower variety.

1.8 HYPOTHESES

The following hypotheses were formulated regarding the postharvest of *Gerbera jamesonii* flowers with different preservatives which will result in the following:

- HO – There will be no stem bending of *Gerbera jamesonii* before the flowers are placed in the preservatives.
- H1 –There will be increased stem bending after the flowers have been placed in preservative solutions.
- H2 – There will be a decrease in stem bending after the flowers have been placed in preservatives.

Research problem statement

The main aim of this research project is to determine suitable preservatives for preventing postharvest stem bending of *Gerbera jamesonii* cutflower varieties. Candidate preservatives will be selected based on their performance during different experiments and reported in the literature review. In order to validate the research output, the research aims to prove that premature stem bending can be prevented or minimised.

The following research problem was formulated:

Flower industry clients expect high quality cutflower products that have a long vaselife. The premature bending of the stems of *Gerbera jamesonii* in the postharvest vaselife is a major concern within the flower industry as well as which cutflower preservative (if any) can be used to minimise stem bending the postharvest of *Gerbera jamesonii*. .

1.9 RESEARCH AIM

The main aim of the research study is to compare various floral preservatives which can be used to prevent stem bending of *Gerbera jamesonii* cutflowers so that postharvest loss of cutflower stems will be minimised and thus improve the marketing of such cutflowers.

The main research questions are:

1. What postharvest challenges exist concerning *Gerbera jamesonii* cutflower?
2. What quality parameters are used to determine postharvest quality of *Gerbera jamesonii* cutflower variety?
3. Which environmental factors influence postharvest quality of *Gerbera jamesonii* cutflower variety?

4. Which floral preservative (if any) can be used to improve postharvest quality of *Gerbera jamesonii* particularly stem bending?

1.10 ASSUMPTIONS

Assumptions that apply in this study are the following:

- *Gerbera jamesonii* cutflower for this research were selected from flowers harvested at Imbali PTY LTD flowers which were sent to the market.
- Environmental conditions that are similar to that of vaselife conditions in the home will be created in the laboratory.
- Cutflower quality of *Gerbera jamesonii* will be similar to what is expected in the market place and this will be defined in the literature review.
- The transportation of *Gerbera jamesonii* cutflower will be typical of the transportation used in the market place.
- Based on the initial test of all the cutflower postharvest parameters such as temperature, solution absorption rate, pH and stem bending will be selected as the main parameters for the study. The parameters used will act as an indication of the postharvest quality for *Gerbera jamesonii* cutflower varieties.

1.11 DISSERTATION OVERVIEW

This dissertation is structured as follows to outline the research study process and activities and to report the research outcomes in a systematic and comprehensive manner:

Chapter 1: Introduction

This chapter introduces the research topic with a detailed outline of the importance of the cutflower industry and provide background information on postharvest challenges. It also explains reasons for undertaking this research study, identifies possible gaps in the literature, deals with the purpose of the research and objectives of the study.

Chapter 2: Literature review

This chapter provides detailed background information on the importance, challenges, and postharvest concerns of cutflowers. It provides important information on the potential solutions of postharvest treatment of cutflowers, as well as factors which have a direct and indirect effect on the postharvest quality of cutflowers in the cutflower industry. This chapter concludes by identifying gaps in the literature and justifying the research.

Chapter 3: Research design and methodology

Chapter three outlines the various research methodology processes applied to achieve the objective of the research study.

Chapter 4: Results and discussion

This chapter includes the results, which have been gathered presented and discussed as well as the different preservatives tested and the method used to determine the optimal preservative that can be used to prevent stem bending of *Gerbera jamesonii* cutflower. The results gathered will be analysed, discussed and interpreted.

Chapter 5: Conclusion and recommendations

This is the last chapter of the dissertation which summaries the main research findings to develop major conclusions arising from the research study. Recommendations are made for the cutflower industry concerning optimum preservatives suitable to prevent and/or minimise stem bending of *Gerbera jamesonii*. Further research and development required in this field of research are highlighted.

CHAPTER 2: LITERATURE REVIEW

The main focus of the literature review was to identify factors affecting the postharvest quality of cutflowers worldwide and the methods implemented to improve postharvest worldwide and specifically in the South African cutflower industry. The use of preservatives to control stem bending of various cutflowers was considered.

2.1 INTRODUCTION

Cutflowers can be defined as flowers that have been harvested from the field or the greenhouse for various purposes such as decoration for events, meeting and funerals. They consist of stems, leaves and flowers (Dris, 2003). They are called cutflowers because they have been removed from the original plant that was grown in soil or growth media supplying it with water and nutrients, and as a result they have to be treated with additives or preservatives that will help to prolong their vase life (Maree, 2010).

According to Amini & Golparvar (2013), consumer patterns and preferences differ since flowers have a specific meaning in people's life. Some people buy flowers to express their affection for their partners, and some buy flowers for office decoration, weddings and funerals. The market is characterised by its preferences for high quality, a high degree of freshness and long shelf life (Ahmad et al, 2013).

Soad et al (2011) stated that well-known and economically important cutflowers are roses, chrysanthemums, carnations, oriental lilies, gerberas, tulips, Asiatic lilies, freesias, alstroemerias, hypericums, irisis, daffodils, lisianthuses, and gladioli. The economic importance of cutflowers has been increasing globally since late 1720's, which led to a rapid increase in the demand for fresh cutflowers since the 1950s. In the Netherland, cutflowers represent the largest segment of the horticultural products, this has resulted in the development of greenhouses in order to grow cutflowers all year round (Sisquella et al., 2013).

2.2 CUTFLOWER INDUSTRY

Cutflowers flowers can be defined as flowers that have been harvested from the field or the greenhouse for various purposes that include decoration for events, meetings and funerals (Maree, 2010). It is called a cutflower because the flower including the flower stalk has been removed from the original plant (Ahmad *et al*., 2013).

This plant was grown in soil or in a growth medium which was supplying it with water and nutrients. Because the flower has been removed from the plant it is now reliant on water and nutrients that are absorbed by the flower stalk. To prolong the life of the flower it is advised that the water that these flowers are standing in is provided with additives that will replace nutrients that they used to get from the growth media (Alaey et al., 2011).

Dole, (2005) indicated that the florist business has been a significant market in corporate and social event worldwide. Flowers play a large part in the decoration of special events, meetings, entrances, reception tables, weddings and stage sets are a few well-known example of how flowers are utilised in the business and social event settings (Buschman & Hillegom, 2005). According to Cimmyt & Abass, (2012), cutflowers represent one of the largest segment of horticultural products after fruits and vegetables. The higher demand resulted in the development of commercial greenhouses in order to grow crops all year round.

2.2.1 Cutflower industry worldwide

In the article written by Slater & Carson, (2003), they indicated that sixty years ago in the year 1956, the demand for cutflowers by consumers around the world was based specifically on the country's local cutflower production. On continents such as Europe, consumption was based on customer's culture that led to a great supply of cutflowers for different purpose such as gifts, occasions and everyday use (Buschman & Hillegom, 2005). Consequently, the industry in Europe began to expand its boundaries, which caused increase the global demand for cutflower production. This background history could be considered as the beginning of commercial cutflower business as known in the 21 century (Mendez, 1991).

The global powerhouse of the cutflower industry is the Netherlands, particularly the Dutch flower market situated in the province of North Holland in the town called Aalsmeer. The Bloemenveiling Aalsmeer flower market continually improves their operations, marketing and also ensures that the crops are fresh in the market (Council, 2006). They pay serious attention to environmental quality control and horticultural sciences in order to ensure that their supply chain is efficient and that made them to become the global powerhouse for cutflower industry worldwide (Mercurio, 2002).

In the United states of America (USA), the early 1990s witnessed a dramatic shift from local growers to low-cost importers in major cutflower sectors because of high production and low income (Herold, 2005). Since 1995, this growth stabilised, with cutflower importers shares the market growth of 60% to 64% (Gebreeyesus & Sonobe, 2012). Most cutflowers sold in the USA, are imported from countries such as Colombia, Ecuador, the European Union and Mexico (Laschkewitsch, 2011).

2.2.2 Cutflower industry in Africa

According to Magoti *et.al*., (2004) Kenya is currently the largest supplier of cutflowers to the EU. It is the second largest developing country, after Colombia that exports cut flowers worldwide. Kenya is also the second largest horticultural exporter in sub-Saharan Africa after South Africa and the second largest developing country supplier of vegetables to the EU after Morocco (Gårdman, 2008).

The Kenyan floriculture sub-sector is the fastest growing sector contributing 18,719 billion rands out of the total horticultural export from Africa (Riddselius, 2011). In the last decade from 1995-2004, the Kenyan cutflower export grew by more than 300% at the time when the country's overall export growth stood at 40%. Over the same period, the volume of flowers exported increased fiftyfold from 29,373 metric tons in 1995 to 81,217.83 metric tons in 2005 (Riisgaard & Gibbon, 2014).

In the year 2000, Zimbabwe was the second highest African supplier of cut flowers to the EU and the third largest overall supplier behind Kenya (Society, 2001). Farmers in this region traditionally grew crops such as maize and tobacco, but diversified their operations by cultivating a few hectares of cut flowers such as roses, proteas, asters and chrysanthemums on their farms (Benschop & Kamenetsky, 2010).

2.2.3 Cutflower industry in South Africa

The South African cutflower industry produces a wide variety of traditional flowers including roses, chrysanthemums, gerberas, carnations, gypsophila and irises. These flowers are commercially grown across the country. Almost 60% are sold on the local market and, the remaining 40% is exported to different parts of the world (Society, 2001).

The total cutflower production of South Africa is currently valued at approximately R400 million and consist of approximately 420 ha of production area and 20 000 ha of natural veld where proteas, pincushions and ferns are harvested (Reinten et al.,2011).

Kittas, Katsoulas, Bartzanas, & Bakker (2013), indicated that there is a very strong demand for South African cutflower crops globally. Countries such as Germany, the United Kingdom, Japan and the Netherlands are the well-known consumers of the South African cutflower crops worldwide. Indigenous crops such as gladioli, nerines, freesias and gerberas have been researched in different parts of Europe and have become major cutflower crops worldwide (Heinz et al., 1993).

South Africa is one of the leading exporters of the protea cutflowers worldwide above countries such as Zimbabwe and Kenya (Tsirogiannis *et al*., 2010). According to Dole (2005), there are several plant species from South Africa which have been used as genetic material to breed different varieties and those species includes clivia, freesia, gerbera, gladiolus and *protea*. *Gerbera jamesonii* hybrids appears to be the leading South African cutflower crops in terms of demand and it is currently the fifth most popular cutflower crop worldwide (Dris, 2003).

2.3 MARKET DEMAND FOR FRESH FLOWERS

The demand for fresh cutflowers is satisfied by an extension in the storage and market life or shelf life, that is achieved by combination of different practices such as proper application of treatment from harvest until retail (Oraee & Zadeh, 2011). Refrigeration, controlled and modified atmosphere during storage and transport as well as application chemical preservatives maintain the freshness of cutflowers (Mahdavi & Kafi, 2012). Customers are demanding products that are free from diseases, wilting, and rotting or any other contaminant or factor reducing the quality of cutflowers (Danaee et al., 2013).

The specific standard requirement in the international flower market is the continued increased emphasis on quality that include factors related to postharvest (van Doorn et al.,1994). Since competition in the world market keep increasing, quality becomes the main factor, hence increasing vaselife of flowers during storage or shelf life is very important (Maree, 2010).

Dole (2005), indicated that the market and consumer preference makes it challenging to predict which flowers are top sellers in the cutflower industry as it can change anytime. According to (Nelson, 2015), roses are still the most preferred cutflower crop occupying the first position in most countries including South Africa with 60% market share globally. Chrysanthemums are the second best-selling with 15% market share. The third position is occupied by carnations with the market share of 10%. Tulip and lilies share fourth position with the market share of 5% and 4% respectively. Gerberas are currently occupying the fifth position with the market share of 3.9% for all flowers.

2.4 *Gerbera jamesonii* AS CUTFLOWER CROP

Gerbera jamesonii commonly known in South Africa as Barberton daisy is a perennial flowering plant belonging to the Asteraceae family (Broholm et al., 2008). The genus *Gerbera* has about 40 different species and present-day cultivars are mostly hybrids namely, black diamond, deliana, zanziba, quartz and candela. They are mainly grown for ornamental purposes and have a diverse range of flowering colours which give it an advantage in the cutflower production market (Ahmad et al., 2013).

2.4.1 Propagation of *Gerbera jamesonii*

Gerbera jamesonii is propagated by seed or division, however, division can be too slow and impractical on a commercial scale (Redman, Dole, Maness, & Anderson, 2002). *In vitro* propagation is currently the best method and is proven to be quick when increasing cultivars for both cut and potted flowering plants (Heinz et al.,1993). *Gerbera jamesonii* can also be propagated by invitro technique which is also known as micropropagation (Mercurio, 2002). This technique involves cuts to the apex portion of young meristematic tissue of the parent plant. The advantages of the micropropagation technique is its ability to multiply a very large number of clones with well-defined characteristic (Reinten et al., 2011). Flowering can be expected within 16 weeks after germination or 11 to 16 weeks after transplanting in*vitro propagated* plugs (Redman *et al*., 2002). Papadopoulos, (1991), indicated that it is very important to place the plants at a correct depth to promote rooting and possible rotting that could cause serious damage to the crown of the young plant. The entire operation is carried out in a special room, in a controlled environment with a special growth media (Wernett, Sheehan, East, & Marousky, 1996).

It is possible to store seeds for twelve months at 5°C , with moisture content of 4.5 to 5.7% and relative humidity of 32% (Ahmad et al., 2013). Pot plants and cutflower crops are commonly grown in the greenhouse and under shade cloth. Cutflowers are widely grown using hydroponic technique and quality seedlings are produced through this method (Mahdavi & Kafi, 2012).

Seeds are commonly sown in plug trays and should not be covered (Dole, 2005). Germination takes place between seven to fourteen days under optimum temperature of 20 to 23°C. However, germination tends to decrease when the temperature rise above 24°C. High humidity of 85% should be provided and maintained until all seedlings are full germinated (Slater & Carson, 2003). According to Kara et a*l*., (1996), reducing seed moisture content can improve the quality of seedlings with optimal temperature at 20 to 23 °C. However, seed should be exposed to 52% to 82% moisture before germination, failure to do so can result in poor germination percentage (Perik et al., 2012).

2.4.2 Growth media

Dole (2005) indicated that any growth media used for propagation of *Gerbera jamesonii* crops should be well drained and contains high percentage of organic matter. Since the roots of the crop can deeply penetrate as far as 50 to 70 cm deep, it is very important that the drainage of the growth media should be as high as possible to allow free movement of the plant roots for adequate absorption of water and nutrients.

When cultivating *Gerbera jamesonii* in the field, the land should be ploughed as much as possible until the soil becomes loose to allow good drainage of water. Growth media such as peat, perlite, vermiculite, calcine-clay and course sand has been successfully used the grow *Gerbera jamesonii* cutflower crop.

Gerbera jamesonii prefer a growth medium with a pH of 5.5 to 6.0 and the pH should constantly be monitored (Tomás-Callejas et al., 2011). According to Papadopoulos (1991), medium with a high soluble salt and a pH level of above 6.5 is always a big concern and should be avoided at all cost (Dole, 2005).

Perlite is a grey-white material of volcanic origin and is usually used to improve drainage and aeration of the growth medium. The pH of perlite is very close to neutral, ranging almost between 6 and 8. It is chemically inactive and sterile. Perlite is mostly used as seed sowing mixture since it has excellent role in drainage and aeration (Facte, Warncke, & Krauskopf, 1983).

Gerbera jamesonii plantlets can be inserted in the perlite and a space of about 2 cm should be provided above the level of substrate to prevent stem rot (Reinten et al., 2011). The grower must ensure that there are enough drainage holes because the growth media perlite tend to obstruct the direction in which roots are supposed to be spreading to and that affect the nutrients absorption by roots (Tsirogiannis et al., 2010).

Vermiculite is also one of the growth media which is used for commercial propagation of *Gerbera jamesonii* cutflower crop (Dole, 2005). It is a geological natural rock which is formed from magnesium aluminium silicate that is heated to high temperature until it expands (Facte et al., 1983). The heat is very significant as it sterilises the product and makes it one of the most useful component for plant soilless growth mediums because it provide air movement in the growth media and has an excellent water holding capacity. It is a very light material with a neutral pH and has a relatively high level of magnesium, potassium and cation exchange capacity (Mercurio, 2002).

