EFFECT OF HOLDING SOLUTIONS ON THE VASE LIFE OF CUT GERBERA (*Gerbera jamesonii* Hook.) FLOWERS

DIVYA, H.S.

PHK 902

DIVISION OF HORTICULTURE

UNIVERSITY OF AGRICULTURAL SCIENCES

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Divya, H.S.

DIVISION OF HORTICULTURE

UNIVERSITY OF AGRICULTURAL SCIENCES

GKVK, BENGALURU-65

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Affectionately dedicated to my

Beloved Parents

and

Shri. Sampath Kumar

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DIVISION OF HORTICULTURE
UNIVERSITY OF AGRICULTURAL SCIENCES
BENGALURU – 560 065

CERTIFICATE

This is to certify that the thesis entitled **"Effect of Holding solutions on the vase life of cut Gerbera *(Gerbera jamesonii* Hook.*)* Flowers"** submitted by **Mrs. DIVYA, H.S., ID No. PHK 902** for the degree of Master of Science (Horticulture) in **Floriculture and Landscape Gardening** to the University of Agricultural Sciences, GKVK, Bengaluru, is a record of research work done by her during the period of her study in this University under my guidance and supervision, and the thesis has not previously formed the basis of the award of any other degree, diploma, associateship, fellowship or similar other titles**.**

Bengaluru
July, 2013

Dr.B. Raju
Major Advisor

Approved by:

Chairman: ______________________

(B. Raju)

Members:

1. ______________________

(K.V. Jayaprasad)

2. ______________________

(S. Jaganath)

3. ______________________

(R. Krishna Manohar)

4. ______________________

(B.C. Mallesha)

5. ______________________

(M.S. Shesha Sayee)

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INTRODUCTION

I. INTRODUCTION

Flower is the best medium to express all the sentiments of heart, joy, happiness, sense of celebration, sorrow and how uniquely these feelings are aired. The love for flowers is as old as human civilization. Evidence of man's love for flowers in India can be found in Rig Veda (3000-2000 B.C.) and the Ramayana (1200-1000 B.C.), depiction of flowers in murals, paintings and coins. Flowers have been traditionally associated with beauty, grace and reverence, but with the change in people's lifestyle, their use and demand patterns changed. The demand for modern flowers like rose, carnations, gerbera, gladiolus, orchid, anthurium etc., is increasing both in domestic as well as global market.

Gerbera (*Gerbera jamesonii* Hook.) came into dictionary of floriculture after it was discovered by pre-Linnean botanist, Gronovious but it received its fortunate name in honour of German naturalist, 'Traugott Gerber' who travelled in Russia in 1743. Gerbera is an internationally important cut flower grown for its colourful, showy and long lasting daisy like flowers. It is one of the nature's beautiful creations having beautiful flowers, exquisite shape, size and bewitching colour. It is commonly known as "Transvaal daisy", "Barbeton daisy" or "African daisy".

Gerbera belongs to the family Asteraceae and is considered to be the native of South African and Asiatic regions. They are mostly found to inhabit temperate and mountain regions. It is well distributed in South Africa, Europe, Asia and Indonesia. About seven species were recorded in India distributed in temperate Himalayas from Kashmir to Nepal at an altitude of 1300 to 3200 meters. Gerberas can be grown successfully both in plains and hills.

Gerbera species of Indian origin are *Gerbera andria, G.kunzeana, G. languinosa, G. macrophylla, G. nivea, G. ovalifolia* and *G. poiloselloides*. The cultivated species in this genus are *Gerbera asplenifolia, G. aurantica, G. kunzeana* and *G. viridifolia.* These are stemless perennial herbs (Bhattacharjee and De, 2003).

Gerberas are stemless and tender perennial herbs. Leaves are radical petioled, lanceolate, deeply lobed, sometimes leathery, narrower at the base and wider at top are arranged in rosette at the base. Flower heads are solitary, many flowered, the conspicuous rays in one or two rows, those of the inner row when present, very short, sub tubular and two lipped. The daisies like flowers are in wide range of colours. The double cultivars sometimes have bi-coloured flowers which are very attractive. The flower stalks are long, thin and leafless and achenes are beaked, pappus or rough bristles in two or more rows.

Gerbera is an elegant garden flower of immense value. They are very attractive in the garden with their star like flowers of varying colors and shades. Born terminally on slender long stems, they form effective, colorful flower borders or beds (Thangaraj *et al.,* 1990). It is in considerable demand in both domestic and export markets. The blooms are attractive, suitable for any type of floral arrangements, gerbera is widely used in bouquets and in dry flower crafts. Due to changes in social and cultural life style of people, cut flowers have found an important place in various social functions of daily activities. The cut flowers have a long vase-life, which fetches premium market prices.

Gerbera is one among the top ten cut flowers of the world flower trade, which rank fifth in the International flower trade. Good quality cut flowers of gerbera can be produced under protected cultivation.

India being gifted with best climate for protected cultivation, the production of gerberas, particularly during winter months is highly profitable when compared to temperate countries, where these are grown under greenhouse conditions. Hence there is good demand for gerberas particularly from European markets during winter months and throughout the year in India. India being geographically located between major export markets like Europe and East Asia, there is an increasing demand for cut flower export from our country.

The flowers are hardy and stand the transportation situation admirably flower longevity depends on the stage of harvest. The exact stage of harvesting varies with the variety, grower, weather conditions and market distance. The flowers are generally cut when the outer ray florets are completely elongated or when outer two rows of disc florets are perpendicular to the flower stem (Salunkhe *et al.*, 1989).

In recent years, cut flowers trade increased many folds in domestic as well as in the international markets. The beauty of the flowers lies with the freshness of the flowers for longer time without losing its aesthetic value. All along the marketing channel, there is enormous loss in the value of cut flowers which could be 50 per cent of the farm value (Bhattacharjee, 1999). The cut flowers are deprived of their natural resources of water and nutrients after detaching from mother plant. Due to that, they have to carry all the life processes at the expense of reserved food materials. Hence, addition of chemical preservatives to the cut flowers is recommended to continue its physiological processes so that the longevity of the flowers can be extended by more number of days (Nair *et al.*, 2000).

Nearly 20-40 per cent of the cut flowers are lost due to improper post-harvest handling. These post-harvest losses can be reduced by adopting suitable harvesting, post harvesting techniques namely by temperature management during storage and following strict sanitation procedures in the grading and packing rooms. Further vase life can be doubled by the judicious use of floral preservatives in the vase solutions. If a greater importance can possibly be assigned to any of the needs of the cut flowers, maintenance of turgidity would have the highest priority (Rogers, 1973). As cut flowers, unlike most agricultural commodities are harvested before they are fully developed, they are expected to continue their growth in consumers home.

Keeping quality is an important parameter for evaluation of cut flower quality, for both domestic and export markets. Addition of chemical preservatives to the holding solution is recommended to prolong the vase-life of cut flowers. All holding solutions must essentially contain two components viz., sugar and germicides. The sugars provide a respiratory substrate, while the germicides control harmful bacteria and prevent plugging of the conducting tissue (Nair *et al.*, 2003).

Two major factors play a dominant role in post harvest physiology of the cut flowers are supply of carbohydrates and water balance in the stem. Sugars are the source of energy for respiration, which maintains turgidity, play an important role in flower freshness. Sucrose treatment leads to an increase in the mechanical rigidity of the stem, which is due to cell wall thickening and lignifications of vascular tissues (Steinitz, 1983).

Cut flowers are more complex which require special attention in developing handling techniques. Several attempts have been made to study the effect of different chemicals, sugars and other substances to extend the longevity of cut flower (Halvey *et al.*, 1979 and Marousky, 1972). Keeping the above points in view, therefore the present investigation is carried out with the following objectives;

a) To study the effect of different mineral salts for extending the vase life of gerbera flowers.

b) To evaluate best concentration of mineral salts in combination with sucrose for extending post harvest longevity of flowers.

c) To study the effect of germicide in the holding solution to extend the vase life of cut gerbera flowers.

REVIEW OF LITERATURE

II. REVIEW OF LITERATURE

Gerbera is one of the important cut flowers in the world and occupies a place of great prominence. Longer vase life is one of the most desired qualities in cut flowers. It is therefore essential to develop suitable techniques to improve the keeping quality of cut flowers. The first review on post harvest physiology of flowers was reviewed by (Aarts, 1957) on keeping quality of cut flowers. Flowers removed from the plant deteriorate much more quickly than those left on the plant under similar environmental conditions (Durkin and kue, 1966). Literature pertaining to post harvest physiology of cut flowers is reviewed in detail by several workers (Rogers, 1973; Halevy and Mayak, 1979, 1981).

Cut flower is a complex delicate organ composed of different morphological units and their interrelationship determines post harvest longevity and quality. Extension of vase life of cut flowers involves two seemingly conflicting processes, the promotion of growth during the first phase and retardation of senescence process during second phase (Halevy and Mayak, 1979). The literature pertaining to postharvest behavior of cut flowers as affected by different chemicals is reviewed under.

2.1 Post harvest physiology of cut flowers

Cut flowers are living, actively metabolizing heterogeneous organs, compound of floral and foliar parts each of which may be at different physiological developing stage. The termination of vase life of many flowers is characterized by wilting and senescence of petals (Halevy and Mayak, 1979). Once cut flowers are detached from parent plant they are delinked from the supply of metabolic raw materials. Therefore, exogenous supply is essential to keep its quality and usefulness. Water is the first and foremost essential component for flowers. A source of energy deriving materials for respiration is also quite important. A clear understanding of the course of senescence will immensely helpful for establishing techniques to overcome ageing process.

Carbohydrate supply and maintenance of water balance (Rogers, 1973) are the two important factors which play a vital role in regulating the longevity of cut flowers. Injury at cut end and presence of microorganisms in the xylem vessel leads to physical blockage. Thus, altering the regular metabolism by secreting metabolic byproducts causing physiological blockage which could prevent absorption, resulting in severe water deficit (Aarts, 1957). Cut flower longevity is shortened by ethylene (Rogers, 1973) because it accelerates the loss of water and decrease water uptake (Mayak and Dilley, 1976) and fresh weight (Nichols, 1968).

2.1.1 Water Relations

Turgidity in plants and flowers is dependent upon a balance between the rate of water loss or utilization and water supply (Masterlenz, 1953; Rogers, 1962 and Tickner, 1942). A high level of turgidity is necessary for development of flower buds to full bloom maturity and is also necessary for the continuous normal metabolic activity in the cut flower (Rogers, 1973).

Continuous keeping of cut flower stems in vase holding solution leads to browning of stems. So to prevent this water must be changed everyday or else treated with chlorine (Barendse, 1981).

Rogers (1973) reported that turgidity in plants and florets depends on the balance between the rate of water loss, utilization and water supply.

Shelf life of cut flowers depends on genetic makeup and water quality. In a study conducted by Jong (1985) where the gerbera cut flowers were held in contaminated water could be kept for only six days as compared to 14 days in fresh water.

Reduction in water conductivity seems to be a common process in many cut flowers. Water deficit and water potential relationship of the petals change with age, resulting in a lower water holding capacity (Van Meetern, 1979; Acock and Nichols, 1979). This is caused by many factors, the major factor being vascular blockage, which starts at the cut end moves upward in the stem over a period of time (Marousky, 1972; Chandrashekaraiah, 1973; Sacalis, 1975).

Pressure potential in water uptake and maintaining turgidity is appreciable. Meeteren (1980) reported leakage of ions from petal cells that lowered the water potential and thereby the pressure potential of the tissue was decreased. This pressure and water potential indicates the keeping quality. Bacteria present in vase water caused plugging of xylem vessels (Hoogerwerf, *et al.,* 1992). Growth of bacteria was lower at grower's level, but become increasingly higher at auction centers. Growth rate of bacteria in retails level was enough to reduce the longevity of cut gerbera cultivars.

Withering of petals is the most visible characteristics of the wilting of cut flowers. It occurs when the circulation of fluids from the base of the stem to the petals slow or even ceases, thus preventing replacement of water lost due to continuing transpiration. (Le Masson and Paulin, 1980)

Plugging of stem, reduced water transport capacity having relation to the presence of microorganism in solution (Ford *et al.,* 1961) which leads to physical plugging by microorganism clustered at the cut end or from the accumulation of pugging substances released by micro-organisms (Aarts, 1957).

Reddy and Singh (1996) reported that increase in water uptake by pulsing treatments of gladiolus might be due to translocated sugars accumulated in flowers increased the osmotic potential and improved the ability of spikes to absorb water.

A two minutes dip of gerbera flowers in benzyl adenine delayed the decrease in water content and increase in ion leakage (Meeteren, 1979)

2.2 Presence of micro-organism

Vase life of cut gerbera flowers are usually not too long as they wilt and starts to bend and these symptoms are considered to be caused by vascular blockage, which inhibits the supply of water to the flower.

Several methods to increase the vase life of cut flowers and keep their freshness for longer periods have been reported. Cut flowers should be free of any deterioration, as this is one of the principal entry points for decay organisms. A major form of deterioration in cut flowers is the blockage of xylem vessels by air and micro-organisms that cause xylem occlusion (Elgimabi and Ahmed, 2009).

Arnold (1930) first reported low water uptake in cut flowers due to blockage by bacteria and their degradation products. Two major factors affecting water absorption through conducting vessels and air embolism and the occurrence of vascular occlusion in cut flower stems. Vascular blockage begins at the cut end moves upward in the stem with time (Durkin and kue, 1966).

Reduction of the vase life of cut flowers by microorganisms in the vase solution has been reported by several workers. Some possible explanations for the action of micro-organisms against cut flowers include bacterial plugging of flower vessel elements (Burdett, 1970; Dansereau and Vines, 1975; Larsen and Frolich, 1969, Marousky, 1977 and Mayak *et al.*, 1977) or possible endogenous production of ethylene. (Fujino *et al.*, 1983; Vandermolen *et al.,* 1983).

Bacterial population rapidly developed at the pH of 4.0 to 7.0 in the cut surface and inside the xylem conduits (Van Doorn *et al.*, 1991). The bacteria blockage is apparently a physical phenomenon, due to the presence of living bacteria and the production of extra cellular polysaccharides combined with dead bacteria and their degradation products. Basal blockage probably develops in basal stem end of all cut flowers which reduced water uptake causing stem plugging which in turn resulted in bent stem (Rogers, 1972).

The rapid proliferation of microorganisms in vase water results in xylem blockage, water stress and further reduction in longevity of cut flowers (Van Doorn and Perik, 1990). It was also reported by De Witte (1994) that the effects of water uptake and vase life were independent of the bacterial strain present in the vase solution.

In certain commonly used vase solution, micro-organisms like bacteria and yeast are capable of reducing cut flower vase life and they exhibit some specificity. Many other vase solution microorganisms have no apparent effect on cut flowers (Zagory and Reid, 1986).

A wide variety of micro-organisms, bacteria and fungi, was isolated from freshly harvested cut flower stems and vase contents of Chrysanthemum (*Dendranthema grandiflora*) cultivar 'Spider', gerbera cultivars 'Appel blosem' and 'Fleur' and Rosa cultivar 'Sonia' (Put, 1990).

Wouter (1994) reported bacteria in the vase water of cut gerbera flowers resulted in an increase in scape bending curvature depending on the concentration of bacteria in the water, cultivar and season. In summer, maximum strain of *Pseudomonas aeruginosa* or mixed population of bacterial species found in cultivar 'Liesbeth' and 'Mickey' but in winter the lowest bacterial concentrations were found, 'Mickey' showed bending at a lower water potential than 'Liesbeth'.

The results of the scanning electron microscope observations showed that only a small fraction of the microbial cells entered into the vascular system with the normal intake of vase water, most microbial cells remained attached to the submerged cut surface while a small fraction of the initially attached microbes were sometimes liberated into the surrounding vase water (Put and Clerks, 2008).

Gerbera flowers cv. 'Yanara' held in BA 4 ppm + SH 25 ppm + sucrose maintained flower quality by controlling microbial growth, lowered scape bending and increased the vase life for a longer duration (Asma *et al.*, 2008).

2.3 Effect of sucrose

Sugars serve as an energy source for respiration or osmotically active compound, which aid in maintaining the turgidity of expanding flower petals. In addition, helps to maintain better freshness of cut flowers. Metabolic sugars like glucose and fructose are similarly effective as sucrose, but sucrose is used in most preservative formulations. Maltose and lactose were active only in low concentrations while, the non-metabolic sugars like mannose and manitol were inactive and harmful (Kofranek and Halevy, 1972; Halevy and Mayak, 1974).

Steinitz (1982) opined that addition of sucrose to the solution increased the mechanical rigidity of the stem by inducing cell wall thickening and lignifications of vascular tissues.

Sucrose is widely used in floral preservatives, which acts as a food source or respiratory substrate and delays the degradation of proteins and improves the water balance of cut flowers (Nair *et al.,* 2003). Sugars alone however, tends to promote microbial growth. Hence, the combination of sugars and biocides might extend the vase life of cut flowers. $AgNO_3$ or sucrose alone was less effective as compared to their combinations with regard to vase-life. Similar observation was made by (Steinitz, 1982 and Awad *et al.,* 1986) in gerbera and zinnia, respectively.

Nowak (1989) reported that the best results were obtained when the inflorescences were pulsed in $AgNO_3$ (200 mg/liter) or in HQC (200 mg/liter) + sucrose (100 g/liter) or in $AgNO_3$ (200 mg/liter) + sucrose (100 g/liter) before transport and they were kept continuously in preservative solution consisting of 8 HQC (200 mg/liter) + sucrose (30 g/liter) after transport.

Supplying cut flowers with exogenous sucrose maintains pool of dry matters and respiratory substrates in flower petals and also induced osmotic adjustment (Nichols, 1973; Bhattacherjee, 1999).

Deambrogio *et al.* (1991) reported that post harvest life was prolonged by all the solutions, where in some cases increased it about 4 fold compared with control (distilled water). A solution of 8 HQS + NaB + Amino acetic acid + 3,4,5-T and sucrose not only increased vase life but was associated with a different type of senescence, probably because of adequate water uptake and low transpiration losses whereas, inflorescence lost turgidity and wilted.

