

# **EFFECT OF DIFFERENT POSTHARVEST SOLUTIONS ON THREE SPECIES WITH POTENTIAL FOR THE CUT FLOWER INDUSTRY**

by

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## ABSTRACT

Evaluation *Brassica juncea*, *Leonotis nepetifolia* and *Kalanchoe delagoensis* was conducted to determine their potential as cut flower crops. Inflorescences were harvested and evaluated with postharvest solutions. Solutions were classified as: Solution 1 ( a control of distilled, deionized water), Solution 2 (19.72 g/L sucrose, 1 mL/L Clorox®, 0.147 g/L citric acid), and Solution 3 (19.72 g/L sucrose, 1mL/L Clorox®, 0.147 g/L citric acid, 0.221 g/L KCl and 0.257 g/L K<sub>2</sub>SO<sub>4</sub>). Daily evaluation for number of flowers was performed until deemed unmarketable. Results of this research demonstrated the potential of *B. juncea* and *L. nepetifolia* as cut flower crops, lasting both species an average of 17 days. The difficulty in handling and transportation of *K. delagoensis* flowers limits its potential for the cut flower industry, even though they can last an average of 19 days.

## RESUMEN

Se condujo una evaluación de *Brassica juncea*, *Leonotis nepetifolia* y *Kalanchoe delagoensis* para determinar su potencial como flor de corte. Inflorescencias fueron colectadas y evaluadas con soluciones de post-cosecha. Las soluciones fueron clasificadas como: Solución 1 (control de agua destilada y deionizada), Solución 2 (19.72 g/L sacarosa, 1 mL/L Clorox®, 0.147 g/L ácido cítrico) y Solución 3 (19.72 g/L sacarosa, 1mL/L Clorox®, 0.147 g/L ácido cítrico, 0.221 g/L KCl y 0.257 g/L K<sub>2</sub>SO<sub>4</sub>). Evaluaciones fueron hechas cada día para número de flores hasta que no eran mercadeables. Los resultados de esta investigación demostraron el potencial de *B. juncea* y *L. nepetifolia* como plantas para flor de corte durando ambas especies un promedio de 17 días. *Kalanchoe delagoensis* presenta dificultades en el manejo y transportación lo que limita su potencial para la industria de flores de corte, a pesar que pueden durar un promedio de 19 días.

To God, my family, friends, and loved ones . . .  
The ones that have always been there for me, and close to me,  
I love you all . . .

### **Las Flores**

Que bellas las flores  
Las de mi jardín  
Brindan con su aroma  
Ansias de vivir.

Ellas son hermosas  
Suaves cual sutil  
Y ayudan a uno  
En su diario vivir.

Su color es bello  
Jamás igualado  
Y ayudan a uno  
en su momento dado.

Su perfume es suave  
Suave cual sutil  
y ayudan a uno  
en su diario vivir.

Por: Ambrosia Pérez Quiles  
(Abuela Bocha)

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# TABLE OF CONTENTS

ABSTRACT.....	II
RESUMEN.....	III
ACKNOWLEDGMENTS.....	V
TABLE OF CONTENTS.....	VI
FIGURE LIST.....	VIII
TABLE LIST .....	XI
1 INTRODUCTION.....	1
1.1 LITERATURE REVIEW.....	4
1.2 MATERIALS AND METHODS.....	8
1.2.1 PLANTING.....	8
1.3 LITERATURE CITED.....	14
2 <i>BRASSICA JUNCEA</i> FLOWERS EVALUATED WTH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE.....	17
2.1 ABSTRACT.....	17
2.2 INTRODUCTION.....	18
2.3 MATERIALS AND METHODS.....	21
2.3.1 SEED COLLECTION AND PLANTING.....	21
2.3.2 TREATMENT SOLUTIONS.....	23
2.3.3 FLOWER EVALUATIONS.....	24
2.4 RESULTS.....	25
2.4.1 EXPERIMENT 1.....	25
2.5 DISCUSSION.....	40
2.6 CONCLUSION.....	41
2.7 LITERATURE CITED.....	42
3 <i>LEONOTIS NEPETIFOLIA</i> FLOWERS EVALUATED WTH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE.....	44
3.1 ABSTRACT.....	44

3.2	INTRODUCTION.....	45
3.3	MATERIALS AND METHODS.....	47
3.3.1	SEED COLLECTION AND PLANTING.....	47
3.3.2	TREATMENT SOLUTIONS.....	49
3.3.3	FLOWER EVALUATIONS.....	50
3.4	RESULTS.....	51
3.4.1	EXPERIMENT 1.....	51
3.4.2	EXPERIMENT 2.....	58
3.4.3	EXPERIMENT 3.....	65
3.5	DISCUSSION.....	71
3.6	CONCLUSION.....	73
3.7	LITERATURE CITED.....	74
4	<i>KALANCHOE DELAGOENSIS</i> FLOWERS EVALUATED WITH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE.....	75
4.1	ABSTRACT.....	75
4.2	INTRODUCTION.....	76
4.3	MATERIALS AND METHODS.....	78
4.3.1	SEED COLLECTION AND PLANTING.....	78
4.3.2	TREATMENT SOLUTIONS.....	79
4.3.3	FLOWER EVALUATIONS.....	80
4.4	RESULTS.....	81
4.4.1	EXPERIMENT 1.....	81
4.4.2	EXPERIMENT 2.....	95
4.5	DISCUSSION.....	102
4.6	CONCLUSION.....	103
4.7	LITERATURE CITED.....	104
5	STUDY CONCLUSION .....	105

# FIGURE LIST

FIGURE 1.	RAISED CONCRETE BEDS.....	9
FIGURE 2.	DRIP IRRIGATION SYSTEM ON THE PRODUCTION BENCH.....	10
FIGURE 3.	METALLIC-COLORED PLASTIC ROW COVER.....	11
FIGURE 4.	TRIPLE STAGGERED ROW PLANTING DESIGN .....	12
FIGURE 5.	WATER CUT II FLOWER CUTTER.....	13
FIGURE 6.	<i>BRASSICA JUNCEA</i> (A) GROWTH HABIT BEFORE FLOWERING, (B) INFLORESCENCE.....	20
FIGURE 7.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>BRASSICA JUNCEA</i> EXPERIMENT 1... ..	27
FIGURE 8.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 1.....	28
FIGURE 9.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 5.....	29
FIGURE 10.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 10.....	30
FIGURE 11.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 15.....	31
FIGURE 12.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 1.....	32
FIGURE 13.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 5.....	33
FIGURE 14.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 10.....	34
FIGURE 15.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 15.....	35
FIGURE 16.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 3, DAY 1.....	36
FIGURE 17.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 3, DAY 5.....	37
FIGURE 18.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 3, DAY 10.....	38
FIGURE 19.	<i>BRASSICA JUNCEA</i> FLOWERS IN EXPERIMENT 1, TRIAL 3, DAY 15.....	39
FIGURE 20.	<i>LEONOTIS NEPETIFOLIA</i> (A) GROWTH HABIT BEFORE FLOWERING, (B) INFLORESCENCE .....	46
FIGURE 21.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>LEONOTIS NEPETIFOLIA</i> EXPERIMENT 1.....	53
FIGURE 22.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 1.....	54
FIGURE 23.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 5.....	55
FIGURE 24.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 10.....	56
FIGURE 25.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 15.....	57



FIGURE 26.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>LEONOTIS NEPETIFOLIA</i> EXPERIMENT 2.....	60
FIGURE 27.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 1.....	61
FIGURE 28.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 5.....	62
FIGURE 29.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 10.....	63
FIGURE 30.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 15.....	64
FIGURE 31.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>LEONOTIS NEPETIFOLIA</i> EXPERIMENT 3.....	67
FIGURE 32.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 3, TRIAL 1, DAY 1.....	68
FIGURE 33.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 3, TRIAL 1, DAY 5.....	69
FIGURE 34.	<i>LEONOTIS NEPETIFOLIA</i> FLOWERS IN EXPERIMENT 3, TRIAL 1, DAY 10.....	70
FIGURE 35.	<i>KALANCHOE DELAGOENSIS</i> (A) GROWTH OF PLANT BEFORE FLOWERING, (B) INFLORESCENCE.....	77
FIGURE 36.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>KALANCHOE DELAGOENSIS</i> EXPERIMENT 1.....	83
FIGURE 37.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 1.....	84
FIGURE 38.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 5.....	85
FIGURE 39.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 10.....	86
FIGURE 40.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 15.....	87
FIGURE 41.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 20.....	88
FIGURE 42.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 1, DAY 25.....	89
FIGURE 43.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 1.....	90
FIGURE 44.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 5.....	91
FIGURE 45.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 10.....	92
FIGURE 46.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 15.....	93
FIGURE 47.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 1, TRIAL 2, DAY 20.....	94
FIGURE 48.	EFFECT OF THREE POSTHARVEST SOLUTIONS ON THE VASE-LIFE OF <i>KALANCHOE DELAGOENSIS</i> EXPERIMENT 2.....	97
FIGURE 49.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 1.....	98
FIGURE 50.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 5.....	99

FIGURE 51.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 10.....	100
FIGURE 52.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 15.....	101
FIGURE 53.	<i>KALANCHOE DELAGOENSIS</i> FLOWERS IN EXPERIMENT 2, TRIAL 1, DAY 20.....	101

# TABLE LIST

TABLE 1.	<i>BRASSICA JUNCEA</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 1.....	26
TABLE 2.	<i>LEONOTIS NEPETIFOLIA</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 1.....	52
TABLE 3.	<i>LEONOTIS NEPETIFOLIA</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 2.....	59
TABLE 4.	<i>LEONOTIS NEPETIFOLIA</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 3.....	66
TABLE 5.	<i>KALANCHOE DELAGOENSIS</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 1.....	82
TABLE 6.	<i>KALANCHOE DELAGOENSIS</i> INFLORESCENCES CONTRAST TEST EVALUATION FOR MAXIMUM NUMBER OF DAYS OF VASE LIFE, MAXIMUM AND AVERAGE NUMBER OF FLOWERS IN EXPERIMENT 2.....	96

# 1 INTRODUCTION

Flowers are used for enjoyment, expression and decoration around the world. They are for some people a source of inspiration, and words are often written about them in books, poems and songs. They are also used to communicate emotions, and to create a pleasant atmosphere at home or work (Armitage, 1993; Armitage and Laushman, 2003).

Consumers are always demanding and searching for new species of flowers that can be used as cut flowers for floral arrangements. The most important attribute for consumers when choosing a cut flower is flower longevity (Jiménez-Maldonado, 1995). Other considerations are size, shape, color, and/or fragrance. Cut flowers should be free from any deterioration, as this is one of the principal entry points for decay organisms (Hardenburg, 1968). A suitable postharvest program is essential for maintaining cut flowers over a long period of time.

Approximately 91% of the flowers in the flower industry of Puerto Rico consist of imports from other countries (Jimenez-Maldonado, 1995). The Oficina de Estadísticas Agrícolas del Departamento de Agricultura del Estado Libre Asociado de Puerto Rico (2007) reported imports of carnations, roses, chrysanthemums and alstroemerias from foreign countries such as Colombia, Ecuador and Netherlands in 2005 of \$3,245,050 and in 2006 of \$3,388,086 from foreign countries such as Colombia, Ecuador and India. From the United States, cut flower imports were \$448,287 in 2005 and \$127,021 in 2006. The reported wholesale value of cut flower production from the “Estado Libre Asociado de Puerto Rico” was \$510,891 in 2002, \$545,434 in 2003, \$1,296,904 in 2004, \$1,661,332 in 2005 and \$786,677 in 2006 from preliminary data (Oficina de Estadísticas

Agrícolas, 2007). The exports of cut flowers from Puerto Rico to the United States resulted in \$8,815.00 in revenue in 2005 and \$2,626.00 in 2006. The exports from Puerto Rico to foreign countries such as Peru, Turkey and Caicos Islands for the year 2006 produced \$76,440 in revenue and \$8,499 in exports to the U.S. Virgin Islands. The exported flowers include heliconias and gingers. The statistics of production, exports and imports of cut flower shows opportunities for cut flower production in Puerto Rico. An alternative to increase income is to find easy-to-grow flowers that have year-round production, with interesting color, form and/or fragrance and that have a long lasting vase-life. Desirable characteristics may include high fecundity, viable seeds, easy germination, climate adaptability, rapid growth, resistance to pest and pathogens, and easy to manage and transport. In order to increase the availability of flowers and to introduce different species, studies on potential specialty cut flowers should be done.

Specialty cut flowers are defined as “something that is not in the market on a regular basis or only for a short period of time” (Armitage and Laushman, 2003). Kelly and Starman (1990) stated that annual and perennial herbs have received increased emphasis as potential cut flower crops. An increase in popularity has been observed in the United States probably because consumers are looking for different colors, shapes and sizes in cut flowers (Armitage, 1980).

Florists mainly use in a floral arrangement: (1) line materials, usually includes tall spikes with blossoms along the stem to establish lines and the outline design. (2) Mass materials, mainly ball-shaped, rounded and quite massive with many petals, in a design to achieve weight and bulk, and are generally used at the focal point or area. (3) Form materials, usually they have a distinctive shape or pattern with a definite and unusual

form and (4) filler materials, used to occupy space and complement a design, they also help in blending other flowers and colors. Other materials include leaves, branches, moss and other things to create a piece of art in every flower arrangement (Mendoza, 1997).

Cut flowers have different vase-life, from as little as 1 to 3 days in cut flowers such as delphinium, orchid (vanda) alstroemeria, candytuft, columbine, clarkia, gaillardia, lupine and violet, 7 to 10 days in cut flowers such as protea, gladiolus, ginger, primose and heliconia, 1 to 2 weeks in cut flowers such as gerbera, marigolds, snapdragons, orchids and roses; or as long as 3 to 4 weeks in cut flowers such as statice, tulips, anthuriums, carnations and chrysanthemums (USDA-ARS, 2004).