2.4.3 Disbudding

Dole (2005) defines disbudding as the practice of reducing plant buds with the aim of promoting better healthy flowers from the ones that are left on the plant. No disbudding is required for the *Gerbera jamesonii* crop, however some growers remove the first flower as soon as it appears with the aim that it will result in uniform elongation of the remaining flower scapes (Ebrahim, 2004).

2.4.4 Flowering condition and development

The first visible flower buds begin to show after 10 to 14 leaves have developed in the primary leaf whorl and after 2 to 6 leaves have developed in the secondary or lateral leaf whorls. It normally requires 11 days for the next flower to become clearly visible under short day short daylight conditions or 18 days under long day light conditions (Reinten et al., 2011). Under short day light condition, the primary flower need 65 days of light exposure from the opening stage until the bud is fully developed (Ribot, 1996).

Dole (2005) indicated that cultivars respond differently to photoperiodism and stated that flower initiation and development are mainly affected by the combination of light intensity and temperature. High light intensity is very significant during the seedling developmental period because flower initiation start after 2 to 3 true leaves are clearly and fully developed (Tomás-Callejas et al., 2011). High temperature above 24°C can negatively impact flower development which lead to the application of plant growth regulators to promote flowering (Huang et al.,1995).

2.4.5 Insects

Gerbera jamesonii is susceptible to various insects such as aphids, mites, fungus gnats, leaf miners, spider mites, thrips, whiteflies, worms, slugs and snails (Heinz et al., 1993).

However, with proper cultural practice and continuous inspection programmes, major damage can be prevented. Thrips and whiteflies in particular the most damaging pests that need to be controlled and monitored from the seedling to the harvest stage (Dole, 2005). The table below are insects attacking *Gerbera jamesonii*, which will affect the growth and development of the crops.

Table 2.1: Insects attacking *Gerbera jamesonii* crop (Mercurio, 2002).

Scientific name	Common name	Description and damage	Control method
Liriomyza trifolii (Agromyzidae Family)	Leaf miners	Small fly belonging to the Agromyzidae family. It feeds by digging a narrow tunnel in the leaf mesophyll of *Gerbera jamesonii* crop which result in a large circle.	All damaged leaves must be removed from the greenhouse.
Tetranycus urticae (Tetranychoidea Family)	Red spider mites	They normally form a web which protects their eggs from their enemies and environmental fluctuations. They have tiny mouthparts modified for piercing and sucking of individual plant cells.	The most and effective chemical pesticides that can be used to control red spider mites are Abemectina, Lufenuron, Bifenthrin,Fenpropathrin, Endosulfan and mixture of Dicofol-Tetradifon.
Thrips tabaci (Sub-order-Terebrantia)	Thrips	Tiny insects that have a morphological thread by which they depose the eggs inside the plant tissue.	Heavy infestation of thrips on plant cause the plant leaves to have excessive air pores

			which become the entry point for fungal diseases to the entire plant. Chemicals that can be used to control thrips are Deltamethrin, Bifenthrin, Endosulfan, Methomyl, Methiocarb and Lefunurin.
Myzus persicae (Suborder-Homoptera)	Aphids	Small, soft bodied, pear shaped insects which are usually green or black in colour. They are commonly found in small colonies on plants, mainly on leaves and new growth.	They are sap feeders, which means they extract food and mineral from the plant resulting in retarded or deformed leaves, which then reduces plant yield and it cause great loss when growing plants for commercial purpose such as cutflowers. Insecticides such as Pirimicarb, Imidacloprid and Methomyl can be used to control aphids in the greenhouse.
Bemisia tabaci (Suborder-Homoptera	Whiteflies	Well-known, common species of white fly which attacks most greenhouse	Whitefly needs a lot of protein for their growth, thus they consume a

		grown crops. Adult whiteflies are mostly found on the underside of the leaves where they lay their eggs.	large quantity of plant sap. Growers must implement the chemical treatment as soon as they identify the infestation of whiteflies on the greenhouse grown crops. The pesticides which can be used to control whiteflies on greenhouse crops are Buprofenzin and Endosulfan.

2.4.6 Disease control

According to (Tomás-Callejas et al., 2011), proper sanitation , venting and continuous plant inspection can prevent both fungal and pathological disease infection in gerberas. Nutrition, pH, and soluble salts need to be continuously monitored to avoid root injury and further root-related problems such as root rot (Aghdam et al., 2012). The table below indicate various diseases and their control measures which may affect the growth and development of *Gerbera jamesonii* crop.

Table 2.2 Diseases that attack *Gerbera jamesonii* crop (Mercurio, 2002).

Scientific name	Common name	Description and damage.	Control method

Phytophtora cryptogea	Crown rot	Crown rot is a parasitic disease that can kill the plants in the space of 10 to 15 days period after infestation. It can easily spread when the area has extremely high humidity particularly in the greenhouse.	The most important prevention means of this pathogen is to always use healthy propagation plantlet material.
Phytium spp	Root rot	Root rot is very common in a warm environment with cultivated crops that prefer the temperatures higher than 25°C and is highly present in damp soil or growth media. It is very detrimental particularly to hydroponic grown crops.	It is essential to use the treatment in a preventative manner. Application of fungicide two to three days before planting directly to the soil or growth media will prevent damage by the root rot disease.
Sclerotinia spp	Stem rot	Stem rot is black in colour and at times clearly visible with the naked eye. It normally attacks the plant crown and the base of the petioles.	It is essential to use the treatment in a preventative manner. Application of fungicide two to three days before planting.

Botryotinia fuckeliana	Botrytis blight	This disease commonly causes soft rottenness on all the affected leaves with large of grey mildew which consists of the multiplication or conidial forms of the fungus.	Botrytis can be prevented by careful horticultural practices such as correct pest and disease prevention, correct irrigation, balance nutrition and sterilisation of growth medium before and after cultivation
Erysiphe Cichoriacearum	White Powdery mildew	This disease normally attacks the plant leaves, petioles and flower heads is characterised by whitish colour on inflorescences with abundant formation of mycelium and spores of the fungus. The leaves of the plant become smaller, curled up and leathery. In a short period, the white inflorescences turn light purplish brown colour, which will then dry up and die.	Triforine (Saprol) can be used to control powdery mildew since it acts as contactice and can be absorbed by leaves. It is essential to act quickly as soon as the plants show of signs of the powdery mildew infection.
Ascochyta gerberae	Leaf spots	Leaf spot can cause a severe damage by creating a circular shaped spots with irregular boarders. The spot are brown-purple in colour and tends to	Leaf spot can be controlled by providing low greenhouse

		form a large necrotic area that causes the leaves to whither. The pathogens spread conidia and spores. It flourishes well in hot and humid condition where there is poor ventilation.	humidity, promotion of good cultural practice such as adequate irrigation, pest and disease control and sanitary plant conditions. Chemical agent with active ingredients containing Propamacarb Hydrochloride at recommended dosage can be used to keep this disease under control.

2.4.7 Physiological disorder

Wernett *et al*., (1996) indicated that physiological disorders are the types of diseases which are not caused by pathogenic organisms, but are the consequence of either adverse climate condition or unfavourable nutritional condition.

2.4.7.1 Cracks or breaks of the flower stem

Mercurio (2002) stated that cracks of the flower stem is a common problem that usually affects varieties that are most sensitive to high temperature. It occurs during postharvest while the stems are still in water. Stem breaks occur mostly to varieties that has a thick and turgid stem, but with small cavities in the stem.

van Meeteren et al (2000) suggested the damage can be reduced by keeping the soil damp on a hot and the sunny day during cultivation. Growers who are not irrigate during sunniest hours in the greenhouse and using all means of lowering temperature and re-establishing a nutritional balance of calcium and potassium can reduce the chance of crack flower stem during postharvest (Redman *et al*., 2002).

2.4.7.2 Premature flower wilting

Tucker (1999) speculated that premature wilting occurs when the flower which has not yet reach the maturity stage begins to wilt, with the flower head bending downwards. The problem is caused by the inadequate carbohydrates level that is needed for the flower to fully develop to maturity (Cimmyt & Abass, 2012). The flowers need to be treated with suitable preservatives immediately after harvest so that there will be enough energy flow to maintain the flowers head (Bradley & Hosier, 1999).

2.4.7.3 Stem bending

According to Mercurio (2002), insufficient flower stem hardening bellow the harvested flower can result in stem collapse which is known as stem bending. Perik et al (2012), sates that stem bending is normally caused by insufficient hardening or maturity of the cutflower stem which begin at the tissue below the stem where it was cut during harvest. Dole (2005) describes stem bending as the artificial turning of plant stems caused by lack of enough turgor pressure to keep it straight. Poor winter growing conditions play a big role on the stem bending problem and the flower head may bent easily (Javad et al., 2011).

Flowers which are grown and harvested in winter seem to be more affected by stem bending problem than the ones grown and harvested in summer (Nowak et al., 1990). Another factor which seems to contribute towards stem bending is the method in which *Gerbera jamesonii* cutflowers are harvested. Instead of stem being cut, they are pulled at the base of the plant and then later the base to allow maximum absorption of water by the stem.

Dole (2005) indicated that the stem bending problem should be minimised at the harvesting stage by harvesting flowers when the two outer rows of floret disc are open and clearly visible. If correct procedures are followed during harvest, *Gerbera jamesonii* cutflowers can stay fresh for two to three weeks, but that will also be determined by the cultivar's ability to react towards the kind of vaselife it receives.

Gerasopoulos and Chebli (1998) stated factors such as bacterial contamination, anatomical characteristics, ethylene and the type of cultivar greatly contribute to the stem bending problem for *Gerbera jamesonii* cutflowers and it is very important to ensure that maximum hygiene is maintained when working with cutflowers specifically the varieties ".

Various floral preservatives with a specific formulation have been developed to help minimise bacterial contamination when working with cut gerberas during the postharvest process. It is very important to follow the instructions on the package to ensure accurate dosage is practised in order to achieve the maximum effect of the particular floral preservative.

2.5 CULTIVATION REQUIREMENTS OF *Gerbera jamesonii*

Gerbera jamesonii is a crop that grows well in an environment which has a lot of sunshine, moderate temperature and humidity day and night (Shvarts et al., 1997). However, the crop environmental condition become slightly different when cultivated in the greenhouse for commercial purpose.

2.5.1 Temperature

Seed germination of *Gerbera jamesonii* is most successful at 20 to 23°C and this temperature range should be maintained until leaf development (Beni & Hatamzadeh, 2013). The developmental rate from visible bud to flower colour is normally fast at an average daily temperature of 24 °C. However higher temperatures always lead to more leaf development (Adachi et al., 2000).

According to Rhodes (1995) a lower greenhouse temperature of 13°C will encourage vegetative growth and promote flower shoots therefore, increasing flowering .

2.5.2 Irrigation water

According Tsirogiannis et al (2010) it is best to water carefully during the first few weeks of transplant because the *Gerbera jamesonii* stems are still relative soft and too much water will promote stem rot. *Gerbera jamesonii* is very sensitive to the level of salt present in irrigation water. *Gerbera jamesonii* crop prefers water with a low concentration of sodium and chlorine respectively, nutrient absorption by roots is very affective when there is lower concentration of sodium and chlorine in irrigation water (Storey, 2006).

Mercurio, (2002) stated that the volumes and frequency of irrigation for the *Gerbera jamesonii* crop cultivated in the greenhouse are regulated by the water losses due to percolation and evapotranspiration. It is essential to utilise the tensionmeter which is an instrument that measures the strength which water is held in the soil and that will prevent overwatering of crops (Tomás-Callejas *et al*., 2011).

2.5.3 Nutrition

Dole (2005) stated that plant nutrition involves the supply of chemical nutrients which are needed by plant in different quantities for optimum growth and most plants obtain their nutrients naturally from soil. The lack of sufficient nutrients must be supplemented to ensure that the plant grow to full height, size and is able to fulfill all its anatomical and pathological functions (Marsh, 2009). The table below indicates the nutrients required by Gerbera jamesonii with relate to their functions and deficiencies.

Table 2.3 Nutrients requirement of *Gerbera jamesonii* crop (Mercurio, 2002).

Plant nutrients	Functions	Deficiency symptoms
Nitrogen	➢ It is a component of proteins,	➢ Both younger and

	promotes good leaf growth as it responsible for the dark green colour of leaves. ➢ It is an important component of chlorophyll in the leaves and stems. ➢ It is important in protein synthesis and integral part of all amino acids which are the building blocks of protein. ➢ It is important in protein synthesis and integral part of all amino acids which are the building blocks of protein.	older leaves will turn yellow. ➢ Leaves fall off earlier than they should, even during growing season.
Potassium	➢ Influences the protein synthesis in *Gerbera jamesonii* crop, which involves the circulation of energy and it also responsible for cell's turgor pressure. ➢ Furthermore, because of its strong mobility it has a fundamental role in the uptake of water by plant from roots to leaves	➢ Deficiency symptoms of potassium in *Gerbera jamesonii* begins with necrosis at the edge of the older leaves. ➢ The most central part of the leaves usually remains green, although necrosis spots may appear.
Phosphorus	➢ Phosphorus is important in *Gerbera jamesonii* crop because	➢ Deficiency symptoms of phosphorus in

	it hardens the vegetative tissue and also play a significant role in the development of roots	*Gerbera jamesonii begin* with a gradual brownish discoloration to the underside of the leaves along the main veins. Subsequently the symptoms affect the whole leaf, both underside and the upperside
Iron	➢ Plays a very important role in the synthesis of chlorophyll and photosynthetic process. It activates numerous biochemical reactions and is absorbed by plant roots as iron chelate.	➢ Extreme shortage of iron in *Gerbera jamesonii* crop eventually results in leaf veins becoming yellow and limits photosynthesis from taking place.
Boron	➢ It participates in various phases of the plant metabolic processes such as cellular division, transportation of plant sap on both xylem and phloem and transpiration.	➢ Causes the plant development to be stunt and produces necrosis of vegetative apexes.

2.6 CUTFLOWER QUALITY CRITERIA

It is impossible to exclude quality when dealing with cutflowers. Cutflower quality cannot be defined by a single factor as quality depends on several factors. Customers tend to measure quality of cutflowers by the duration that they last after harvest. Since different types of cutflowers have different postharvest life, they will react differently, even when exposed under similar conditions, some flowers will last longer than others (Maree, 2010).

2.6.1 Bud flower size

Dole (2005) indicated that the bigger the flower bud the better the quality of the flowering stems will become. Some flowers have a smaller flower bud, while some have several flower buds, such is often found in cutflowers such as roses, chrysanthemums and carnations, in flowers such as gerberas, quality does not depend on bud numbers, but size as they have single type of flower disc.

2.6.2 Sharpness of flower colour

One of the most significant characteristics of most flowers is colour. Uniformity and sharpness of the colour of the flower are considered as the main factors determining flower quality. Flower colour is mostly affected by poor cultivation conditions such as excessive heat and poor pest and disease management. The world top selling cutflower crops are mostly chosen because of their flower colour. Even if the cultivar looks healthier and appealing, colour will determine how the customer receive it and that will also affect its overall performance in the market (Maree, 2010).

2.6.3 Leaf colour and size

The results of poor cultivation and diseases are clearly visible in the leaves of plants and that can have a dramatic effect on the colour of the flower because the quality of flower, size and colour is determined by the nutrients obtained during cultivation.

Lack of certain nutrients can quickly show by the appearance of yellowing along leaf veins, tips, or edges. Excessive heat can result in burnt tips, while pests and diseases can cause leaves to curl, discolour or die. Healthy plants tend to have larger leaves and more active flowers with uniform colour. Consumers turn to look at the leaves when buying flowers, even if they will remove them (Dole, 2005).

2.6.4 Stem thickness, straightness and length

The stem of the flower must be able to support the flower head. Healthy plants will produce thicker stems that will be able to handle the flower head without any difficulty. However, some cultivars have thicker stems than others. Proper cultivation practices such as regular irrigation, fertilisation, adequate light and pest management will ensure that stems are strong, straight and in good health (Redman et al., 2002).

2.6.5 Weight of cutflower

A healthy cutflower will weigh more than a poor quality one, but that depends on the type of cutflower crop. Crops such as roses, chrysanthemums and lilies have to be weighed to determine their quality which will also have an effect on their market price (Adachi et al., 2000).