(Burzo *et al.*, 1992) reported that flowers held in distilled water or a preservative solution containing 2.5 per cent dextrose, 150 ppm 8 HQS and 200 ppm potassium chloride extended the vase life up to 12 days at 20-23 and 60-65 per cent relative humidity. Pulsing gladiolus spikes with sucrose five per cent enhanced vase life over control (Nijasure *et al.*, 2004).

Sucrose plays a dominant role in maintaining water balance (Nichols, 1973), mitochondrial structure and functions (Kaltaler and Steponkus, 1976) thereby, increase the vase life of cut flowers. Treating cut flowers with sucrose has found to have maximum percentage of bloom (Pathak *et al.,* 1979). Standard carnations were bloomed when placed in high concentration of sucrose (Halevy, 1987). Excessively high concentration of sugar can damage foliage and petals, it is probably because of their ability for osmotic adjustment is less than that of petals. The reducing sugars increase initially then decrease steadily in both leaves and petals (Behera, 1993).

2.4 Effect of mineral salts/ Chemical preservatives

The use of flower preservatives to promote the quality and to prolong the life of cut flowers has been known for many years. There are different types of chemicals being used to improve the vase life and quality of cut flowers. Preservative solutions can be used for different purposes like pulsing, conditioning and holding. It also controls growth of bacteria and fungi in the vase solution mainly because of their germicidal property. Several experiment were conducted to study the effect of different chemicals, germicides, sugars, metabolic salts, acidifying agents and harmones on the post harvest longevity of cut flowers having commercial value (Mayak and Dilley, 1976; Abdel-Kader and Rogers, 1986). Certain nontoxic mineral salts notably, aluminium sulphate (Aarts, 1957; Mantur and Nalawadi, 1989), silver nitrate (Halevy *et al.,* 1978; Nowak, 1981, Nowak and Plinch, 1981), $CaCl_2$ (Balakrishna, 1987), can improve the water balance, thereby extended the longevity of cut flowers. Salts of some metals such as Ag, Co, Ni, Zn, Ca and Al had markedly reduced the ethylene liberation in cut gladiolus stems (Murali, 1990).

2.4.1 Effect of Aluminium

Aluminum sulphate is one among the many chemicals used usually for its anti microbial action as a bactericide which helps in improving the vase life of cut flowers. Aluminium compounds acidify the holding solution and lower the pH thus, reducing microbial growth and development (Schnabl and Ziegler, 1974; Aarts, 1957). In addition aluminium ions affect the stomatal status by diminishing the stomatal opening and subsequently decrease the water evaporation (Schnabl and Ziegler, 1975; Schnabl, 1976).Starch synthesis and inhibition of starch hydrolysis is also influenced by aluminum salts (Schnabl and Ziegler, 1975). It is known that aluminium sulphate acts as an effective bacterial filter (Put *et al.*, 1992).

Floral preservative solution containing aluminum sulphate at 150 mg L^{-1} under 25^0C extended the vase life of cut eustoma (*Eustoma grandiflorum* Shinn.cv. Hei Hou) (Liao *et al.*, 2001).

Shobha and Gowda (1993) reported that aluminum sulphate (0.75mM) showed an increase in vase life by 3.5 days over control with improved quality of cut roses. In addition to HQS, many germicides, such as silver nitrate, aluminum sulphate, copper sulphate, cobalt chloride etc. have been shown to inhibit bacterial growth in cut flower stems (Van Doorn, 1997; Van Meeteren, 2000).

'Sophia Laurence' recorded the maximum vase life among the five rose scion varieties Gladiator, Arjun, Sophia Laurence, Golden Times and Montezuma used in aluminum sulphate 70 ppm solution while 'Montezuma' recorded the minimum vase life (Karadi and patil, 2007).

Longer vase life along with higher water uptake and more water loss was observed in rose cultivar 'Cream Prophyta' on application of aluminum sulphate at the rate of 600 ppm as compared to the control (Yogitha, 1997). Aluminum sulphate in vase water decreased the number of bacteria in the stems and increased the vase life with an increased fresh weight in cut roses (Doorn *et al.*, 1990; De.Stighter, 1978; Nagarajaiah, 1992).

Suhrita *et al.*, (2008) reported that gerbera cv. 'Calcutta Orange' held among different vase solutions, sucrose 3 % combined with 8 HQS 200 ppm and sucrose 4 % including aluminum sulphate 200 ppm were found better.

Dias (1994) reported maximum vase of 8.9 days with aluminium sulphate for cut roses cv. 'Arjun' followed by citric acid. In China aster maximum vase life was obtained with 0.2 per cent $Al_2(SO_4)_3$ in 2 per cent sucrose (Mantur and Nalawadi, 1989).

2.4.2 Effect of silver

Silver nitrate is one of the most important effective bactericide in most commercial preservative formulations (Aarts, 1957; Nowak and Rudnicki, 1990). Silver nitrate is relatively immobile in the stem (Kofranek and Paul, 1975) but silver thiosulphate (STS) moves readily in the stem (Veen and Van de Geijn, 1978). Enhanced water uptake and reduced bacterial count was recorded with $AgNO_3$ treatment in cut roses (Ketsa *et al.,* 1993) and also found silver thiosulphate was less effective than $AgNO_3$ in prolonging vase life.

The investigation revealed that the best holding solution for cut gerbera blooms would be a combination of silver nitrate and sucrose. The vase-life was prolonged by about nine days by holding the flowers in solution containing 20 ppm $AgNO_3$ + 4 % sucrose (Nair *et al.,* 2003).

Silver nitrate ranging in concentration from 10 to 50 mg l^{-1}, together with 5 % sucrose as holding solution significantly increased the vase life of Christian Dior cut roses; the optimum concentration of silver nitrate was 20 mg 1^{-1}. The holding solution containing 5 % sucrose + 20 mg L^{-1} $AgNO_3$, also significantly increased the vase life of rose cultivars 'Eiffel Tower', 'Swartmore' and 'Yankee' but not 'Kings Ransom' and 'Confidence'. Silver thiosulphate complex was not as effective as Silver nitrate for the increase in vase life or in the reduction of microbial population (Saichol *et al.*, 1992).

The experiment revealed, significant influence of sucrose and silver nitrate at different concentrations on the vase life of two roses (*Rosa hybrida*), namely Trika and Whisky Mac. In all the treatments containing sucrose and silver nitrate, the $AgNO_3$ concentration at 150 ppm prolonged the maximum number of days in both the cultivars, which were 4.3 and 3.2 days more in Whisky Mac and Trika, respectively as compared to control (Shahid, 2005).

The application of silver nitrate with different doses gave some positive results with respect to improved stem and leaf size, and the length of plantlets usually remained smaller, attributing to the absence of cells enlargement in the presence of profused cell multiplication (Khalid *et al.*, 1991; Taylor *et al.*, 1994).

Extended vase life of up to 7-8 days compared with control was observed in carnation treated with one mM silver thiosulphate (Han and Lee, 1992). Shoba (1992) reported that maximum uptake of water and vase life of 9.77 days was obtained in the spikes treated with 0.75 mM silver thiosulphate, pretreatment with silver thiosulphate solution is sufficient enough to provide 2.5 mM Ag^{+} per spike prevented floret abscission in snap dragons (*Antrrhinum majus*) caused either by ethylene or by addition of ethephon to the vase solution (Delbert *et al.,* 1980).

2.4.3 Effect of 8-HQS

The vase life of cut rose flowers was studied with 8-HQS concentrations of 100, 200 and 300 ppm, longevity of the flower prolonged by all 8-HQS treatments. The best concentration was 100 ppm. The effect was further improved when 8-HQS was combined with 3 % sucrose, which recorded the best vase life compared to other concentrations of sucrose (Elgimabi and Ahmed, 2009).

Use of 8-HQS extended the vase life of all cut flowers studied. The best concentration was 400 ppm. The effect is better when combined with 50 g 1^{-1} sucrose for carnation and rose cut flowers. On the other hand, this dose of 8-HQS without sucrose was better for chrysanthemum and solidago flowers. This suitable dose of 8-HQS led to control the microorganism growth and hence suppressed their growth and consequently prevented the xylem occlusion (Fahmy, 2003).

Treatment with sucrose in combination with 8-hydroxyquinoline sulphate (HQS) extends the vase life of cut rose flowers and the vascular occlusion may be responsible for short vase life because HQS inhibits vascular occlusion of cut stems (Ichimura *et al.*, 1999).

In comparison to other antimicrobial agents, CIO_2 and 8-hydroxyquinoline sulphate (8-HQS) were more effective in extending the vase life of Gerbera cultivars 'Julia', 'Lorka' and 'Vilassar' when included in vase water containing 0.2 g 1^{-1} citric acid 10 g 1^{-1} sucrose (Macnish and Leonard, 2010).

Suneetha (1994) reported that the maximum vase life in three cultivars of gladiolus viz, 'Her Majesty', 'Vinks glory' and 'Oscar' was recorded in a holding solution of 5 per cent sucrose plus 600 ppm 8-HQS. In case of 'Her Majesty' sucrose plus $AgNO_3$ (100 or 200 ppm) solutions were also equally effective.

Preservative solution containing 8-HQS (150 ppm) plus sucrose (2 per cent) increased vase life and improved quality of flowers, reduced ethylene production from flowers, inhibited microbial contamination and maintained structural role of vascular cambium tissue in the stem of Delphinium (Song *et al.*, 1995).

The cut gerberas held in 200 ppm 8-HQS showed longest vase life (8 days) with lowest electrolyte leakage, higher water potentials and higher levels of proteins and phenols in flower scapes (Prashanth *et al.*, 2007).

2.5 Effect of germicides

All preservative formulations include at least one compound with germicidal activity. Among these, most common and active compounds are silver nitrate and 8-HQS.Germicides controlled microbial growth and partially decreased the resistance to water flow when used in vase solution for cut tuberose (Mukhopadhyay, 1980;

Pathak *et al.,* 1979) rose (Marousky, 1969) and other cut flowers (Larsen and Cromarty, 1967), thereby helping the flower stems to maintain a higher rate of water uptake. Wiggins and Payne (1963) opined that cut flowers kept in solution containing only germicides often keep less time than in plain water. Preservatives like sodium dichloroisocyanuric acid (DICA) or BCDMH or HQC showed no effect on longevity in chrysanthemum, carnation, gerbera and iris (Jones and Hill, 1993). 8-hydroxy quinolone sulphate (8-HQS) has strong inhibiting effects on fungi, yeast and bacteria. The efficiency of 8-HQS on prolonging the vase life of cut roses (Marousky, 1969) was reported to be due to decreased vascular blockage in the stem, increased water absorption and stomatal closure.

Manjusha (2000) reported that among all the chemicals tried at optimum concentration, silver nitrate 1 mM + citric acid 1 mM + 7 % sucrose was most effective in enhancing vase life of gerbera cv. Sath baba.

The improvement in vase-life of cut flowers in 20 ppm silver nitrate ($AgNO_3$) solution might be due to the fact that it is a very effective biocide, which completely inhibits the microbial growth (Nair *et al.,* 2003). It is in conformity with the findings of (Ketsa *et al.*, 1995) who opined that $AgNO_3$ prevented microbial occlusion of xylem vessels in Dendrobium, thereby enhancing water uptake and increasing longevity of flowers.

The test solution used were distilled water (control), 0.1 M sucrose and 0.2 mM 1-dimethy1-4-(phenylsulfonyl), semicarbazide (DPSS) solutions. 8-Hydroxyquinoline sulphate at 200 mg 1^{-1} was added to each solution as a germicide found better than control (Shigeru *et al.*, 2005).

In addition to HQS, many germicides such as silver nitrate and aluminum sulphate, have been shown to inhibit bacterial growth in cut rose stems (Van Doorn, 1997). The germicide 8-hydroxyquinoline sulphate (8-HQS) is one of the very important preservatives used in floral industry (Elgimabi and Ahmed, 2009).

Several preservatives/chemicals i.e. silver nitrate, aluminum sulphate, cobalt sulphate, 8-hydroxyquinoline sulphate, boric acid, citric acid, ascorbic acid, sucrose etc. have been used in different formulations and combinations to enhance the vase life of tuberose (Saini *et al.*, 1994; Reddy *et al.*, 1995; Reddy and singh, 1996; Sathyanarayana *et al.,* 1996; De and Barman, 1998).

Beura *et al.*, (2001) showed that the combination treatment of 8-HQS and sucrose improved the postharvest quality of Gladiolus spikes.

Yoo and Kim (2003) reported that fresh weight, water uptake and flower diameter were highest when flowers were placed in a solution containing 400 mg HQS/liter and 3 % sucrose also inhibited scape bending during storage and significantly prolonged vase life of cut gerbera flowers.

Chauhan (2004) studied the effect of preservative chemicals at different concentrations on vase life gerbera cv. 'Scilla' and reported that citric acid at 200 ppm showed maximum vase life (11.48 days) followed by silver nitrate at 400 ppm (10.9 days).

Singh *et al.,* (2003) reported that maximum vase life with treatments of 8-HQC, cobalt chloride and aluminium sulphate found in carnations. (Bhaskar *et al.*, 2003) reported that calcium nitrate and aluminium sulphate were found effective in increasing the permeability of cell membrane and keeping down the peroxidative changes and increased the vase life.

The effect of some biocides on the vase life of cut gerbera cv. Glory stems (50 cm long) was studied by (Manreet-Sooch *et al.,* 2002). Flowers held in Aluminium sulphate at 100 ppm, cobalt chloride at 300 ppm, and sodium hypochlorite and commercial bleach each containing 25 ppm chlorine increased the vase life of gerbera to 6.00, 8.47, 7.60 and 8.87 days, respectively.

Dhekney *et al.*, (2000) reported that gerbera flowers recorded maximum vase life (7 days) with GA_3 at 200ppm and salicylic acid at 50 ppm as compared to control (5.33 days) and also with $AgNO_3$ 200 ppm + sucrose + citric acid (10.33 days).

In cv. 'Red Corso' and 'Cabaret' of carnations, 8-HQC was significantly best treatment in extending the vase life of cut flowers (Anonymous, 1999) this results were similar with (Kumar *et al.,* 1999)

Singh and Arora (1995), reported that cut stems of chrysanthemums maintained very high water potential of flowers and leaves when held in solutions of 8-HQC, $AgNO_3$ and chrysal which improved the vase life of flowers.

2.6 Effect of mineral salts in combination with sucrose and germicides

The commercial cut flower preservatives spring and chrysal were compared with a mixture prepared from 40 mg silver nitrate, 50 mg sodium benzoate, 30 mg sugar, 7.5 mg aluminum sulphate and 2 mg kinetin per liter of water for extending the vase life of cut roses, Carnations, Gerbera and Gypsophila. The experiment mixture gave the longest vase life (Yldrm *et al.*, 1995).

An experiment was conducted to compare the natural and chemical floral preservatives in cut gerbera in increasing the vase life. Among the preservatives tested 50 % coconut water (natural floral preservative) was proved to be the best in extending the vase life of cut gerbera flowers, followed by 4 % sucrose + 20 ppm $AgNO_3$, 60 % coconut water and 6 % sucrose + 30 ppm $AgNO_3$. There was no significant difference between the best two treatments (Nair *et al.*, 2000).

Gerbera jamesonii cv. Local Red flowers were treated with 4, 6, 8 and 10 % sucrose and 150, 200 and 250 ppm silver nitrate for 24h to determine the effect of pulsing on the shelf life of cut flowers. Pulsing with 4 % sucrose or with 250 ppm of silver nitrate for 24 h increased the vase life by 3 days compared to the control (7 days). The maximum vase life of flowers was 10 days (Nagaraj *et al.,* 2000).

Chong *et al.*, (1988) reported that the solution containing sucrose (5%) + silver nitrate (50 ppm) + 8-HQC (200 ppm) extended the vase life of carnation flowers up to 2.4 days compared to control. cut rose cv. Gladiator flowers showed a long vase life when held in 300 ppm aluminum sulphate + 5 per cent sucrose + 200 ppm 8-HQC+ 300 ppm citric acid (Patil and Singh, 1995).

Suma (2000) reported that lowest differences between weight of alstromeria cut flowers by treating with a combination of 0.2 mm silver thiosullphate + 4 per cent sucrose + 200 ppm 8-hydroxyl quinoline sulphate.

Chikkasubbanna and sharada (2002) reported in carnation cultivar ‘Sunrise’ recorded maximum vase life of 15.80 days in 100 ppm silver nitrate + 4 per cent sucrose + 200 ppm 8-HQ compared to 7.40 days in control while in cultivar ‘Pentara’, maximum vase life of

10.80 was recorded in 0.4 mm silver thiosulphate + 6 per cent sucrose + 400 ppm hydroxy quinoline as against control (4.30 days).

Chikkasubbanna and Yogitha (2002) reported in rose cultivar 'Cream prophyta' recorded a maximum vase life of 16.80 days in 600 ppm aluminum sulphate + 2 % sucrose + 150 ppm 8-HQS compared to control (13.80 days), while in cv. 'Sacha', the maximum vase life (15.60 days) was noticed in 400 ppm aluminum sulphate + 1 % sucrose + 150 ppm 8-HQS as against 12.80 days of vase life in control.

Cut gerbera variety 'scilla' showed a maximum vase life (16 days). When held in 200 ppm hydroxy quinoline sulphate + 100 ppm cobalt + 4 % sucrose (Dasgupta, 2006).