In the present work, three naturalized species of flowering plants *Brassica juncea* (native to Central Asia, Northwest India), *Leonotis nepetifolia*, (native to Tropical and subtropical Africa) and *Kalanchoe delagoensis* (native to Madagascar) were identified and evaluated for the market of specialty cut flowers. Several solutions were used to evaluate the extension of the cut flower vase-life and to determine the best program to ensure postharvest quality.

## 1.1 LITERATURE REVIEW

Water, temperature and fertility affect the growth of plants in the field and in turn affect cut flower postharvest life (Armitage, 1993; Armitage and Laushman, 2003; Yi Wang, 1997). Once a flower is cut, certain handling procedures are done to maximize its vase-life, as the longevity of a flower varies after it has been cut depending on treatments (Behe, 1993; Sacalis, 1993; Wernett et al., 1996). Some practices include: 1) Harvesting of the flower early in the morning when plants are more turgid and water content of the stem is high (Armitage, 1993; Armitage and Laushman, 2003; Hardenburg et al., 1986; Reid, 2002; Teixeira da Silva, 2003); 2) Using sharp knives for a clean cut to help prevent the entrance of microorganisms; 3) Placing flowers immediately in containers with water or preservative solutions and keeping them in refrigerated rooms; 4) Cutting the stem underwater to avoid air embolisms, which are plugs caused when air is sucked up by the stem when it is cut out of the water, preventing the normal movement of the water throughout the stem (Hardenburg et al., 1986; Sacalis, 1993; van Leperen et al., 2001); 5) Stripping of foliage on the sections of the stem that remain below water; 6) Use of chemical preservatives in the water to increase storage or vase-life (Hardenburg, 1968).

Generally, flowers should be harvested at bud stage or when they begin to show color. Others need to be harvested when they have one or two basal flowers open or when they are fully opened, but all flowers must be harvested at the minimum harvest maturity; the stage at which the harvested buds can open fully and have satisfactory display life after they are cut and distributed (Armitage, 1993; Reid, 2002).

Postharvest solutions can improve water uptake, delay aging and deterioration and improve flower opening. Several commercial preservative materials are available. Most contain sugar, a bactericide (often a chlorine compound), and an acid substance to reduce the pH of the water to 3.5. Sucrose and other carbohydrates are needed to provide the energy for maintenance and development of the cut flower (Armitage, 1980; Armitage and Laushman, 2003; Hardenburg et al., 1986; Nowak and Rudnicki, 1990; Sacalis, 1993).

Sugar dissolved in water serves as substrate for respiration and other metabolic activities and is usually given at concentration varying from 1% to 7% (Devlin, 1969). Adding sucrose helps prolong vase-life and bud opening of some flowers (Doi and Reid, 1995; Sacalis, 1993). Carnation flowers placed in preservative solutions soon after cutting lasted 17 days at room temperature compared to flowers placed in tap water that lasted only for 7 days (Hardenburg, 1968). Constant application of 1%, 2% or 5% sucrose to individual open flowers of *Gloriosa rothschildiana* significantly enhanced vase-life by 12% indicating that the vase-life of the flower was extended by delaying senescence in the flowers (Jones and Truett, 1992). Similar results were observed with a *Limonium* hybrid (5 days in water compared to 17 days in solution 2% sucrose) (Doi and Reid, 1995), *Alpinia purpurata* (6 days in water compared to 14 days in solution 2% sucrose) (Broschat and Donselman, 1987; Tjia, 1988) and *Physostenia* (6 days in water compared to 14 days in solution 2% sucrose) (Kelly and Starman, 1990). Sucrose treatments also significantly enhanced opening and coloration of mature buds, resulting in longer vase-life (Jones and Truett, 1992).



A bactericide helps prevent plugging of water-conducting tissue by controlling the growth of harmful bacteria. Lowering the pH of the water improves the water uptake keeping flowers hydrated, while discouraging microbial growth (Armitage, 1980; Armitage and Laushman, 2003; Faragher et al., 2002; Hardenburg, 1968; Hardenburg et al., 1986; Sacalis, 1993). The most commonly used acid ion for cut flowers is citric acid.

Many tropical flowering plants do not respond to preservatives added to the holding solutions. *Heliconia psittacorum*, for example, shows no effect for the extension of vase-life with the addition of floral preservatives (Donselman and Broschat, 1988) or the addition of citric acid (Kai-po et. al., 1989).

The environmental storage conditions can also affect the quality of cut flowers. Light promotes color intensity of the flowers and inhibits the yellowing of the foliage during storage. The temperature in the storage room should be low, between 5 °C and 13 °C to increase the vase-life of the flowers. Lower temperature decreases flower metabolic processes, such as respiration, thus extending the flowers' quality for a longer period of time. Tropical flowers should be excluded from low temperature because they might suffer chilling injury which makes flowers to turn clear, then brown and then they are dead. The recommended temperature for tropical flowers is between 13 °C to 17 °C (Sacalis, 1993).

Ethylene is a natural gas plant hormone released by all flowers. It causes individual flowers and leaves to wilt and drop, senescence of the flowers, and reduces quality of cut flowers. Low concentrations such as less than one part per million (<1ppm) for short periods can result in premature senescing, shattering or other damages. In

order to avoid the effect of ethylene cut flowers should be stored in cold or refrigerated storage, because low temperature reduces the ethylene production, therefore decreasing the effect and damage of ethylene (Reid, 2002; Armitage, 1993).

## 1.2 MATERIALS AND METHODS

### 1.2.1 *Planting*

A concrete raised bed (11.8 m x 0.94 m) was prepared at the University of Puerto Rico, Mayagüez Campus with a mixture of vegetative compost and sand (1:1) and roto-tilled twice (Fig. 1). Drip irrigation was applied as needed based on visual assessments of the species and soil (Fig. 2). A metallic-colored plastic row cover was set on the ground for weed and insect control (Fig. 3). Holes (10 cm diam.) were cut in the plastic for planting (Fig. 4).

Once the first flowers opened, nine spikes were harvested between 0500 and 0600 hours using a sharp knife for each trial. The flowers were transferred to a 5-gallon bucket filled with distilled water. They were manually taken to the laboratory where the stems were cut underwater to a length of 60 cm with a Water Cut II (DB Manufacturing, Middleton, WI) flower cutter (Fig. 5). All leaves on the lower section of the stem were removed. Flowers were randomly allocated among the solutions.



**Figure 1. Raised concrete beds** (11.8 m x 0.94 m). Prepared at the University of Puerto Rico, Mayagüez Campus. The beds were filled with a mixture of soil and sand (1:1) and roto-tilled twice.



**Figure 2. Drip irrigation system in the production bench.**





**Figure 3. Metallic-colored plastic row cover.**



**Figure 4. Triple staggered row planting design.**





**Figure 5. Water Cut II flower cutter.** (DB Manufacturing, Middleton, WI)



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## **2 *BRASSICA JUNCEA* (L.) FLOWERS EVALUATED WITH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE**

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Additional index words: Postharvest flower management, cut flower production, Brown mustard, Oriental mustard, Chinese mustard, Indian mustard.

### **2.1 ABSTRACT**

*Brassica juncea*, a species of flowering plant naturalized from Asia, was identified and evaluated for the market of specialty flowers. Cut flowers have a limited vase-life that depends on the cultivar, time of harvest, and postharvest handling. The objective of this study was to evaluate the adaptability of *B. juncea* as a potential cut flower crop, including the effect of two postharvest solutions and a control on the extension of the vase-life. The solutions were classified as: Solution 1 (control of deionized, distilled water), Solution 2 (19.72 g/L sucrose, 1 mL/L Clorox®, 0.147 g/L citric acid in deionized, distilled water), and Solution 3 (19.72 g/L sucrose, 1mL/L Clorox®, 0.147 g/L citric acid, 0.221 g/L KCl and 0.257 g/L K<sub>2</sub>SO<sub>4</sub> in deionized, distilled water). The experiment had three trials. Evaluation of flower number was performed daily until they were deemed unmarketable. Overall, solutions 2 and 3 had the best results for length of vase-life, maximum number of flowers and average number of flowers. In this experiment, the vase-life was 11 days for solution 1, 22 days for solution 2 and 2 days for solution 3. From this experiment, it is recommended to keep *Brassica juncea* flowers in a solution containing sucrose to obtain the best vase-life. The results of this research demonstrated the potential of *Brassica juncea* as a cut flower crop.

## 2.2 INTRODUCTION

*Brassica juncea* (L.) Czernajew (Fig. 6) (*Brassicaceae* or *Cruciferae*) commonly known as mustard, is native to Asia. The name mustard is derived from the Latin (*mustum ardens*) that means burning must in reference to the spicy seed. Other common names of this plant include: Brown mustard, Oriental mustard, Chinese mustard, and Indian mustard. *Brassica juncea* is a perennial herb that usually grows as an annual or biennial attaining a height of 1 m or more. The leaves are alternate, and 8-20 cm long. The lower leaves are pinnately lobed or coarsely toothed, while the upper ones are less lobed. The bright yellow fragrant flowers in the terminal clusters are 1.5 cm and are positioned on short stems at the ends of the branches. The flowers are hermaphrodite and are mainly pollinated by bees.

*Brassica juncea* is known from six different municipalities and is found in sites from 150-1060 m in elevation throughout Puerto Rico. It blooms throughout the year. There are four sepals and four clawed, lemon yellow petals, with six stamens (four long and two short) with curling anthers in each flower. When flowering, the raceme continues to elongate as the flowers mature in order to produce seed pods. The seed pods are siliques 4.5 cm long and are close to the stems (Anonymous, 1987; Albrecht-Llamas, 2003; Duke, 1983; Liogier, 1990).

In order to have adequate market-life, the harvest stage index for *B. juncea* inflorescence should be when the first flowers open at the top part of the inflorescence. This ensures that flowers are not picked too early, where they may not open, or too mature, where they will have a short life. Most annuals are harvested at this stage (Armitage, 1993).

Information on the postharvest handling of *Brassica* is scarce. Therefore, an evaluation was conducted on the postharvest cut flower quality. Cut stalks with inflorescences were placed in two solutions and a control to observe the potential for prolonging the vase-life of the flowers.



Figure 6. *Brassica juncea* (A) growth habit before flowering, (B) inflorescence.

## 2.3 MATERIALS AND METHODS

### 2.3.1 Seed collection and planting

Seeds of *Brassica juncea* were collected in August 2005 from mature inflorescences in Lares, Puerto Rico and stored at 13° C for one month before planting. A raised concrete bed (11.8 m x 0.94 m) was prepared at the University of Puerto Rico, Mayagüez Campus with a mixture of vegetative compost and sand (1:1) and roto-tilled twice (Fig. 1). Drip irrigation system was established (Fig. 2). A metallic-colored plastic row cover was set on the ground for weed and insect control (Fig. 3). Holes (10 cm diam.) were cut in the plastic and a triple, staggered row design was used to plant the seeds in September, with spacing of 30 cm between rows and 60 cm within the row for a total of 53 plants in the bed (Fig. 4). Drip irrigation was applied as needed based on visual assessments of the species and soil. A solution of 20-20-20 fertilizer (Tropical® TF Puerto Rico Corp., Sabana Seca, Puerto Rico) was applied according to label directions every fifteen days until bloom. Mavrik Aquaflow® insecticide (Sandoz Agro, Inc., Des Plaines, Illinois) was applied as needed according to label directions when leaf damage caused by insects appeared.

Once the first flowers opened, in December, nine spikes or inflorescences were harvested for each of three trials with a total replicates of twenty-seven spikes. Harvests occurred between 0500 and 0600, using a sharp knife, and the inflorescences were immediately transferred to a gallon bucket filled with distilled water. They were manually taken to the laboratory, where stems were cut underwater to a length of 60 cm with a Water Cut II (DB Manufacturing, Middleton, WI) flower cutter (Fig. 5). All leaves on the



lower section of the stem were removed. Flowers were randomly allocated among the solutions.

### *2.3.2 Treatment solutions*

Each inflorescence was immediately placed in a 500 mL Erlenmeyer flask with 300 mL of solution. Solutions were prepared in a 1 L container and divided into three replications (individual Erlenmeyer flasks) per treatment. Treatment solutions were as follows: 1) distilled, deionized water (control); 2) distilled, deionized water, 19.72 g sucrose (2%), 2 mL sodium hypochlorite (Clorox® 0.2%), 0.147 g citric acid, and 3) Solution 2 + 0.221 g KCl and 0.257 g K<sub>2</sub>SO<sub>4</sub> adopted from Sacalis (1993). Additional citric acid (1%) was added to solutions 2 and 3 to titrate to pH 3.5.

### *2.3.3 Flower evaluations*

Three samples for each of the three solutions were set in a Biotronette Mark III Model 846 (Lab-line Instruments, Inc., Melrose Park, Illinois) environmental chamber that controlled the temperature at 19° C, with four fluorescent light bulbs (2700 lumen/bulb; 8 h light/16 h dark/day). The trial was repeated two more times (trials 2 and 3) with 2 or 3 days between each experiment. Number of flowers was counted daily and pictures were taken for reference. Water uptake was measured and additional solution was added using a syringe to maintain 300-mL of solution. Solutions were changed every other day and stems were re-cut when any indication of plugging appeared. The evaluation lasted until the flowers were no longer marketable, as judged by visible browning and wilting of the flower stem or the inflorescences.