This is because the healthier stem will be thicker and have more flowers, more buds, more leaves and be fully turgid. Many cutflowers are often graded according to the weight (Darras et al., 2012). However, in crops such as *Gerbera jamesonii*, stem thickness is more significant than the stem weight because the stem should be able to handle the flower without bending (Ansari et al., 2011).

2.6.6 Absence of spray residue

Proper cultural management such as irrigation, pest and diseases management plays a very significant role in the quality of the final cutflower product (Dole, 2005). A high quality flower stem is the one that does not display visual signs of pests and diseases. Damage from handling, spray residues on leaves, stem and flower heads are amongst the factors degrading the quality of cutflower stem (Maree, 2010).

2.7 POSTHARVEST AND GENERAL CHALLENGES OF *Gerbera jamesonii*.

Herold (2005) stated that most horticultural crops including *Gerbera jamesonii* are at high quality during harvest and must be handled with care to reduce quality reduction. Factors affecting the postharvest quality of the crops exist before the cultivation process and it continues until the crop's shelf-life (Aghdam et al., 2012). Growers should properly plan the postharvest process during production and be able to develop a monitoring strategy for the crop (Shimizu-Yumoto & Ichimura, 2013).

2.7.1 Harvesting challenges

Crops should be harvested at the optimum stage so that it will have a maximum postharvest life (Dole, 2005). Factors that form part of proper harvesting include harvesting time, stage, and method. Some crops enjoy a long postharvest life when they are harvested straight after first opening of flowers, while others prefer to be harvested when the flower is fully opened (Shimizu-Yumoto & Ichimura, 2013).

2.7.1.1 Harvesting time

According to Wouter et al (2011), *Gerbera jamesonii* cutflowers need to harvested in the cool day, this is usually in the morning or late afternoon. Early in the morning flowers are still full turgid, that is when they are full of water and firm (Heinz et al., 1993).

Mahdavi & Kafi (2012), stated that during the heat of the day, more water is lost than can be taken up because of temporary wilting taking place, even if flowers are picked and immediately placed in water, the results are not as good as compared to morning harvest and quality can be lost as well. The flower might stand up again, especially when placed in a cool room, but a lot of unseen damage may already have been done (Celikel & Reid, 2002).

Nowak & Rudnicki (1990), indicates that morning harvest or cutting has advantage in terms of better turgidity, but at times, flowers which may be still wet have a high chance of infected by fungal diseases because plant may still have dew on their leaf surface. Evening harvest or cutting may have an advantage on *Gerbera jamesonii* cutflower crop in terms of higher carbohydrates concentration in flowering stems (Wani & Saha, 2012).

Morning harvest is highly recommended for *Gerbera jamesonii* cutflowers which lose water very quickly after harvest, since flowers are still at full turgor in the morning, they should then be placed in water with floral preservative solution and be taken straight to cool room for prevention of water loss and in that way, quality is enhanced (Kikuchi et al., 1995).

2.7.1.2 Stage of Harvest

The opening stage at which flowers are harvested has a direct influence on their vaselife and how well the flower will continue to open (Sisquella et al., 2013). However, if flowers are harvested too early, the carbohydrates which contain starch and sugar reserve is very low (Pun & Ichimura, 2003). These carbohydrates are source of energy or food needed by the flower to live and to continue open, it help maintain the turgidity , thus preventing the flower from droping or wilting too quickly (Arrom & Munné-Bosch, 2012).

Maree (2010) indicated the flowers that are harvested too late might have past their prime time and also have a shorter vaselife at the consumer level. It is not always easy to determine the exact stage at which flowers must be harvested. Beside the carbohydrate factor, there is also the market demand factor, different markets and consumers want their flowers at different opening stages, for instances gerberas that are harvested for local market and consumers is often more open than those harvested for export market due to the logistic factors (Celikel & Reid, 2002).

Bernaert et al (2013) stated that flowers that will be sold immediately to the final consumer can be harvested more matured than plants sold to wholesale or shipped long distances. Some crops can be harvested at an early opening stage of development during the summer season than in winter season because higher summer light can result in greater carbohydrates level in plants, than winter since warm temperature contribute to faster flower development in the marketing chain or in the consumer's home (van Meeteren et al,. 2000).

Gerberas are harvested when the two outer rings of the tubular flower show the development of pollen on their stamen (Laitinen, Broholm, Albert, Teeri, & Elomaa, 2006). It is very important to harvest the flower before the development of the second tubular ring because the flower postharvest life is shorter compares to other cutflower crops such as roses and chrysanthemums (Mansouri, 2012).

2.7.1.3 Method of harvest

Ahmad et al (2013) indicated that sharp clean tools should be used for removal of flowers from the mother plant. Generally, the mode of harvest for most flowers does not crucially affect the further vaselife if flowers are immediately placed in water or a floral preservative solution after harvest (Darras et al., 2012).

Mercurio (2002) indicated that the *Gerbera jamesonii* flower stem must be gently pulled from the crown or base of the plant using a sideways movement from left to right until the flower stem is detached from the plant. After the flower has been detached from the plant, a final cut should made to allow maximum absorption of water (Wernett et al., 1996). Angle cut is not important for herbaceous crops such as *Gerbera jamesonii* because they can absorb water through external epidermal tissue (Nowak & Rudnicki, 1990).

The crushing of a stem at the cut should be avoided at all cost, as this can cause the *Gerbera jamesonii* cutflower stem to start losing energy through the wounds which then encourage micro-organisms which may in turn cause the stem to rot (Mahdavi & Kafi, 2012). *Gerbera jamesonii* cutflowers stems should be cut close to the growth media, this will allow the stem to last longer during its vaselife period (Alaey et al., 2011).

2.7.2 Postharvest challenges of *Gerbera jamesonii*

Perik et al., (2012) stated that the length of the time the *Gerbera jamesonii* cutflower stems last after harvesting and packing can range from seven to 21 days, but depends on the methods and techniques used both during storage phase in water, cultivation and acclimatisation in the greenhouse during harvest. Genetic factor such as different cultivars should be properly considered because it can cause serious problems in the postharvest period of *Gerbera jamesonii* crop and it might lead to problems such as stem bending and withering of petals (Jong, 1978).

2.7.2.1 Temperature after harvest

After harvest, *Gerbera jamesonii* cutflowers should be transported from the greenhouse to the cool storage as soon as possible to minimise postharvest shock and transpiration (Dole, 2005). During the entire sequence of operations, *Gerbera jamesonii* cutflowers should be maintained at a low temperature according to specific optimal requirement for a particular variety (Amini & Golparvar, 2013). The surrounding temperature is one the most important factor affecting postharvest quality of *Gerbera jamesonii* cutflowers (Celikel & Reid, 2002). High temperatures increase floral development, senescence process *Gerbera jamesonii* cutflowers , meanwhile low temperatures reduce the utilisation of carbohydrates and other processes such respiration and transpiration in plant postharvest life (Wernett et al., 1996).

At low temperatures, cutflowers produce less ethylene, which is a plant hormone that causes ageing or fast maturation in harvested flowers, and the sensitivity to ethylene present in the surrounding atmosphere decreases (Borochov & Mayak, 1984). Low temperature negatively affect the rate of water absorption by cutflowers and it also discourages the development of harmful micro-organism which are detrimental to the vaselife of *Gerbera jamesonii* cutflowers (Javad et al.,2011).

According to (Scariot et al., 2014) ethylene it’s an invisible gas that is produced by plants as part of their natural cycle. Ethylene is also produced by non-natural products which include combustion engines, cigarette smoke and propane heaters. Just like humans, plants are capable of producing certain hormones useful to the normal day to day functions such as growth, development and maturation (Scariot et al., 2014).

Dole (2005) indicated that not all flowers are affected or sensitive to ethylene, including flowers like *Gerbera jamesonii*. The direct impact of ethylene is that it reduces the postharvest life of cutflowers because flowers wilt, incomplete flower abortion, and it even prevent immature bulbs from opening. Plant sensitivity to ethylene varies from high to low.

2.7.2.2 Humidity after harvest

According to Acquaah (2005) cutflowers contain a considerable amount of water, so if they are exposed to the postharvest storage or surrounding with a lower humidity, they will lose water easily and that can lead to sudden reduction in their initial fresh weight. Cutflowers that have lost 10 to 15 percent of their fresh weight are considered to have wilted. This proves that water vapour in intercellular spaces is close to 100% percent, whereas the content of water vapour in surrounding condition is usually much lower than what the plant intercellular contain (Beni & Hatamzadeh, 2013).

Dole (2005) indicated that *Gerbera jamesonii* themselves regulate the intensity of transpiration by closing the stomata on the leaves. It is not possible to completely stop transpiration of water from cutflowers, but water loss can be reduced dramatically by increasing the relative humidity in the grading and packaging area, in storage rooms and by lowering the temperature and limiting air circulation (Van Doorn & Han, 2011).

Mercurio (2002) indicated that the ideal postharvest humidity level for *Gerbera jamesonii* cutflower should be 60 to 65 percent during storage. However, the normal room humidity level of Gerberas do not pose any postharvest threat as long as ideal preservatives are used (Oraee & Zadeh, 2011).

2.7.2.3 Light during postharvest

After harvest, *Gerbera jamesonii* cutflowers flowers are usually stored and transported under low light intensity or in total darkness (Colquhoun et al., 2013).

Postharvest light does not significantly affect the longevity of *Gerbera jamesonii* cutflowers, especially when flowers are treated with floral preservatives containing sugar (Arrom & Munné-Bosch, 2012). Shortage of light during long distance transportation or prolong storage rapidly increase the yellowing of leaves in most cutflowers, but does not affect the postharvest life of *Gerbera jamesonii* cutflowers (Kara et al., 1996).

High light intensity is required mostly for opening of flowers which are harvested at the bud stage. However, with *Gerbera jamesonii* when two outer rings of tubular flowers show development of pollen on their stamen, there is no need to provide light because flowers have already opened (Costa et al., 2013).

2.7.2.4 Postharvest handling process

According to Celikel & Reid (2002), horticultural produce remains alive long after being harvested. Like other living organisms, such as plants, harvesting is an amputation, which means that part of the plant is removed from the roots which used to supply it with water and nutrients. Once the plant is harvested and separated from its source of water and nutrients, it must inevitably die, the role of postharvest handling is to prolong the vaselife as long as possible (Redman et al., 2002).

Careful handling of *Gerbera jamesonii* cutflowers to prevent damage and rapid loss of quality is very significant after the flowers have been harvested and need to be transported to retailer markets (Laitinen et al., 2006). It is very important to handle *Gerbera jamesonii* cutflowers with care to eliminate problems such as bruising, breakage of flowers, and wounded plant tissue which can lead to the production of ethylene gas (Pun & Ichimura, 2003). Ethylene is a natural plant hormone that accelerates flower maturation and can have a dramatic negative effect on the vaselife of *Gerbera jamesonii* cutflowers, it is recommended that fruits and vegetable produce should not be stored in the same room as *Gerbera jamesonii* cutflowers to eliminate ethylene damage (Aghdam et al., 2012).

Redman et al (2002) stated that once *Gerbera jamesonii* cutflowers are harvested, there is a series of steps or tasks that need to be completed to prepare the flowers for the market and those series steps include grading, packing, hydration, recutting, pre-cooling, and cold storage. Not all of the above mentioned factors are necessary to all flowers, but are recommended for *Gerbera jamesonii* cutflower crop to improve its postharvest life (Javad et al., 2011).

2.7.2.5 Postharvest pre-cooling

Elhindi (2012) indicated that precooling consists of rapid steps that need to be taken to remove field temperature on *Gerbera jamesonii* cutflowers before storage. Low temperature reduces the respiration process which in turn helps flowers to last longer during vaselife. Forced air cooling of about 18 to 20°C is the best method that can be used to cool *Gerbera jamesonii* cutflowers if are packed in bunch. This method can be used to cool flowers which are placed in a bucket or packed in dry boxes. The pre-cooling of *Gerbera jamesonii* cutflowers is an important step that need to be practised from individual selling to a large wholesale market (Lee & Kader, 2000).

2.7.2.6 Postharvest cold storage

Cold storage is recommended for most flowers including *Gerbera jamesonii,* especially if flowers are to be transported for long distances (Cimmyt & Abass, 2012). *Gerbera jamesonii* cutflowers should never be stored with fruits and vegetable because the ethylene production, which is a gas that normally causes fast maturation of cutflowers and that can be destructive to the crop postharvest vaselife. *Gerbera jamesonii* cutflowers storage and vaselife are considered to be two different aspects, but customers are only interested in the vaselife of the flowers, while the grower needs to have knowledge of both to determine how long flowers can be kept in cold storage (Celikel & Reid, 2002).

2.7.2.7 Postharvest water quality

Nowak et al (1990) indicated that after harvest, flowers should be placed in water, depending on its source, water may contain different chemical compound, may vary in pH, and may be contaminated with various organic matter and microorganisms.

The salinity of water is a very important factor influencing the quality and vaselife of the flowers. Sensitivity of cutflowers to water salinity differs among different species. The presence of iron in water also influences the vaselife (Skutnik, Lukaszewska, Serek, & Rabiza, 2001).

Hard water containing calcium and magnesium is less harmful to flowers than soft water containing more sodium ions (Elibox & Umaharan, 2010). Water with a low pH of three to four is much better for cutflowers than water with higher pH. When the water pH is lower, microbial growth is limited and water uptake by flowers increased. In general it is better to use deionised or distilled water for cutflowers. Deionised water help to dissolve the various floral preservatives because their chemical components do not react with water contaminants and do not promote bacterial activities (Danaee, Mostofi, & Moradi, 2011).

Alimoradi *et al*., (2013) indicated that if demineralised water is not available, tap water may be used, but it should be boiled, cooled and poured carefully to eliminate any participated sediment. Boiled water contains less air than tap water and is more readily absorbed and transported up the flower stems. Air bubbles block water transporting vessels inside the stem and that results in slow water movement up the stem (Kikuchi et al., 1995).

A treatment which removes air bubbles from water is filtration through Millipore filters using a vacuum pump. However this treatment is expensive and is a disadvantage most growers due to its high cost (Macnish et al., 2008). Warming the water to 38-40 °C and then allow it to cool down to less than 22 °C also improves water absorption, for warm water moves more easily through the stem than cold water. Treatment with water usually benefits flowers which are slightly wilted (Ahmad et al., 2013).

Ahmad *et al.,* (2013) stated that *Gerbera jamesonii* cutflowers should be treated with water with neutral pH and preservatives with low sugar content should be used to enhance water absorption to prevent postharvest stem bending.

2.8 FLORAL PRESERVATIVES

Preservatives contain anti-bacterial components to eliminate micro-organisms in the water as well as on stems of the flowers (Dole, 2005). Microbes that grow and multiply in water infect and block the vessels inside the flower stems, therefore prevent flowers from absorbing water while the transpiration process continues (Cimmyt & Abass, 2012). Silva *et al*., (2013) indicated that most floral preservatives contain carbohydrates, germicide, ethylene inhibitors, growth regulators and some mineral compound. Carbohydrates are the main source of nutrition for cutflowers and the source of energy necessary for maintaining all biochemical and physiological processes after separation from the mother plant.

Sugars support the fundamental process for prolonging the vaselife of cutflowers, such as maintaining mitochondrial structure and functions, improving water balance by regulating transpiration, and increasing water absorption (Pun & Ichimura, 2003). Sucrose is the sugar most often used in floral preservatives, but in some formulations, glucose and fructose may also be included in the formulation. Optimal concentrations of sugar such as sucrose differ in preservatives, but in some formulation glucose and fructose may also be used (Oraee & Zadeh, 2011).

Maree (2010) indicated that many cutflower preservatives have been formulated specifically to treat a specific flower or groups of flowers. This is aimed directly to control a specific problem that flowers have such as stem bending, ethylene sensitivity, yellowing, rotting and wilting.

Asrar (2012) indicated that most flowers that respond well to commercial slow release chlorine solution and aluminium sulphate-based hydration solutions include gerberas, helipterum, hydrangea, hypericum, and ranunculus. Flowers that require a low sugar preservatives treatment include lilies, lisianthus, lilac and sunflower. Flowers that require a high sugar treatment include proteas, leucadendrons and tuberoses (Reinten *et al*., 2011).

The efficiency of floral preservation will vary greatly since it is greatly affected by the quality of water and species. Trials need to be performed to determine the one that suit the flower species that you are growing. It is very important to always follow mixing direction because floral preservatives either can ineffective or detrimental if supplied to the flowers in the wrong concentration. Flowers will be damaged if the preservative concentration is too high, however if the concentration is too low, the preservative will be ineffective and postharvest quality will be negatively affected (Dole, 2005).