2.7 Effect of mineral salts in combination with sucrose

Aluminium sulphate in combination with sucrose was found best for the normal opening of even most tightly closed buds of carnation and mimosa (Accati and Sulis, 1980). The combination was also effective in maintaining the flower colour (Weinstein, 1959 and Ahn and urn, 1991) and for extending the vase life of roses (Gherghi *et al.,* 1983 and Yogitha, 1997), carnation (Amariutei *et al.*, 1982), dahlia (Belynskaja, 1964), gladiolus (Deswal and patil, 1983), tuberose (Balakrishna, 1987) and chrysanthemums (Barman *et al.*, 1996 and Deotle *et al.*, 1995). Calcium with sucrose in holding solution was effective in flower opening (Gerber, 1976) and improving the decorative value of tulips (Van staden, 1976) and cut carnation by increasing the flower diameter and colour intensity (Belynskaja *et al.,* 1985). The combinations prevent fading of petals and extended the vase life of cut roses (Nagarajaiah, 1985), carnations (Belynskaja *et al.,* 1985; Gerber, 1976) and tulips (van Staden, 1976).The calcium and sucrose combination was also effective in exending the vase life of tuberose

(Balakrishna, 1987). Silver nitrate in combination with sucrose significantly increased the vase life of cut rose flowers (Ketsa *et al.,* 1993). The cut rose cv. 'Landora' when placed in potassium aluminium sulphate solution along with sucrose showed longest vase life (Rath *et al.,* 1991).

Prashanth *et al.*(2007) reported 8-HQS 200 ppm + $AgNO_3$ 200 ppm + sucrose 5 % significantly increased the vase life (12 days) of gerbera flowers and reduced the microbial activity indicated by lower optical density (0.0210), increased water uptake thereby maintaining tissue water potential at higher levels (-5.683 bars), hence reducing scape bending curvature (0.00^0).

Kumar and Singh (2004) reported that sucrose and GA_3, influenced water uptake, vase life, fresh weight, floret opening and overall observations suggested an increase in vase life with sucrose and plant growth regulator treatments.

Sucrose (2 %) + $AgNO_3$ (25 ppm) + citric acid (75 ppm) and Sucrose (2 %) + 8- HQC (500 ppm) are recommended best solution for bud opening and increased vase life in chrysanthemum (Gupta *et al.*, 2006).

Nair *et al.* (2003) reported that gerbera flowers took maximum number of days for flower head drooping which was recorded in 20 ppm $AgNO_3$+ 4% sucrose (16.12), followed by 20 ppm $AgNO_3$+ 6% sucrose (14.80). The control (distilled water) recorded the minimum number of days (6.93) for flower head drooping.

2.8 Post harvest malformation

Post harvest malformations such as stem bending, flower drooping and petal necrosis are common disorders in gerbera (Steinitz, 1983).

Drooping of gerbera flowers was due to the water shortage and microorganisms mainly caused vessel blockage. This can be prevented by stopping the growth of microorganisms by adding the preservative and pricking the stalk about 10 cm below the flower, which leads to the escape of air from the cavity (Meeteren, 1977).

Stem break occurs when direct uptake of water is inhibited by bacterial activity than indirect uptake through cavity. This also depends on the season for example in winter this is rarely observed, where as in summer 90 to 100 per cent flower were affected. This could be prevented by pre treating the stalks by sodium hypochlorite or silver nitrate in the vase water (Meeteren, 1978).

Prevention of stem break and increased longevity of cut flowers could be achieved by using a solution containing an anti microbial agent, an acidifying agent and sucrose either applied continuously or as a pulsing treatment (Abdul Khader and Rogers, 1986).

2.9 Vase life

The difference in shelf life and vase life of gerbera flowers of different species is inherently influenced by, and varies among, different cultivars of same species. Hence several workers judgment is given below

The cv. Cream Clementine had the largest vase life (12 days), while the cv. Yellow Clementine had the shortest (9.4 days) vase life (Fischer *et al.,* 1982).

Variation in the morphological characters of gerbera such as flower diameter, stem length and vase life of single (Tuba and Terrafame), semidouble (Rebecca and Pascal) and double (Maria and Merlin) cultivars was observed by Garbaldi and Deambrigo (1989).

Borate (2002) mentioned that out of eight cultivars of gerbera Testarossa produced attractive red colour flowers having long vase life of 10.40 days in distilled water.

Dhane (2003) recorded that variety Thalassa produced flowers with maximum vase life (9.33 days) in plain while Tonneke produced flowers with minimum 6.66 days vase life was at par with variety Yarna (7.00 days).

Parthasarathy and Nagaraju (2003) mentioned the highest longevity of gerbera cultivars (16.60 days) was found during October-November under mid hills of Meghalaya.

Sankari *et al.* (2010) reported that among 30 varieties of gerbera, Rosalin variety recorded maximum duration of flowering (11 days) and vase life (10 days) under Yercaud hills and subtropical regions.

Singh and Sangama (2002) studied the influence of cultivars and flower stalk length on vase life of gerbera and they observed that longer stems had a longer vase life compared with shorter stems. Lyonella recorded the longest vase life (5.06 to 9.13 days), followed by Tiramisu (4.96 to 8.76 days), while Thalassa had the shortest (3.93 to 7.03 days).

MATERIAL AND METHODS

III. MATERIAL AND METHODS

Present investigation was carried out to study the effect of holding solutions on the vase life of gerbera cultivars during the year 2012-13 at the Division of Horticulture, Gandhi Krishi Vignana Kendra, University of Agriculture Sciences, Bengaluru in the laboratory of Regional Horticulture Research and Extension center, University of Horticultural Sciences, Bagalkot, GKVK campus, Bengaluru. Details of the location, the materials used and techniques adopted for the study are presented here under.

3.1 Source of gerbera flowers

The cut gerbera flowers of cultivars 'Salvador' and 'Esmara' used for this study were grown under standard greenhouse conditions were procured from Chowdeshwari Hi-tech poly house, Rajankunte, Bengaluru. The flowers were grown by following recommended production techniques to achieve high quality for export.

3.2 Details of chemicals used

The chemicals used while conducting in this study are as below

a) Aluminum sulphate : $Al_2(SO_4)_3.16H_2O$

b) Sucrose LR (Saccharose) : $C_{12}H_{22}O_{11}$

c) 8-Hydroxy Quinoline Sulphate (8-HQS): $C_9H_7NO.1/2H_2SO_4$

d) Sodium thiosulphate: $Na_2S_2O_3.\ 5H_2O$

e) Silver nitrate : $AgNO_3$

f) Silver thiosulphate: $Ag\ (S_2O_3)_3$- stock solution of $AgNO_3$ (0.1M) and Sodium thiosulphate (0.1 M) were prepared and stored in dark. Silver thiosulphate (STS) was prepared as needed on the day of the experiment by combining calculated volumes of these solutions and distilled water. One molar ratio between Silver and thiosulphate of one to four was satisfactory (Reid *et al,* 1980) and this ratio was used throughout the study for all concentrations of STS prepared. Nearly all of the silver present in such solutions was in the form of Ag $(S_2O_3)_3$ complex.

3.3 Details of the experimental procedure

The gerbera cvs. 'Salvador' and 'Esmara' cut flowers procured for vase life study, were harvested when outer ray florets were completely elongated or when outer two rows of disc florets were perpendicular to the flower stalk. Flowers immediately after harvest they were placed in clean water and brought carefully to the laboratory within 24 hours of harvest without causing any damage. Then they were imposed with set of treatments.

The flowers were sorted out for uniform flower size so as to maintain uniformity within the replication. Stems were then cut to a uniform length of 50 cm, then each flower stalk was placed in 600 ml bottle containing 500 ml of aqueous solutions of different chemical preservatives were used individually or in combination as described separately in each experiment. It is generally preferable to use distilled water or deionized water as standardized water to decreases experimental variability. Each treatment unit consisted of five flowers with each flower representing a replication. Observations recorded in different experiments are as follows:

1. **Water uptake**

The difference between consecutive weights of the bottle with the solution (without flower) represents the water uptake for the period. The Cumulative water uptake was recorded for the entire period of vase life of cut flower.

2. Water loss

The difference between consecutive weights of bottle + solution + flower represents transpiration loss of water in (g) for the known period. Cumulative water loss was recorded for the entire period of vase life of the cut flower.

3. Water balance

The difference between the water uptake and water loss represents the water balance in grams.

4. Fresh weight of the flower

Fresh weight of the flower (in grams) was recorded daily by calculating the difference between weight of the bottle + solution + flower and weight of the bottle + solution.

5. Vase life

Vase life commenced at the onset of placing the flowers in holding solutions up to the date of discard. Vase life (days) was decided depending upon wilting of one or two petals of outer row of ray florets.

6. Bacterial count

Dilution plate count technique was adopted to estimate the bacterial population. When wilting symptoms started, 1ml solution from each replication from each treatment was taken. Afterwards serial dilution was made up to 10^{-5} dilutions among that 5 dilutions 10^{-3}, 10^{-4} and 10^{-5} were selected and plated on nutrient agar. Under each dilution three plates were used and the number of colonies of bacteria was counted after 48 hrs of incubation.

3.4 Experiment-I

Evaluation for the best vase solution using individual chemicals in different concentrations.

The experiment were carried out to study the effect of Aluminium sulphate $Al_2 (SO_4)_3$, silver thiosulphate (STS) and silver nitrate ($AgNO_3$) as vase solution at different concentration on the post harvest life of cut gerbera cvs. 'Salvador' and 'Esmara'. Deionized water was used as control.

Treatments: 13

Replications: 3

Design: Completely Randomized Design (CRD)

Treatment details:

T_1: Aluminium sulphate 75 ppm

T_2: Aluminium sulphate 100 ppm

T_3: Aluminium sulphate 125 ppm

T_4: Aluminium sulphate 150 pp

T_5: Silver nitrate 5 ppm

T_6: Silver nitrate 15 ppm

T_7: Silver nitrate 25 ppm

T_8: Silver nitrate 35 ppm

T_9: Silver thiosulphate 0.2 mM

T_{10}: Silver thiosulphate 0.3 mM

T_{11}: Silver thiosulphate 0.4 mM

T_{12}: Silver thiosulphate 0.5 mM

T_{13}: control

Plate 2: General view of an Experimental lay out cv. 'Salvador'

Plate 2a: General view of an Experimental lay out cv. 'Esmara'

3.5 Experiment-II

Evaluation for the best vase solution obtained by using the best concentration of individual chemicals (obtained from experiment-I) in combination with sucrose.

Except for the treatments, cultivars used, number of replications, design used and other experimental procedure of this experiment was similar to that experiment-I

Treatments: 7

Replications: 3

Design: Completely Randomized Design (CRD)

Treatment details:

T_1: Best concentration of Aluminium sulphate + 2 % Sucrose

T_2: Best concentration of Aluminium sulphate + 4 % Sucrose

T_3: Best concentration of Silver nitrate + 2 % Sucrose

T_4: Best concentration of Silver nitrate + 4 % Sucrose

T_5: Best concentration of Silver thiosulphate + 2 % Sucrose

T_6: Best concentration of Silver thiosulphate + 4 % Sucrose

T_7: control

3.6 Experiment-III

Evaluation for the best vase solution using best concentration of mineral salts and sucrose (obtained from experiment-II) in combination with 8-HQS.

Cultivars used number of replications and design used remained the same as experiment-I.

Treatments: 7

Replications: 3

Design: Completely Randomized Design (CRD)

Treatment details:

T_1: Best concentration of Aluminium sulphate and Sucrose + 100 ppm 8HQS

T_2: Best concentration of Aluminium sulphate and Sucrose + 200 ppm 8HQS

T_3: Best concentration of Silver nitrate and Sucrose + 100 ppm 8HQS

T_4: Best concentration of Silver nitrate and Sucrose + 200 ppm 8HQS

T_5: Best concentration of Silver thiosulphate and Sucrose + 100 ppm 8HQS

T_6: Best concentration of Silver thiosulphate and Sucrose + 200 ppm 8HQS

T_7: control

Plate 3: View of an Experiment III of cv. 'Salvador'

Plate 3a: View of an Experiment III of cv. 'Esmara'

3.7 Statistical analysis

The data obtained from the experiment was subjected to statistical analysis by using completely randomized design (Panse and Sukhatme, 1978). The F test values were tested at five per cent level of significance.

Plate 1: General view of cut flowers collection site

Plate 1a: Gerbera cultivars 'Esmara' and 'Salvador' selected for the study

RESULTS

IV EXPERIMENTAL RESULTS

Results of the present investigation on the effect of different chemicals on vase life of cut flowers of gerbera cultivars 'Salvador' and 'Esmara' are presented in this chapter.

4.1 Experiment I:

Evaluation for the best vase solution using individual mineral salts at different concentrations.

The experiment was out lined to find out the effect of $Al_2 (SO_4)_3$, $AgNO_3$ and STS on the post harvest behavior of cut gerbera and to find out the optimum concentration to extend the longevity of cut flowers.

4.1.1 Water relations

Data with respect to the effect of different mineral salts on the cumulative water uptake, cumulative water loss, water uptake to water loss ratio and water balance of cut gerbera cultivars 'Salvador' and 'Esmara' are presented in Table 1 and 1a respectively.

A) Cumulative water uptake

Cumulative water uptake during 12 days period in cv. 'Salvador' was recorded, except $Al_2 (SO_4)_3$ (125 and 150 ppm) and STS (0.3, 0.4 and 0.5 mM) treatments all other treatments showed higher cumulative water uptake than the control (Table 1). $Al_2 (SO_4)_3$ (100 ppm), $AgNO_3$ (15 ppm) and STS (0.2 mM) recorded maximum cumulative water uptake (58.77, 62.35, 53.60 g/fl, respectively) compared to other concentration and least (49.13, 60.32, 44.44 g/fl) was recorded in 150 ppm $Al_2 (SO_4)_3$, 5 ppm $AgNO_3$, 0.5 mM STS respectively. Among all the treatments the highest of 62.35 g/fl cumulative water uptake was recorded in 15 ppm Silver nitrate and the least of 44.44 g/fl in 0.5 mM STS.

In cv. 'Esmara' the treatments $Al_2(SO_4)_3$, STS and $AgNO_3$ significantly influenced the cumulative water uptake during 12 days period as compared to the control (Table 1a). $Al_2(SO_4)_3$ (100 ppm), STS (0.2 mM) and $AgNO_3$ (15 ppm) recorded the maximum water uptake of (78.93 g/fl, 63.82 and 79.46 g/fl, respectively) and the least (63.46, 73.19 and 55.87 g/fl) was recorded in $Al_2(SO_4)_3$ (150 ppm), $AgNO_3$ (35 ppm) and STS (0.5 mM) as compared other treatments. Among all the treatments, highest 79.46 g/fl cumulative water uptake was recorded in 15 ppm $AgNO_3$ and the least 55.87 g/fl in 0.5mM STS. (Fig.1)

B) Cumulative Water Loss

In case of cv. 'Salvador' all the concentration of $Al_2(SO_4)_3$ and $AgNO_3$ recorded maximum water loss than the control (59.57 g/fl). The treatment with $AgNO_3$ significantly influenced the cumulative water loss as compared to control. The maximum (65.83, 68.55 and 59.00 g/fl) cumulative water loss was recorded in 100 ppm $Al_2(SO_4)_3$, 35 ppm $AgNO_3$ and 0.2 mM STS respectively, as against to other concentrations and the minimum cumulative water loss of (58.21, 66.55 and 53.43 g/fl) were recorded in 150 ppm $Al_2(SO_4)_3$, 25 ppm $AgNO_3$ and 0.5 mM STS respectively. The highest cumulative water loss 68.55 g/fl was recorded in 35 ppm $AgNO_3$ and the least 53.43 g/fl in 0.5 mM STS on par with 0.4 mM STS.

Gerbera cv. 'Esmara' treated with $Al_2(SO_4)_3$, STS and $AgNO_3$ significantly influenced the water loss as compared to control. The flowers treated with 100 ppm $Al_2(SO_4)_3$, 15 ppm $AgNO_3$ and 0.2 mM STS recorded higher cumulative water loss (86.01, 84.20 and 71.36 g/fl, respectively) than other concentrations and the least (75.84, 78.79 and 63.32 g/fl) was recorded in 150 ppm $Al_2(SO_4)_3$, 35 ppm $AgNO_3$ and 0.5 mM STS. The maximum (86.01 g/fl) cumulative water loss was recorded in 100 ppm $Al_2 (SO_4)_3$ and the least (63.32 g/fl) in 0.5 mM STS compared to control. (Fig.1)

C) Water uptake: water loss ratio

In the gerbera cv. 'Salvador' all the treatments of $AgNO_3$ showed positive water uptake to water loss ratio. Higher ratio was obtained with 15 ppm $AgNO_3$ treatment and the least was found in the treatment 0.5 mM STS as against other treatments and control.

In the cv. 'Esmara' all the treatments of $AgNO_3$ showed positive water uptake to water loss ratio as compared to control and higher ratio was obtained with 15 ppm $AgNO_3$, treatment (T_7) and (T_8) were found to be at par with each other and the least was found in the treatment 150 ppm $Al_2 (SO_4)_3$ as compared to other treatments and control.

D) Water balance

It can be observed from Table 1and 1a in both the Gerbera cvs. 'Salvador' and 'Esmara' recorded a negative water balance in all the treatments including control.

4.1.2 Fresh Weight

In cv. 'Salvador' the fresh weight was more in the treatment $Al_2(SO_4)_3$ 100 ppm (99.42 g/fl) on the second day compare to other treatments of $Al_2 (SO_4)_3$ and at 12^{th} day of vase life it was found to be (69.67 g/fl) in the same concentration which is more than the control (Table 2). In 15ppm $AgNO_3$ maximum of (110.36 g/fl) fresh weight was recorded on 3^{rd} day and at the end of 12^{th} day it was found to be (74.00 g/fl) which is greater than the control. (95.93 g/fl) of fresh weight was recorded in 0.2 mM STS on second day and on 12^{th} day (65.13 g/fl) highest fresh weight was recorded. The results (Table 2) indicate that

Table 1: Effect of different mineral salts as vase solution on the water relation of cut gerbera flower cv. 'Salvador' [g/fl].