Statistical analysis was done using SAS 2003 (Copyright © 2002-2003 by SAS Institute Inc., Cary, NC, USA). Contrast tests using the mean (mean to compare the estimated average) were performed to determine if differences occurred among solutions for the days of vase-life and maximum number of flowers in the experiment.

## 2.4 RESULTS

### 2.4.1 Experiment 1

*Brassica juncea* germinated five days after planted. The growth of the plant lasted four months with a rapid growth. After four months stems started to elongate and were then harvested when the first flower appeared. In the investigation, a significant difference in the F-test between the control group compared to the two experimental groups was observed in the evaluation of *Brassica* for vase-life (days) indicating that one of the solutions was better than the other on days of vase-life, maximum number of flowers and the average number of flowers (Table 1) Flowers in solutions 2 and 3 lasted twice as long as flowers in solution 1. Figures 8 to 11 show the quality of the inflorescences throughout the length of the experiment for trial 1, Figures 12 to 15 for trial 2, and Figures 16 to 19 for trial 3. An average of the vase-life of the flower shows that the species can last up to 11 days for solution 1 (control), 22 days for solution 2 and 21 days for solution 3 (Fig. 7). Inflorescences of *Brassica juncea* did respond positively to the addition of sucrose and sucrose and nutrients for this experiment in all three trials. By adding sucrose to the water solution *Brassica juncea* inflorescences can last up to 18 days and have a desirable amount of flowers.

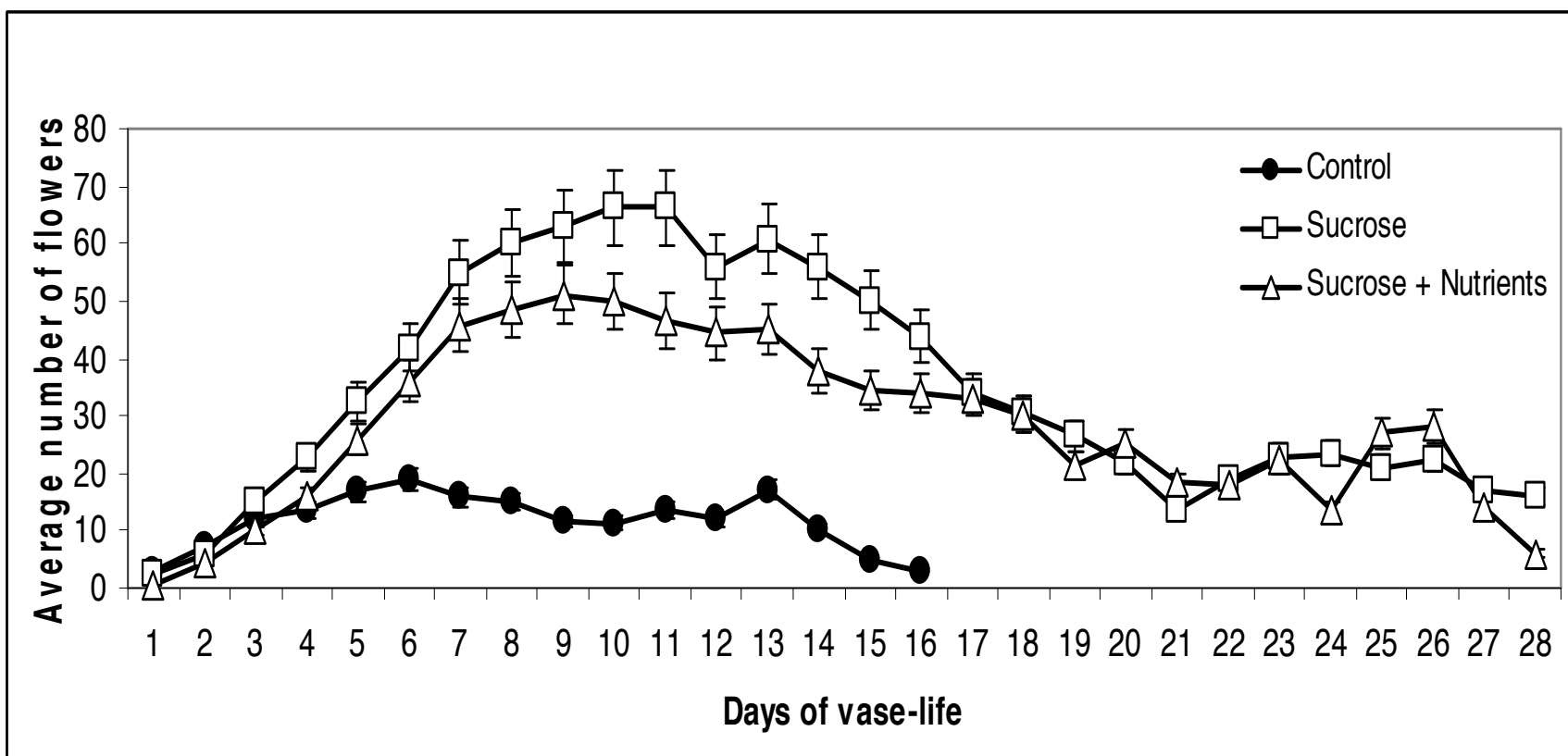
Some plants were affected by the larvae of the Lepidopter *Ascia monuste* (Pyralidae), commonly known as armyworm. This plague was controlled with the use of Mavrik Aquaflow. The incidence with armyworm did not affect the plant growth rate or production of flowers.

**Table 1. *Brassica juncea* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 1.**

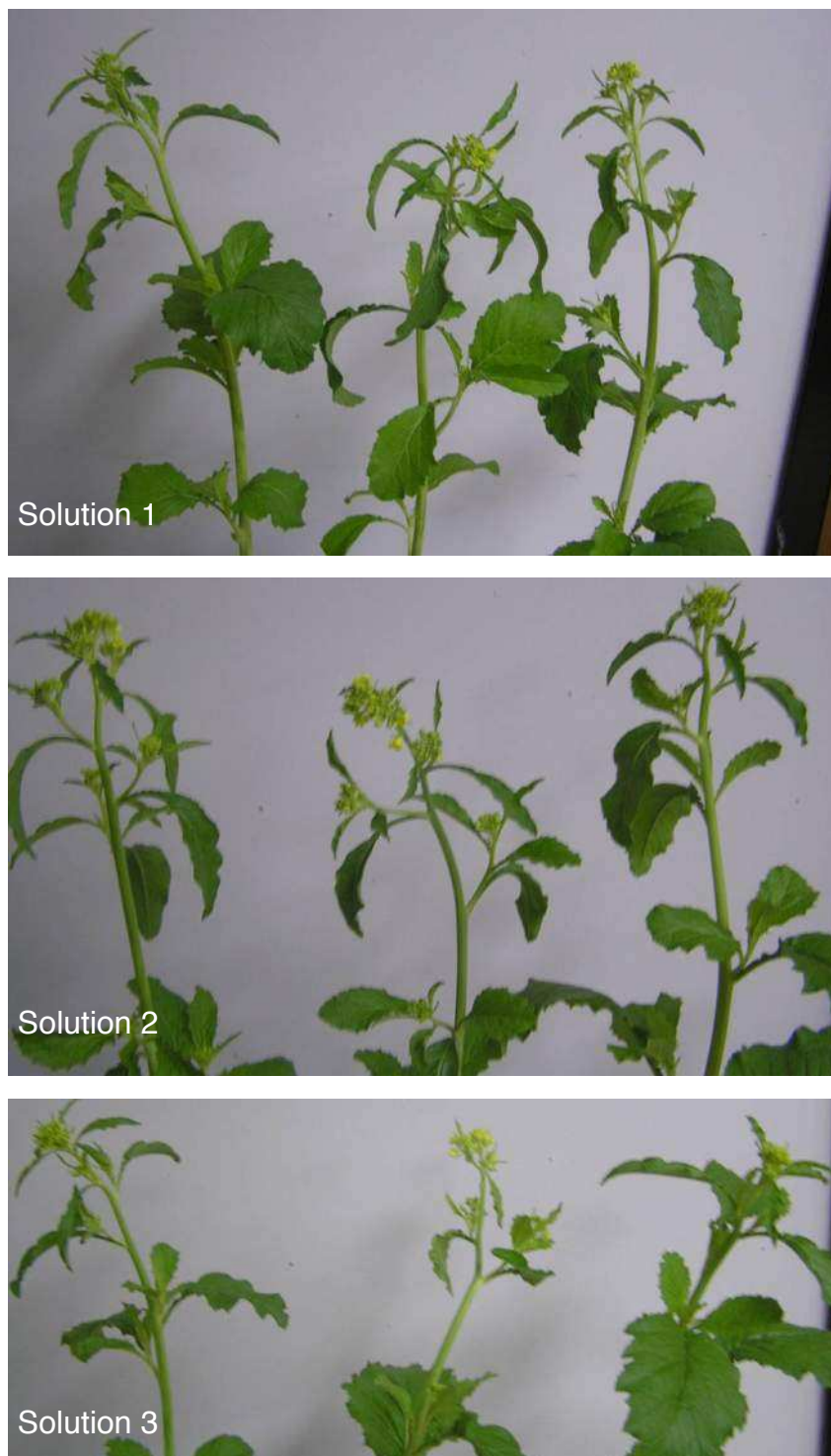
		LSMean		
		Max. No. Days	Max. No. Flowers	Avg. No. Flowers
Trial	1	17.44	63.11	34.67
	2	17.66	53.67	28.23
	3	18.56	37.44	19.56
F-test	Solutions	< 0.0001*	0.0002*	0.0005*
Solution	(1) Control	10.67	23.67	12.46
	(2) Sucrose	21.88	73.00	39.33
	(3) Sucrose + Nutrients	21.11	57.56	30.67
Contrast	Sol (1) vs. Sols (2+3)	< 0.0001*	< 0.0001*	< 0.0002*
	Sol (2) vs. Sol (3)	< 0.6415 <sub>NS</sub>	0.1457 <sub>NS</sub>	0.1587 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

<sub>NS</sub>, \*, Non-significant or significant at  $P \leq 0.05$  respectively



**Figure 7. Effect of three postharvest solutions on the vase-life of *Brassica juncea* experiment 1.** Solutions were: (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.



**Figure 8. *Brassica juncea* flowers in experiment 1, trial 1, day 1. Solutions 1, 2 and 3 respectively (each solution has three replicates).**



**Figure 9. *Brassica juncea* flowers in experiment 1, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).**





**Figure 10. *Brassica juncea* flowers in experiment 1, trial 1, day 10.** Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 11. *Brassica juncea* flowers in experiment 1, trial 1, day 15. Solutions 2 and 3, respectively (each solution has three replicates).**



**Figure 12. *Brassica juncea* flowers in experiment 1, trial 2, day 1. Solutions 1, 2 and 3, respectively (each solution has three replicates).**



**Figure 13.** *Brassica juncea* flowers in experiment 1, trial 2, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 14. *Brassica juncea* flowers in experiment 1, trial 2, day 10. Solutions 2 and 3, respectively (each solution has three replicates).**





**Figure 15. *Brassica juncea* flowers in experiment 1, trial 2, day 15.** Solutions 2 and 3, respectively (each solution has three replicates).



**Figure 16. *Brassica juncea* flowers in experiment 1, trial 3, day 1.** Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 17. *Brassica juncea* flowers in experiment 1, trial 3, day 5.** Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 18.** *Brassica juncea* flowers in experiment 1, trial 3, day 10. Solutions 2 and 3, respectively (each solution has three replicates).



**Figure 19. *Brassica juncea* flowers in experiment 1, trial 3, day 15.** Solutions 2 and 3, respectively (each solution has three replicates).

## 2.5 DISCUSSION

The statistical analysis of the experiment showed significant differences among solutions for the mean of days of vase-life and maximum number of flowers. Table 1 shows that *Brassica* in the solution 1 had a lower average number of flowers and shorter vase-life in comparison with solutions 2 and 3. This result indicated that the addition of sucrose and the combination of sucrose, KCl and K<sub>2</sub>SO<sub>4</sub> help the prolonging of the vase-life of the *Brassica juncea* flowers.

Solution 2 had the highest number of flowers. The addition of solution 2 might be sufficient for prolonging the vase-life of *Brassica* flowers. The addition of KCl and K<sub>2</sub>SO<sub>4</sub> to the postharvest solution did not increase the vase-life beyond the addition of sucrose alone. This experiment showed that solution 2 in the postharvest solution for *Brassica* flowers was essential for the opening and prolonging of the vase-life, as well as for increasing the number of flowers.

Doi and Reid (1995) reported similar results in *Limonium* hybrid 'Fantasia', where sucrose promoted flower opening and extended the vase-life. Jones and Truett (1992) showed that the presence of 2% of sucrose in the vase solution of *Gloriosa rothschildiana* promoted bud opening and dramatically increased the life of the inflorescences to 17 days compared to 7 days in distilled water by improving solution uptake and delaying senescence in fully developed flowers. When flowers are at bud stage, a supply of sucrose helps them to increase the number of flowers (Broschat and Donselman 1987; Doi and Reid, 1995; Han, 1992; Hardenburg, 1968; Kelly and Starman, 1990; Sacalis, 1993; Tjia 1988).

## 2.6 CONCLUSION

The addition of sucrose increased vase-life, maximum number of flowers and the average number of flowers of *Brassica*. These results indicated that sucrose in the postharvest solution is beneficial for the opening and the prolonging of the flowers vase-life. A continuous supply of sucrose in the vase solution not only nearly doubled the vase-life of the inflorescence, but also increased the length of the inflorescence and the percentage of flower heads that flowered.