Hydrators are very essential in promoting water uptake since they contain chemicals that reduce water pH. They usually do not contain sugar, thus they are not used for holding flowers fin the long term. Some flowers can be physical damaged if their cut stems are kept in hydration for a long time. Commercial hydration solutions are available and the amount of time the stems should be kept in the hydration solution varies from a few second to 48 hours (Asrar, 2012).

The “quick dip” solutions” which are instant hydrations can be used to reduce the amount of micro-organisms on the stem. There are different types of preservative solutions that can be used for holding flowers eight to 24 hours under a specific storage temperature until the final shipping process is complete. Products that contain a high percentage of sugar can be used to promote bud opening, promote flower development, as well as maintain flower quality during storage and transportation (Arrom & Munné-Bosch, 2012).

2.9 ECONOMIC CHALLENGES

Redman *et al*., (2002) indicated it is important for growers to produce good quality crops so that they can stay competitive in global floriculture business. They should start paying attention to their crops from production stage until the product is delivered to the customer (Mahdavi & Kafi, 2012). Growers should aim in selling good quality *Gerbera jamesonii* cutflowers so that they will sustain their competitive advantage in the global floriculture market (Danaee et al., 2013).

2.9.1 Product quality

Perik *et al*., (2012) indicated that improper harvesting method and rough handling of cutflowers can result in bruising and scars on the stems and leaves which will then reduce the quality of the flowers and then affect the market price. Fresh produce that is damaged fail to attract the international market, reduce the country's export performance, create a bad reputation and eventually result in a huge economical loss to the country.

To minimise this economic damage, it is vital to create postharvest awareness of flowers on the part of growers, harvesters, and retailers and that they educate themselves as to the challenges and possible solutions (Soad et al., 2011). The government also needs to intervene by supporting growers with infrastructures such as storage or pack-houses, handling, packing, marketing facilities and technical support. This will play a very significant role in economic growth of the country (Marsh, 2009).

Gerbera Jamesonii currently ranks third among the world's top five selling cutflower crops, so it is important to handle the cutflowers with care, minimise damage improve its postharvest quality to boost the sales of the product and in turn affect the economic status of a country (Atanda, Pessu, Agoda, Isong, & Ikotun, 2011).

2.9.2 Level of income by growers

The grower's level of income plays a very significant role as it affects the level of amount of capital invested on the farm. The income generated from the products sold will determine whether the grower is financial capable to invest in better facilities such as packing house, propagation materials, storage facilities and transportation which will play a big role in preventing or reducing loss of products after harvest (Mekonnen et al., 2012).

Lower investment has been identified as one of the main factor which negatively affect the postharvest quality of fresh products. The lack of enough funds prevent growers from purchasing recommended containers for transport, build high quality packhouse and purchasing of preservatives which will then aid to the quality of harvested crops (Darras et al., 2010).

Gerbera jamesonii can be propagated through different methods, sexual and asexual. Although the crop is capable of producing quality flowers through good cultivation practices, loss is mostly experienced at postharvest stage (Shimizu-Yumoto & Ichimura, 2010). *Gebera jamesonii* growers should fairly invest part of their income generated from sales on postharvest activities such as storage, parkhouse, the use of floral preservatives and transportation, that can lead to more income generated as quality flowers will be sold (Javad et al., 2011).

2.9.3 Consumer behaviour

Magoti et al (2004) stated that the level of postharvest losses at the consumer level is mainly determined by their educational level, income, taste, product knowledge, preference and attitude towards the products. Growers should make it theirprioty to ensure that their have a specific person who deals with customers and that person should ensure that the relationship with consumers is good. It is expected that the higher the product knowledge a consumer has, the better the product will be taken care of and correct postharvest technique is likely to be applied (Tomás-Callejas et al., 2011).

Gerbera jamesonii growers should ensure that their have a good relationship with their customers so that they can be able to assist them with any postharvest challenges that they encounter and that will improve their image in the floriculture business because they will gain their customer trust (Yu et al., 1999).

2.10 AGRICULTURAL POLICY

Mercurio (2002) stated that the involvement of agricultural policy makers will be very important in the development and growth of postharvest section in the industry. Priority should be given to their ability to create important policies and environment which will encourage postharvest practices. More extensive effort by agricultural extensions would be needed by policy makers who will also take into consideration the economic importance of postharvest practice by farmers or growers.

Creating a policy guideline that will encourage research in postharvest and developmental activities of fresh produce particularly cutflower crops such as *Gerbera jamesonii* should be carried out by researchers at institutions and universities to determine and establish the best suitable technology from the grower, retailer to the consumer will be significant (Magoti et al., 2004) .

2.11 GAP IN THE LITERATURE REVIEW

Although *Gerbera jamesonii* is generally a healthy cutflower with a few problems, it is prone to bent-neck or stem bending during its vaselife (Danaee et al., 2011). The insufficient flower stem hardening below the flower head which can result in stem collapse remains one of the major problems of the *Gerbera jamesonii* cutflower (Kara et al.,1996). This problem has a negative effect on the cutflower crop. Intensive research has been done on the cultivation of gerberas worldwide, but more research still need to be done on the postharvest stem bending of the crop. However, few research have been published in South Africa and internationally regarding postharvest treatment of *Gerbera jamesonii* (Reinten et al., 2011).

Stem bending has been identified as a problem in the postharvest life of *Gerbera jamesonii* as being of economic importance in the cutflower industry in South Africa

(Javad et al., 2011). The stem bending problem negatively affects the overall total sales of their product to the market. Research has been done on the topic postharvest treatment of Gerbera jamesonii and its vaselife challenges (Shvarts et al., 1997).

2.12 JUSTIFICATION

The focus of this study was to compare different cutflower preservatives to improve postharvest quality of Gerbera cutflowers. According to Dole (2005) factors affecting the postharvest life of *Gerbera jamesonii* start when the crop is harvested. The quality of the crop is extremely high just after harvesting, and this crop needs to be carefully handled and stored to reduce the loss in quality.

Dris (2003) stated that the *Gerbera jamesonii* cutflower must be handled with care and provision of suitable optimum condition is vital. Optimum conditions include correct temperature, relative humidity, correct carbohydrate level, free water stress and ethylene. The planning of postharvest process should begin before crops are planted. The postharvest planning process should be the first process before the production process begins.

Each cutflower crop and in particular *Gerbera jamesonii* has a specific postharvest requirement that should be able to prolong it’s after-harvest life. It is significant for a grower to set up trials where different species and cultivars can be tested before starting mass production since consumer’s reflection on a specific product can either have a negative or positive impact on its market life (Dris, 2003).

From this literature review, it can be concluded that studies have been conducted on the postharvest treatment of *Gerbera jamesonii,* but no intensive research has been done to determine the optimal preventing postharvest stem bending of *Gerbera jamesonii* cutflower crop. Different postharvest preservatives have been used to identify which one is suitable to improve postharvest of *Gerbera jamesonii* cutflower crop.

The gap, and where this study comes in, is that little research in South Africa on the finding the optimum preservative that can be used to control postharvest stem bending of *Gerbera jamesonii* cutflower.

2.13 CONCLUDING STATEMENT

Based on the literature review conducted during this study, it was found that although *Gerbera jamesonii* is generally a healthy cutflower with few problems. It is prone to bent-neck or stem bending during its vaselife (Danaee et al., 2011). The insufficient flower stem hardening below the flower head which can result in stem collapse remains one of the major problems of the *Gerbera jamesonii* cutflower (Kara et al.,1996). This problem has a negative effect on the cutflower crop. Intensive research has been done on the cultivation of gerberas worldwide, but more research still need to be done on the postharvest stem bending of the crop. Little research have been published internationally and in South Africa regarding postharvest treatment of stem bending of *Gerbera jamesonii* (Reinten et al., 2011). However, this research study will focus on the determination of an optimum preservative that can be used to control stem bending of *Gerbera jamesonii*.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

3.1 INTRODUCTION

In this chapter, an overview of the research methodology applied and followed is presented, to determine the optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* cutflower with the industry standard such as straight stem and good-looking flowers which are free from pest and diseases. This chapter discusses the research approach applied during the course of the study. Data collection and sampling methods are discussed in detail. Reliability and validity of the study are discussed and explained.

Based on the literature that was reviewed, it was determined that the best research process to be followed was a quantitative research method. This method provides comprehensive results on similar topics and the data collection through this method was proven to yield good results (Tony, 2002).

The following were done to answer the research aims and objectives of the research project:

- The healthy stems of *Gerbera jamesonii* cutflower variety stems were used for trials and stem bending was measured daily.
- The experiment was designed to determine the optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* cutflower stems.
- The experiment was carried out for a period of eight weeks.
- The cutflower stems were purchased from the grower early in the morning (Imbali Cutflowers (PTY) limited in Johannesburg East).
- The experiments were performed at the University of South Africa Science Campus laboratory located in Florida, Johannesburg.
- The cutflower stems were placed inside the preservatives and deionised water during their vaselife period.

- The cutflowers stems were recut immediately after arrival at the laboratory and then placed in different glass vase with deionised water containing different preservatives to determine the optimal preservative to minimise postharvest stem bending of *Gerbera jamesonii* cutflower varieties (including control).

3.2 LITERATURE REVIEW

Initially, the internet search was conducted in 2014, using Google and related key words identified from the proposed study area to identify a trend and do a comparative analysis of the study topic. The word “postharvest” showed 190 000 hits. The search strings were used as “postharvest treatment” the hits reduced to 79 000. When the search strings such as “cutflower preservatives” were used, the hits reduced to 24 000. The search strings such as “postharvest treatment” of cutflowers were used, the hits reduced to 16 500. Search strings such as “Postharvest treatment of *Gerbera jamesonii*” were used; the hits were reduced to 4000. The search strings such as “Optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* cutflower varieties” the hits reduced to 19. This literature search indicates that prevention of postharvest treatment of bending cutflowers is significant and well-known concept worldwide, but once search included additional information such as “Optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* cutflower varieties” the number of search hits reduced dramatically. It confirmed that there was a definite need for research to be done, particularly on preservatives which can be used to control stem bending which affect the postharvest quality of *Gerbera jamesonii*.

Different sources were used for the literature review such as Scopus and Science Direct. The UNISA library was also utilised to access relevant books and journals.

The literature search comprised a review of available and applicable data from national and international sources, covering various aspects related, associated with this research both directly and indirectly. It included various project, technical reports, peerreviewed literature, guidelines, books and research studies on postharvest treatment of cutflowers.

The aim of the literature review was to evaluate and determine the current status of postharvest conditions worldwide and then locally in South Africa.

3.3 RESEARCH PROCESS

Based on the outcome of the literature review, the research process was designed and the following actions, which guided the research, were implemented:

- The cutflower source, preservatives, deionised water, glass bottles and the parameters used to determine the optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* for this research study were identified and defined.
- From this information specific parameters were identified for measuring stem bending of *Gerbera jamesonii*. The results of these measurements were used to determine optimal preservatives for preventing stem bending of *Gerbera jamesonii* cutflower varieties.
- The industrial standard of postharvest process, storage and treatment, nationally and internationally was critically researched and considered.
- Different floral preservatives and the variety of cutflower were identified and evaluated in the physical research of this study to determine which suitable floral preservative can minimise postharvest stem bending of *Gerbera jamesonii*.

All of the above mentioned aspects were taken into consideration to fill the knowledge gap and develop the subsequent research design.

3.4 STUDY AREA AND COLLECTION SITE

Cutflowers stem samples were purchased from the local commercial grower known as Imbali Cutflowers Pty Ltd based in East Rand Gauteng. This commercial grower is a well-known and trusted supplier of *Gerbera jamesonii* cutflowers countrywide (Pers.Comm-Lekuleni, 2013).

Agreement in the form of an email from Imbali Cutflowers is attached as an Appendix III.

The research experiments were conducted at the UNISA laboratories on the Science Campus, in Florida. It was decided to utilise the variety “Black diamond” due to its high sales on the market during this study. Black diamond were obtained from a commercial grower in spring 2015 and transferred to the UNISA laboratories for the experiment.

3.5 RESEARCH DESIGN

The research design was done to provide answers to the hypothesis.

The quantitative method of research was carried out to determine optimal preservatives for preventing postharvest stem bending of *Gebera jamesonii* ”Black diamond” for data collection. The research design involved an experiment with five repetitions. The repetitions included four different preservative solutions and one control (only deionized water.

To determine stem bending the experiment were repeated for a period of eight weeks. In total 450 stems were purchased, placed in different preservative solutions for treatment. Each flower stem was measured separately to determine the percentage stem bending.

The reason for using a quantitative approach method was based on the article “The effect of benzyladenine as a preservative on the stem bending of gerbera cutflowers’ (Danaee et al., 2013). A similar method was followed to for this experiment

Other quality requirements and parameters possible influencing stem bending of *Garbera jamesonii* “Black diamond” are investigated and reported.

3.6 RESEARCH INSTRUMENTS

The research used several different types of data-gathering equipments to reach the goal of the study. Below is the entire different data gathering equipments used during this study?

- Ruler and protractor - to measure the degree of bending from 90 °.
- pH meter– to measure water pH during the experiment.
- Preservatives- solutions to be tested during the experiment.
- Thermometer- to monitor the surrounding room temperature.

3.6.1 Protractor and a ruler

This instrument was used to measure the degrees of stem bending. Stem bending was measured daily using the protractor and the angle of bending was recorded from day one till the end of the vaselife period. A ruler was aligned with the flower head of the stem to ensure consistent reading of the protractor. Danaee *et al*., (2013) grouped postharvest stem of *Gerbera jamesonii* “Black diamond” as follows:

- ➢ Bending between 0° - 5° Less bending
- ➢ Bending between 5°- 10° Minimum bending
- ➢ Bending between 10°- 20° Moderate bending
- ➢ Bending between 20° - 50° Maximum bending
- ➢ Bending above 50° upward- Stem collapse

3.6.2 Preservatives

The identity of the different preservatives used is found in Table 3.1. For ethical reasons, future publication of the work and the next chapters of this dissertation reference will be made to the preservative number and the commercial names.

Table 3.1: Different preservatives used to investigate stem bending for this study.

Preservative Numbers	Commercial Name of the Preservatives Used
Preservative 1	Floralife 100 + Floralife quick dip
Preservative 2	Floralife ultra 200 + Floralife quick dip
Preservative 3	Chrysal cvbn + Chrysal dip
Preservative 4	Chrysal clear universal + Chrysal dip

Deionised water was used as a control for the experiment. An instant hydration solution was used to promote immediate solution uptake before the stems were placed in preservatives.

The choice of the preservatives was determined by availability in the market and what the industry is currently using.

3.6.3 Thermometer

A thermometer was used to monitor room temperature during the experiment.

3.7 RELIABILITY AND VALIDITY OF THE QUANTITATIVE RESEARCH

Tony (2002) stated that it is very important to ensure that the equipments used for quantitative research are consistent and stable to measure the data and it should be reliable. Mouton (2001) reported that the ability of other researchers to duplicate the procedure, analysis and conclusions of the study and still get the accurate results is dependent of reliability of measuring instruments and clear methodology used in a particular study. The research instruments play a very significant role since they contribute towards the replicability of the study.

Other postharvest experiment can be applied with similar method in different parts of the world and still get the similar types of results as obtained by other researchers (Javad et al., 2011).

The above mentioned equipments were used to measure parameters which have been proven to be factors contributing in stem bending. Stem bending was measured and analysed in the laboratory using the method used by other researchers such as Danaee et al.(2013).

A pilot experiment was done following a quantitative method where temperature, humidity, and stem bending were measured and analysed by Danaee et al (2013).

3.8 METHODOLOGY FOLLOWED DURING RESEARCH

Ten flower stems were placed in a glass vase containing the preservatives. The experiment was designed with three replications per preservative (Four preservatives and control). Each glass vase contained 10 flower stems and a total of 150 flower stems were used during the experiment. The experiment was performed in the UNISA laboratory equipped with instruments to measure stem bending, temperature, and water pH and water absorption rate.

3.8.1 Research methodology

- Four different preservatives were used during the experiment.
- One control (Deionized water) was used.
- 15 glass vases were used during the experimental process.
- Three vases (including control) were prepared for each preservative.