Treatment	**CWU**	**CWL**	**CWU/CWL**	**Balance**
T_1: 75 ppm Aluminium sulphate	55.40	64.20	0.86	-8.80
T_2: 100 ppm Aluminium sulphate	58.77	65.83	0.89	-7.06
T_3:125 ppm Aluminium sulphate	51.24	59.92	0.86	-8.68
T_4: 150 ppm Aluminium sulphate	49.13	58.21	0.84	-9.08
T_5: 5 ppm Silver nitrate	60.32	66.44	0.91	-6.12
T_6: 15 ppm Silver nitrate	62.35	66.83	0.93	-4.48
T_7: 25 ppm Silver nitrate	61.26	66.55	0.92	-5.29
T_8:35 ppm Silver nitrate	61.42	68.55	0.89	-7.13
T_9: 0.2 mM Silver thiosulphate	53.60	59.00	0.91	-5.40
T_{10}: 0.3 mM Silver thiosulphate	47.74	54.97	0.87	-7.24
T_{11}: 0.4 mM Silver thiosulphate	46.00	53.49	0.86	-7.49
T_{12}: 0.5 mM Silver thiosulphate	44.44	53.43	0.83	-8.99
T_{13}: Control (Distilled water)	52.49	59.57	0.88	-7.08
F test	*	*	*	*
S Em±	0.98	0.62	0.2	0.006
C.D @5%	2.98	1.89	0.57	0.02

CWU: Cumulative water uptake
CWL: Cumulative water Loss

Table 1a: Effect of different mineral salts as vase solution on the water relation of cut gerbera flower cv. 'Esmara'[g/fl].

Treatment	CWU	CWL	CWU/CWL	Balance
T_1: 75 ppm Aluminium sulphate	69.56	80.52	0.86	-10.95
T_2: 100 ppm Aluminium sulphate	78.93	86.01	0.91	-7.08
T_3:125 ppm Aluminium sulphate	66.56	76.07	0.87	-9.51
T_4: 150 ppm Aluminium sulphate	63.46	75.84	0.84	-12.38
T_5: 5 ppm Silver nitrate	78.60	83.47	0.94	-4.87
T_6: 15 ppm Silver nitrate	79.46	84.2	0.94	-4.74
T_7: 25 ppm Silver nitrate	74.59	79.91	0.93	-5.33
T_8:35 ppm Silver nitrate	73.19	78.79	0.93	-5.60
T_9: 0.2 mM Silver thiosulphate	63.82	71.36	0.89	-7.54
$T_{10:}$ 0.3 mM Silver thiosulphate	55.95	64.08	0.87	-8.13
T_{11}: 0.4 mM Silver thiosulphate	56.30	64.38	0.87	-8.08
T_{12}: 0.5 mM Silver thiosulphate	55.87	63.32	0.88	-7.45
T_{13}: Control (Distilled water)	55.96	63.73	0.88	-7.77
F test	*	*	*	*
S Em±	1.4	0.87	0.01	0.37
C.D @5%	4.24	2.64	0.03	1.11

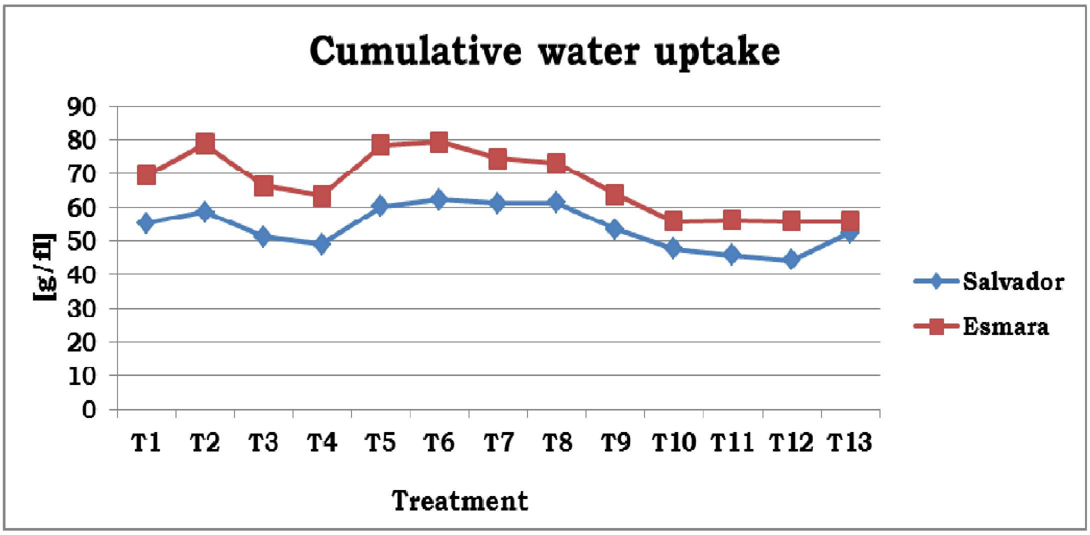
CWU: Cumulative water uptake
CWL: Cumulative water Loss

Table 2: Effect of different concentration of mineral salts on fresh weight of gerbera flower cv. 'Salvador'.

	Fresh weight (g/fl)											
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Day 11**	**Day 12**
T_1:75 ppm Aluminium sulphate	95.62	95.44	95.00	93.40	90.33	87.13	83.00	78.53	74.87	69.60	63.67	60.33
T_2:100 ppm Aluminium sulphate	96.69	99.42	97.33	96.33	93.87	91.60	89.07	85.53	81.80	77.27	74.87	69.67
T_3:125 ppm Aluminium sulphate	91.40	94.89	94.13	92.20	87.93	83.13	78.07	72.47	69.67	64.60	57.00	48.00
T_4:150 ppm Aluminium sulphate	91.80	91.56	88.20	85.87	81.60	77.67	73.67	68.33	64.27	58.80	52.07	46.40
T_5:5 ppm Silver nitrate	101.53	104.20	105.67	104.80	102.20	99.53	95.40	90.87	85.87	79.87	75.20	70.53
T_6:15 ppm Silver nitrate	104.60	108.96	110.36	106.75	103.13	102.13	99.27	95.67	90.67	84.67	78.67	74.00
T_7:25 ppm Silver nitrate	94.51	100.51	102.13	102.93	102.20	101.20	92.00	89.07	84.07	78.07	72.07	68.07
T_8:35 ppm Silver nitrate	90.49	96.58	99.53	100.33	99.40	97.87	94.67	90.80	85.80	79.80	73.47	68.47
T_9:0.2 mM Silver thiosulphate	90.56	95.93	88.47	88.33	86.07	84.27	82.00	79.20	76.27	72.53	69.47	65.13
$T_{10:}$ 0.3 mM Silver thiosulphate	92.31	95.69	91.53	90.67	88.73	86.93	84.67	80.93	77.53	71.60	63.80	56.13
T_{11}:0.4 mM Silver thiosulphate	87.38	87.49	88.00	87.33	84.40	81.67	78.33	74.20	70.00	65.40	58.60	49.93
T_{12}:0.5 mM Silver thiosulphate	90.73	92.20	91.00	90.07	86.87	82.73	77.73	71.53	65.93	60.60	54.13	45.80
T_{13}: Control (Distilled water)	95.38	96.24	94.13	92.13	88.8	85.2	81.07	76.33	72.8	67.27	59.73	51.4
F test	*	*	*	*	*	*	*	*	*	*	*	*
S Em±	2.14	3.37	3.81	3.71	3.61	3.63	4.12	4.27	4.33	4.58	5.24	5.64
C.D @5%	6.22	9.81	11.09	10.78	10.49	10.56	11.99	12.41	12.59	13.32	15.25	16.41

Table 2a: Effect of different concentration of mineral salts on fresh weight of gerbera flower cv. 'Esmara'.

Fresh weight (g/fl)												
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Day 11**	**Day 12**
T_1:75 ppm Aluminium sulphate	103.80	104.89	102.73	98.78	93.20	87.89	81.78	79.22	76.43	71.22	61.67	58.44
T_2:100 ppm Aluminium sulphate	109.58	108.11	105.02	101.38	95.87	91.56	87.51	82.38	76.96	71.58	67.73	63.89
T_3:125 ppm Aluminium sulphate	107.89	109.67	106.62	102.13	96.00	87.78	85.22	80.44	77.00	71.89	66.11	58.33
T_4:150 ppm Aluminium sulphate	113.18	114.84	109.67	103.04	95.27	86.18	81.29	77.84	73.84	65.07	57.62	51.29
T_5:5 ppm Silver nitrate	101.78	108.76	109.84	110.33	105.87	99.91	94.88	87.92	83.24	78.76	70.98	68.09
T_6:15 ppm Silver nitrate	109.07	105.36	107.42	108.67	107.60	103.27	98.38	93.16	88.38	82.49	80.49	78.71
T_7:25 ppm Silver nitrate	108.29	114.78	117.53	118.53	118.93	110.89	101.21	95.21	91.05	88.01	83.22	76.67
T_8:35 ppm Silver nitrate	97.51	103.76	105.56	106.47	105.06	102.23	100.03	98.09	93.09	86.61	77.98	69.53
T_9:0.2 mM Silver thiosulphate	104.24	110.78	108.02	106.69	101.4	100.13	94.96	89.73	83.33	77.87	71.47	63.87
$T_{10:}$0.3 mM Silver thiosulphate	101.60	106.78	103.51	102.29	97.60	95.73	90.13	85.33	79.23	74.78	68.65	60.96
T_{11}:0.4 mM Silver thiosulphate	97.98	102.09	99.64	96.47	94.27	92.16	88.33	83.87	78.38	72.00	64.78	59.13
T_{12}:0.5 mM Silver thiosulphate	95.80	102.67	100.84	99.24	96.60	94.09	90.93	85.38	80.30	71.58	62.02	58.58
T_{13}:Control (Distilled water)	109.73	110.42	107.09	100.56	92.20	82.89	78.93	75.38	70.16	64.82	59.75	54.96
F test	*	*	*	*	*	*	*	*	*	*	*	*
S Em±	2.14	3.37	3.81	3.71	3.61	3.63	4.12	4.27	4.33	4.58	5.24	5.64
C.D @5%	6.22	9.81	11.09	10.78	10.49	10.56	11.99	12.41	12.59	13.32	15.25	16.41



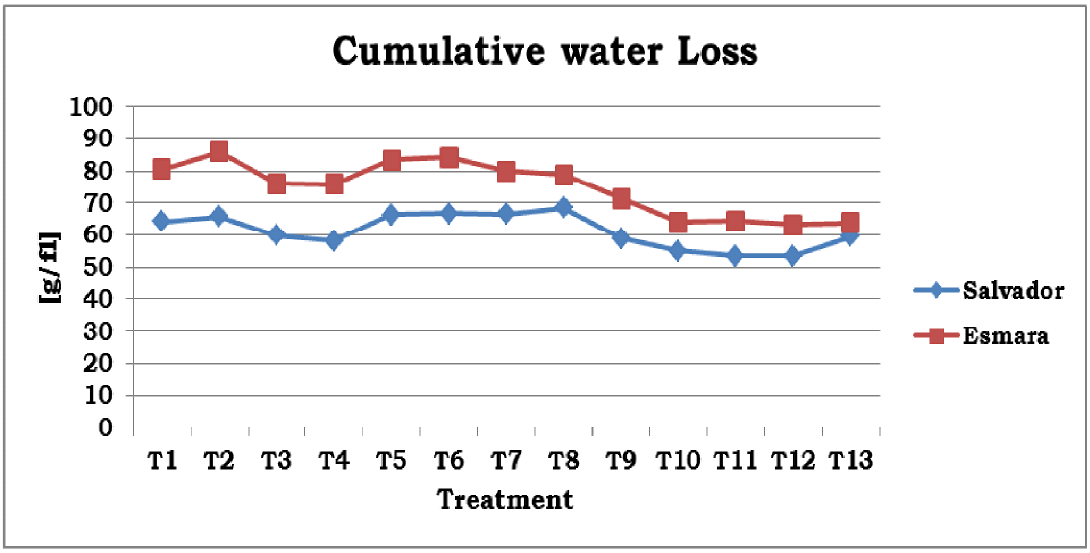


Fig. 1: Effect of different mineral salts on water uptake and water loss of cut gerbera flower cvs. 'Salvador' and 'Esmara'.

T_1: Aluminium sulphate 75 ppm

T_2: Aluminium sulphate 100 ppm

T_3: Aluminium sulphate 125 ppm

T_4: Aluminium sulphate 150 ppm

T_5: Silver nitrate 5 ppm

T_6: Silver nitrate 15 ppm

T_7: Silver nitrate 25 ppm

T_8: Silver nitrate 35 ppm

T_9: Silver thiosulphate 0.2 mM

T_{10}: Silver thiosulphate 0.3 mM

T_{11}: Silver thiosulphate 0.4 mM

T_{12}: Silver thiosulphate 0.5 mM

T_{13}: control (Distilled water)

the flowers held in 15 ppm $AgNO_3$ showed maximum fresh weight of (74.00 g/fl) when compared to control (51.4 g/fl) and the least (45.80 g/fl) of fresh weight was recorded in 0.5 mM STS at the end of the vase life period.

In case of cv. 'Esmara' on 12th day, all the treatments recorded higher fresh weight than the control except in 150 ppm Al_2 $(SO_4)_3$ (Table 2a). In the treatment Al2 $(SO_4)_3$ 100 ppm and $AgNO_3$ 15 ppm initial fresh weight was on par with control. Al_2 $(SO_4)_3$ 100 ppm (63.89 g/fl), $AgNO_3$ 15 ppm (78.71 g/fl) and 0.2 mM STS (63.87 g/fl) of fresh weight was recorded on 12th day which is found to be maximum when compared to control (54.96 g/fl). Among all the treatments (78.71 g/fl) of higher fresh weight was recorded in $AgNO_3$ 15 ppm and the least (51.29 g/fl) recorded in 150 ppm Al_2 $(SO_4)_3$ on 12th day.

4.1.3 Vase life

The data pertaining to the vase life of cut gerbera cvs. 'Salvador' and 'Esmara' as affected by different chemicals is recorded in Table 3 and Fig.2. The vase life of 'Salvador' was significantly influenced by the holding solutions having 100 ppm Al_2 $(SO_4)_3$, 15 ppm $AgNO_3$ and 0.2 mM STS as compared to control. Among the individual, vase solutions with 100 ppm Al_2 $(SO_4)_3$, 15 ppm $AgNO_3$ and 0.2 mM STS recorded longer (12.11, 13.00 and 12.11 days, respectively) vase life than the other concentrations. Among all the treatments the highest vase life of 13.00 days was recorded in 15 ppm silver nitrate and the least (9.67 days) was found in control.

In cv. 'Esmara' the vase life was influenced by the holding solution 100 ppm Al_2 $(SO_4)_3$, 15 ppm $AgNO_3$ and 0.2 mM STS recorded longer vase life (12.00, 12.33 and 12.00 days respectively) than other treatments and compared to control. Among all the treatments 15 ppm $AgNO_3$ recorded highest vase life (12.33 days) and the least (9.33 days) in control.

Table 3: Effect of different concentration of mineral salts as vase solution on the vase life [days] of gerbera flower cv. 'Salvador' and 'Esmara'.

Vase life [days]		
Treatment	**cv. Salvador**	**cv. Esmara**
T_1: 75 ppm Aluminium sulphate	10.78	10.00
T_2: 100ppm Aluminium sulphate	12.11	12.00
T_3:125ppm Aluminium sulphate	9.78	10.67
T_4: 150ppm Aluminium sulphate	11.22	10.33
T_5: 5ppm Silver nitrate	12.22	11.00
T_6:15ppm Silver nitrate	13.00	12.33
T_7: 25ppm Silver nitrate	10.67	11.00
T_8:35ppm Silver nitrate	11.22	10.00
T_9: 0.2 mM Silver thiosulphate	12.11	12.00
$T_{10:}$ 0.3 mM Silver thiosulphate	11.00	11.00
T_{11}: 0.4 mM Silver thiosulphate	10.33	10.00
T_{12}: 0.5 mM Silver thiosulphate	10.44	9.00
T_{13}: Control (Distilled water)	9.67	9.33
F test	*	*
S Em±	0.41	0.49
C.D @5%	1.18	1.42

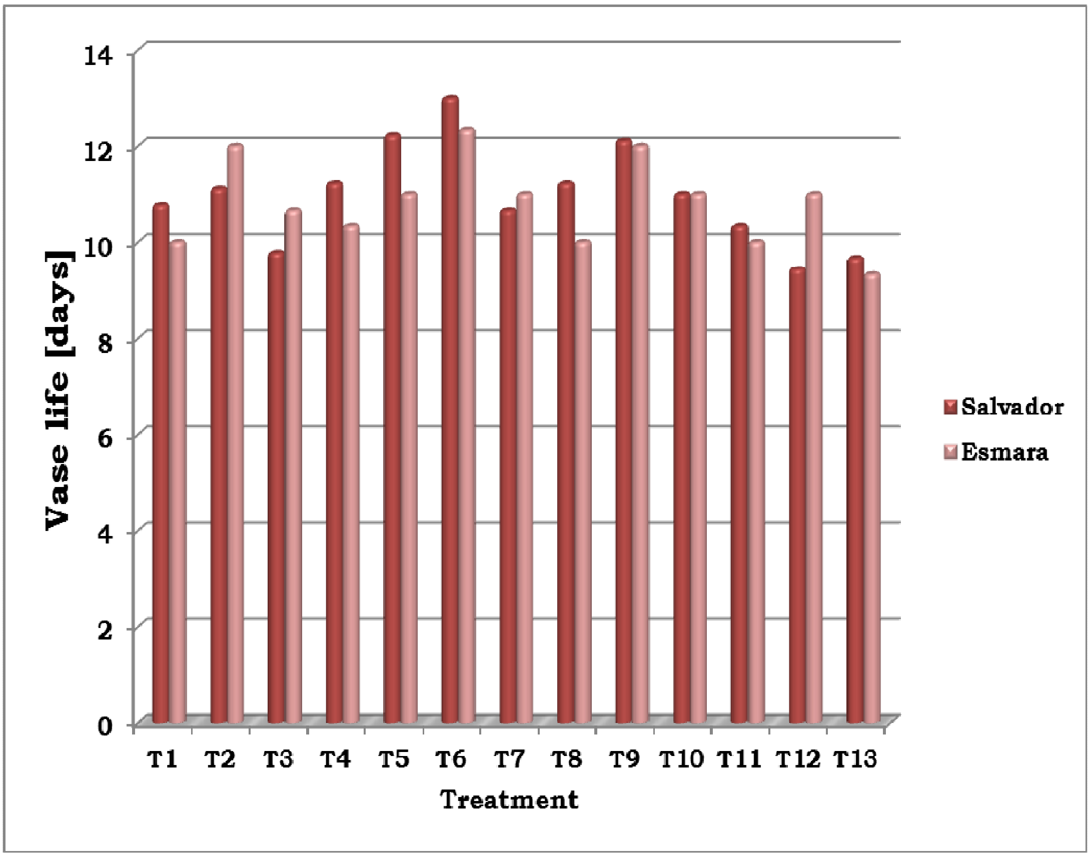


Fig. 2: Effect of different concentration of mineral salts as vase solution on the vase life [days] of gerbera flower cv. 'Salvador' and 'Esmara'.