This research indicates that the spikes of *Brassica* could have an adequate vase-life of up to 21 days with a solution containing sucrose. Additions of sucrose and possibly KCl and  $K_2SO_4$  to the water can promote the opening and the extension of the vase-life of the inflorescences of *Brassica*. Future studies can test the production of ethylene, ethylene sensitivity, and different concentrations of sugars and nutrients to provide detailed information on the optimum postharvest handling and potential vase-life of cut flowers of *Brassica*.

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### 3 *LEONOTIS NEPETIFOLIA* FLOWERS EVALUATED WITH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE

Muñiz Colón, Gladycia C.<sup>1</sup>, Lizzette González Gill<sup>2</sup>, María del C. Librán <sup>2</sup>, Gary Breckon <sup>3</sup>.

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Additional index words: Postharvest flower management, cut flower production, Botón de Cadete, Molinillo, Klip dagga, Annual lion's ear, Lion's Tail, Candlestick

#### 3.1 **ABSTRACT**

*Leonotis nepetifolia* (L.) R. Br. was identified and evaluated for the market of specialty flowers. Cut flowers have a limited vase-life that depends on the cultivar, time of harvest, and postharvest handling. The objective of this study was to evaluate the adaptability of *L. nepetifolia* as a potential cut flower crop, including the effect of two postharvest solutions and a control on the extension of the vase-life. The solutions were classified as: Solution 1 (control of deionized, distilled water), Solution 2 (19.72 g/L sucrose, 1 mL/L Clorox®, 0.147 g/L citric acid in deionized, distilled water), and Solution 3 (19.72 g/L sucrose, 1mL/L Clorox®, 0.147 g/L citric acid, 0.221 g/L KCl and 0.257 g/L K<sub>2</sub>SO<sub>4</sub> in deionized, distilled water). There were three experiments, experiment one consisted of one trial of primary stems and experiments two and three consisted one trial each of secondary stems. Evaluation of flower number was performed daily until the flowers were deemed unmarketable. A statistically significant difference was observed among the solutions in all the experiments. In the first experiment the vase-life was of 17 days for solution 1, 16 days for solution 2 and 20 days for solution 3. In the second experiment the vase-life was of 16 days for solution 1, 19 days for solutions 2 and 17 days for solution 3. In the third experiment the vase-life was of 14 days for solution 1 and 17 days for solutions 2 and 3. *Leonotis nepetifolia* flowers are recommended to be kept in a solution containing distilled, deionized water to obtain the best vase-life for secondary stems; primary stems are recommended to be placed in a solution containing sucrose and nutrients. The results of this research demonstrated the potential of *Leonotis nepetifolia* as cut flower crop.

## 3.2 INTRODUCTION

*Leonotis nepetifolia* (L.) R. Br., (*Lamiaceae* or *Labiatae*) (Fig. 20) is an herbaceous plant native to South Africa (Honeylocust, 1998). Common names of this plant include: Klip Dagga, Annual lion's ear, Lion's Tail, and Candlestick. It is an erect, loosely branched annual that can grow to 2.4 m tall with primary and secondary stems. The stems are strongly angled with opposite oblong or lance-shaped leaves that are 5 to 12 cm in length, and up to 10 cm broad with a coarsely toothed margin. The species is typically found in sunny, usually disturbed sites from 25 to 500 m in elevation, throughout Puerto Rico. The inflorescence emerges from the leaf axils and consists of several round spiny clusters, each one measuring 5.1-10.2 cm across; velvety orange, curved flowers of about 2.5 cm long are borne on the clusters. Both the bright orange color of the flower and the cluster arrangement are visually interesting qualities that are desirable for a cut flower. As the flower stems elongate, new flower clusters continue to develop above the older ones. (Albrecht-Llamas, 2003; Foster, 1993; Hardenburg, 1968; Liogier, 1990; Liogier, 1995).

In order to have adequate market life, the harvest stage index for *Leonotis* inflorescence should be when the first flowers open at the top part of the first cluster. Most annuals are harvested at this stage (Armitage, 1993).

Information on the postharvest handling of *Leonotis* is nonexistent. Therefore an evaluation was conducted on the postharvest cut flower quality of *Leonotis*. In addition, the flowers were placed in three solutions to observe the potential for prolonging the vase-life of the flowers.





**Figure 20. *Leonotis nepetifolia* (A) growth habit before flowering, (B) inflorescence.**

### 3.3 MATERIALS AND METHODS

#### 3.3.1 Seed collection and planting

Seeds of *Leonotis nepetifolia* were collected in June 2005 from mature inflorescences of plants growing in the wild in Guánica, Puerto Rico and stored at 13 °C for two months before planting. A raised concrete bed (11.8 m x 0.94 m) was prepared at the University of Puerto Rico, Mayagüez Campus with a mixture of vegetative compost and sand (1:1) and roto-tilled twice (Fig. 1). Drip irrigation was established (Fig. 2). A metallic-colored plastic row cover was set on the ground for weed and insect control (Fig. 3). Holes (10 cm diam.) were cut in the plastic for planting and a triple, staggered row design was used to plant the seeds in August, with spacing of 30 cm between rows and 60 cm within the row for a total of 53 plants in the bed (Fig. 4). Drip irrigation was applied as needed based on visual assessments of the species and soil. A solution of 20-20-20 fertilizer (Tropical® TF Puerto Rico Corp., Sabana Seca, Puerto Rico) was applied according to label direction every fifteen days until bloom. Mavrik Aquaflow® insecticide (Sandoz Agro, Inc., Des Plaines, Illinois) was applied as needed according to label directions when leaf damage caused by insects appeared. The stalks were pinched when plants were young (15.2 cm to 22.86 cm tall) to encourage branching.

In experiment one, once the first flowers opened on the first cluster, a trial of nine spikes from primary axis were harvested between 0500 and 0600, using a sharp knife in November. For experiments two and three, a trial of nine spikes each was harvested for a total of nine spikes of secondary axis per experiment. All spikes were immediately

transferred to a gallon bucket filled with distilled water. They were manually taken to the laboratory, where stems were cut underwater to a length of 60 cm with a Water Cut II (DB Manufacturing, Middleton, WI) flower cutter (Fig. 5). All leaves on the lower section of the stem were removed. Flowers were randomly allocated among the solutions.

### *3.3.2 Treatment solutions*

Each cut stem was immediately placed in a 500 mL Erlenmeyer flask with 300 mL of solution. Solutions were prepared in a 1 L container and divided into three replicates (individual Erlenmeyer flasks) per treatment. Treatment solutions were as follows: 1) distilled, deionized water (control); 2) distilled, deionized water, 19.72 g sucrose (2%), 2 mL sodium hypochlorite (Clorox® 0.2%), 0.147 g citric acid, and 3) Solution 2 with 0.221 g KCl and 0.257 g K<sub>2</sub>SO<sub>4</sub> adopted from Sacalis (1993). Additional citric acid at 1% was added to solutions 2 and 3 to titrate to pH 3.5.

### *3.3.3 Flower evaluations*

Three replicates for each of the three solutions were set in a Biotronette Mark III Model 846 (Lab-line Instruments, Inc., Melrose Park, Illinois) environmental chamber that controlled the temperature at 19° C, with four fluorescent light bulbs (2700 lumen/bulb; 8 h light/16 h dark/day). The experiment was repeated two more times (experiment 2 and experiment 3) with 2 or 3 days between each experiment. Number of flowers was counted daily and pictures were taken for reference. Water uptake was measured and additional solution was added using a syringe to maintain 300-mL of solution. Solutions were changed every other day and stems were re-cut when any indication of plugging appeared. The evaluation lasted until the flowers were no longer marketable, as judged by visible browning and wilting of the flower stem or the inflorescences.

Statistical analysis was done using SAS 2003 (Copyright © 2002-2003 by SAS Institute Inc., Cary, NC, USA). Contrast tests using the mean (mean to compare the estimated average) were performed to determine if differences occurred among solutions for the days of vase-life and maximum number of flowers in the experiment.

### 3.4 RESULTS

#### 3.4.1 Experiment 1

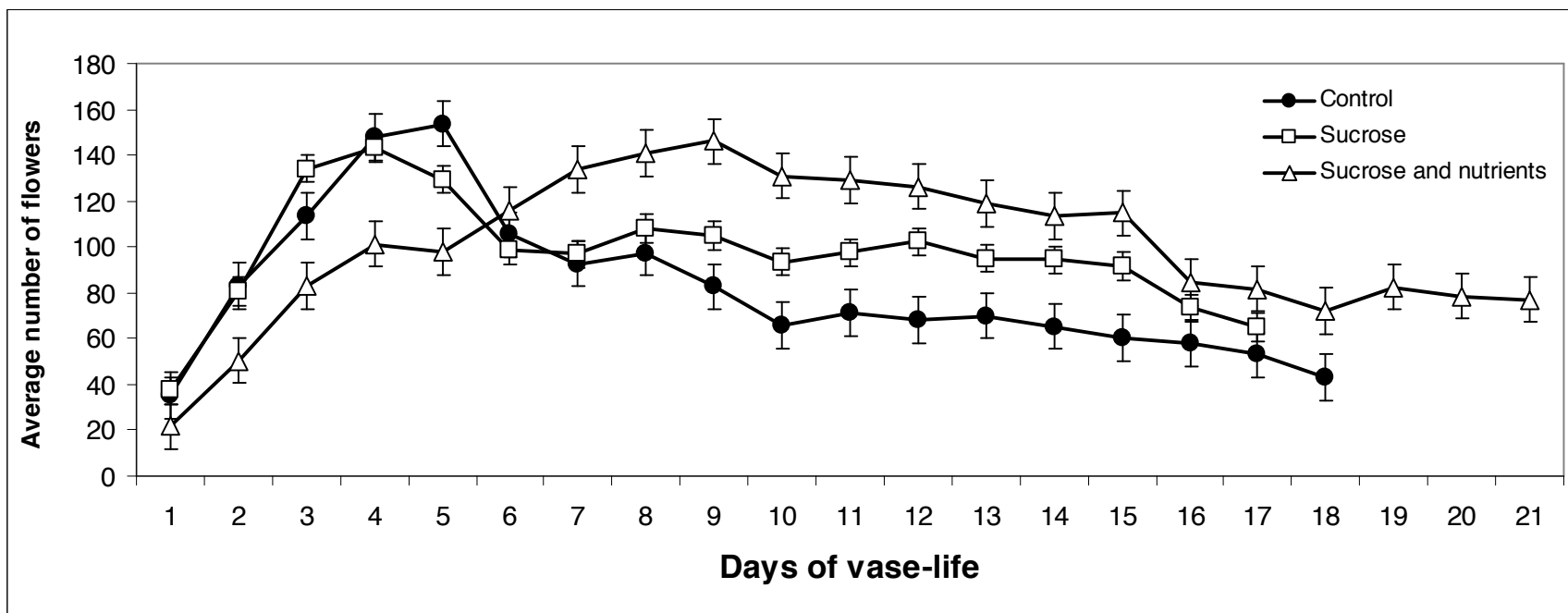
*Leonotis nepetifolia* germinated ten days after planted. The growth of the plant lasted four months with a rapid growth. After a month axils on the stems started to appear and from stems on primary axils and stems on secondary axils. Stems were harvested from the primary axils when the first flower appeared on the clusters four months after planted. In the investigation, a significant A significant difference between the control group compared to the two experimental groups was observed in the contrast test evaluation of *L. nepetifolia* for vase-life indicating that one of the solutions was better than the other. Solution 3 showed the highest mean days of vase-life (Table 2) compared with solutions 1 and 2. The addition of sucrose and nutrients may influence in the prolonging of the vase-life of the inflorescences and visual aspect (Figure 22 to Figure 25). In a solution containing sucrose and nutrients *L. nepetifolia* inflorescences can last up to 20 days and have desirable amount of flowers. There was no significant difference between solutions on the mean maximum number of flowers of *L. nepetifolia*. The average vase-life (Fig. 21) of the flower shows that the species can last up to 17 days for solution 1 and 16 days for solution 2 and 20 days for solution 3. Figures 22 to 25 show the quality of the inflorescences throughout the length of experiment 1 trial 1.

**Table 2. *Leonotis nepetifolia* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 1.**

		LSMean		
		Max. No. Days	Max. No. Flowers	Avg. No. Flowers
Trial	1	17.56	155.33	84.13
F-test	Solutions	0.0228*	0.9372 <sub>NS</sub>	0.5184 <sub>NS</sub>
Solution	(1) Control	16.67	160.67	83.10
	(2) Sucrose	16.33	144.67	68.63
	(3) Sucrose + Nutrients	19.67	160.67	100.67
Contrast	Sol (1) vs. Sols (2+3)	0.1536 <sub>NS</sub>	0.8623 <sub>NS</sub>	0.9483 <sub>NS</sub>
	Sol (2) vs. Sol (3)	0.0123*	0.7645 <sub>NS</sub>	0.2717 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

<sub>NS</sub>, \*, Non-significant or significant at  $P \leq 0.05$  respectively



**Figure 21. Effect of three postharvest solutions on the vase-life of *Leonotis nepetifolia* experiment 1.** Solutions were: (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.