- Dosages were different for all the preservatives as recommended by the manufacture.
- 400 ml of solution containing water and preservatives was poured in each glass vase.
- Ten flower stems were placed in each glass vase.
- Flower stems were kept in the glass vase for a period of 12 days.
- Daily each single stem was measured to determine the level of bending.
- Two straight lines (vertical and horizontal) were drawn on an A2 page.
- The protractor was placed on top of the horizontal line with the 90 degree indication on the vertical line.
- Each stem was placed on a vertical line drawn on the A2 paper and the protractor was used to measure the level of bending (See Figure 3.1).
- Bending was expressed in degrees. The figure below shows how stem bending measurements were performed during data collection period.

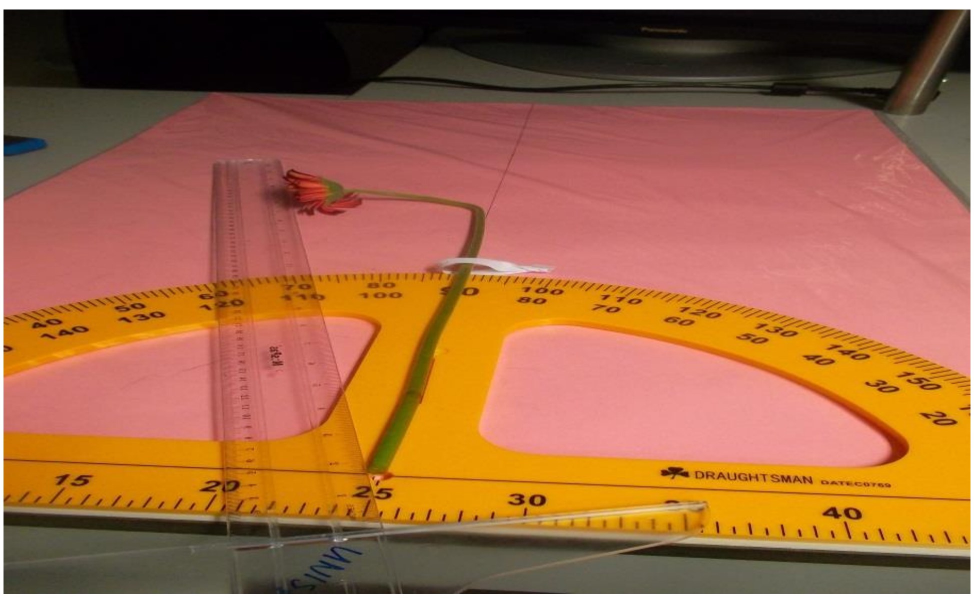

Figure 3.1: Stem bending measurement using a protractor on an A2 page with a straight line (own photograph 20.09.2015).

- Measurements to determine solution absorption rate were done every 24 hours and preservative solution was changed every 2 days.

- The solution absorption rate was determined by measuring the solution remaining in the glass vase and recorded as ml e.g., (400ml − 200ml =200 ml).
- The original amount of solution (400ml) was subtracted by the amount of water remaining in the vase glass after two days.
- Solutions were changed every two days, flower stems were placed on the newly prepared solution after stem bending and water absorption rate were measured.
- The bottom of each of the cutflower stems was recut to 3 cm every two days to minimise rotting and opening of fresh wound to ensure maximum solution absorption rate. Three centimeter was removed each time.
- Temperature was measured daily by recording the reading from the thermometer before the cutflower stem bending measurement were taken.
- Water pH was measured daily by recording the reading from the pH meter while it was still in the solution.

3.8.2 Measures to ensure consistency of the results.

The following measures were followed to ensure consistency of the process and the results:

- Cutflower stems were obtained from a reliable grower well recognized by the industry.
- The vase glasses were equal designed in terms of size and materials.
- Measuring cylinders with calibration levels were used to ensure the correct amount of liquid in mL. The figure below shows how preservatives solution was measured during data collection period:

Figure 3.2 Calibrated measuring cylinder to ensure the correct amount of preservatives solution was added to the vase glass (own photograph 20.09.2015).

- The chemical preservatives were obtained from reliable suppliers.
- The preservative solution was changed every two days to ensure that there is optimum absorption by flower stems and discourage bacterial activities.
- Flower stems were re-cut every two days to ensure that there was no rotting at the base of the stem.
- Stem bending was measured every 24 hours exactly at 09:00 am to ensure there is consistent measurement.
- All glass vases were sterilised every second day with the product called floral sanitary to prevent bacterial development. The figure below shows how vase glass was sterilised during the experimental process:

Figure 3.3: Sterilisation of glass vases used during the experiment (own photograph 10.10.2015).

- Every preservative was prepared in bulk and the correct amount was decanted into the different vases to ensure consistency of the concentration.
- The same preservatives and deionized water were used throughout the whole process.
- Stem bending, solution absorption, pH and temperature records, as well as the sampling dates were kept and then transferred to a Microsoft Excel spreadsheet to be utilised for statistical purpose.

3.9 STATISTICAL ANALYSIS

The data from the observations was analysed using one-way analysis of variance and ANOVA multiple range test at the P< 0.05, for the determination of the optimal preservatives for preventing postharvest stem bending of *Gerbera jamesonii* ‘Black diamond”(Heinz et al., 1993).

The data was collected and captured in Microsoft Excel and analysed using one-way analysis of variance and Duncan’s multiple tests at P<0.05. Graphs were used to show the range of the data of the parameters.

3.10 ETHICAL CONSIDERATION

Ethical consideration impacts this study whereby the names of the chemical preservatives at some stage were excluded for the purpose of protecting the brands. The general principle of ethical consideration is that no damage, harm should originate from the research project. Brands should be respected, and their rights, privacy and integrity should be taken into consideration. To ensure ethically acceptable research and adhere to UNISA’s policy on ethics, the research proposal was approved by CAES committee in November 2014, ethical number (2014/CAES/1530). See appendix I.

CHAPTER 4: RESULTS AND DISCUSSION

4.1 INTRODUCTION

In order to identify optimal preservatives for minimising postharvest stem bending of *Gerbera jamesonii* ”Black diamond”, experimental data was collected in this research study. The results are presented as follows:

- Firstly, temperature and water pH is presented as parameter which does not have a direct effect on the results, but has been measured.
- Secondly, the results of stem bending and solution absorption rate are presented as main parameters affecting postharvest stem bending of *Gerbera jamesonii* “Black diamond”.
- Lastly the results of stem bending and water absorption are evaluated and discussed.

4.2 RESULTS

4.2.1 Water pH data

pH is a measure of the hydrogen concentration. The pH of water is a measure of its acidity or alkalinity. It is measured on a scale that runs from 0 to 14, although a water pH of 7 is neutral, whereas a pH above 7 is alkaline and below 7 is acid. Water of low pH 3-4 is much better for flowers than water with higher pH. In water with low pH, microbial growth is limited and water uptake by cutflowers is higher (Darras et al., 2012).

The water pH for all the repetitions in the experiment was at neutral (7).

4.2.2 Temperature data

The surrounding temperature is one the most important factor affecting postharvest quality of cutflowers (Celikel & Reid, 2002). Higher temperature increase floral development and senescence process, meanwhile lower temperature reduce the transpiration rate, the utilisation of carbohydrates and other materials in plant life (Wernett et al., 1996). At lower temperatures, cutflowers produce less ethylene, and the sensitivity to ethylene present in the surrounding atmosphere decrease.

The room temperature during this experiment was recorded daily and remained constant at 22 degrees Celsius.

4.2.3 Solution absorption rate data

The solution absorption rate was identified as one of the parameters which contribute to the postharvest stem bending of *Gerbera jamesonii* cutflower variety in this study. The results of the water absorption rate per preservative as one of the selected parameter for minimising stem bending are shown below.

4.2.3.1 Solution absorption rate for control (deionised water)

Deionised water was selected and used as the control solvent to determine the water absorption rate by *Gerbera jamesonii* 'Black diamond'. The absorption rates were done in replicate measurements called repetition 1, 2 or 3. The results that show the performance of deionised water can be seen in the Figure 4.1 below:

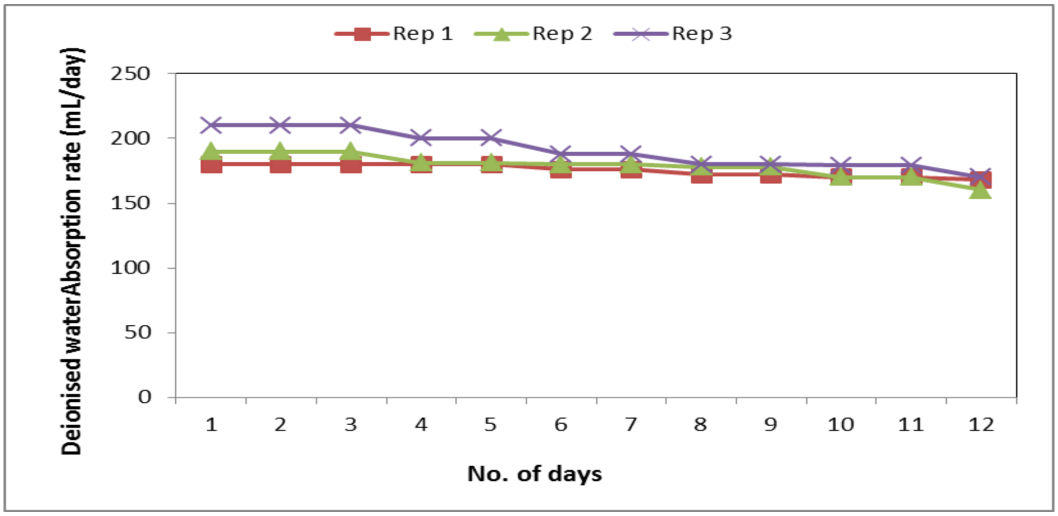

Figure 4.1 Water absorption rate average for deionised water (Control).

a) Repetition 1

The first set of the experimental results for cutflower stems placed in deionised water show noticeable change from day 1, whereby 200 mL was measured from day 1 up to day 3. A slight decrease was noticeable on days 4 and 5 whereby 180 mL was measured. The absorption rate decreased further to 176 mL and 172 mL on days 6 and 7, respectively. The absorption rate began to stabilize between days 8 and 11 whereby the absorption rate of 170 mL was measured. The slight decrease was noticeable on day 12 whereby the absorption rate was 168 mL.

b) Repetition 2

The second experimental results for cutflower stems placed in deionised water was noticeable in the first three days, with absorption rates of 190 mL being measured. The Specific water absorption rate measurements per day were: 181 mL on day 5 and 6, 181 mL on day 7, 180 mL on day 8 and 9, 170 mL on day 10 and 11. The lowest absorption rate measured for repetition 2 was 160 mL on day 12.

c) Repetition 3

The third repeat measured the highest absorption rate for the first 3 days of the experiment, where by the amount of 210 mL (day 1, 2 and 3) was measured. A gradual decrease was noticed on day 4 and 5, whereby the amount of 200 mL was recorded respectively. The absorption rate then further decreased on day 6 and 7, whereby 181 mL were measured. The absorption rate then further decreased on day 8 and 9 measuring (180 mL). There was a slight decrease on day 10 and 11, whereby the absorption rate of 179 mL. The lowest absorption rate of 170 mL for repletion 3 was measured on day 12.

4.2.3.2 Solution absorption rate for preservative 1

Similar to the experiment undertaken with the control, the absorption rates were done in replicate measurements called repetition 1, 2 or 3. The results for preservative 1 can be seen in Figure 4.2 below:

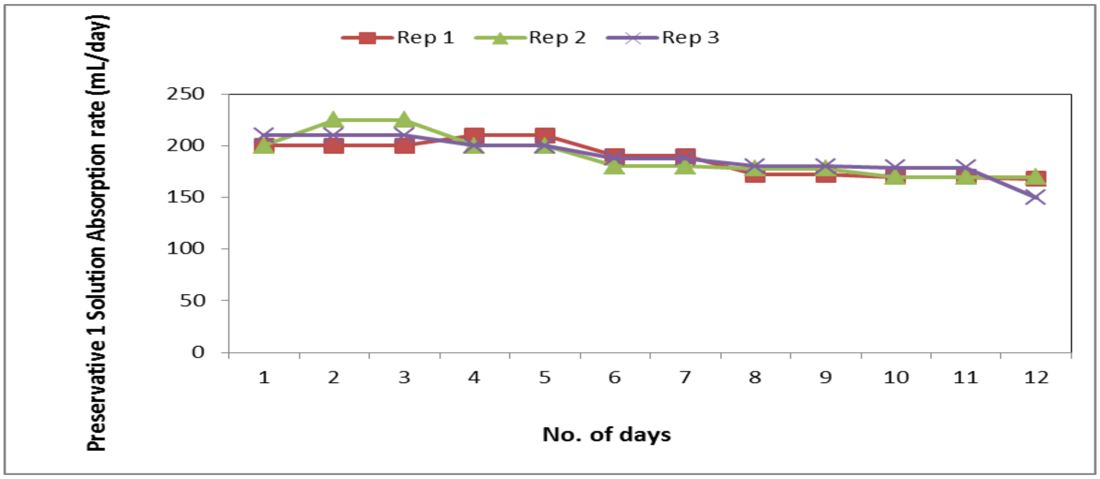

Figure 4.2: Solution absorption rate average for preservative 1.

a) Repetition 1

The first set of the experimental results for cutflower stems placed in preservative 1 show noticeable change from day 1, whereby 200 mL was measured up to day 3. A noticeable increase in solution absorption rate was measured on day 4 and 5 with 210 mL respectively. There was a slight decrease on day 6 and 7 with 190 mL measured. The specific solution absorption rate measurements per day were: 172 mL on day 8 and 9, 170 mL on day 10 and 11. The lowest solution absorption rate for repetition 1 was 168 mL on day 12.

b) Repetition 2

The second experimental results for cutflower stems placed in preservative 1 show noticeable change from day 1, whereby 200 mL was measured. A noticeable increase in solution absorption rate was measured on day 2 and 3 with 225 mL respectively. There was a slight decrease on day 4 and 5 with 200 mL measured respectively. The specific solution absorption rate measurements per day were: 180 mL on day 6 and 7, 178 mL on day 8 and 9, 170 mL on day 10 and 11. The lowest solution absorption rate measured for repetition 2 was 16 mL on day 12.

c) Repetition 3

The third experimental results for cutflower stems placed in preservative 1 show noticeable change from on the first 3 days, whereby 210 mL was measured. A noticeable decrease in solution absorption rate was measured on day 4 and 5 with 200 mL respectively. The specific solution absorption rate measurements per day were: 188 mL on day 6 and 7, 180 mL on day 8 and 9, 178 mL on day 10 and 176 on day 11. The lowest solution absorption rate measured for repetition 3 was 150 mL.