T_1: Aluminium sulphate 75 ppm

T_2: Aluminium sulphate 100 ppm

T_3: Aluminium sulphate 125 ppm

T_4: Aluminium sulphate 150 ppm

T_5: Silver nitrate 5 ppm

T_6: Silver nitrate 15 ppm

T_7: Silver nitrate 25 ppm

T_8: Silver nitrate 35 ppm

T_9: Silver thiosulphate 0.2 mM

T_{10}: Silver thiosulphate 0.3 mM

T_{11}: Silver thiosulphate 0.4 mM

T_{12}: Silver thiosulphate 0.5 mM

T_{13}: Control (Distilled water)

4.2 Experiment II:

Evaluation for the best vase solution obtained by using the different concentration of individual mineral salts (obtained from experiment-I) in combination with sucrose.

4.2.1 Water relations

The data obtained for different mineral salts in combination with sucrose on the cumulative water uptake, cumulative water loss, water uptake to water loss ratio and water balance of cut gerbera cultivars 'Salvador' and 'Esmara' are presented in Table 4 and 4a, respectively.

A) Cumulative water uptake

Cumulative water uptake during 10 days of vase life differed significantly in the cultivars, 'Salvador' and 'Esmara'. Both the cultivars treated with $Al_2(SO_4)_3$, $AgNO_3$ and STS in combination with sucrose recorded higher cumulative water uptake than the control. Highly significant influence on the cumulative water uptake was recorded in flowers treated with $AgNO_3$ and sucrose combinations. In cv. 'Salvador' $Al_2(SO_4)_3$ (100 ppm), $AgNO_3$ (15 ppm) and STS (0.2 mM) recorded higher cumulative water uptake (51.20, 71.25 and 57.84 g/fl, respectively) in combination with four per cent sucrose. Among all the treatments imposed the maximum cumulative water uptake (71.25 g/fl) was recorded in 15 ppm $AgNO_3$ with four per cent sucrose and the least of (50.92 g/fl) in 100 ppm $Al_2(SO_4)_3$ with 2 % sucrose (Table 4 and Fig.3)

In cv.'Esmara' (Table 4a) the cumulative water uptake was significantly influenced by holding solutions containing 15 ppm $AgNO_3$ with two and four per cent sucrose (84.20 and 86.69 g/fl, respectively) and 100 ppm $Al_2(SO_4)_3$ with two per cent sucrose (73.49 g/fl) and

0.2mM STS with four per cent sucrose (69.98 g/fl) compared to control (68.93 g/fl). Among all the treatment imposed the maximum cumulative water uptake (86.69 g/fl) was recorded in the flower treated with 15 ppm $AgNO_3$ plus four per cent sucrose and (68.71 g/fl) in 100 ppm Al_2 $(SO_4)_3$ with four per cent sucrose was on par with control.

B) Cumulative Water Loss

In case of cv. 'Salvador' the water loss was significantly influenced by sucrose two and four per cent against control. Both the concentration of $AgNO_3$ with two and four per cent sucrose (69.87 and 73.25 g/fl, respectively) recorded maximum water loss than the control. 15 ppm $AgNO_3$ four per cent sucrose (73.25 g/fl), 100 ppm Al_2 $(SO_4)_3$ with two per cent sucrose (57.49 g/fl) and 0.2mM STS with four per cent sucrose (61.31 g/fl) showed maximum water loss compared to control (53.65 g/fl). However, flowers treated with 15 ppm $AgNO_3$ with four per cent sucrose recorded highest water loss of (73.25 g/fl) and the least cumulative water loss of (57.04 g/fl) was observed in 100 ppm Al_2 $(SO_4)_3$ plus four per cent sucrose which was on par with two percent sucrose (Table 4).

Gerbera cv. 'Esmara' all the treatments with two and four per cent sucrose of Al_2 $(SO_4)_3$, STS and $AgNO_3$ positively influenced the cumulative water loss as compared to control. Both the treatments of $AgNO_3$ with two and four per cent sucrose (89.12 and 89.65 g/fl) were on par with each other. Among all the treatments imposed the highest cumulative water loss (89.65 g/fl) was recorded in 15 ppm $AgNO_3$ plus four per cent sucrose and the least (76.17 g/fl) in 0.2 mM STS plus four per cent sucrose on par with 100 ppm Al_2 $(SO_4)_3$ with four percent sucrose and control (Table 4a).

Table 4: Effect of different mineral salts in combination with sucrose on water relation of cut gerbera flower cv. 'Salvador'[g/fl].

Treatment	CWU	CWL	CWU/ CWL	Balance
T_1: 100ppm Aluminum sulphate +2% sucrose	50.92	57.49	0.89	-6.57
T_2: 100ppm Aluminum sulphate +4% sucrose	51.20	57.04	0.90	-5.84
T_3:15ppm Silver nitrate +2% sucrose	68.23	69.87	0.97	-2.00
T_4:15ppm Silver nitrate +4% sucrose	71.25	73.25	0.98	-1.64
T_5:0.2mM Silver thiosulphate +2% sucrose	56.31	60.39	0.93	-4.08
T_6:0.2mM Silver thiosulphate +4% sucrose	57.84	61.31	0.94	-3.47
T_7: Control (Distilled water)	47.55	53.65	0.89	-6.11
F test	*	*	*	*
S Em±	0.93	1.01	0.01	0.47
C.D @5%	2.83	3.03	0.03	1.46

CWU: Cumulative water uptake
CWL: Cumulative water Loss

Table 4a: Effect of different mineral salts in combination with sucrose on water relation of cut gerbera flower cv. 'Esmara'[g/fl].

Treatment	CWU	CWL	CWU/ CWL	Balance
T_1: 100ppm Aluminum sulphate +2% sucrose	73.49	80.12	0.92	-6.63
T_2: 100ppm Aluminum sulphate +4% sucrose	68.71	76.81	0.89	-8.11
T_3:15ppm Silver nitrate +2% sucrose	84.20	89.12	0.94	-4.92
T_4:15ppm Silver nitrate +4% sucrose	86.69	89.65	0.97	-2.96
T_5:0.2mM Silver thiosulphate +2% sucrose	71.99	77.55	0.90	-7.56
T_6:0.2mM Silver thiosulphate +4% sucrose	69.98	76.17	0.92	-6.19
T_7: Control (Distilled water)	68.93	76.39	0.90	-7.48
F test	*	*	*	*
S Em±	1.00	1.49	0.006	0.65
C.D @5%	3.12	4.58	0.02	2.03

CWU: Cumulative water uptake
CWL: Cumulative water Loss

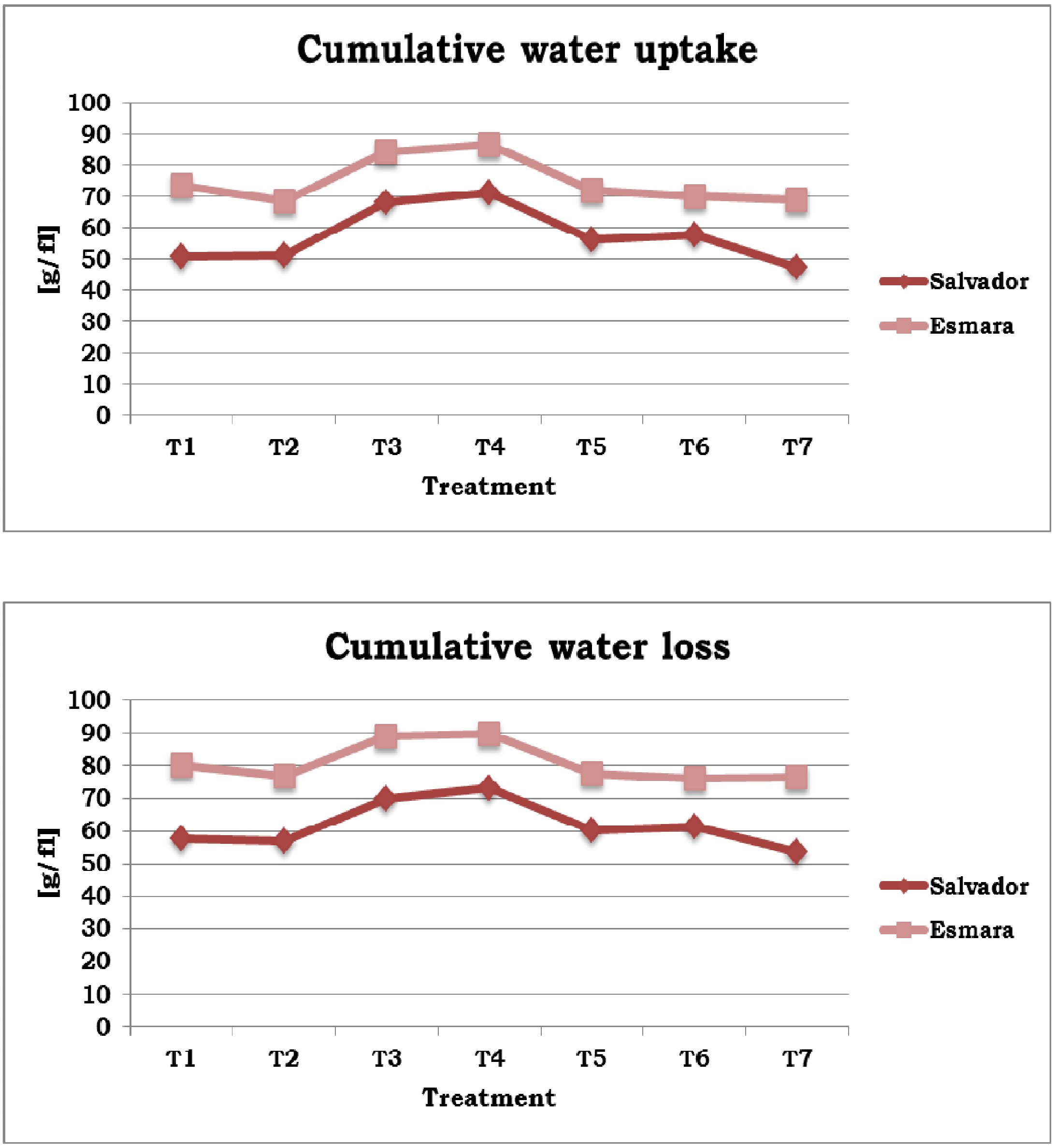


Fig. 3: Effect of best concentration of mineral salts in combination with sucrose on water uptake and water loss of cut gerbera flower cvs. 'Salvador' and 'Esmara'

$\mathbf{T_1}$: 100 ppm Aluminium sulphate +2% Sucrose

$\mathbf{T_2}$: 100 ppm Aluminium sulphate +4% Sucrose

$\mathbf{T_3}$: 15 ppm Silver nitrate+2% Sucrose

$\mathbf{T_4}$: 15 ppm Silver nitrate+4% Sucrose

$\mathbf{T_5}$: 0.2 mM Silver thiosulphate+2% Sucrose

$\mathbf{T_6}$: 0.2 mM Silver thiosulphate+4% Sucrose

$\mathbf{T_7}$: control (Distilled water)

C) Water uptake: water loss ratio

In the gerbera cv. 'Salvador' all the treatments of $AgNO_3$, $Al_2(SO_4)_3$ and STS with two and four per cent sucrose showed positive water uptake to water loss ratio as compared to control. Higher ratio was obtained with 15 ppm $AgNO_3$ with four per cent sucrose treatment and the least was found in the treatment 100 ppm $Al_2(SO_4)_3$ with two per cent sucrose at par with control.

In the cv. 'Esmara' all the treatments with two and four per cent sucrose, except 100 ppm $Al_2(SO_4)_3$ with four per cent sucrose showed positive water uptake to water loss ratio as compared to control and higher ratio was obtained with 15 ppm $AgNO_3$ with four per cent sucrose treatment and the least was found in the treatment 100 ppm $Al_2(SO_4)_3$ plus four per cent sucrose as compared to other treatments and control. Whereas, 100 ppm $Al_2(SO_4)_3$ plus two per cent sucrose and 0.2 mM STS with 4 % sucrose at par with each other and 0.2 mM STS with 2 % sucrose at par with control.

D) Water balance

It can be observed from Table 4 and 4a in both the Gerbera cvs. 'Salvador' and 'Esmara' recorded a negative water balance in all the treatments with two and four per cent sucrose including control.

4.2.2 Fresh Weight

In both the cvs. 'Salvador' and 'Esmara' all the mineral salts in combination with sucrose were significantly effective in maintaining the fresh weight (Table 5 and 5a, respectively). In cv. 'Salvador' except 100 ppm $Al_2(SO_4)_3$ plus two per cent sucrose all the treatments showed higher fresh weight on 10^{th} day compare to control. In 100 ppm $Al_2(SO_4)_3$ plus four per cent sucrose higher fresh weight (92.2 g/fl and 91.07 g/fl) was recorded on 2nd and 3rd day respectively and on 10th day it was found to be (57.27 g/fl). In 15 ppm $AgNO_3$ plus two percent sucrose on par with four per cent sucrose from day 2 to day 4 and on 10th day (79.40 g/fl) was recorded which is maximum compared to control. 0.2 mM STS plus four per cent also recorded maximum fresh weight of (66.67 g/fl) than the control (54.8 g/fl). Among all the treatments 15 ppm $AgNO_3$ with four percent sucrose recorded maximum (79.4 g/fl) fresh weight and the least (52.33 g/fl) was found in 100ppm Al_2 $(SO_4)_3$ with two percent sucrose on the 10th day.

In cv. 'Esmara' all the treatments in combination with two and four percent sucrose showed higher fresh weight from day 1 to day 10 compared to control. In 100ppm Al_2 $(SO_4)_3$ with two per cent sucrose fresh weight (80.4 g/fl) was more than the control on10th day. In 15ppm $AgNO_3$ plus four percent sucrose recorded maximum fresh weight (125.2 g/fl) on the 3rd day which was found to be maximum among all the treatments and on the 10th day it was (96.2 g/fl). 0.2 mM STS plus four per cent sucrose also recorded maximum fresh weight of (76.03 g/fl) than the control (65.47 g/fl). Among all the treatments 15 ppm $AgNO_3$ with four per cent sucrose recorded maximum (96.2 g/fl) fresh weight and the least (68.33 g/fl) was found in 100ppm Al_2 $(SO_4)_3$ with four per cent sucrose on the 10th day.

The four per cent sucrose combination with mineral salts was proved superior over two per cent sucrose combination in cv. 'Salvador' but in cv. 'Esmara' Al_2 $(SO_4)_3$ has performed better in two per cent sucrose.

Table 5: Effect of best concentration of mineral salts with sucrose on fresh weight of gerbera flower cv. 'Salvador'

Fresh weight (g/fl)										
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**
T_1: 100ppm Aluminum sulphate +2% sucrose	85.20	89.07	86.00	81.80	74.93	69.80	64.80	62.33	59.00	52.33
T_2: 100ppm Aluminum sulphate +4% sucrose	86.47	92.20	91.07	88.93	81.40	75.93	70.53	66.93	60.93	57.27
T_3:15ppm Silver nitrate +2% sucrose	88.47	95.93	97.93	98.00	95.93	90.23	85.77	81.87	80.60	78.47
T_4:15ppm Silver nitrate +4% sucrose	87.60	95.93	97.60	98.20	96.93	94.80	88.47	88.20	85.33	79.40
T_5:0.2mM Silver thiosulphate +2% sucrose	83.07	91.27	90.00	91.47	89.80	85.27	80.77	76.20	71.73	65.73
T_6:0.2mM Silver thiosulphate +4% sucrose	87.07	87.53	91.53	93.4	88.2	83.8	80.17	76.68	72.32	66.67
T_7: Control (Distilled water)	85.33	90.60	86.47	83.20	78.93	74.13	69.80	65.80	61.13	54.80
F test	*	*	*	*	*	*	*	*	*	*
S Em±	2.43	2.55	2.69	2.92	2.96	3.27	3.60	3.37	3.22	3.32
C.D @5%	7.35	7.41	7.82	8.48	8.59	9.50	10.46	9.80	9.36	9.65

Table 5a: Effect of best concentration of mineral salts with sucrose on fresh weight of gerbera flower cv. 'Esmara'

Fresh weight (g/fl)										
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**
T_1: 100ppm Aluminum sulphate +2% sucrose	103.30	110.53	107.40	103.00	99.40	101.60	100.20	94.23	89.70	80.40
T_2: 100ppm Aluminum sulphate +4% sucrose	108.87	116.20	112.73	104.73	97.93	89.07	81.93	77.33	74.33	68.33
T_3:15ppm Silver nitrate +2% sucrose	103.00	110.73	112.53	109.13	103.00	97.60	94.00	89.13	83.53	78.40
T_4:15ppm Silver nitrate +4% sucrose	111.00	121.53	125.20	121.87	120.80	116.40	109.13	101.60	99.67	96.20
T_5:0.2mM Silver thiosulphate +2% sucrose	114.33	119.27	119.73	116.27	108.27	100.60	95.73	90.20	83.20	76.53
T_6:0.2mM Silver thiosulphate +4% sucrose	107.00	117.20	117.47	114.53	107.87	101.60	98.53	91.03	84.03	76.03
T_7: Control (Distilled water)	98.6	104.93	100.53	94.73	87.73	79.93	77.87	74.13	71.13	65.47
F test	*	*	*	*	*	*	*	*	*	*
S Em±	3.49	3.08	3.09	2.85	3.42	2.97	3.27	3.36	3.91	4.49
C.D @5%	10.15	8.96	8.98	8.28	9.95	8.64	9.50	9.76	11.37	13.06

4.2.3 Vase life

The data pertaining to the effect of different mineral salts in combination with sucrose on the vase life of cut gerbera cvs. 'Salvador' and 'Esmara' is presented in Table 6 and Fig.4.