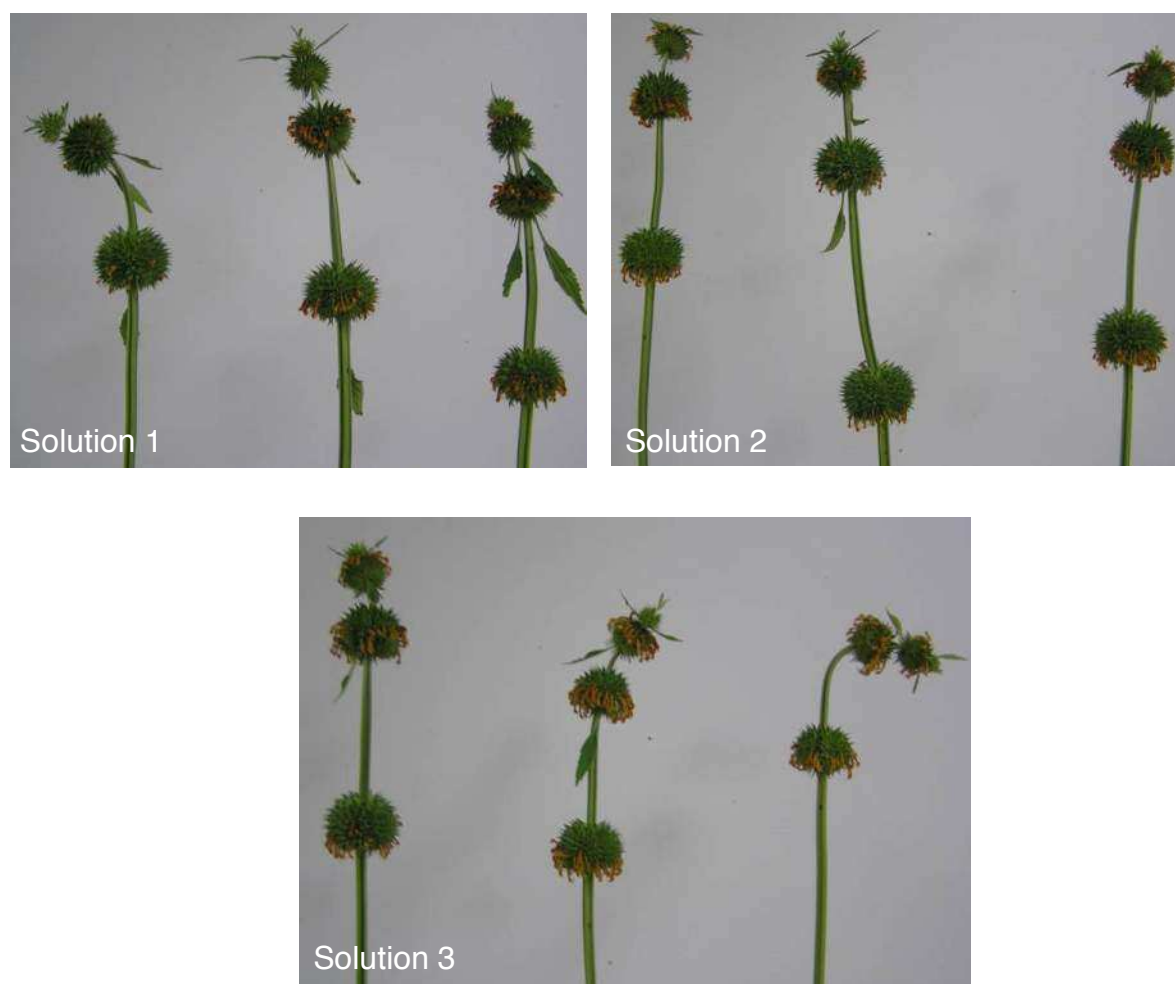
**Figure 22.** *Leonotis nepetifolia* flowers in experiment 1, trial 1, day 1. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 23.** *Leonotis nepetifolia* flowers in experiment 1, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 24.** *Leonotis nepetifolia* flowers in experiment 1, trial 1, day 10. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 25.** *Leonotis nepetifolia* flowers in experiment 1, trial 1, day 15. Solutions 1, 2 and 3, respectively (each solution has three replicates).

### 3.4.2 Experiment 2

*Leonotis nepetifolia* germinated ten days after planted. The growth of the plant lasted four months with a rapid growth. After a month axils on the stems started to appear and from stems on primary axils and stems on secondary axils. Stems were harvested from the secondary axils when the first flower appeared on the clusters four months after planted. There was no significant difference in the F-test of solutions for days of vase-life or the average number of flowers. A significant difference in the maximum number of flowers was observed indicating that one of the solutions was better than the other. In the contrast test a statistical difference is shown among the solutions for maximum number of flowers and the average number of flowers. Solution 1 presented the highest maximum number of flowers (Table 3). Even though the addition of sucrose may influence in the prolonging of the vase-life of the inflorescences the visual aspect decays (Figure 27 to Figure 30). By maintaining *Leonotis nepetifolia* inflorescences in water solution they can last up to 16 days and have a desirable amount of flowers. An average of the vase-life of the flower (Fig. 26) showed that this species can last up to 16 days in solution 1, and 19 days in solution 2 and 17 days in solution 3. Figures 27 to 30 show the quality of the inflorescences throughout the length of experiment 2 trial 1.

**Table 3. *Leonotis nepetifolia* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 2.**

		LSMean		
		Max. No. Days	Max. No. Flowers	Avg. No. Flowers
Trial	1	17.33	117.11	66.49
F-test	Solutions	0.3596 <sub>NS</sub>	0.0097*	0.0553 <sub>NS</sub>
Solution	(1) Control	16.33	142.67	82.67
	(2) Sucrose	18.67	82.00	48.30
	(3) Sucrose + Nutrients	17.00	126.67	68.50
Contrast	Sol (1) vs. Sols (2+3)	0.3036 <sub>NS</sub>	0.0162*	0.0445*
	Sol (2) vs. Sol (3)	0.3206 <sub>NS</sub>	0.0156*	0.1176 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

<sub>NS</sub>, \*, Non-significant or significant at  $P \leq 0.05$  respectively

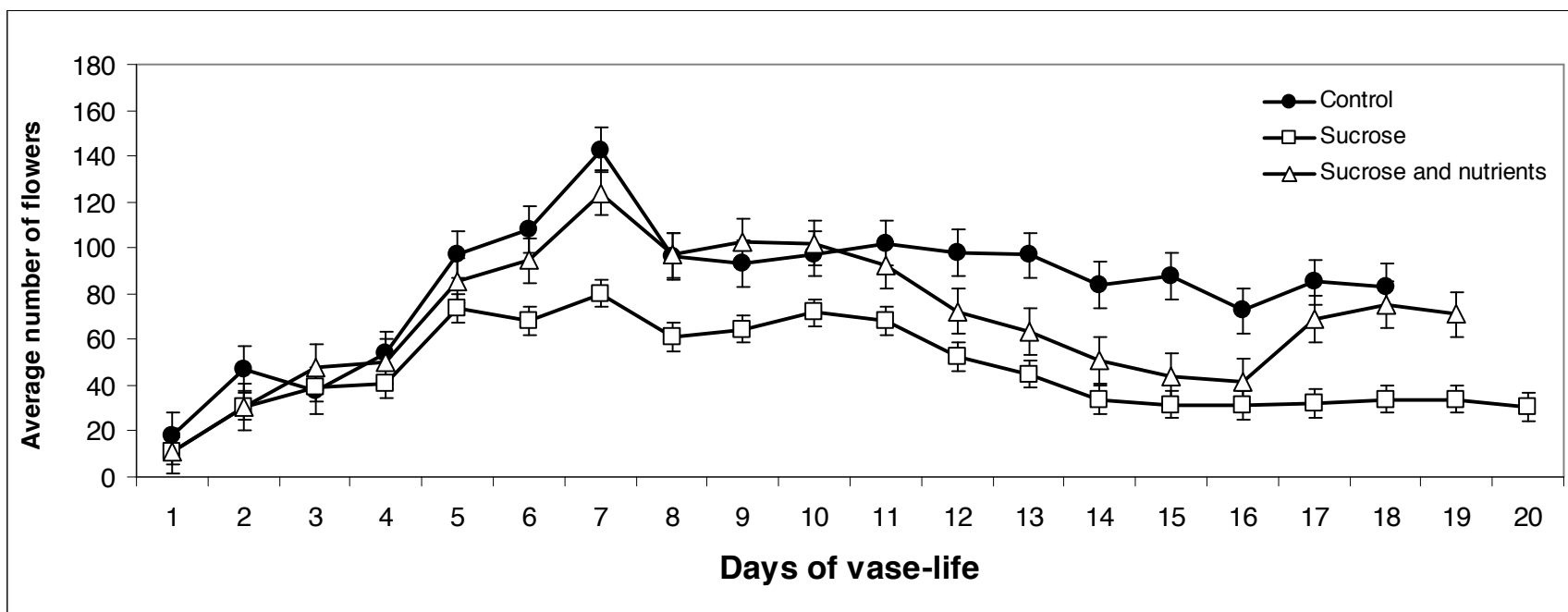


Figure 26. Effect of three postharvest solutions on the vase-life of *Leonotis nepetifolia* experiment 2. Solutions were: (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.

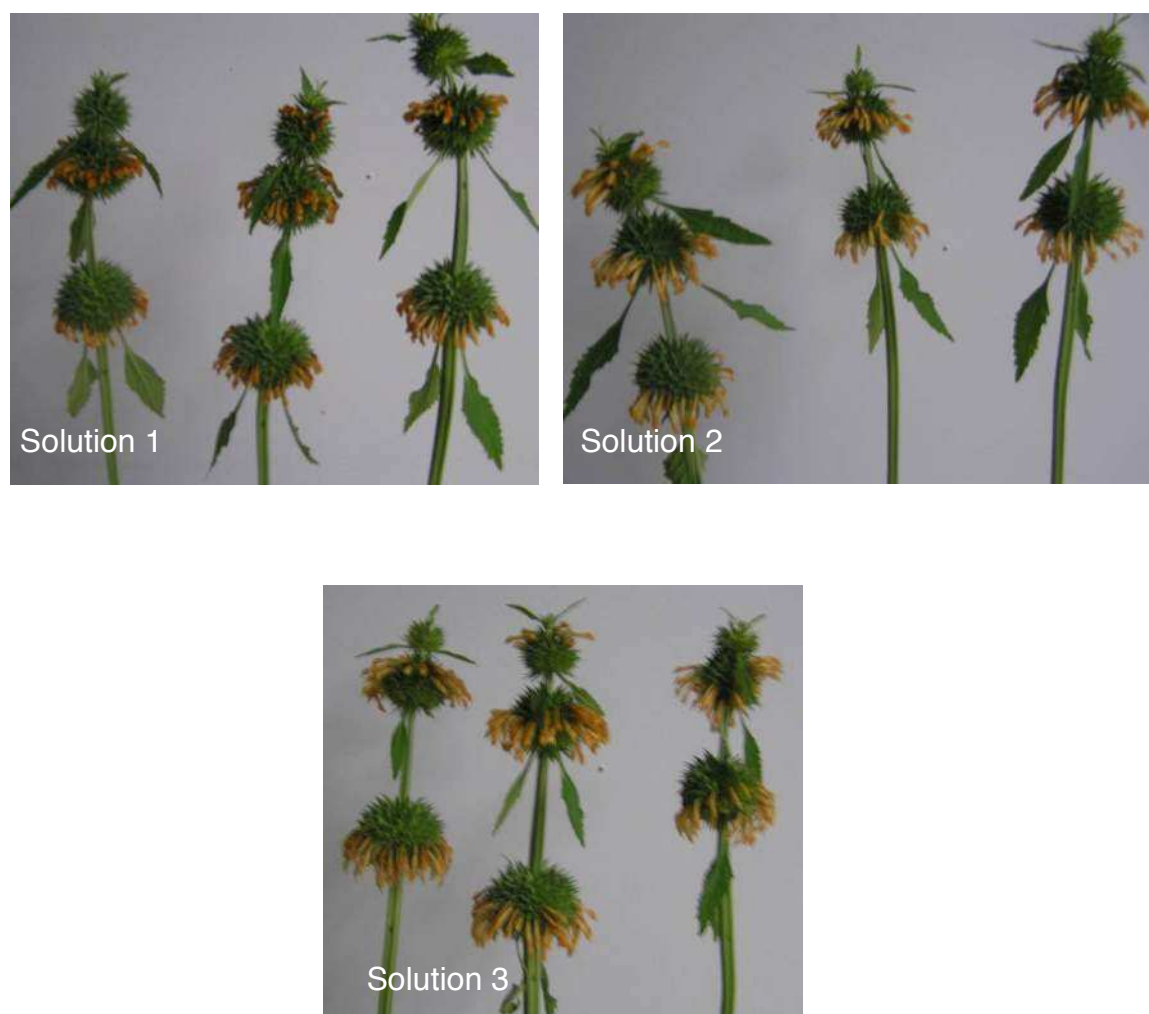


**Figure 27. *Leonotis nepetifolia* flowers in experiment 2 trial 1, day 1.** Solutions 1, 2 and 3, respectively (each solution has three replicates).