4.2.3.3 Solution absorption rate for preservative 2

The solution absorption rate results of preservative 2 can be seen in Figure 4.3 below:

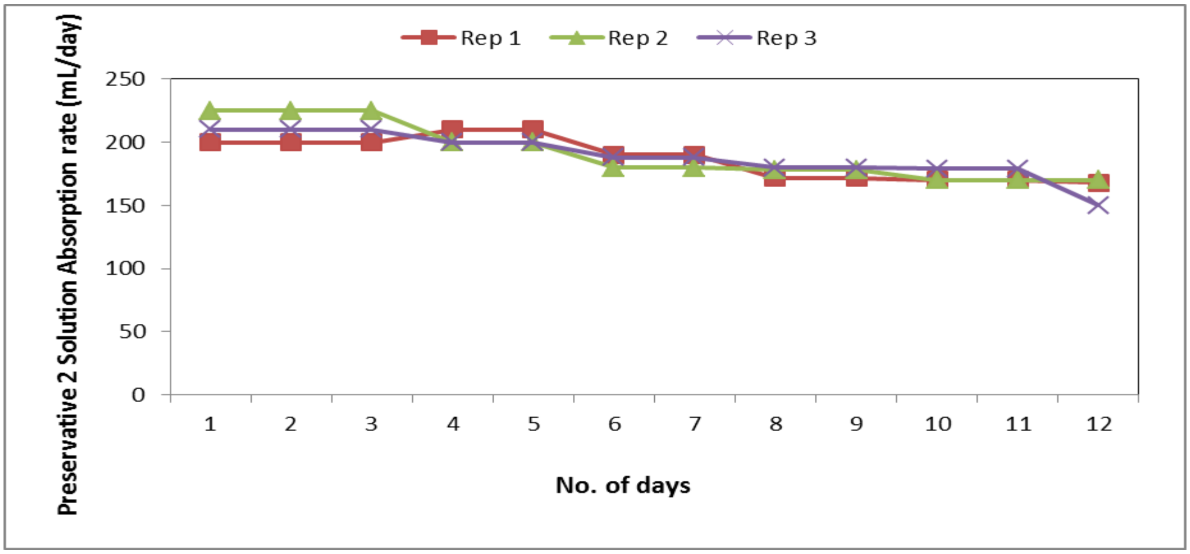

Figure 4.3: Solution absorption rate average for preservative 2.

a) Repetition 1

The first set of experimental results for cutflower stems placed in preservative 2 show noticeable change from the first 3 days of the experiment, whereby the amount of 200 mL (day 1, 2 and 3) was measured. A noticeable increase in solution absorption rate was measured on day 4 and 5, whereby the absorption rate of 210 mL was measured respectively. A gradual decrease was then noticed on day 6 and 7, whereby the absorption rate of 190 mL respectively. The specific solution absorption rate measurements per day were: 172 mL on day 8 and 9, 171mL on day 10, and 169 mL on day 11. The lowest solution absorption rate for repetition 1 measured was 167 mL on day 12.

b) Repetition 2

The second experimental results for cutflower stems placed in preservative 2 show change from day the first 3 days of the of the experiment, whereby the amount of 225 mL (day 1, 2, and 3) was measured. A slight decrease in solution absorption rate was measured on day 4 and 5 with 200 mL measured respectively. The specific solution absorption rate measurements per day were: 180 mL on day 6 and 7, 179 mL on day 8, 176 mL on day 9, 10 and 11. The lowest absorption rate measured for repetition 2 was 170 mL on day 12.

c) Repetition 3

The third experimental results for cutflower stems placed in preservative 2 show noticeable change from the first 3 days of the experiment, whereby the amount of 210 mL (day 1, 2, and 3) was measured. A slight decrease in solution absorption rate was measured on day 4 and 6 with 200 mL measured respectively. The specific solution absorption rate measurements per day were: 188 mL on day 6 and 7, 180 mL on day 8 and 9, 178 mL for day 10, 175 mL for day 11. The lowest absorption rate measured for repetition 3 was 150 ml on day 12.

4.2.3.4 Solution absorption rate for preservative 3

The results that show the performance of preservative 3 can be seen in Figure 4.4 below:

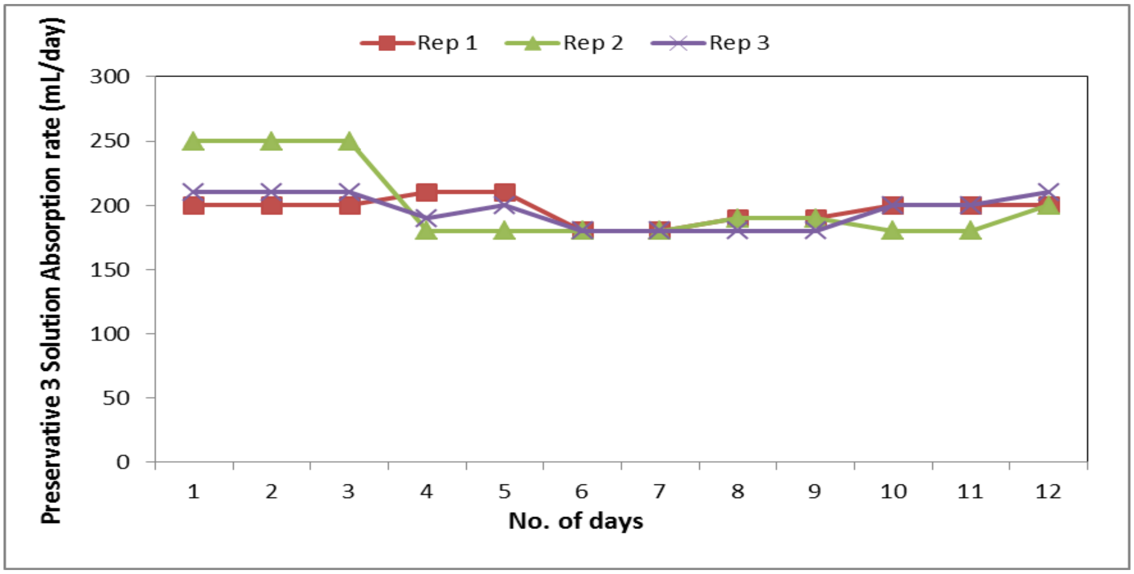

Figure 4.4: Solution absorption rate average for preservative 3

a) Repetition 1

The first set of the experimental results for cutflower stems placed in preservative 3 show noticeable change from the first 3 days, whereby 200 mL (day 1, 2 and 3) was measured respectively. A slight increase was noticed on day 4 and 5, whereby the amount of 210 mL was measured respectively. The specific solution absorption rate measurements per day were: 180 mL on day 6 and 7, 190 mL on day 8 and 9, 200 mL on day 10, 11 and 12.

b) Repetition 2

The second set of the experimental results for cutflower stems placed in preservative 3 show noticeable change from the first 3 days, whereby 250 mL (day 1, 2 and 3) was measured respectively. A noticeable in solution absorption rate was measured on day 4, 5, 6 and 7 with 180 mL measured respectively. There was an increase in solution absorption rate on day 8 and 9, whereby the absorption rate stabilized with absorption rate of repetition 1 at 190 mL respectively. The specific solution rates measurements per day were: 180 mL on day 10 and 11. The absorption rate measured on day 12 was 200 mL.

c) Repetition 3

The third set of experiment results for cutflower stems placed in preservative 3 show noticeable change from the first 3 day, whereby 210 mL (day 1, 2 and 3) was measured respectively. A slight increase was noticeable on day 4 whereby 200 mL was measured. The specific solution absorption rate measurements per day were: 200 mL, on day 5, 180 mL on day 6, 7, 8 and 9, 200 mL on day 10 and 11. The absorption rate measured on day 12 was 210 mL.

4.2.3.5 Solution absorption rate for preservative 4

The results that show the performance of preservative 4 can be seen on the figure 4.5 below.

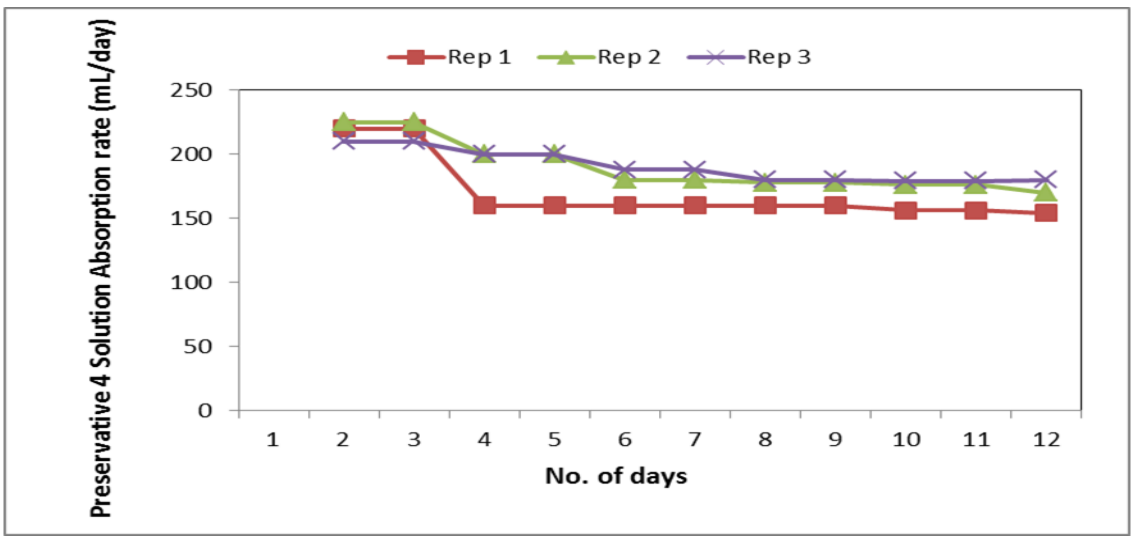

Figure 4.5: Solution absorption rate average for preservative 4

a) Repetition 1

The first set of the experimental results for the cutflower stems placed in preservative 4 show noticeable change from the first 2 days, whereby 220 mL (day 1, and 2) was measured. A noticeable sharp decrease in solution absorption rate was measured on day 3, 4, 5, 6, 7, 8 and 9 with 160 mL respectively. The specific solution absorption rate measurements per day were: 156 mL on day 10, and 155 mL on day 11. The lowest solution absorption rate measured for repetition 1 was 154 mL on day 12.

b) Repetition 2

The second set of the experimental results for the cutflower stems placed in preservative 4 show noticeable change from the first 2 days, whereby 225 mL (day 1 and 2) was measured. A slight decrease in solution absorption rate was noticeable on day 4 and 5 whereby 200 mL was measured respectively. The specific solution absorption rate measurements per day were: 180 mL on day 6 and 7, 178 mL on day 8, 177 mL on day 9, 176 mL on day 10 and 11. The lowest solution absorption rate measured for repetition 2 was 170 on day 12.

c) Repetition 3

The third set of the experimental results for the cutflower stems placed in preservative 4 show noticeable change from the first 3 days, whereby 210 mL (day 1, 2 and 3) was measured. A slight decrease in solution absorption rate was noticeable on day 4 and 5, whereby the solution absorption rate stabilized with solution rate of repetition 2 on day 4 and 5 measuring 200 mL respectively. The specific solution absorption rate measurements per day were: 188 mL on day 6 and 7, 180 mL on day 8 and 9, 179 on day 10 and 11. The absorption rate measured for repetition 3 was 180 mL on day 12.

4.3 RESULTS OF STEM BENDING

The results of the selected four preservatives used during research were recorded and are presented below.

4.3.1. Stem bending results for deionised water (control)

The performance of deionized water, serving as the control, in influencing stem bending was studied and the results repeated three times under the same experimental condition are shown in Figure 4.6 below.

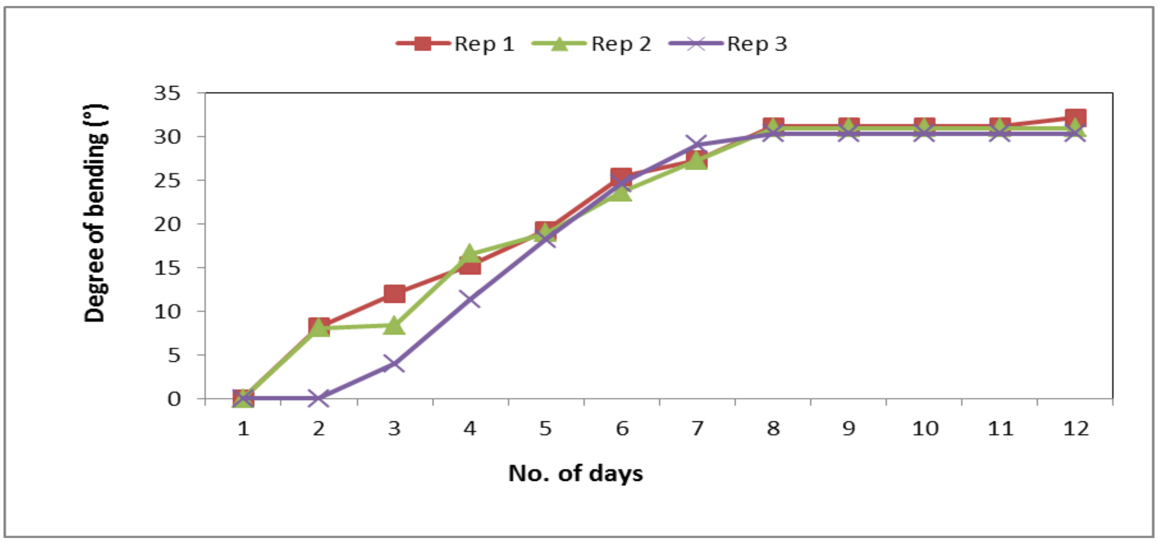

Figure 4.6: The effect of deionized water on stem bending samples.

a) Repetition 1

During repetition 1, there was no stem bending on day 1, but Stem bending increased from days 2 to 8 with the following specific degrees measured per day: 8.2 ^{o} on day 2, 12 ^{o} on day 3, 15.3 ^{o} on day 4, 19.3 ^{o} on day 5, 25.4 ^{o} on day 6, 27.4 ^{o} on day 7, and 31.2 ^{o} on day 8. Stem bending stopped increasing and stabilized from day 8 to day 11 with a measurement of 31.2 ^{o}. The highest stem bending was 32.6 ^{o} and was measured on day 12.

b) Repetition 2

During repetition 2, there was no the stem bending measured on day 1, a similar behaviour observed under repetition 1. Stem bending was measured from day 2 to day 8 with the following specific measurements per day: 8.1 ^{o} on day 2, 8.4 ^{o} on day 3, 16.6 ^{o} on day 4, 19.3 ^{o} on day 5, 25.5 ^{o} on day 6, 27.4 ^{o} on day 7 and 31.3 ^{o} on day 8. Stem bending stopped increasing and stabilized from day 8 to day 12 with a measurement of 31.2 ^{o}.

c) Repetition 3

During repetition 3, there was no stem bending on days 1 and 2. Stem bending increased from day 3 to day 8, the same behaviour was observed during repetitions 1 and 2. Stem bending measurements per day were: 4 ^{o} on day 3, 11.4 ^{o} on day 4, 18.3 ^{o} on day 5, 24.7 ^{o} on day 6, 29.1 ^{o} on day 7 and 30.4 ^{o} on day 8. Stem bending stopped increasing and stabilized between days 8 to day 12 with a measurement of 30.4 ^{o}. The postharvest condition of flowers placed in deionised water after 12 days can be seen on seen figure 4.7 below:

Figure 4.7: Triplicate of cutflower stems treated with deionized water (control) on day 12 of the experiment (own photograph 01. 09.2015).

4.3.2. Stem bending results Preservative 1

The performances of solutions prepared by dissolving four (4) different commercially available preservatives in deionized in influencing stem bending were studied.

The results that show the performance of solution of preservative 1 repeated three times under the same experimental conditions are shown in Figure 4.8 below:

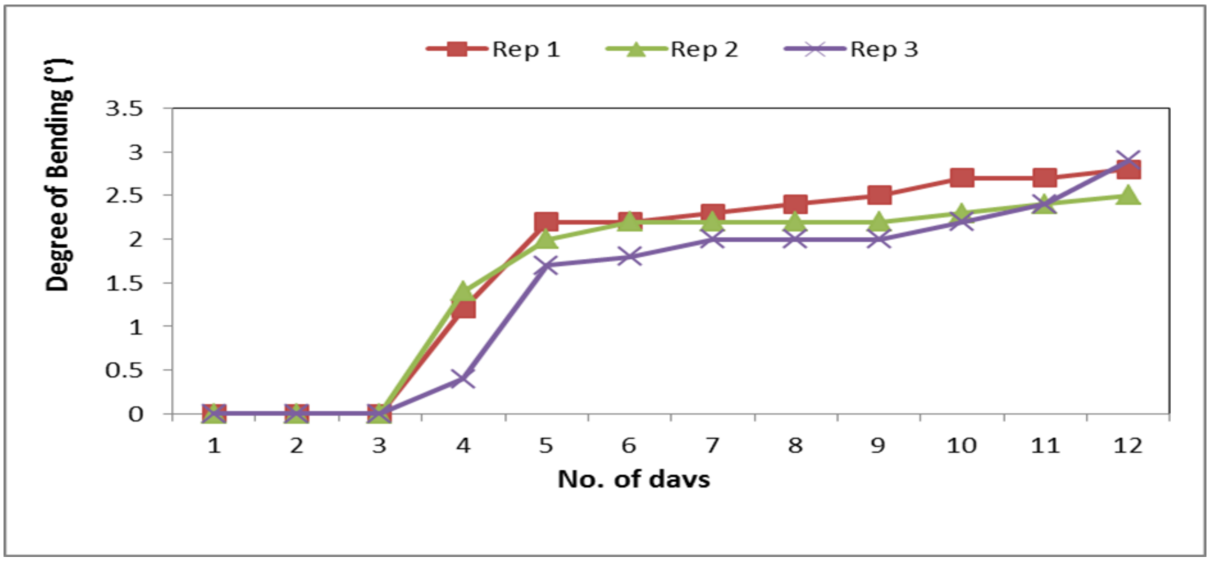

Figure 4.8: The effect of preservative 1 on stem bending samples.

a) Repetition 1

During repetition 1, there was no stem bending in the first 3 days of the experiment. Stem bending increased from day 4 with a measurement of 1.2 ^{o}. The remaining stem bending measurements per day were 2.2 ^{o} on days 5 and 6, 2.3 ^{o} on day 7, 2.4 ^{o} on day 8, 2.5 ^{o} on day 9, 2.7 ^{o} on days 10 and 11. The highest stem bending of 2.8 ^{o} was measured on day 12.

b) Repetition 2

During repetition 2, there was no stem bending in the first 3 days. A noticeable sharp increase in stem bending was measured from day 4 to day 5 with 1.4 ^{o} and 2 ^{o} respectively. A similar trend was observed during repetition 1, whereby there were no stem bending measured on the first 3 days of the experiment. Stem bending stopped increasing and stabilized at 2.2 ^{o} between day 6 and day 9. There was a slightly increase in stem bending which was then observed with 2.3 ^{o} on day 10, and 2.4 ^{o} on day 11. The highest stem bending measured for repetition 2 was 2.5 ^{o} on day 12.

c) Repetition 3

During repetition 3, there was no stem bending in the first 3 days. An increase in stem bending happened with 0.4 ^{o} and 1.7 ^{o} measurements obtained on days 4 and 5 respectively. There was a slightly increase in stem bending of 1.8 ^{o} on day 6. The stem stabilized at 2 ^{o} between days 7 and 9. The stem bending continued to increase on day 10 and 11 with 2.2 ^{o} and 2.4 ^{o} measurements. The highest stem bending of 2.9 ^{o} was measured on day 12. The postharvest condition of stem treated with preservative 1 after 12 days of the experiment can be seen on the figure 4.9 below:

Figure 4.9: Triplicate of cutflower stems treated with preservative 1 on day 12 of the experiment (Own photograph 01.09.2015).