In cv. 'Salvador' all the treatments in combination with two and four per cent sucrose showed significant increase in the vase life, among them 100 ppm $Al_2 (SO_4)_3$ plus four per cent sucrose showed (12.33 days) of vase life, (14.33 days) in 15 ppm $AgNO_3$ plus four per cent sucrose and (11.00 days) of vase life in 0.2 mM STS with four per cent sucrose when compared to other treatments and control. The maximum vase life (14.33 days) was found in 15ppm $AgNO_3$ with four per cent sucrose and the least (8.33 days) was found in control.

In cv. 'Esmara' all the treatments in combination with sucrose showed significant increase in the vase life compared to control whereas, longer vase life (13.00 days) was observed in 100 ppm $Al_2 (SO_4)_3$ with two per cent sucrose and the minimum vase life of (8.00 days) was registered in control.

Table 6: Effect of best concentration of mineral salts with sucrose on the vase life [days] of gerbera flower cv. 'Salvador' and 'Esmara

Vase life [days]		
Treatment	**cv. Salvador**	**cv. Esmara**
T_1: 100ppm Aluminum sulphate +2% sucrose	10.33	13.00
T_2: 100ppm Aluminum sulphate +4% sucrose	12.33	11.00
T_3: 15ppm Silver nitrate +2% sucrose	11.67	11.67
T_4: 15ppm Silver nitrate +4% sucrose	14.33	13.00
T_5: 0.2mM Silver thiosulphate +2% sucrose	10.33	11.00
T_6: 0.2mM Silver thiosulphate +4% sucrose	11.00	12.33
T_7: Control (Distilled water)	8.33	8.00
F test	*	*
S Em±	0.28	0.41
C.D @5%	0.81	1.20

Plate 4: Effect of 15 ppm $AgNO_3$ plus 4% sucrose in vase solution on quality of cut Gerbera after 12 days in both the cultivars

Plate 4a: Effect of 100 ppm $Al_2(SO_4)_3$ plus 2 percent sucrose in vase solution on quality of cut Gerbera after 12 days in Salvador compared to control.

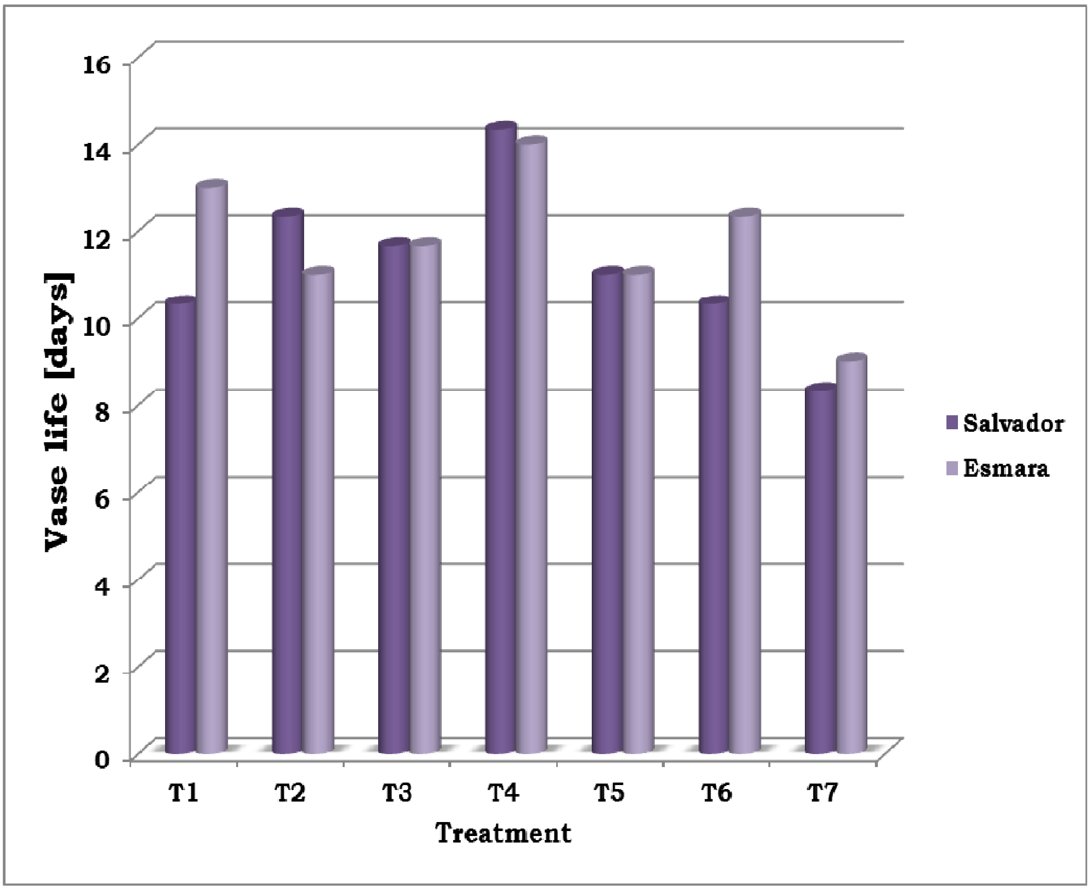


Fig. 4: Effect of best concentration of mineral salts with sucrose on the vase life [days] of gerbera flower cvs. 'Salvador' and 'Esmara'.

T_1: 100 ppm Aluminium sulphate +2% Sucrose

T_2: 100 ppm Aluminium sulphate +4% Sucrose

T_3: 15 ppm Silver nitrate+2% Sucrose

T_4: 15 ppm Silver nitrate+4% Sucrose

T_5: 0.2 mM Silver thiosulphate+2% Sucrose

T_6: 0.2 mM Silver thiosulphate+4% Sucrose

T_7: control (Distilled water)

4.3 Experiment III:

Evaluation for the best vase solution using best concentration of mineral salts and sucrose in combination with 8-HQS.

4.3.1 Water relations

The data obtained for different mineral salts in combination of sucrose with 8-HQS as vase solution on the cumulative water uptake, cumulative water loss, water uptake to water loss ratio and water balance of cut gerbera cultivars 'Salvador' and 'Esmara' are presented in Table 7 and 7a respectively.

A) Cumulative water uptake

In cv.'Salvador' all the treatment combinations showed higher cumulative water uptake till 9 days in holding solutions (Table 7 and Fig.5). Flowers treated with 100 ppm $Al_2(SO_4)_3$ and four per cent sucrose in combination with 200 ppm 8-HQS, 15 ppm $AgNO_3$ and four per cent sucrose in combination with 200 ppm 8-HQS and 0.2 mM STS and four per cent sucrose in combination with 200ppm 8-HQS recorded higher cumulative water uptake (58.15, 55.27 and 58.88 g/fl, respectively) than the control. (T2) and (T5) at par with each other and both are on par with (T6).The highest water uptake (58.88 g/fl) was recorded in 0.2 mM STS + four per cent sucrose + 200 ppm 8-HQS and the least (54.67 g/fl) in 15 ppm $AgNO_3$ + four per cent sucrose+ 100ppm 8-HQS.

In cv.'Esmara'. all the treatment combinations showed higher Cumulative water uptake than the control (57.51 g/fl) .The highest water uptake (80.69 g/fl) was recorded in 100ppm $Al_2(SO_4)_3$ plus two per cent sucrose in combination with 200ppm 8-HQS (Table 7a) and the least (58.37 g/fl) in 0.2mM STS and four per cent sucrose in combination with 100 ppm 8-HQS.

B) Cumulative Water Loss

In case of cv. 'Salvador' the treatments significantly influenced the water loss as compared to control. The flowers treated with 0.2 mM STS + four per cent sucrose + 100 ppm 8-HQS recorded maximum cumulative water loss (63.32 g/fl) and the minimum (57.87 g/fl)15 ppm $AgNO_3$ and four per cent sucrose in combination with 100 ppm 8-HQS.

In cv. 'Esmara' all the treatments showed higher cumulative water loss than the control. Among the treatments maximum cumulative water loss (89.20 g/fl) found in 100 ppm $Al_2 (SO_4)_3$ and two per cent sucrose in combination with 100 ppm 8-HQS and the least was observed in (61.79 g/fl) 0.2mM STS and four per cent sucrose in combination with 100 ppm 8-HQS.(Fig.5)

C) Water uptake: water loss ratio

In the gerbera cv. 'Salvador' all the treatments of $AgNO_3$, $Al_2 (SO_4)_3$ and STS with four per cent sucrose in combination with 8-HQS showed higher water uptake to water loss ratio as compared to control. Higher ratio was obtained with 100 ppm $Al_2 (SO_4)_3$ + four per cent sucrose + 200 ppm 8-HQS and the least was observed in 0.2mM STS + four per cent sucrose + 200 ppm 8-HQS.

In the cv. 'Esmara' all the treatments with $AgNO_3$, $Al_2 (SO_4)_3$ and STS with four and two per cent sucrose in combination with 8-HQS showed higher water uptake to water loss ratio as compared to control except (T1). Higher ratio was obtained in the treatment 15 ppm $AgNO_3$ plus four percent sucrose plus 200 ppm 8-HQS.

Table 7: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS as vase solution on water relation of cut gerbera flower cv. 'Salvador' [g/fl]

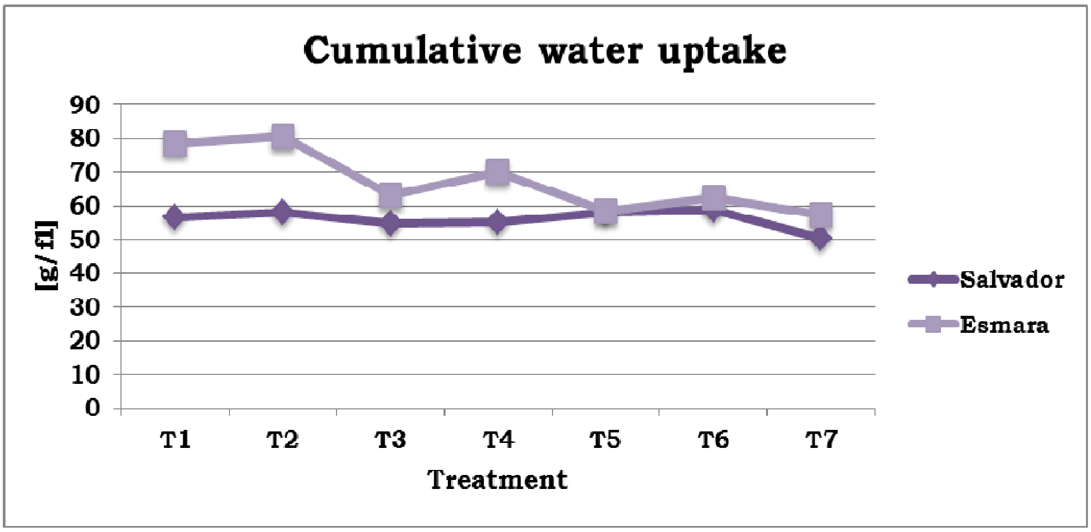
Treatment	CWU	CWL	CWU/CWL	Balance
T_1: 100ppm Aluminum sulphate +4% sucrose +100ppm 8-HQS	56.48	59.83	0.94	-3.35
T_2: 100ppm Aluminum sulphate +4% sucrose +200ppm 8-HQS	58.15	60.72	0.96	-2.57
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	54.67	57.87	0.94	-3.20
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	55.27	57.32	0.96	-2.05
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	58.15	62.37	0.93	-4.22
T_6:0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	58.88	63.32	0.92	-4.44
T_7: Control (Distilled water)	50.51	57.03	0.89	-6.52
F test	*	*	*	*
S Em±	0.61	0.76	0.006	0.3
C.D @5%	1.86	2.33	0.02	0.94

CWU: Cumulative water uptake
CWL: Cumulative water Loss

Table 7a: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS as vase solution on water relation of cut gerbera flower cv. 'Esmara' [g/fl]

Treatment	CWU	CWL	CWU/CWL	Balance
T_1: 100ppm Aluminum sulphate +2% sucrose +100ppm 8-HQS	78.36	89.20	0.88	-10.84
T_2: 100ppm Aluminum sulphate +2% sucrose +200ppm 8-HQS	80.69	83.41	0.96	-2.72
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	63.28	66.56	0.95	-3.28
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	70.12	71.43	0.98	-1.31
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	58.37	61.79	0.94	-3.41
T_6: 0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	62.33	64.95	0.95	-2.62
T_7: Control (Distilled water)	57.51	61.76	0.93	-4.25
F test	*	*	*	*
S Em±	0.7	1.18	0.01	0.61
C.D @5%	2.12	3.56	0.04	1.84

CWU: Cumulative water uptake
CWL: Cumulative water Loss



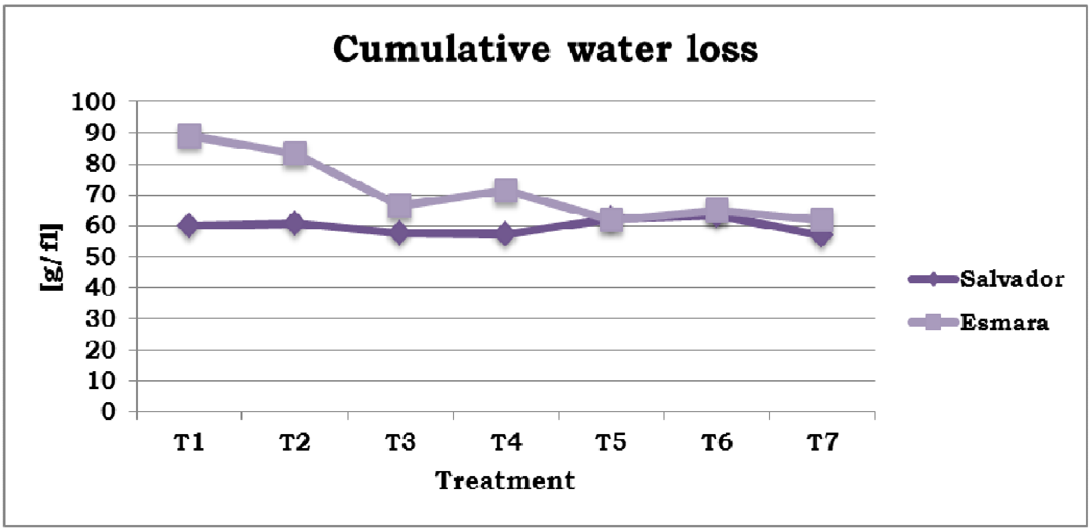


Fig. 5: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS on water uptake and water loss of cut gerbera flower cvs 'Salvador' and 'Esmara'.

T_1: 100 ppm Aluminium sulphate +4% Sucrose+100 ppm 8-HQS

T_2: 100 ppm Aluminium sulphate +4% Sucrose+200 ppm 8-HQS

T_3: 15 ppm Silver nitrate+4% Sucrose+100 ppm 8-HQS

T_4: 15 ppm Silver nitrate+4% Sucrose+200 ppm 8-HQS

T_5: 0.2 mM Silver thiosulphate+4% Sucrose+100 ppm 8-HQS

T_6: 0.2 mM Silver thiosulphate+4% Sucrose+200 ppm 8-HQS

T_7: control (Distilled water)

D) Water balance

It can be observed from table 7 and 7a in both the Gerbera cvs. 'Salvador' and 'Esmara' recorded a negative water balance in all the treatments with two and four per cent sucrose in combination with 8-HQS including control.

4.3.2 Fresh Weight

In both the cvs. 'Salvador' and 'Esmara' all the mineral salts in combination with sucrose were significantly effective in maintaining the fresh weight (Table 8 and 8a, respectively).In cv. 'Salvador' all the treatments recorded higher fresh weight till 9th day when compared to control. On day 9 (73.27 g/fl) fresh weight was recorded in 100 ppm $Al_2 (SO_4)_3$ + four per cent sucrose + 200 ppm 8-HQS, (71.4 g/fl) in 15 ppm $AgNO_3$ plus four percent sucrose plus 200 ppm 8-HQS and (70.3 g/fl) in 0.2 mM STS + four per cent sucrose + 200 ppm 8-HQS among all the treatment combination 100 ppm $Al_2 (SO_4)_3$ + four per cent sucrose + 200 ppm 8-HQS is found to be best which recorded higher fresh weight (73.27g/fl) and the least (59.67 g/fl) was found in 0.2 mM STS and four per cent sucrose in combination with 100 ppm 8-HQS.

In cv. 'Esmara' all the treatment combination recorded higher fresh weight compared to control among them 100 ppm $Al_2 (SO_4)_3$ + two per cent sucrose + 200 ppm 8-HQS showed higher fresh weight (84.07 g/fl) and the lower fresh weight (42.07 g/fl) was recorded in 100 ppm $Al_2 (SO_4)_3$ + two per cent sucrose + 100 ppm 8-HQS. It was found that (T5) on par with (T6).

The 200 ppm 8-HQS with four percent sucrose in combination with mineral salts was proved superior over 100 ppm 8-HQS in both the cultivars 'Salvador' and 'Esmara'.

Table 8: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS on fresh weight of gerbera flower cv. 'Salvador'.