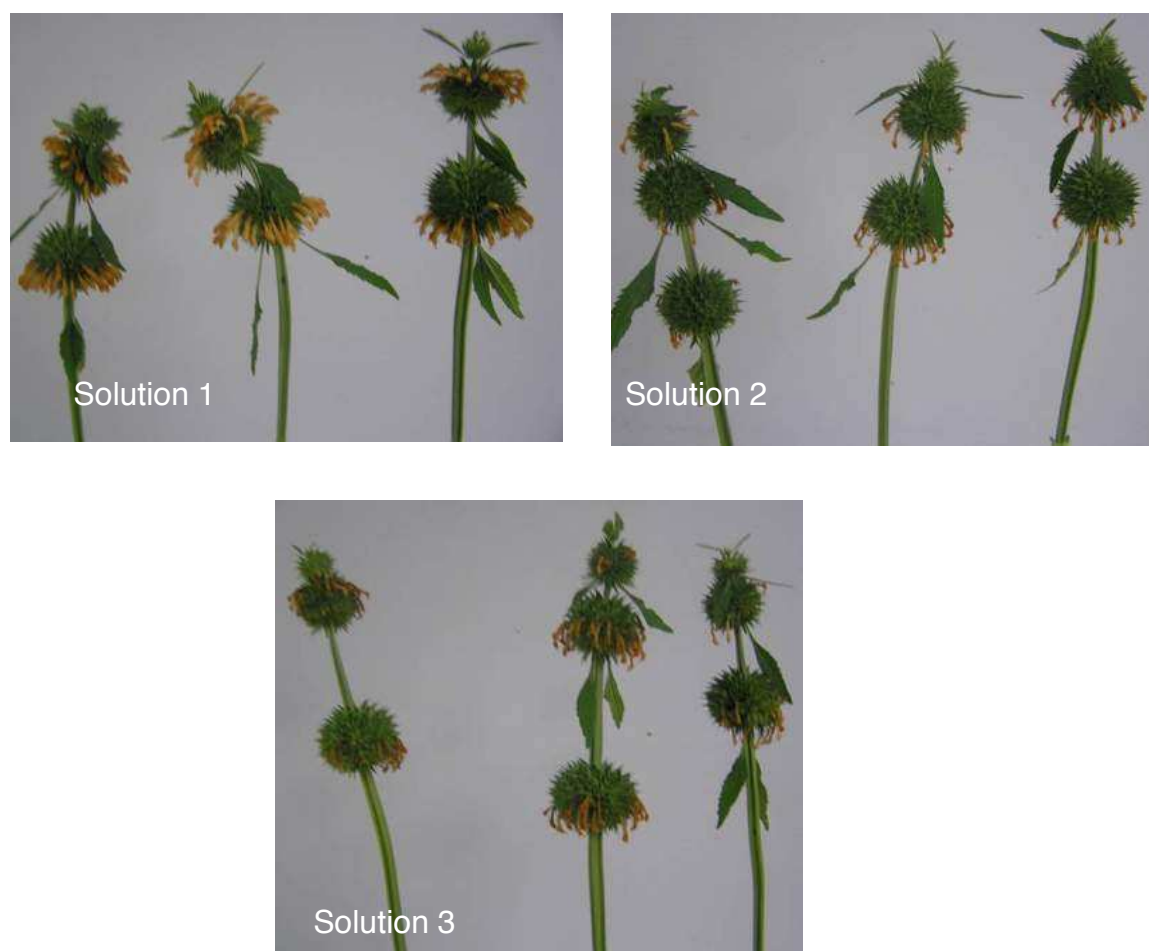




**Figure 28.** *Leonotis nepetifolia* flowers in experiment 2, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates)



**Figure 29.** *Leonotis nepetifolia* flowers in experiment 2, trial 1, day 10. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 30.** *Leonotis nepetifolia* flowers in experiment 2, trial 1, day 15. Solutions 1, 2 and 3, respectively (each solution has three replicates).

### 3.4.3 Experiment 3

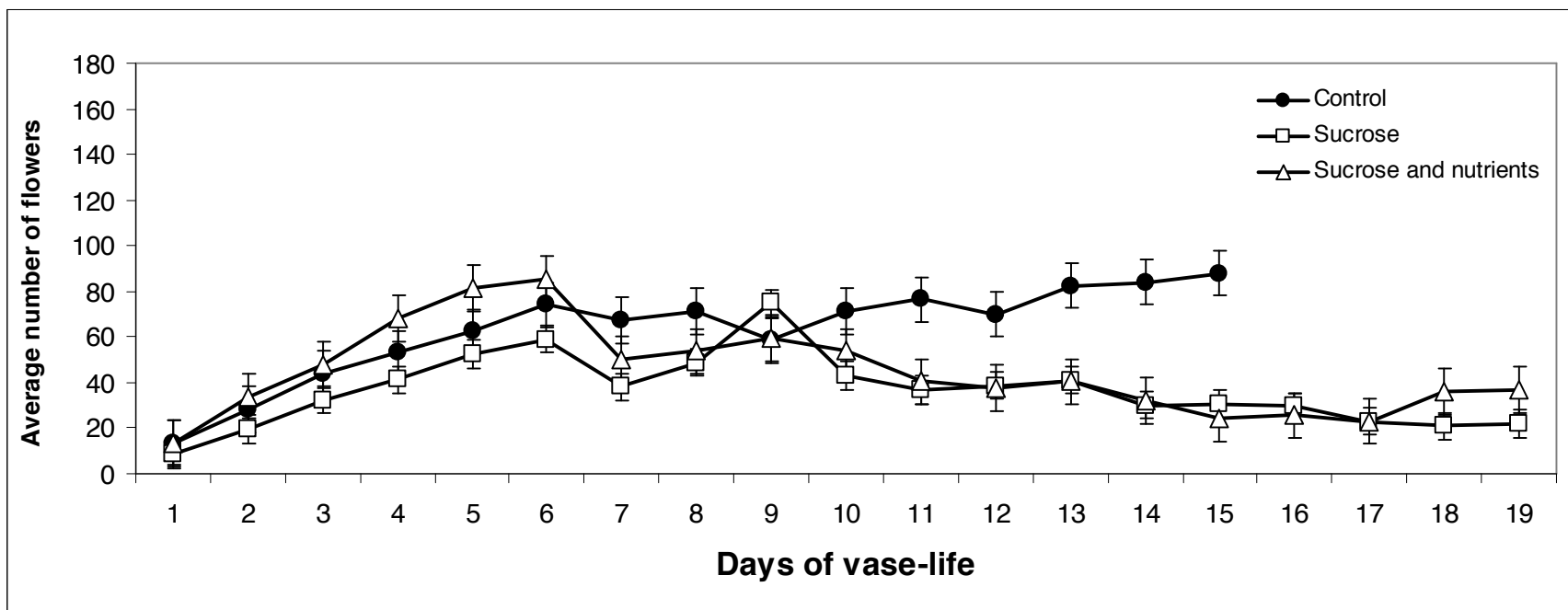
*Leonotis nepetifolia* germinated ten days after planted. The growth of the plant lasted four months with a rapid growth. After a month axils on the stems started to appear and from stems on primary axils and stems on secondary axils. Stems were harvested from the secondary axils when the first flower appeared on the clusters four months after planted. There was no significant difference in the F-test of solutions for days of vase-life, maximum number of flowers and average number of flowers. In the contrast test no statistical difference is shown among the solutions for days of vase-life and maximum number of flowers. Solution 1 presented a high maximum number of flowers (Table 4) and average number of flowers. Even though the addition of sucrose may influence in the prolonging of the vase-life of the inflorescences the visual aspect decays (Figure 32 to Figure 34). By maintaining *Leonotis nepetifolia* inflorescences in water solution they can last up to 14 days and have a desirable amount of flowers. An average of the vase-life of the flower (Fig. 31) showed that this species can last up to 14 days in solution 1 and 17 days in solutions 2 and 3. Figures 32 to 34 show the quality of the inflorescences throughout the length of experiment 3 trial 1.

**Table 4. *Leonotis nepetifolia* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 3.**

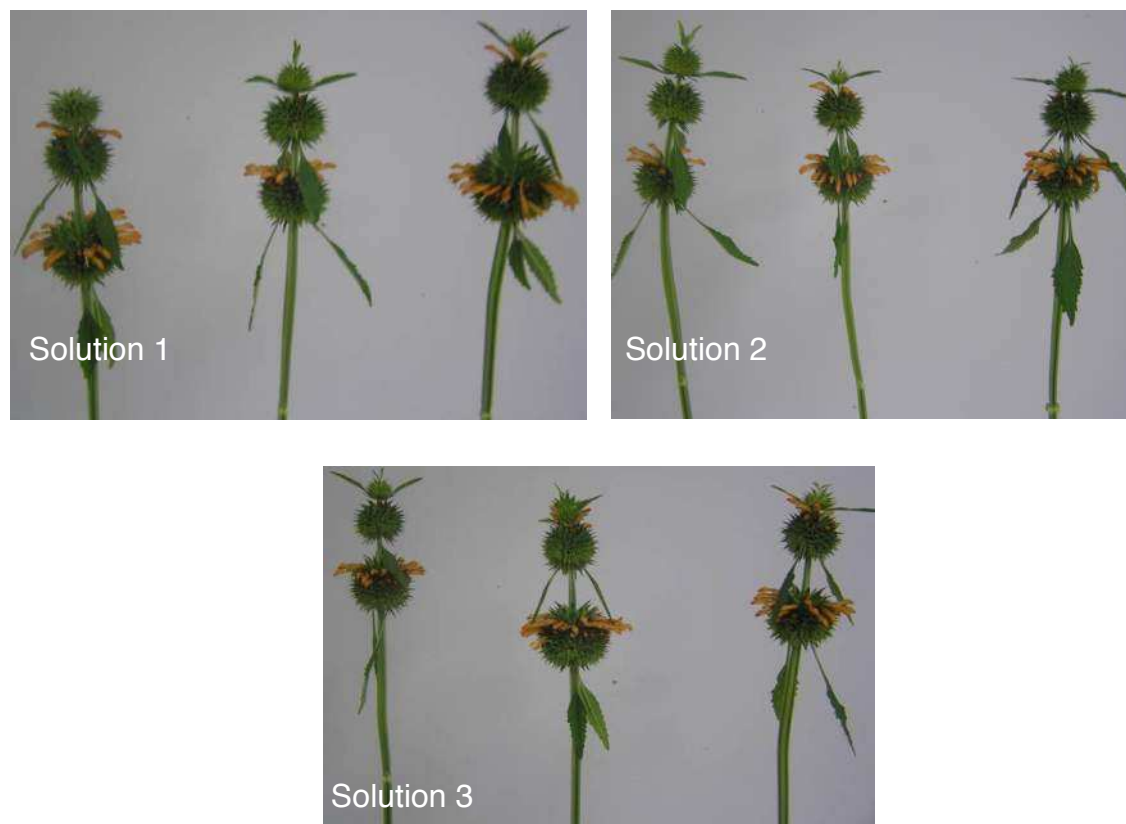
		LSMean		
		Max. No. Days	Max. No. Flower	Avg. No. Flower
Trial	1	15.78	80.56	47.97
F-test	Solutions	0.2846 <sub>NS</sub>	0.5001 <sub>NS</sub>	0.0836 <sub>NS</sub>
Solution	(1) Control	14.00	80.67	59.47
	(2) Sucrose	16.67	75.00	38.03
	(3) Sucrose + Nutrients	16.67	86.00	46.40
Contrast	Sol (1) vs. Sols (2+3)	0.1277 <sub>NS</sub>	0.9833 <sub>NS</sub>	0.0428*
	Sol (2) vs. Sol (3)	1.0000 <sub>NS</sub>	0.2584 <sub>NS</sub>	0.3232 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

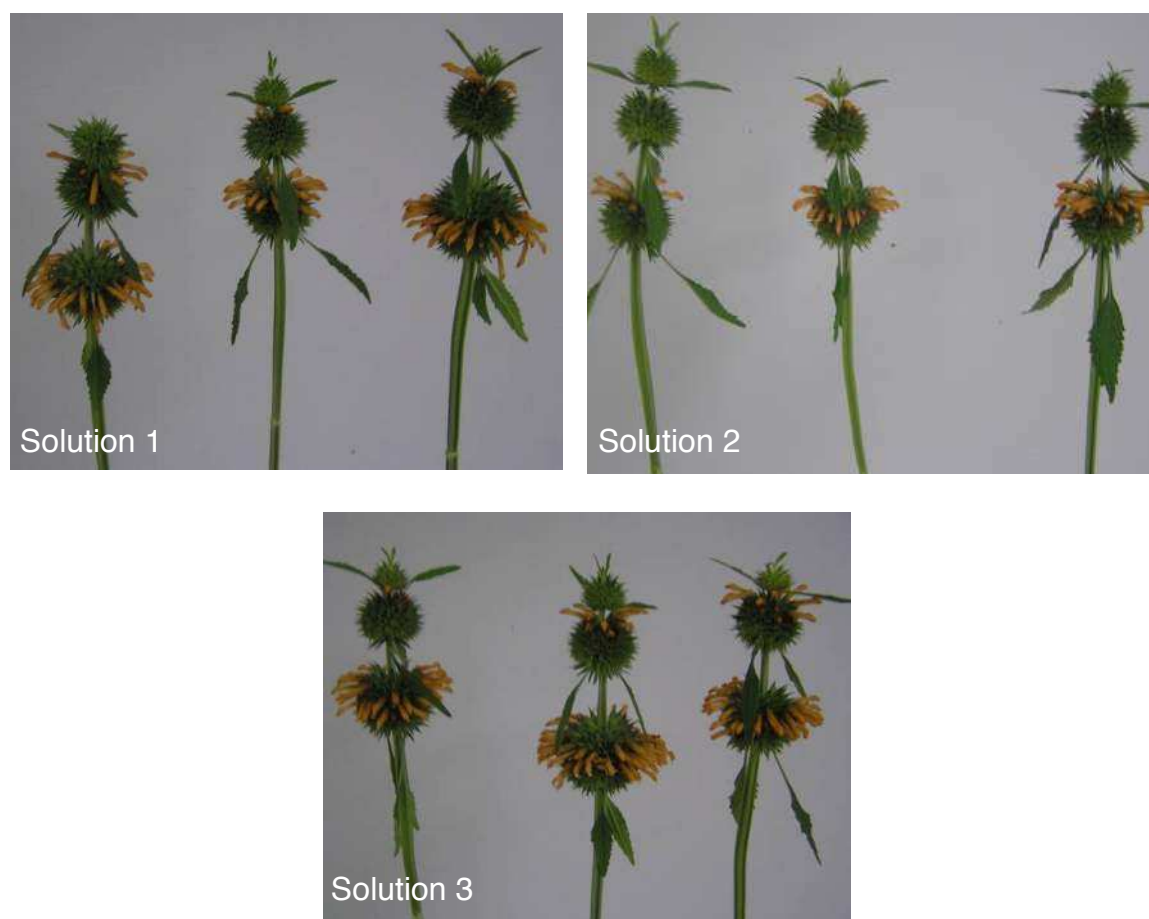
NS, \*, Non-significant or significant at  $P \leq 0.05$  respectively



**Figure 31. Effect of three postharvest solutions on the vase-life of *Leonotis nepetifolia* experiment 3.** Solutions were: (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.