4.3.3 Stem bending results for Preservative 2

The results that show performance of solution of preservative 2 can be seen in the Figure below:

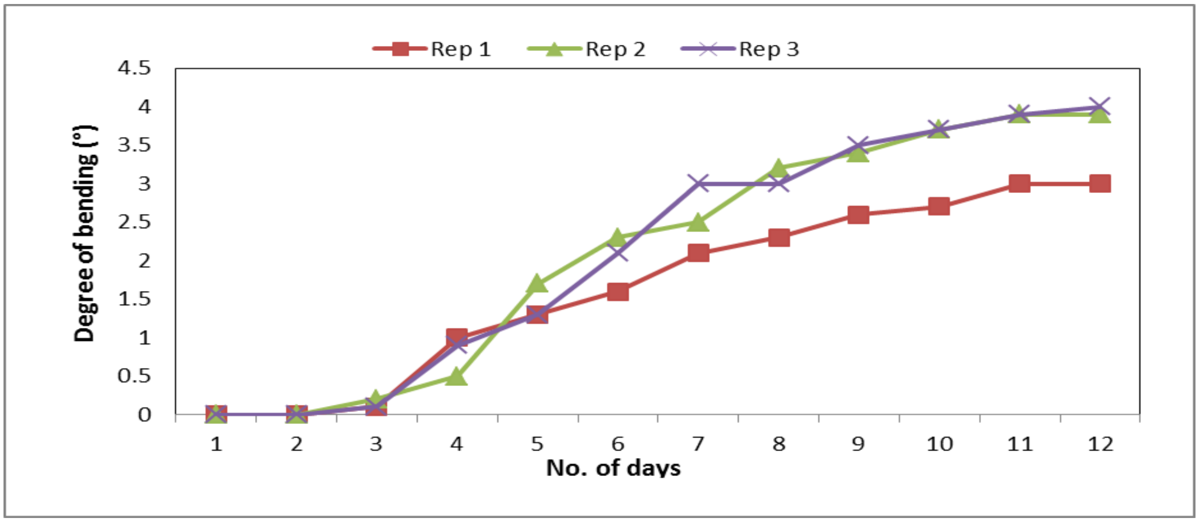

Figure 4.10: The effect of preservative 2 on stem bending samples.

There was no stem bending measured in the first two days during the triplicate measurements which are discussed below.

a) Repetition 1

During repetition 1, there was a slightly increase in stem bending on days 3, 4, 5 and 6, whereby the stem bending degrees measured were 0.1 ^{o}, 1 ^{o}, 1.3 ^{o} and 1.6 ^{o} respectively. Stem bending continued to increase on days 7, 8, 9 and 10, with measurements of 2.1 ^{o}, 2.3 ^{o}, 2.6 ^{o} and 2.7 ^{o} respectively. The maximum stem bending of 3 ^{o} was measured on days 11 and 12.

b) Repetition 2

During repetition 2, there was a steady increase in stem bending from day 3 to day 12. The specific stem bending measurements per day were: 0.2 ^{o} on day 3, 0.5 ^{o} on day 4, 1.7 ^{o} on day 5, 2.3 ^{o} on day 6, 2.5 ^{o} on day 7, 3.2 ^{o} on day 8, 3.4 ^{o} on day 9, 3.6 ^{o} on day 10, 3.7 ^{o} on day 11. The maximum stem bending of 3.9 ^{o} was measured on day 12.

c) Repetition 3

During repetition 3, there was a steady increase in stem bending from day 3 to day 12 and similar trends were observed under repetition 1 and 2. The specific stem bending measurements per day were: 0.1 ^{o} on day 3, 0.9 ^{o} on day 4, 1.3 ^{o} on day 5, 2.1 ^{o} on day 6, 3 ^{o} on day 7, 3.2 ^{o} on day 8, 3.4 ^{o} on day 9, 3.6 ^{o} on day 10 and 3.7 ^{o} on day 11. The highest stem bending of 4 ^{o} was measured on day 12.

4.3.4 Stem bending results for Preservative 3

The results shows performance of preservative 3 can be seen on the figure 4.9 below:

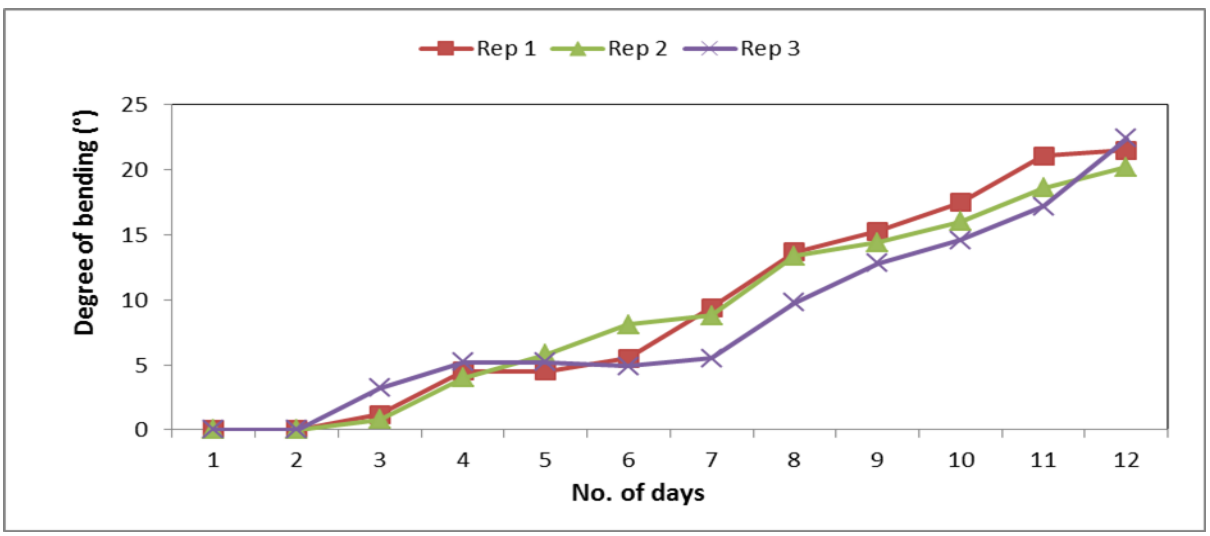

Figure 4.11: The effect of preservative 3 for stem bending samples.

a) Repetition 1

Under repetition 1, there was no stem bending measured in the first two during the triplicate measurements. The specific stem bending measurements per day were: 1.2 ^{o} on day 3, 4.5 ^{o} on day 4 and 5, 5.5 ^{o} on day 6. There was a steady increased in stem bending with measurements of 9.4 ^{o} on day 7, 13.7 ^{o} on day 8, 15.3 ^{o} on day 9, and 17.5

^{o} on day 10. The measurement stem bending of 21.1 ^{o} was obtained on day 11.The maximum stem bending 21.5 ^{o} was measured on day 12.

b) Repetition 2

During repetition 2, there was no stem bending in the first two days. The stem bending of 0.8 ^{o} was measured on day 3. There was a noticeable sharp increase in stem bending of 4 ^{o} on day 4, 5.8 ^{o} on day 5, 8.1 ^{o} on day 6, and 8.8 ^{o} on day 7. Stem bending gradually increased and the specific measurements per day were: 13.4 ^{o} on day 8, 14.4 ^{o} on day 9, 16 ^{o} on day 10 and 18.6 on day 11. The maximum stem bending measured for repetition 2 was 20.2.

c) Repetition 3

During repetition 3, there was no stem bending recorded in the two days. There was a slight increase of 3.2 ^{o} on day 3. There was a noticeable increase in stem bending measurement of 5.2 ^{o} on day 4 and 5. There was a slightly decrease in stem bending on day 6, with the measurement of 4.9 ^{o}. The specific stem bending measurements per day were: 5.5 ^{o} on day 7, 9.8 ^{o} on day 8, 12.8 ^{o} on day 9, 14.6 ^{o} on day 10 and 17.2 ^{o} on day 11. The maximum stem bending measured for repetition 3 was 22.4 ^{o} on day 12.

4.3.5 Stem bending results for Preservative 4

The results shows performance of preservative 4 can be seen in Figure 4.10 below:

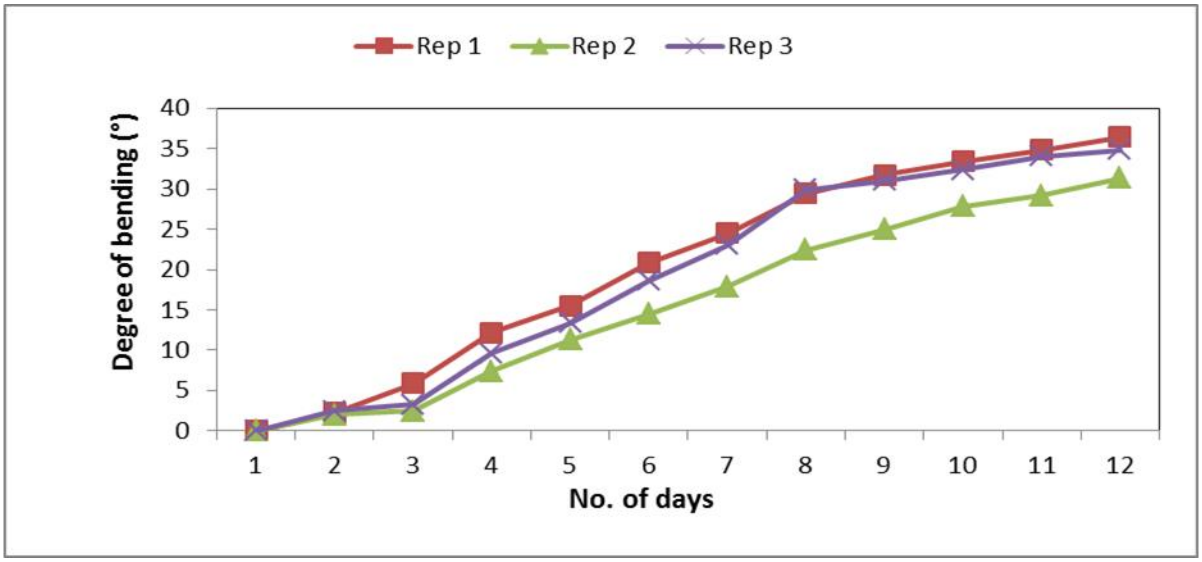

Figure 4.12: The effect of preservative 4 for Stem bending samples

a) Repetition 1

During repetition 1, there was no stem bending in the first day. There was a slight increase in stem bending which was observed with 2.2 ^{o} on day 2, and 5.9 ^{o} on day 3. A noticeable sharp increase in stem bending was measured from day 4, 5 and 6 with 12.2 ^{o,} 15.5 ^{o} and 20.8 ^{o} respectively. The specific stem bending measurements per day were: 24.5 ^{o} on day 7, 29.4 ^{o} on day 8, 31.7 ^{o} on day 9, 33.4 ^{o} on day 10 and 34.8 ^{o} on day 11. The maximum stem bending measured for repetition 1 was 36.4 ^{o} on day 12.

b) Repetition 2

During repetition 2, there was no stem bending in the first day. There was a slight increase in stem bending which was observed with 2 ^{o} on day 2 and 2.5 ^{o} on day 3. A noticeable sharp increase in stem bending was measured from day 4, 5 and 6 with 7.4 ^{o} on day 4, 11.3 ^{o} and 11.3 ^{o} respectively. The specific stem bending measurements per day were: 14.5 ^{o} on day 6, 17.9 ^{o} on day 7, 22.4 ^{o} on day 8, 25 ^{o} on day 9, 27.8 ^{o} on day 10 and 29.2 ^{o} on day 11. The maximum stem bending recorded for repetition 2 was 31.4 on day 12.

c) Repetition 3

During repetition 3, there was no stem bending in the first day. There was a slight increase in stem bending which was observed with 2.5 ^{o} on day 2 and 3.3 ^{o} on day 3. A noticeable sharp increase in stem bending was measured from day 4, 5 and 6 with 9.6 ^{o} for day 4, 13.4 ^{o} on day 5 and 18.6 on day 6. The specific stem bending measurements per day were: 23.1 ^{o} on day 7, 29.9 ^{o} for day 8, 31 ^{o} on day 9, 32.4 ^{o} on day 10 and 34.3 ^{o} on day 11. The maximum stem bending measured for repetition 3 was 34.8 ^{o} on day 12.

4.4 DISCUSSION

4.4.1 Water pH and temperature

Water pH and temperature had no influence on the results of stem bending in this experiment.

4.4.2 Preservatives and control

Table 4.1 Comparison of the maximum stem bending per preservative

Replications	**Control**	**Preservative 1**	**Preservative 2**	**Preservative 3**	**Preservative 4**
R1	32.2	2.8	3	21.5	36.4
R2	31	2.5	3.9	20.2	31.3
R3	30.4	2.9	4	22.4	34.1
Averages	**31.0**	**2.7**	**3.6**	**21.3**	**33.9**

In principle, the preservatives that produce lower degrees of stem bending are known to be better performing and also the preferred ones. The results on Table 4.1 show that preservatives 1 and 2 produced the lowest stem bending with averages of 2.7 ^{o} and 3.6 ^{o} respectively. Preservatives 3 and 4 produced the third and fourth highest stem bending averages of 21.3 ^{o} and 33.9 ^{o} respectively. Since the control solvent do not contain a preservative, it produced the one of the highest average stem bending of 31.0 ^{o}. Solutions prepared with preservatives 3 and 4 were rejected and not recommended because they could not limit the degree of stem bending when compared to solutions prepared with preservatives 1 and 2. Based on the principle that the lower the stem bending, the better the performance of preservative is, the mean average stem bending of 2.7 for preservative 1 shows that the preservative is capable of minimising postharvest stem bending of *Gerbera jamesonii* “Black diamond” cutflower stems for 12 days period.

The average stem bending of 3.6 for preservative 2, indicate that preservative 2 can also minimize postharvest stem bending of *Gerbera jamesonii* “Black diamond” within 12 days period. However, the best performing preservative remains preservative 1. The results also show that preservative 3 and 4 are unable to control postharvest stem bending of *Gerbera jamesonii* “Black diamond’.

Figure 4.13 shows curves of degrees of stem bending per day for preservatives 1, 2 3 and 4 which were plotted on the same axes. The observed trends support the view that preservatives 1 and 2 performed well in reducing the degrees of stem bending. Preservative 3 came a distance third in stem bending performance.