Fresh weight [g/fl]									
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**
T_1: 100ppm Aluminum sulphate +4% sucrose +100ppm 8-HQS	79.07	82.2	79.67	78.67	77.33	77.00	72.00	72.67	67.33
T_2: 100ppm Aluminum sulphate +4% sucrose +200ppm 8-HQS	84.67	86.27	83.6	82.6	82.93	80.6	82.93	83.27	73.27
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	79.73	83.93	85.07	86.07	87.07	85.07	79.4	70.07	63.73
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	84.47	87.93	87.07	85.40	82.07	87.07	86.40	79.73	71.40
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	81.87	83.87	81.00	78.67	77.67	73.33	70.33	61.00	59.67
T_6: 0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	91.40	93.27	91.93	90.93	89.60	85.60	80.27	77.27	70.30
T_7: Control (Distilled water)	81.87	81.67	78.27	76.93	75.93	77.27	64.60	58.60	49.27
F test	*	*	*	*	*	*	*	*	*
S Em±	3.00	3.23	3.33	4.10	4.94	5.65	5.15	5.33	6.38
C.D @5%	8.73	9.38	9.69	11.93	14.35	16.42	14.97	15.49	18.54

Table 8a: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS on fresh weight of gerbera flower cv. "Eswara"

Fresh weight [g/fl]									
Treatment	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**
T_1: 100ppm Aluminum sulphate +2% sucrose +100ppm 8-HQS	96.27	101.07	91.40	81.73	73.73	64.07	56.07	48.73	42.07
T_2: 100ppm Aluminum sulphate +2% sucrose +200ppm 8-HQS	90.6	94.27	93.73	92.73	91.4	89.73	87.07	85.73	84.07
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	85.8	90.6	87.2	83.53	80.53	77.53	73.53	68.87	64.53
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	86.47	92.27	88.73	84.40	81.07	77.40	74.73	72.07	70.07
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	84.33	87.40	87.93	84.60	80.27	75.27	71.93	69.60	69.27
T_6: 0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	97.40	102.07	98.67	94.33	90.00	84.33	80.00	75.67	69.33
T_7: Control (Distilled water)	92.00	97.20	92.40	87.07	80.73	75.73	71.73	67.40	63.40
F test	*	*	*	*	*	*	*	*	*
S Em±	1.22	1.64	1.81	2.89	4.31	5.73	6.97	8.24	9.28
C.D @5%	3.55	4.76	5.25	8.39	12.54	16.67	20.25	23.96	26.96

4.3.3 Vase life

The data pertaining to the effect of best concentration of mineral salts and sucrose in combination with 8-HQS on the vase life of cut gerbera cvs. 'Salvador' and 'Esmara' is presented in Table 9 and Fig.6.

In both the cultivars, the treatment combination as compared to the control significantly influenced the vase life. In cv. 'Salvador', the treatment involving 200 ppm 8-HQS showed better vase life as compared to flowers treated with 100 ppm 8-HQS. The excellent vase life of (11.68 days) was recorded in 15 ppm $AgNO_3$ plus four per cent sucrose plus 200 ppm 8-HQS and the minimum vase life of (6.33 days) was recorded in control.

The cv. 'Esmara' showed maximum vase life of (10.68 days) in 100 ppm $Al_2 (SO_4)_3$ plus two per cent sucrose plus 200 ppm 8-HQS and minimum of (6.00 days) in control.

4.3.4 Presence of bacteria in the vase solution

Data with respect to the presence of bacteria in the vase solution of cut gerbera cultivars is presented in Table 10 and Fig.7. After dilution plating and incubation the, number of colony forming units were counted. Composition of vase solutions significantly influenced the number of colony forming bacteria in vase solutions taken on 5th day from vase. After 48 hrs of culture in cv. 'Salvador' control showed maximum bacterial colonies (64.44×10^4 CFU/ ml) and the minimum colonies (2.34×10^4 CFU/ ml) was found in the treatment combination of 15 ppm $AgNO_3$ + 4 % sucrose + 200 ppm 8-HQS.

In cv. 'Esmara' control recorded maximum bacterial colonies (66.67×10^4 CFU/ml) and the minimum colonies (9.78×10^4 CFU/ ml)

Table 9: Effect of best concentration of mineral salts and sucrose in combination with 8-HQS on the vase life [days] of gerbera flower cv. 'Salvador' and 'Esmara'.

Vase life [days]		
Treatment	**cv. Salvador**	**cv. Esmara**
T_1: 100ppm Aluminum sulphate +4% sucrose +100ppm 8-HQS	8.00	7.33
T_2: 100ppm Aluminum sulphate +4% sucrose +200ppm 8-HQS	10.67	10.68
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	8.33	8.67
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	11.68	9.00
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	8.67	8.33
T_6: 0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	9.33	9.00
T_7: Control (Distilled water)	6.33	6.00
F test	*	*
S Em±	0.36	0.29
C.D @5%	1.04	0.85

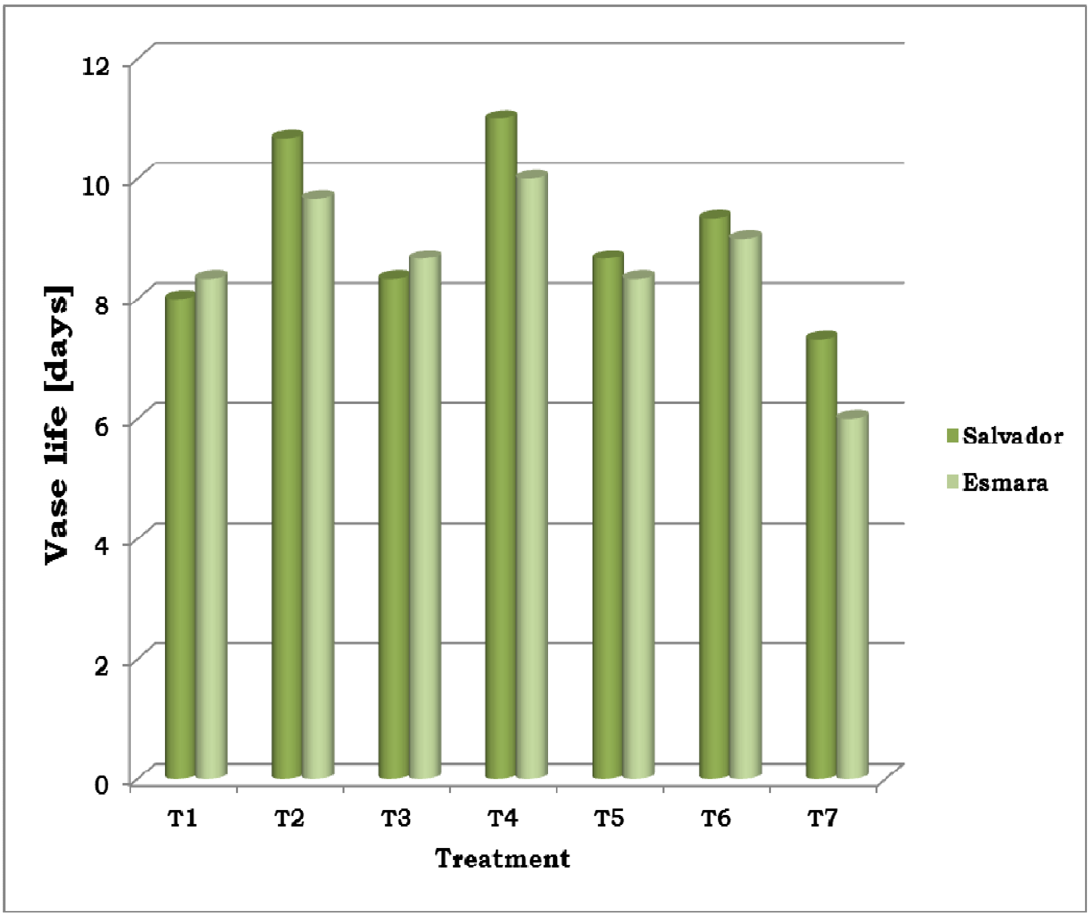


Fig. 6: Effect of best concentration of mineral salts and sucrose in combination with 8- HQS on the vase life [days] of gerbera flower cvs. 'Salvador' and 'Esmara'.

T_1: 100 ppm Aluminium sulphate +4% Sucrose+100 ppm 8-HQS

T_2: 100 ppm Aluminium sulphate +4% Sucrose+200 ppm 8-HQS

T_3: 15 ppm Silver nitrate+4% Sucrose+100 ppm 8-HQS

T_4: 15 ppm Silver nitrate+4% Sucrose+200 ppm 8-HQS

T_5: 0.2 mM Silver thiosulphate+4% Sucrose+100 ppm 8-HQS

T_6: 0.2 mM Silver thiosulphate+4% Sucrose+200 ppm 8-HQS

T_7: control (Distilled water)

Table 10: Effect of chemical preservatives on bacteria in vase solution (CFU/ml) during vase life period of cut gerbera flowers cvs. 'Salvador' and 'Esmara'

Treatment	CFU × 10^4ml in vase	
	cv. Salvador	cv. Esmara
T_1: 100ppm Aluminum sulphate +4% sucrose +100ppm 8-HQS	15.11	17.67
T_2: 100ppm Aluminum sulphate +4% sucrose +200ppm 8-HQS	13.44	9.78
T_3:15ppm Silver nitrate +4% sucrose +100ppm 8-HQS	10.67	11.72
T_4:15ppm Silver nitrate +4% sucrose +200ppm 8-HQS	2.34	10.56
T_5:0.2mM Silver thiosulphate +4% sucrose +100ppm 8-HQS	10.11	11.56
T_6:0.2mM Silver thiosulphate +4% sucrose+200ppm 8-HQS	9.78	10.78
T_7: Control (Distilled water)	64.44	66.67
F test	*	*
S Em±	2.70	2.88
C.D @5%	7.84	8.37

CFU-Colony forming unit

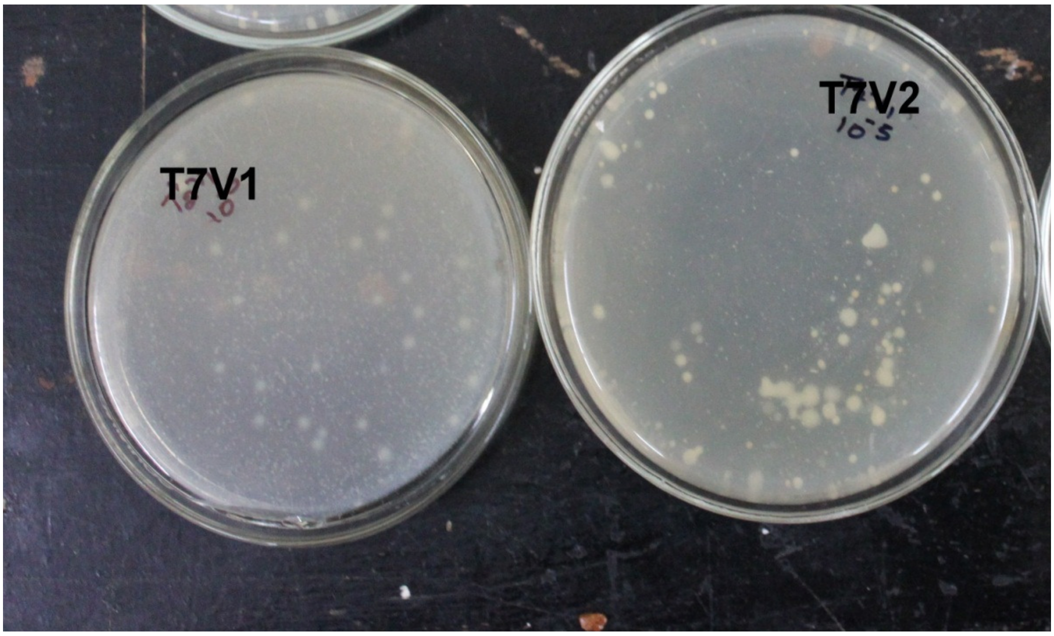


Plate 5: Effect of preservatives on bacteria in T_7-Control (distilled water) after 48 hrs of incubation in both the cultivars.

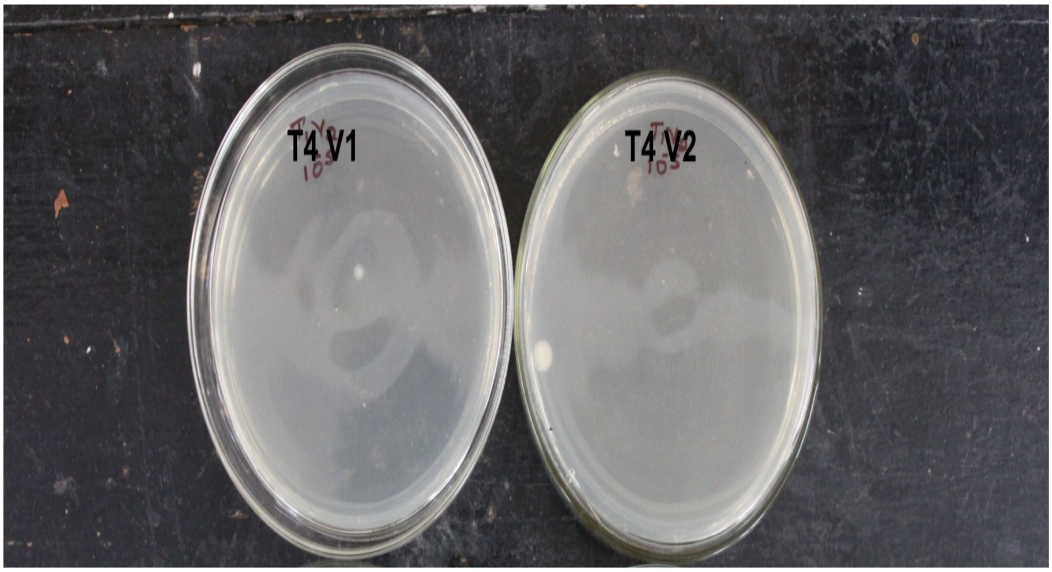


Plate 5a: Effect of 15 ppm $AgNO_3$ +4% sucrose+200 ppm 8-HQS on bacteria in vase solution after 48 hrs of incubation in both the cultivars.

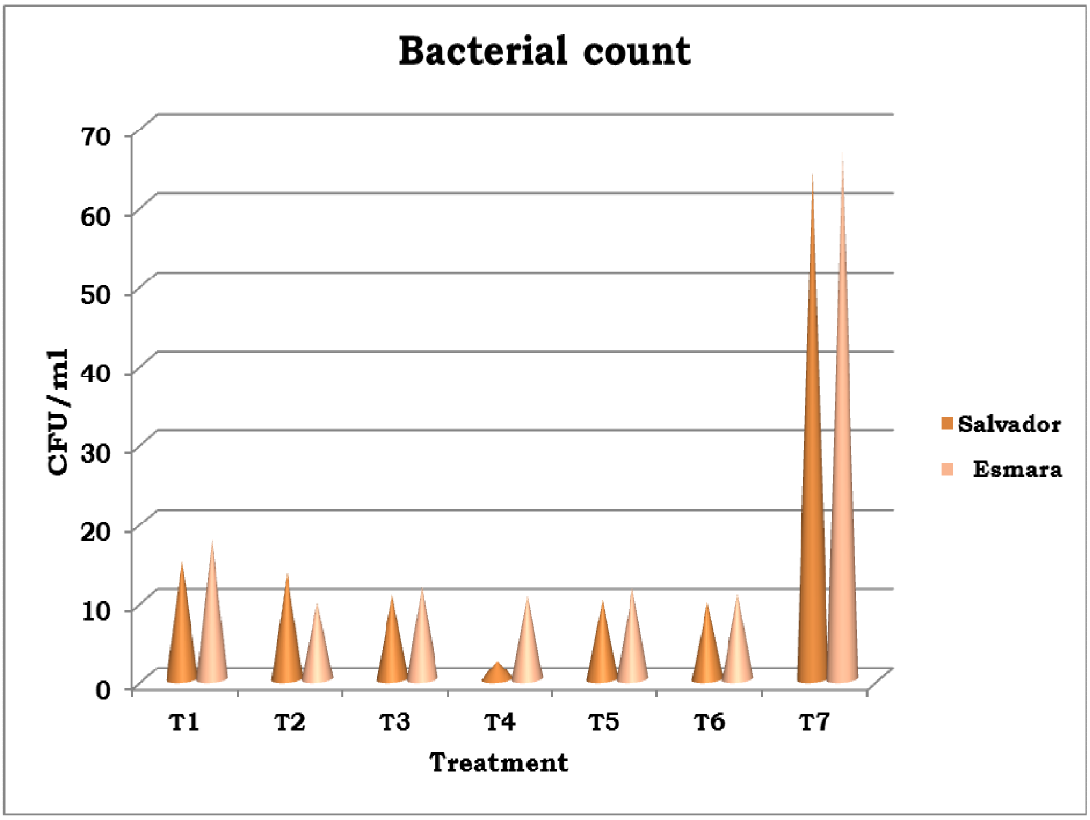


Fig.7: Effect of chemical preservatives on bacteria in vase solution (CFU/ml) during vase life period of cut gerbera flowers cvs. 'Salvador' and 'Esmara'

T_1: 100 ppm Aluminium sulphate +4% Sucrose+100 ppm 8-HQS

T_2: 100 ppm Aluminium sulphate +4% Sucrose+200 ppm 8-HQS

T_3: 15 ppm Silver nitrate+4% Sucrose+100 ppm 8-HQS

T_4: 15 ppm Silver nitrate+4% Sucrose+200 ppm 8-HQS

T_5: 0.2 mM Silver thiosulphate+4% Sucrose+100 ppm 8-HQS

T_6: 0.2 mM Silver thiosulphate+4% Sucrose+200 ppm 8-HQS

T_7: control (Distilled water)

Plate 6: Effect of T_4-15 ppm $AgNO_3$ plus 4% sucrose plus 8-HQS on vase life of cv. 'Salvador' on 5th day

Plate 6a: Effect of T_4-15 ppm $AgNO_3$ plus 4% sucrose plus 8-HQS on vase life of cv.'Esmara' on 5th day

was found in the treatment 100 ppm $Al_2 (SO_4)_3$ + 2 % sucrose + 200 ppm 8-HQS when compared to other treatments. This treatment combination improved the vase life by ensuring the supply of reducing sugar and exhibited more stress fighting capacity by raising the total phenol content compared to control.