**Figure 32. *Leonotis nepetifolia* flowers in experiment 3, trial 1, day 1. Solutions 1, 2 and 3, respectively (Each solution has three replicates).**



**Figure 33.** *Leonotis nepetifolia* flowers in experiment 3, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 34.** *Leonotis nepetifolia* flowers in experiment 3, trial 1, day 10. Solutions 1, 2 and 3, respectively (each solution has three replicates).

### 3.5 DISCUSSION

The significant differences observed for vase-life in experiment 1 indicate that one of the solutions helped extend the vase-life of *Leonotis nepetifolia* flowers. Solution 3, containing sucrose, KCl and K<sub>2</sub>SO<sub>4</sub> (Table 2), increased the number of days and the average number of flowers. The addition of solutions 2 and 3 stimulated flower opening for a longer period of time.

In experiments 2 and 3, all solutions had similar results for vase-life, but solutions 1 and 3 promoted the maximum and average number of flowers (Tables 3 and 4). The addition of sucrose or KCl and K<sub>2</sub>SO<sub>4</sub> did not prolong the vase-life of the flowers of *Leonotis nepetifolia* significantly. In this study, primary stems may have responded to the addition of sucrose and nutrients for the extension of vase-life, but not for increasing number of flowers. Flowers maintained in water can have a similar effect that those in sucrose or sucrose and nutrients together. The visual aspect of the flowers was favorable when they were kept in water solution.

Some postharvest studies have shown extension of vase-life of flowers were: Doi and Reid (1995) demonstrated that sucrose promoted flower opening and extended the vase-life in *Limonium* hybrid 'Fantasia'. Jones and Truett (1992) showed that the presence of 2% of sucrose in the vase solution of *Gloriosa rothschildiana* promoted bud opening and dramatically increased the life of the inflorescences to 17 days, compared to 7 days in distilled water, by improving solution uptake and delaying senescence in fully developed flowers.

In our study *Leonotis* did not respond to the addition of solution 2 for bud opening or extension of vase-life. Therefore, we recommend maintaining flowers in water only for adequate vase-life.

### 3.6 CONCLUSION

Cut *Leonotis nepetifolia* primary stems should be kept in a solution containing sucrose and nutrients for the extension of vase-life and a desired appearance. Secondary flower stems can be placed in distilled, deionized water and maintained for a long period of time, with similar results to those of treatments with sucrose and sucrose and nutrients. In all cases flowers remain in the cluster but their appearance starts to decay after certain time depending on the solution. They started to decay first in solution 1 and 2 for the primary stems and in solutions 2 and 3 in secondary stems.

In conclusion, this research indicated that the spikes of *L. nepetifolia* had a desired vase-life of up to 21 days with a solution containing sucrose and nutrients for the primary stems, with secondary and tertiary stems the vase-life of the flowers decreased.

Future studies should verify the effect of the production of ethylene, ethylene sensitivity, different concentrations of sugars and nutrients, to determine the optimum postharvest handling and potential vase-life of cut flowers of *Leonotis nepetifolia*.

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## 4 *KALANCHOE DELAGOENSIS* FLOWERS EVALUATED WITH SUCROSE AND NUTRIENTS FOR THE EXTENSION OF VASE-LIFE

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Additional index words: Postharvest flower management, cut flower production, Mother of Millions, Mission Bells, Christmas Bells.

### 4.1 ABSTRACT

*Kalanchoe delagoensis* Ecklon & Zeyher (*Crassulaceae*), a species of flowering plant, native to Madagascar, was identified and evaluated for the market of specialty flowers. Cut flowers have a limited vase-life that depends on the cultivar, time of harvest, and postharvest handling. The objective of this study was to evaluate the adaptability of *K. delagoensis* as a potential cut flower crop, including the effect of two postharvest solutions and a control on the extension of the vase-life. The solutions were classified as: Solution 1 ( control of deionized, distilled water), Solution 2 (19.72 g/L sucrose, 1 mL/L Clorox®, 0.147 g/L citric acid in deionized, distilled water), and Solution 3 (19.72 g/L sucrose, 1mL/L Clorox®, 0.147 g/L citric acid, 0.221 g/L KCl and 0.257 g/L K<sub>2</sub>SO<sub>4</sub> in deionized, distilled water). Evaluation of flower number was performed daily until the flowers were deemed unmarketable. In this study two experiments were realized, in experiment one no significant statistical differences were observed among the solutions for vase-life maximum number of flowers or average number of flowers. Experiment two showed a significant difference among the solutions in maximum number of flowers and average number of flowers. In experiment 1 the vase-life was 20 days for solution 1, 16 days for solution 2 and 17 days for solution 3. In experiment 2 the vase-life was 12 days for solution 1, 13 days for solution 2 and 18 days for solution 3. *Kalanchoe delagoensis* flowers are recommended to be kept in distilled, deionized water to obtain the best vase-life when the area of the cymes is of a smaller size, on a bigger size of diameter in the cymes addition of sucrose is recommended for a longer vase-life. The results of this research demonstrated that the difficulty in handling and transportation of *Kalanchoe delagoensis* flowers limits its potential for the cut flower industry.

## 4.2 INTRODUCTION

*Kalanchoe delagoensis* Ecklon & Zeyher (Crassulaceae) (Fig. 40) is an erect, smooth, fleshy succulent plant native to Madagascar. This plant is found approximately in 12 regions, typically in sites from 1 to 825 m in elevation, throughout Puerto Rico. Common names of this plant include: mother of millions, mission bells and Christmas bells. It is a smooth and glaucous perennial herb with simple leaves, usually alternate, subcylindrical, 3-15 cm long, 0.3-0.6 cm wide, often spotted with reddish brown, margins near apex with 3-9 conical teeth between which spoon-shaped bulbils are produced. It is a plant that generally needs little care and requires long nights to flower. This plant is not uniform in growth, form or color. The flowers grow in corymbose cymes 10-20 cm wide, each one pendent on pedicels 0.5-2 cm long; sepals connate, the tube 0.3-0.6 cm long, the lobes triangular, 0.5-0.7 cm long. The flowers vary in color from white or yellow to orange and red, 2.5-4 cm long, the lobes obovate, 0.5-1 cm long (Albrecht-Llamas, 2003; Land Protection 2004; Liogier, 1997; Taiz and Zeiger, 2002).

Information on the postharvest handling of *K. delagoensis* is scarce. Therefore, an evaluation was conducted on the postharvest cut flower quality of *K. delagoensis*. In addition, the flowers were placed in three different solutions to observe the potential for prolonging vase-life of the flowers.



**Figure 35. *Kalanchoe delagoensis* (A) growth of plant before flowering, (B) inflorescence.**



## 4.3 MATERIALS AND METHODS

### 4.3.1 Seed collection and planning

Small plants of *Kalanchoe delagoensis* were collected in February 2005 in Guánica, Puerto Rico and planted in a greenhouse for six months. A concrete raised bed (11.8 m x 0.94 m) was prepared at the University of Puerto Rico, Mayagüez Campus with a mixture of vegetative compost and sand (1:1) and roto-tilled twice (Fig. 1). Drip irrigation was established (Fig. 2). A metallic-colored plastic row cover was set on the ground for weed and insect control (Fig. 3). Holes (10 cm diam.) were cut in the plastic for planting and a triple, staggered row design was used to plant in September, with spacing of 15 cm between rows and 30 cm within the row for a total of 106 plants in the bed (Fig. 4). Drip irrigation was applied as needed based on visual assessments of the plants and soil. A solution of 20-20-20 fertilizer (Tropical® TF Puerto Rico Corp., Sabana Seca, Puerto Rico) was applied according to label every fifteen days until bloom.

Once the first flowers opened, nine spikes per trial for a total of two trials for experiment one and one trial in experiment two. Inflorescences were harvested in December between 0500 and 0600, using a sharp knife, and then transferred to a gallon bucket filled with distilled water. They were manually taken to the laboratory, where stems were cut underwater to a length of 60 cm with a Water Cut II (DB Manufacturing, Middleton, WI) flower cutter (Fig. 5). All leaves on the lower section of the stem were removed. Flowers were randomly allocated among the solutions.

### *4.3.2 Treatment solutions*

Each inflorescence was immediately placed in a 500 mL Erlenmeyer flask with 300 mL of solution. Solutions were prepared in a 1 L container and divided into three replications (individual Erlenmeyer flasks) per treatment. Treatments solutions were as follows: 1) distilled, deionized water (control); 2) distilled, deionized water, 19.72 g sucrose (2%), 2 mL sodium hypochlorite (Clorox® 0.2%), 0.147 g citric acid, and 3) Solution 2 + 0.221 g KCl and 0.257 g K<sub>2</sub>SO<sub>4</sub> adopted from Sacalis (1993). Additional citric acid (1%) was added to solutions 2 and 3 to titrate to pH 3.5.

### 4.3.3 *Flower evaluations*

Three samples for each of the three solutions were set in a Biotronette Mark III Model 846 (Lab-line Instruments, Inc., Melrose Park, Illinois) environmental chamber that controlled the temperature at 19° C, with four fluorescent light bulbs (2700 lumen/bulb; 8 h light/16 h dark/day). The trial was repeated two more times (trials 2 and 3) with 2 or 3 days between each experiment. Number of flowers was counted daily and pictures were taken for reference. Water uptake was measured and additional solution was added using a syringe to maintain 300-mL of solution. Solutions were changed every other day and stems were re-cut when any indication of plugging appeared. The evaluation lasted until the flowers were no longer marketable, as judged by visible browning and wilting of the flower stem or the inflorescences.

Statistical analysis was done using SAS 2003 (Copyright © 2002-2003 by SAS Institute Inc., Cary, NC, USA). Contrast tests using the mean (mean to compare the estimated average) were performed to determine if differences occurred among solutions for the days of vase-life and maximum number of flowers in the experiment.

## 4.4 RESULTS

### 4.4.1 Experiment 1

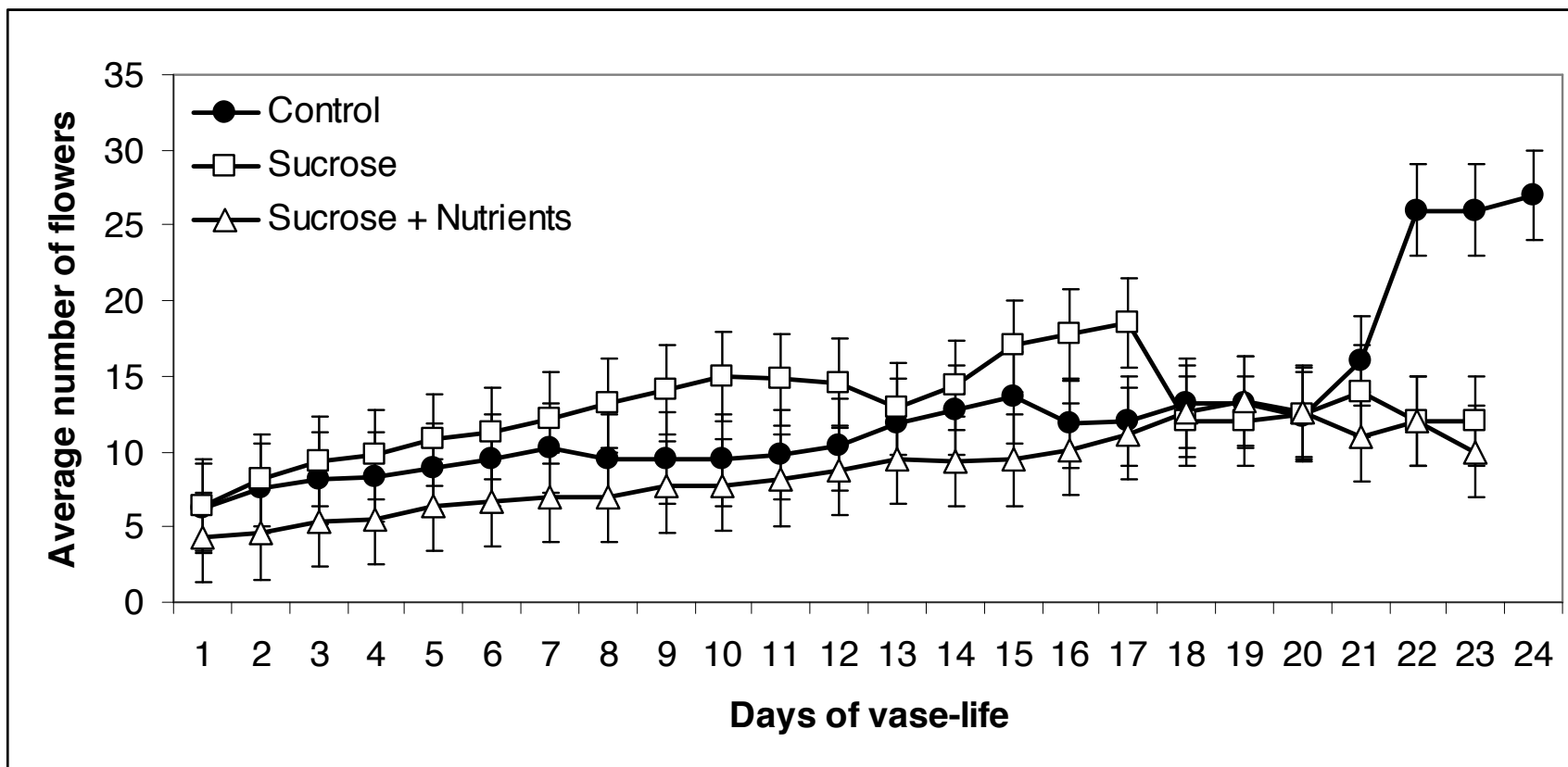
*Kalanchoe delagoensis* plants took 10 months to grow from small plants to an adult plant. It is a slow growing plant, but has many seedlings and they all grow very well. Some plants were needed to be removed from the beds in order to allow spacing between them. Cymes were harvested when the first flower appeared on them. There was no significant difference in the F-test of solutions for days of vase-life, maximum number of flowers or the average number of flowers. In the contrast test no statistical difference was observed between the control and the solutions (Table 5). By maintaining in water solution *Kalanchoe delagoensis* inflorescences can last up to 20 days and have desirable amount of flowers. An average of the vase-life of the flowers (Fig. 36) showed that this species can last up to 20 days in solution 1, 16 days in solution 2 and 17 days in solution 3. Figures 37 to 47 show the quality of the inflorescences throughout the length of the experiment. *Kalanchoe delagoensis* presented some difficulties during the experiment. The flower stems were very brittle, which affected handling. Flowers broke easily during harvesting and transportation. The color of the flower was also affected by the postharvest solutions.