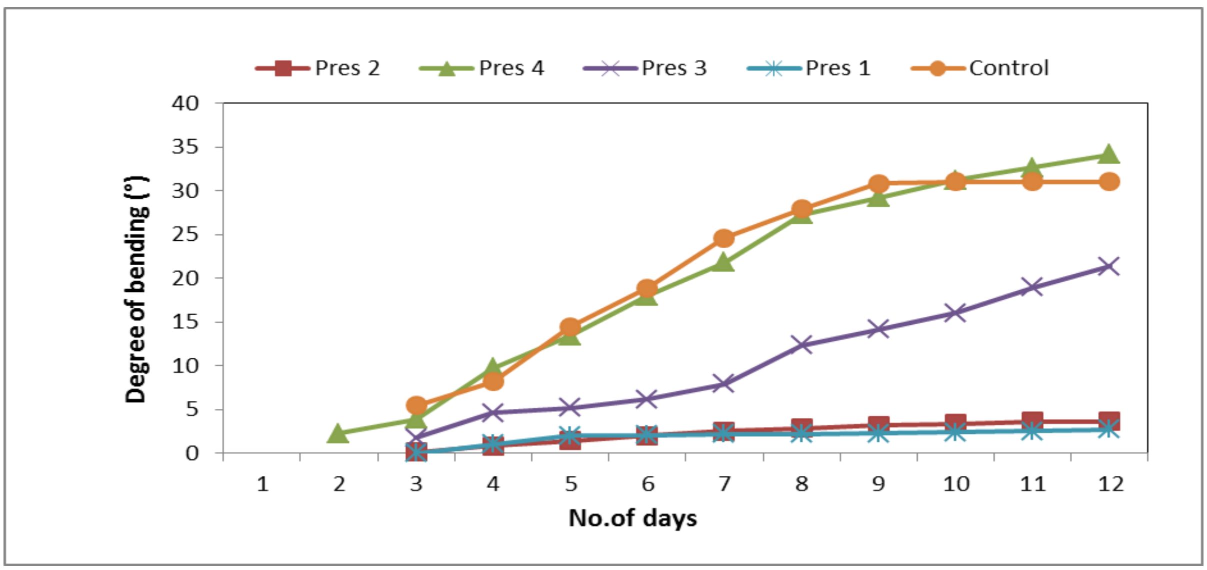

Figure 4.13: The stem bending prevention performance of preservatives.

4.5 RELATIONSHIP BETWEEN STEM BENDING AND SOLUTION ABSORPTION RATE

It was necessary to find out if there was a relationship between postharvest stem bending and solution absorption rate by cutflower stems. The results of the relationship between stem bending and absorption rate of solutions as selected relative parameters which aimed to minimise postharvest stem bending of *Gerbera jamesonii* “Black diamond” can be seen in the Figure 4.12 below.

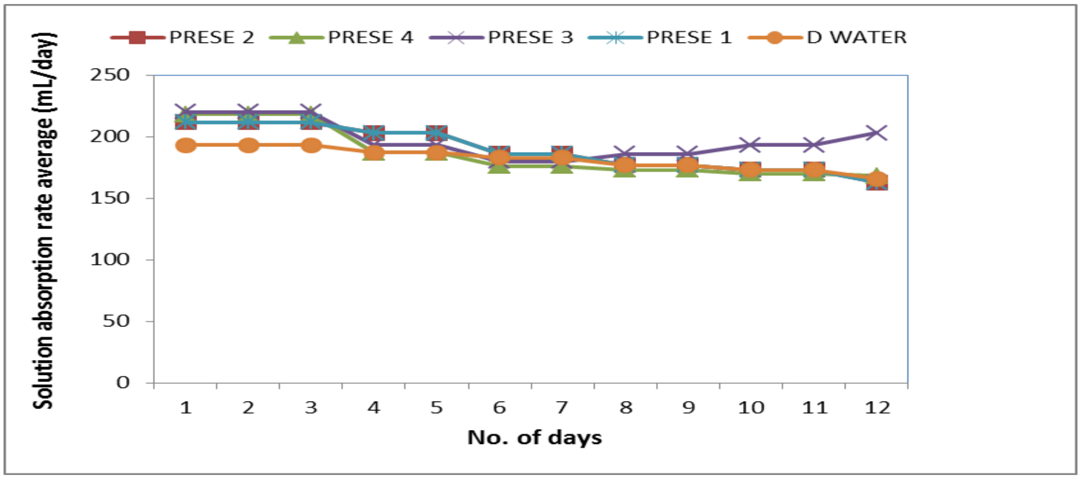

Figure 4:14: Performance results of solution absorption rate.

The experimental results show that there is no concrete relationship between stem bending and solution absorption rate. Even though, the rate of solution absorption was reasonable high on all the preservatives, preservative 1 and preservative 2 measured the lowest degrees of bending compares to preservative 3 and 4 and deionised water.

Even though the water absorption rate was constantly high throughout the experiment, it did not have any effect on the prevention of postharvest stem bending.

4.6 STATISTICAL ANALYSIS

The data from the experimental results was analysed using a one-way repeated measure (ANOVA) to determine the optimal preservative for preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond” for both stem bending and solution absorption rate, a one-way repeated measures anova was used. This tests whether or not there is a significant difference between the applied treatments. If a significant difference is observed, a post-hoc test needs to be carried out. The post-hoc test which was done in this case was Bonferroni, which makes pairwise comparisons between the applied treatments. This is useful to determine which of the treatments are significantly different from each other (Fowler,1998).

The data was captured in Microsoft Excel and analysed using SPSS. The data that satisfied the assumptions required for the use of parametric methods was analysed using one way repeated measure ANOVA and Bonferroni test for post-hoc analysis. The use of (ANOVA) analysis of variances was to test for the significance variances of means in stem bending and solution absorption rate. All experimental results were carried out at 95 percent confidence interval. Graphs were used to show the range of data of the parameters.

All the experimental results were carried out to a 95% confidence interval. Statistical results for the parameter solution absorption rate and stem bending as seen in figure 4.16 and 4.17 match with average results and findings for preservative 1, 2, 3, 4 and the control.

It is therefore, concluded based on the results that preservative 1 and Preservative 2 does have the ability to prevent postharvest stem bending and increasing solution absorption rate of *Gerbera jamesonii* “Black diamond” for the period of 12 days when compared to preservative 3, 4 and control.

4.7 FINAL THOUGHT

There was a small difference in the results for solution absorption rate for all the preservatives including the control. There was no significant difference in the results of the parameter pH. The pH recording for all the preservatives as well as the control was at neutral level (7.0). Room temperature was kept constant at 22 degrees Celsius.

After comparing the experimental results for stem bending and solution absorption rate. It is proven that preservative 1 and preservative 2 are capable of preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond”. However, preservative 1 will enable growers to obtain maximum results with regards to prevention of postharvest stem bending of *Gerbera jamesonii* “Black diamond”.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 ACCOMPLISHMENT OF OBJECTIVES

Having completed this research project, the following objectives were accomplished:

1. What postharvest challenges exist concerning *Gerbera jamesonii* cutflowers.

This objective was achieved by completing the literature review:

- Factors such as stage of harvest, harvesting time, method of harvest, temperature after harvest, and handling processes were identified and summarised.

2. What quality parameters are used to determine postharvest quality of *Gerbera jamesonii* cutflower varieties.

This objective was achieved through the literature review and the experimental process:

- Firstly, the quality parameters which are used to determine postharvest quality of *Gerbera jamesonii* were identified namely: stem bending, floral preservatives, pH, and solution absorption rate.
- Secondly, the literature review determined the effect of the above mention parameters
- Thirdly, an experiment was conducted whereby all the above mentioned parameters were measured, the data recorded and sent to the statistician for analysis.
- The results of all the preservatives including the control were analysed and compared against each other to determine which one is capable of preventing postharvest stem bending of *Gerbera jamesonii* cutflower variety. It was found that that there was a significant difference in abilities from all the preservatives.

- Preservative 1 and 2 measured lower bending average rate compared to preservative 2, 3 and control.

3. **What environmental factors influence postharvest quality of *Gerbera jamesonii* ”Black diamond”?**

   This objective was achieved through the literature review:

   - The environmental factors influencing postharvest quality of *Gerbera jamesonii* “Black diamond” such as light, harvesting techniques, time, pre-cooling, cold storage and postharvest water pH were identified and summarised under literature review.

4. **Which floral preservative (if any) can be used to improve postharvest quality of *Gerbera jamesonii* particularly stem bending.**

   This objective was achieved through data gathered, processed and analysed from the experimental results.

   - Data gathered from the experiment was processed, statistically analysed and conclusion were drawn based on the results found.
   - Preservatives 1 and 2 out-performed the other preservatives including the control.
   - Based on the statistically analysed results, only preservative 1 and 2 are capable of preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond”.

5.2 HYPOTHESES

The following hypotheses were set regarding the preservative which will prevent postharvest stem bending of *Gerbera jamesonii* “Black diamond”:

- H0- There will be no change in stem bending of *Gerbera jamesonii* after treatment with preservatives.
  Hypothesis is rejected.

- H1- There will be increased stem bending after treatment with preservatives.

  Hypothesis is accepted for preservative 3 and 4, but rejected for 1, 2 and control.

- H2- There will be decrease in stem bending after treatment with preservatives.

  Hypothesis is accepted for preservative 1 and 2, but rejected for 3, 4 and control.

5.3 CONCLUSION AND RECOMMENDATION

5.3.1 Conclusion

The detailed literature review of this study indicated that there are several factors affecting the postharvest quality of cutflowers. Most of the factors were factors which include temperature, water pH, stem bending and solution absorption rate were identified and tested to determine how each one of them affect the postharvest of quality of cutflowers particularly stem bending of *Gerbera jamesonii* “Black diamond”.

This research study investigated the optimal preservatives for the prevention of postharvest stem bending of *Gerbera jamesonii* “Black diamond”. The preservatives which are capable of controlling postharvest stem bending of *Gerbera jamesonii* “Black diamond” was determined by comparing the results gathered during the experiment and it was found that only preservative 1 and 2 are capable of preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond”. It was also found that there was a significant difference between the four preservatives as well as the control.

5.3.2 Recommendation for further studies

Research could be conducted on breeding a potential variety which will be resistant to postharvest stem bending. Plant breeding has been successful tools in creating varieties which are disease resistant, high yield crops and creation of totally new variety, so this need to be invested.

- Research need to be conducted the stem hardness of *Gerbera jamesonii* varieties produced through the hydroponic system compares the ones produced through the growth media component such as peat, vermiculite and perlite. This need to be investigated and findings can be used to control stem bending *of Gerbera jamesonii* cutflower varieties.
- Growers should develop a postharvest sampling room where several species or cultivars will be trialed, treated and observed on how they react towards the

postharvest factors such as temperature, relative humidity, water pH and different preservatives to determine their postharvest life. In generally, new cultivar or specie should be trialed and tested before it’s sent to the market, and this help the grower to gather detailed postharvest information about a particular specie or cultivar (Alaey et al., 2011).

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APPENDIX I: ETHICAL CLEARENCE LETTER

UNISA university of south africa

CAES RESEARCH ETHICS REVIEW COMMITTEE

Date: 10/11/2014

Ref #: **2014/CAES/153**
Name of applicant: **Mr MK Maluleke**
Student #: **53376544**

Dear Mr Maluleke,

Decision: Ethics Approval

Proposal: Determination of the optimal prservatives for preventing postharvest stem bending of *Gebera jamesonii* cutflower varieties

Supervisor: Prof SJ Moja

Qualification: Postgraduate degree

Thank you for the application for research ethics clearance by the CAES Research Ethics Review Committee for the above mentioned research. Final approval is granted for the duration of the project.

Please consider point 4 below for further action.

The application was reviewed in compliance with the Unisa Policy on Research Ethics by the CAES Research Ethics Review Committee on 06 November 2014.

The proposed research may now commence with the proviso that:

1) *The researcher/s will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.*
2) *Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study, as well as changes in the methodology, should be communicated in writing to the CAES Research Ethics Review Committee. An amended application could be requested if there are substantial changes from the existing proposal, especially if those changes affect any of the study-related risks for the research participants.*
3) *The researcher will ensure that the research project adheres to any applicable*

University of South Africa
Preller Street, Muckleneuk Ridge, City of Tshwane
PO Box 392 UNISA 0003 South Africa
Telephone: +27 12 429 3111 Facsimile: +27 12 429 4150
www.unisa.ac.za

national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study.

4) *The researcher is advised to use pseudonyms for the various preservatives to be tested in the final report.*

Note:

The reference number [top right corner of this communiqué] should be clearly indicated on all forms of communication [e.g. Webmail, E-mail messages, letters] with the intended research participants, as well as with the CAES RERC.

Kind regards,

Signature
CAES RERC Chair: Prof EL Kempen

Signature
CAES Executive Dean: Prof MJ Linington

PLEASE NOTE PROVISIONS.

APPENDIX II: PROPOSED ARTICLE

Title: Determination of the optimal preservative for preventing postharvest stem bending of *Gerbera jamesonii* “Black diamond**”.**

Authors: Mdungazi Knox Maluleke, Shandung Moja and Elize van Staden.

Journal: South African Journal of Botany.

Year: 2016

APPENDIX III: PLAGURISM REPORT III

From: Semenya, Khomotso
To: Maluleke, Mdungazi
Subject: turnitin
Date: 06 June 2016 11:04:32

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APPENDIX IV: COMMUNICATION WITH SUPPLIER OF CUTFLOWER STEMS

From: Tania Henkel
To: Maluleke, Mdungazi
Subject: Imbali
Date: 15 September 2015 11:39:03
Attachments: image001.png
Imbali Map.pdf

Good day Knox,

As discussed, please see attached map to our premises. If you are using Google maps the farm next to us is pinned – Maluvha.

With regards to the stem lengths: first grade is 40 cm and Choice grade is 50 cm.

As for depositing money, unfortunately the cash deposit fee is high, so we would prefer either EFT payment or cash upon collection. Our banking details are:

Bank: Nedbank
Branch: Arcadia
Branch code: 163345
Acc. No: 1656 286 157

I look forward to meeting you on Thursday.

Regards,
Tania

083 632 1054

imbali
cut flowers
PO Box 26965
Hout Bay 7872
Tel: 082 457-3033
Fax: 0866 064 064

APPENDIX V: COMMUNICATION WITH PRESERVATIVES SUPPLIERS

Hadeco (Pty) Ltd
Reg No: 1946/022129/07
P.O Box 7, Maraisburg, 1700, South Africa
6 Falls Road, Little Falls, Roodepoort,
South Africa
Tel: +27 10 140 1300 Fax:+27 11 958 1409
Email: info@hadeco.co.za
VAT No: 4470104417

ORDER CONFIRMATION

Invoice To	Deliver To		
CASH SALES CHRYSAL	CASH SALES CHRYSAL C.O.D.	**Date**	2015/03/31
		Account	0000403
		Cust Vat No	
		Your Ref	MALULEKE MK
		Our Ref	120069
		Page	1
1700			

Line	Customer Product Code	Total	Description	Approx Del Week	Unit Price	Total Excl Vat	Vat	Total Incl Vat
7110		1	1 X 1LT CHRYSAL EASY DIP	2015/14	95.00	95.00	13.30	108.30
7217		1	CLEAR UNIVERSA LQUID 1000 X 1L	2015/14	1095.00	1095.00	153.30	1248.30
7224		1	CHRYS ROSE LIQUID 1000 X 1L	2015/14	1150.00	1150.00	161.00	1311.00
7312		1	CVBn CHR PRE-TR GERBERA 1X800	2015/14	275.00	275.00	38.50	313.50

Payment Terms	ADVANCE PAYMNT	Total	RAND	2615.00	366.10	2981.10

Bank: Standard Bank of South Africa - Branch: Clearwater - Branch Code: 00 1206 - Account: 331 793 962

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We give no warranty, express or implied, as to description, quality or productiveness of any seeds, bulbs, roots or plants, and will not be in any way responsible for the crop. In the event that the amount reflected on this invoice is not disputed within a period of 14 days, such amount shall constitute conclusive proof of the amount due and payable

Open Rubric

From: Floral
To: knox2mdu@gmail.com
Cc: Maluleke, Mdungazi
Subject: Quotation QUA11367
Date: 24 July 2015 09:57:50
Attachments: Quotation QUA11367.PDF

Quotation QUA11367 from Elro J Braak (Pty) Ltd