DISCUSSION

V. DISCUSSION

Gerbera is an internationally important cut flower, which can contribute largely to the floriculture industry by virtue of its yield potential, colour variation and long vase life. A major criterion for the success depends on their quality and post harvest longevity. Hence, to improve the post harvest life of the cut flowers there are many operations carried out during export, transit of flowers which increase the flower quality and enhance the vase life. Use of preservative solutions has been successful in case of many flowers. Floral preservatives contain water to maintain turgidity, sugar as an energy source with biocide to inhibit microbial growth and development.

In the present study mineral salts were used alone or in combination with sucrose and mineral salts and sucrose in combination with 8-HQS were tried in the vase solutions. Results obtained in the investigations are discussed in this chapter.

5.1 Effect of alumunium sulphate [$Al_2 (SO_4)_3$]

Aluminium sulphate compounds acidify the holding solution and decrease the pH thus becoming toxic to microbial growth and proliferation. Aluminium is effective in reducing the rate of transpiration thereby, increase in the vase life of roses. There was an increase in water uptake by the cut gerbera flowers with $Al_2 (SO_4)_3$ treatments as compared to the control. In cv. 'Salvador' higher water uptake (58.77 g/fl) was recorded in 100 ppm $Al_2 (SO_4)_3$ over control (52.49 g/fl). Whereas, in 'Esmara' flowers treated with 100ppm $Al_2 (SO_4)_3$ showed maximum water uptake of (78.93 g/fl) against (55.96 g/fl) in the control. This enhanced water uptake is attributed to the effect of aluminium ions in containing microbial growth as a bacterial filter (Put *et al.*, 1992) and hence reducing vascular blockage thus, resulting in greater water uptake (Marousky, 1972; Rutting, 1991). The flowers treated with $Al_2 (SO_4)_3$ recorded higher water loss but still had longer vase life. Results obtained in this experiment are in accordance with the data recorded by Dias (1994) and Yogitha (1997).

Treatments with $Al_2 (SO_4)_3$ recorded better fresh weight in gerbera flowers compared to the control. In cv. 'Salvador' treatment with 100 ppm $Al_2 (SO_4)_3$ recorded higher fresh weight (69.97 g/fl). In case of 'Esmara', maximum fresh weight of (63.89 g/fl) was recorded in 100 ppm $Al_2(SO_4)_3$ compared to control (54.96 g/fl). Schnabl and Ziegher (1975) and Rajgopalan and Khader (1993), Chikkasubbanna and Yogitha (2002) revealed that hydrolysis of starch was inhibited by aluminium, on inhibition of starch hydrolysis increased the fresh weight of flowers.

Flowers treated with $Al_2 (SO_4)_3$ showed better vase life compared to other chemicals and control. 'Salvador' recorded maximum vase life of (12.11 days) in flowers treated with 100 ppm $Al_2 (SO_4)_3$ as against (9.67 days) in control. 'Esmara' recorded highest vase life of (12.00 days) in 100 ppm $Al_2 (SO_4)_3$ as against control (9.33 days).These results are similar to those results obtained by Weinstein (1959), Ahn and Um (1991) and Rajgopalan and Khader (1993), Patil and Singh (1995) reported that vase solutions containing $Al_2 (SO_4)_3$ extended the vase life of cut flowers.

5.2 Effect of silver nitrate ($AgNO_3$)

Silver nitrate is an effective bactericide in most preservative formulations, it also acts as an ethylene action inhibitor.

The water uptake of gerbera flowers was improved by $AgNO_3$ treatments as compared to the control. In cv. 'Salvador' higher water uptake (62.35 g/fl) was recorded in 15 ppm $AgNO_3$. This may be due to germicidal action of $AgNO_3$ (Aarts, 1957;Ketsa *et al.,* 1993; Hussein, 1994) and prevention of stem blockage leading to better water flow through the stems**.** Marousky (1969) reported that water absorption is inversely proportional to vascular blockage.

In cv. 'Esmara' higher water uptake (79.46 g/fl) was recorded in 15 ppm $AgNO_3$ an improvement in the water balance was recorded by treatments with $AgNO_3$. Turgidity in flowers is generally depends upon a balance between the rate of water loss and water supply.

There was a positive influence on the fresh weight of gerbera flower as compared to the control when treated with $AgNO_3$, in both the cultivars. Maximum fresh weight (74.00 and 78.71 g/fl respectively) was recorded in 15ppm $AgNO_3$. This increase in fresh weight might be attributed to the improvement in water uptake by $AgNO_3$ treatments as a result of anti bacterial properties (Aarts, 1957; Halevy and Mayak, 1981; Ketsa *et al*., 1993).

Vase life of gerbera flowers treated with $AgNO_3$ was extended compared to the control. In both the cvs. 'Salvador' and 'Esmara' the higher vase life (13.00 and 12.33days, respectively) was recorded in 15 ppm $AgNO_3$. This improvement in vase life by using $AgNO_3$ may probably due to the anti ethylene effect of silver applied as $AgNO_3$ (Halevy and Mayak, 1981; Ketsa *et al*., 1993, Veen, 1986). Halevy and Mayak (1981) reported that ethylene is one of the plant harmone which plays a major role in flower senescence. Rath *et al.,* (1991) showed an increase in the vase life of rose cultivars Laura, Love and Larndora by $AgNO_3$ treatment and potassium aluminium sulpahte combination. Silver nitrate undoubtedly influence vase life not only by its ethylene inhibiting action, but also due to its bactericidal property has noticed in rose cultivar Asami Red (Okhaw *et al.,* 1999).

5.3 Effect of silver thiosulphate (STS)

STS is highly mobile in the plant transport system and prevents damage induced by ethylene. STS is also an anti ethylene agent, it inhibits ethylene action.

There was a greater influence on the water uptake in flowers treated with STS compared to the control. In cv. 'Salvador' the higher water uptake (53.60 g/fl) was recorded in 0.2 mM STS and in cv. 'Esmara' the highest water uptake (63.82 g/fl) was recorded in 0.2mM STS. This could be attributed to the silver in STS acting as a bactericide (Halevy and Mayak, 1981). The STS complex moves freely with the transpiration stream (Veen, 1983, 1986 and 1987) and the amount of silver ions absorbed by the individual stems depends on the amount of solution absorbed by the cut flower (Reid *et al.*, 1989).

There was a positive influence noticed on the fresh weight of flowers treated with STS compared to the control in case of both the cultivars. Reid *et al.,* (1989) observed that STS complex treatment of carnations significantly influenced their post harvest life.

Cultivars 'Salvador' and 'Esmara' showed an improvement in the vase life over the control by the application of STS. In cv. 'Salvador' maximum vase life of (12.11 days) was recorded in 0.2 mM STS as against (9.67 days) in control and in cv. 'Esmara' the increased vase life (12.00 days) was recorded in 0.2 mM STS compared to control (9.33 days). Faragher and Mayak (1984) reported that the vase life of 'Mercedes' roses was increased by STS treatment and it further acts as an ethylene inhibitor (Halevy and Mayak, 1981). Vase life of Gabrilla roses was extended by pulsing with STS (Mor *et al.*, 1989).

5.4 Effect of mineral salts in combination with sucrose

The optimum concentrations of each chemical to standardize vase solutions were obtained from experiment-I. They were further used in combination with sucrose at two per cent and four per cent in experiment-II to know their effect on the post harvest life of cut gerbera flowers.

Ageing process in flowers is concomitant with time by losing moisture and fading of colours. Hence, efforts were made to develop appropriate preservative solution or prolonging the post harvest life of gerbera. An extended vase life of cut flower depends on its water relations and retarding the rate of senescence, which can be achieved by using certain chemicals. The life of a cut flower can be extended by holding it in a solution containing sucrose, provided the growth of microorganisms and biogenesis of ethylene are controlled (Lau and Yang, 1976). With this scientific data, different mineral salts in combination with sucrose were tried and results obtained are discussed below.

Gerbera cvs. 'Salvador' and 'Esmara' flowers treated with $Al_2(SO_4)_3$ in combinations with two per cent and four per cent sucrose recorded higher water uptake than control. This might be due to ability of aluminium to acidify holding solution thus inhibiting bacterial growth by improving water uptake (Halevy and Mayak, 1981). Among all the treatment imposed on gerbera cv. 'Salvador', the highest water uptake of (71.25 g/fl) was recorded in 15ppm $AgNO_3$ coupled with four per cent sucrose as compared to control (47.55 g/fl) or alone (62.35 g/fl). Whereas cv. 'Esmara' showed maximum water uptake of (86.69 g/fl) against (68.93 g/fl) control or alone (79.46 g/fl) when treated with 15ppm $AgNO_3$. These results are supported by earlier findings of Ketsa *et al.,* 1993, that adequate moisture levels can be maintained in cut roses given sufficient water uptake or water retention, or may be both.

The addition of sucrose along with mineral salts in the vase solution showed a better maintenance of fresh weight during entire post harvest life of cut gerbera cultivars as compared to the control or when the mineral salts were used alone. These results are similar to data obtained by Wilkins (1963) he explained that an increase in fresh weight of cut flowers due to addition of sucrose. Reduction in moisture stress in cut flowers by decreasing the aperture size of leaf stomata (Aarts 1957; Marousky, 1969, 1972). The maximum cumulative fresh weight (96.2 g/fl) was observed in holding solution containing 15 ppm silver nitrate with four per cent sucrose in cv. 'Esmara'. This increase in fresh weight may be attributed to the improvement in water uptake by silver nitrate treatments by its bactericidal properties (Halevy and Mayak, 1981). Mineral salts in combination with sucrose recorded an improvement in vase life compared to control. In both cvs. 'Salvador' and 'Esmara' the maximum vase life of (14.33 and 13.00 days) was recorded in holding solution containing 15 ppm $AgNO_3$ combined with four per cent sucrose against (8.33 and 8.00 days) in control. Kesta *et al.*, (1993) and Rath *et al.* (1991) observed that the combination of $AgNO_3$ with sucrose was effective to extending the vase life of roses.

Sucrose is an important component for extending of shelf life and the improved vase life by addition of sucrose was attributed to its role in maintaining pool of dry matter and substrates for respiration particularly in petals (Coorts, 1973). Sucrose delays starch hydrolysis and lipid degradation (Molnar and Parups, 1977), maintaining mitochondrial structure and functions (Kaltaler and Steponkus, 1976) and retarding loss of membrane integrity (Paulin, 1986). Sucrose also enhances vase life by improving the role of cytokinin. It delays senescence of cut flowers by reducing the effect of ethylene action (Mayak and Dilley, 1976).

5.5 Effect of best concentration of mineral salts and sucrose in combination with 8-HQS

The best concentration of mineral salts and sucrose in vase solution was obtained from experiment-II and this was further combined with 8-HQS to find out the effect on the post harvest life of cut gerbera flowers.

In both the cultivar 'Salvador' and 'Esmara' all the treatment recorded higher water uptake compared to the control. This is in accordance with results obtained by Aarts (1957), Durkin and Kue (1966) and Burdett (1970), 8-HQS improved water uptake due to its anti-microbial action. The number of bacteria associated with the cut surface and in the xylem interior of rose stems was reduced by anti-microbial treatments (Van Doorn and Perik, 1990) and as a result stem blockage was reduced (Ketsa and Treetaruyanodha, 1988) and ultimately enhancing the water uptake. Since the water uptake by flowers treated with 8-HQS was high, there was a greater water loss in these treatments in both the cultivars.

There was positive influence on the fresh weight of flowers treated with 8-HQS compared to control. In both cultivars 'Salvador' and 'Esmara', treatments of mineral salts with sucrose and 8-HQS are found to be better. Ketsa and Treetaruyanodha(1988) noticed that 8-HQS and sucrose reduced bluing, bent neck and increased the fresh weight and water conductivity of cut roses.

In cv. ‘Salvador’ 200 ppm 8-HQS with 15 ppm $AgNO_3$ and four per cent sucrose (71.40 g/fl) and cv. ‘Esmara’ 200 ppm 8-HQS with 100 ppm $Al_2 (SO_4)_3$ and four per cent sucrose (84.07 g/fl) recorded better fresh weight than the control.

In both cv. ‘Salvador’ the maximum vase life of (11.68 days) was recorded in holding solution containing 15ppm $AgNO_3$ combined with four per cent sucrose and 200 ppm 8-HQS against (6.33 days) in control and in cv. ‘Esmara’ vase life of (10.68 days) was recorded in holding solution containing 100 ppm $Al_2 (SO_4)_3$ combined with two per cent sucrose and 200 ppm 8-HQS against (6.00 days) in control.

Chua (1970) suggested that 8-HQS showed cytokinin like activity in retarding senescence. HQ inhibits ethylene production in rose stamens. Various combinations of 8-HQS and sucrose prolong the vase life (Lukaszewska, 1986; Garibaldi and Deambrogio, (1993), water uptake, fresh weight and water conductivity in cut roses (Ketsa and Treetaruyanodha, 1988).

5.6 Presence of Bacteria in the vase solution

Bacterial examination of vase solution of both the gerbera cultivars ‘Salvador’ and ‘Esmara’ revealed that the presence of bacterial colonies are more in control as compared in other treatment combination. Highest microbial growth in control might be due to rapid occlusion of stem xylem vessels by micro-organisms which might have prevented further entry of water into the stem and thereby reduced the longevity. The unique ecological conditions in the vase fluid and to a lesser extent, the antagonistic activities of many of the microbial species of the mixed vase flora might have led to normal senescence symptoms. These results were in accordance with the findings of Put (1990) in cut Chrysanthemums, gerberas and roses.

In both the cultivar cv. 'Salvador' with treatment combination 15 ppm Silver nitrate + 4 % sucrose + 200 ppm 8-HQS recorded lowest bacterial colonies compared to in control and in cv. 'Esmara' 100 ppm $Al_2 (SO_4)_3$ combined with two per cent sucrose and 200 ppm 8-HQS recorded minimum bacterial colonies , the results of this corroborated with the findings of Deambrogio *et al.*, (1991), Buzro *et al.*, (1993), Amariutei *et al.*, (1995), YooYong Kweon and Kim-Won Sun (2003), who clearly mentioned that floral preservatives maintain higher fresh weight, reduce respiration rate and check deterioration of cell ultra-structure. Use of germicides like 8-HQS helped to prevent rapid growth of bacteria. Without adding germicides, accumulation of microorganisms at the cut end of the flower stem submerged and incubated in the vase water, blocks the xylem vessels and became responsible for reduced water uptake by the flower.

SUMMARY

VI. SUMMARY

Experiments were carried out to extend the vas life of cut gerbera cvs. 'Salvador' and 'Esmara' by using different mineral salts, sucrose and germicide at the Division of Horticulture, University of Agricultural Sciences, Gandhi Krishi Vignana Kendra, Bengaluru in the laboratory of Regional Horticulture Research and Extension center, University of Horticultural Sciences, Bagalkot, GKVK campus, Bengaluru during the year 2012-2013.

The prime objective was to standardize the concentration of vase solution for cut gerbera cvs. 'Salvador' and 'Esmara' by the use of mineral slats alone or in combination with sucrose and germicide.

The mineral salts used were aluminium sulphate, silver nitrate and silver thiosulphate. Two levels of sucrose (2 and 4 percent) and the germicide 8-HQS (100 and 200ppm) were used in the experiments. The findings of the investigations are summarized here under.

6.1 Aluminium Sulphate

Aluminium sulphate at 100 ppm concentration in vase solution was found optimum for both the cultivars. Introducing $Al_2 (SO_4)_3$ into the vase solution increased the water uptake over the control. Water loss was in line with water uptake. Fresh weight of the flowers was maintained at higher levels with optimum concentration of $Al_2 (SO_4)_3$. Treatments had significant influence on the vase life compared to the control

6.2 Silver nitrate

Silver nitrate at 15 ppm concentration in vase solution was optimum. The water uptake and absorption rate was found better than control and there was an improvement in water balance. Fresh weight of the flowers was maintained at higher levels. $AgNO_3$ treatments showed increased vase life compared to control.

6.3 Silver thiosulphate

Silver thiosulphate at 0.2 mM concentration in vase solution was found better for both the cultivars. Though, there was no significant influence on water uptake, water loss was maintained low so the fresh weight was maintained high.

6.4 Mineral salts in combination with sucrose

All the treatment combination with two and four per cent sucrose, showed better result with respect to water uptake, fresh weight, water balance and vase life. In both the cultivars, four per cent sucrose was found optimum. Among the treatments better water uptake, fresh weight, water balance and vase life was noticed in 15 ppm $AgNO_3$ plus four per cent sucrose in cv. 'Salvador' and 100 ppm $Al_2 (SO_4)_3$ plus two per cent sucrose in cv. 'Esmara' when used as holding solution.

6.5 Best combination of mineral salts and sucrose with 8-HQS

The most effective combination for cv. 'Salvador' was 15 ppm $AgNO_3$ plus four per cent sucrose plus 200 ppm 8-HQS. For cv. 'Esmara' the optimum concentration was 100 ppm $Al_2 (SO_4)_3$ plus two per cent sucrose plus 200 ppm 8-HQS. Introducing the chemicals at this level in the vase of flowers was maintained leading to increased vase life.

6.6 Presence of Bacteria in the vase solution

The presence of bacteria in the vase solution of cut flowers significantly decreased the vase life of cut gerbera cultivars. The presence of bacteria caused vascular blockage resulting in reduction of water uptake and fresh weight.

The data obtained in this experiment clearly indicates that presence of bacteria were more in control as compared to the combination of other treatments.

Future line of work

Based on the experiment conducted and the results obtained, the following future line of work is suggested

1. Similar experiment may be conducted by using bio preservatives
2. Different varieties of gerbera flowers may be subjected to similar experiments for general recommendation
3. Different packaging treatments may be imposed with holding solutions

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* Originals not seen.

APPENDIX

APPENDIX-I

Weather data recorded during the experimental period from February-April, 2013

Month	**Temperature (^0C)**		**Relative Humidity (%)**
February	23	18	70
March	30	22	35
April	31	25	32