**Table 5. *Kalanchoe delagoensis* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 1.**

		LSMean		
		Max. No. Days	Max. No. Flowers	Avg. No. Flowers
Trial	1	19.56	13.33	9.17
	2	16.22	12.44	7.71
F-test	Solutions	0.1758 <sub>NS</sub>	0.5391 <sub>NS</sub>	0.8336 <sub>NS</sub>
Solution	(1) Control	20.17	14.50	9.08
	(2) Sucrose	16.33	11.67	7.95
	(3) Sucrose + Nutrients	17.17	12.50	8.28
Contrast	Sol (1) vs. Sols (2+3)	0.0720 <sub>NS</sub>	0.2940 <sub>NS</sub>	0.5695 <sub>NS</sub>
	Sol (2) vs. Sol (3)	0.6885 <sub>NS</sub>	0.7499 <sub>NS</sub>	0.8644 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

<sub>NS</sub>, \*, Non-significant or significant at  $P \leq 0.05$  respectively



**Figure 36. Effect of three postharvest solutions on the vase-life of *Kalanchoe delagoensis* experiment 1.** Solutions were: (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.



**Figure 37.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 1. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 38.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 39.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 10. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 40.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 15. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 41.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 20. Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 42.** *Kalanchoe delagoensis* flowers in experiment 1, trial 1, day 25. Solution 3 (each solution has three replicates).



**Figure 43.** *Kalanchoe delagoensis* flowers in experiment 1, trial 2, day 1. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 44.** *Kalanchoe delagoensis* flowers in experiment 1, trial 2, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 45. *Kalanchoe delagoensis* flowers in experiment 1, trial 2, day 10.** Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 46.** *Kalanchoe delagoensis* flowers in experiment 1, trial 2, day 15. Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 47. *Kalanchoe delagoensis* flowers in experiment 1, trial 2, day 20.** Solutions 1 and 3 (each solution has three replicates).

#### 4.4.2 Experiment 2

*Kalanchoe delagoensis* plants took 10 months to grow from small plants to an adult plant. It is a slow growing plant, but has many seedlings and they all grow very well. Some plants were needed to be removed from the beds in order to allow spacing between them. Cymes were harvested when the first flower appeared on them. There was a significant difference in the F-test of solutions for maximum number of flowers or the average number of flowers. In the contrast test no statistical difference was observed between the control and the solutions for days of vase-life, maximum number of flowers or average number of flowers. A statistical difference was observed between solutions 2 and 3 in the maximum number of flowers (Table 6). By maintaining in solution 2, *Kalanchoe delagoensis* inflorescences can last up to 13 days and have a desirable amount of flowers. An average of the vase-life of the flowers (Fig. 48) showed that this species can last up to 12 days in solution 1, 13 days in solution 2 and 18 days in solution 3. Figures 49 to 53 show the quality of the inflorescences throughout the length of the experiment. *Kalanchoe delagoensis* presented some difficulties during the experiment. The flower stems were very brittle, which affected handling. Flowers broke easily during harvesting and transportation. The color of the flower was also affected by the postharvest solutions.

**Table 6. *Kalanchoe delagoensis* inflorescences contrast test evaluation for maximum number of days of vase-life, maximum and average number of flowers in experiment 2.**

		LSMean		
		Max. No. Days	Max. No. Flowers	Avg. No. Flowers
Trial	1	14.56	20.55	14.30
F-test	Solutions	0.0928 <sub>NS</sub>	0.0407*	0.0055*
Solution	(1) Control	12.00	18.00	12.93
	(2) Sucrose	13.33	31.33	22.73
	(3) Sucrose + Nutrients	18.33	12.33	7.23
Contrast	Sol (1) vs. Sols (2+3)	0.1245 <sub>NS</sub>	0.4719 <sub>NS</sub>	0.4551 <sub>NS</sub>
	Sol (2) vs. Sol (3)	0.0903 <sub>NS</sub>	0.0165*	0.0020 <sub>NS</sub>

Mean separation in rows by Contrast test  $P \leq 0.05$

NS, \*, Non-significant or significant at  $P \leq 0.05$  respectively

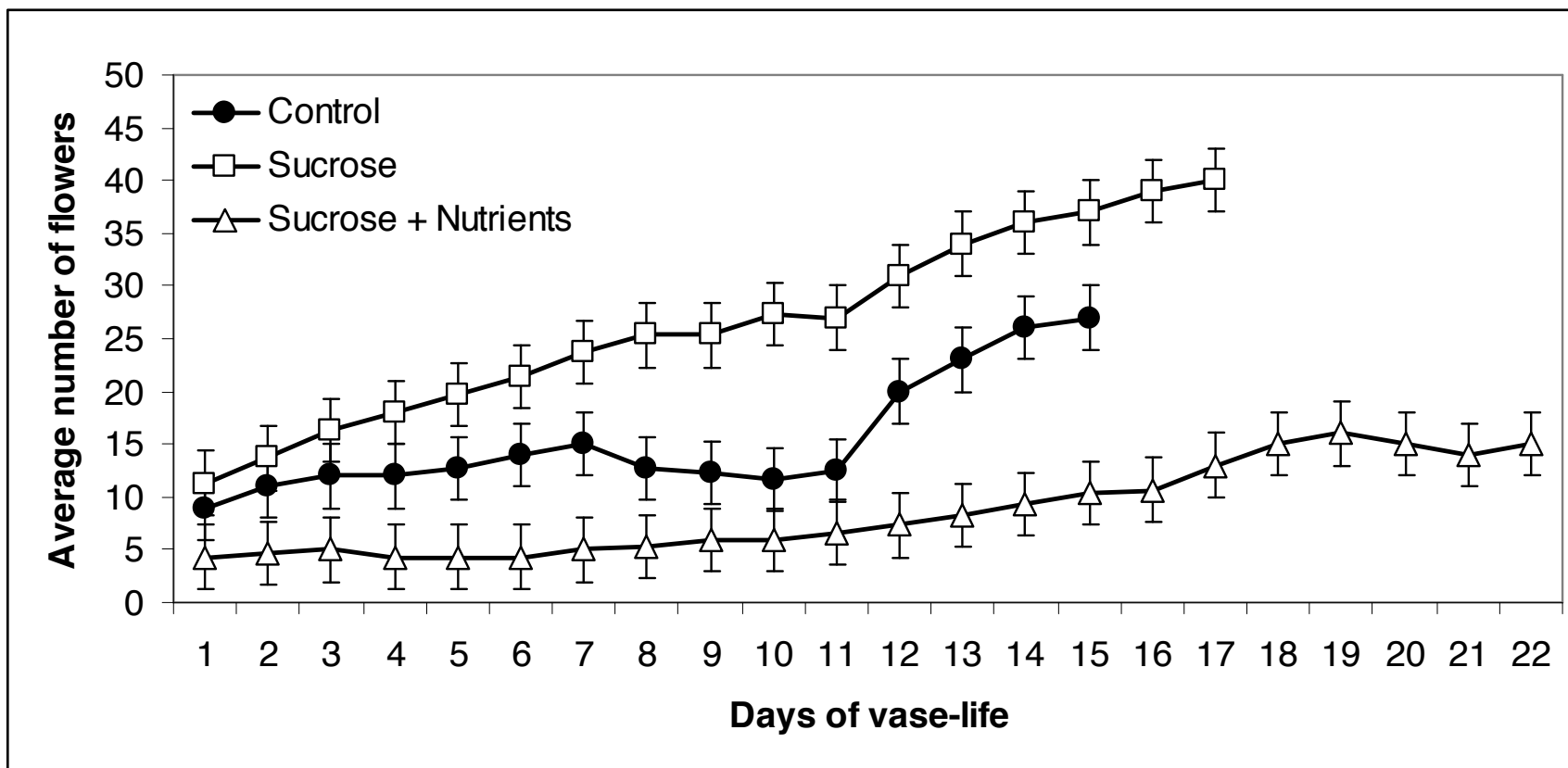


Figure 48. Effect of three postharvest solutions on the vase-life of *Kalanchoe delagoensis* experiment 2. **Solutions were:** (1) distilled, deionized water (control), 2) sucrose, pH 3.5 and sodium hypochlorite, and 3) sucrose, pH 3.5, sodium hypochlorite and KCl and K<sub>2</sub>SO<sub>4</sub>. Three trials with three flower spikes for a total of nine spikes were used for each solution and the average number of flowers was calculated daily until flowers were deemed unmarketable. Marketable quality was defined as the number of days from cut to discard; flowers were discarded when browning of the flower spike occurred.



**Figure 49.** *Kalanchoe delagoensis* flowers in experiment 2, trial 1, day 1. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 50.** *Kalanchoe delagoensis* flowers in experiment 2, trial 1, day 5. Solutions 1, 2 and 3, respectively (each solution has three replicates).





**Figure 51.** *Kalanchoe delagoensis* flowers in experiment 2, trial 1, day 10. Solutions 1, 2 and 3, respectively (each solution has three replicates).



**Figure 52.** *Kalanchoe delagoensis* flowers in experiment 2, trial 1, day 15. Solutions 2 and 3, respectively (each solution has three replicates).



**Figure 53.** *Kalanchoe delagoensis* flowers in experiment 2, trial 1, day 20. Solution 3 (each solution has three replicates).



## 4.5 DISCUSSION

Since no significant difference was observed in the vase-life and maximum number of flowers among solutions for experiment 1, we can conclude that maintaining flowers in distilled, deionized water (solution 1) provides adequate vase-life of *Kalanchoe delagoensis* flowers. In experiment 2 the additions of solution 2 was helpful for maximum number of flowers and the average number of flowers. This can be attributed to the fact that the flower stems used for this experiment were of a larger size, requiring the addition of sucrose for development. The difference in the results between the experiments can be attributed to the fact that the first experiment consisted of cymes of 13 cm in diameter and in the second experiment were of cymes of 18 cm in diameter. A higher diameter cyme might be stimulated in during the vegetative growth and floral production.

Doi and Reid (1995) reported similar results in *Limonium* 'Fantasia' where sucrose promoted flower opening and extended the vase-life. Immature flower buds failed to develop without an additional carbohydrate supply. The presence of 2% of sucrose in the vase solution promoted bud opening and dramatically increased the life of cut inflorescences to 17 days (Han et al., 1990; Han, 1992). In other studies the continuous addition of sucrose significantly extended vase-life in *Gloriosa rothschildiana* by improving solution uptake and delaying senescence in fully developed flowers (Jones and Truett, 1992).

## 4.6 CONCLUSION

The use of sucrose did not demonstrate a significant impact in prolonging the vase-life or the opening of the flowers on the clusters. In summary, this research indicates that *Kalanchoe delagoensis* can have a vase-life of up to 24 days with a solution containing sucrose and nutrients, without increasing the number of flowers. The brittleness of the flowers is not a positive characteristic for the cut flower industry.

Other studies, such as production of ethylene, ethylene sensitivity, different concentrations of sugars and nutrients, could help provide detailed information on the postharvest handling and potential vase-life of cut flowers of *Kalanchoe delagoensis*.

## 4.7 LITERATURE CITED

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## 5 STUDY CONCLUSION

*Brassica juncea* cut flowers should be placed in a sucrose solution (Solution 2) after harvest for maximum vase-life and maximum number of flowers. It is an easy to grow plant with bright yellow flowers and nice aroma. This plant could be used as filler in flower arrangements to increase color and to give a full soft look to connect mass and line flowers. The results of this research demonstrated the potential of *Brassica juncea* as a cut flower crop.

*Leonotis nepetifolia* cut flowers can be placed in distilled, deionized water (Solution 1) to maintain the flowers for a long period of time. This plant can be used for the bright orange color and unusual form as mass or line element, in a flower arrangement. This flower stem can be used without the flowers as a dry material for decorations. Further research might give a better view of the use of this flower stem as a dry flower. The results of this research demonstrated the potential of *Leonotis nepetifolia* as cut flower crop.

*Kalanchoe delagoensis* can be placed in distilled deionized water (solution 1) to maintain the flowers for a long period of time. The brittleness of the flowers is not a positive characteristic for the cut flower industry because of the difficulties in handling and transportation of the flowers, therefore limiting its potential for the cut flower industry.