ENHANCEMENT OF POSTHARVEST LIFE OF *DENDROBIUM* FLOWER

By

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THESIS

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1997

Dedicated

to my

beloved Parents

DECLARATION

I hereby declare that this thesis entitled **"Enhancement of postharvest life of *Dendrobium* flower"** is a *bonafide* record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

Vellayani,
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CERTIFICATE

Certified that this thesis entitled **"Enhancement of postharvest life of *Dendrobium* flower"** is a record of research work done independently by **Mrs. Jomy. T. G.** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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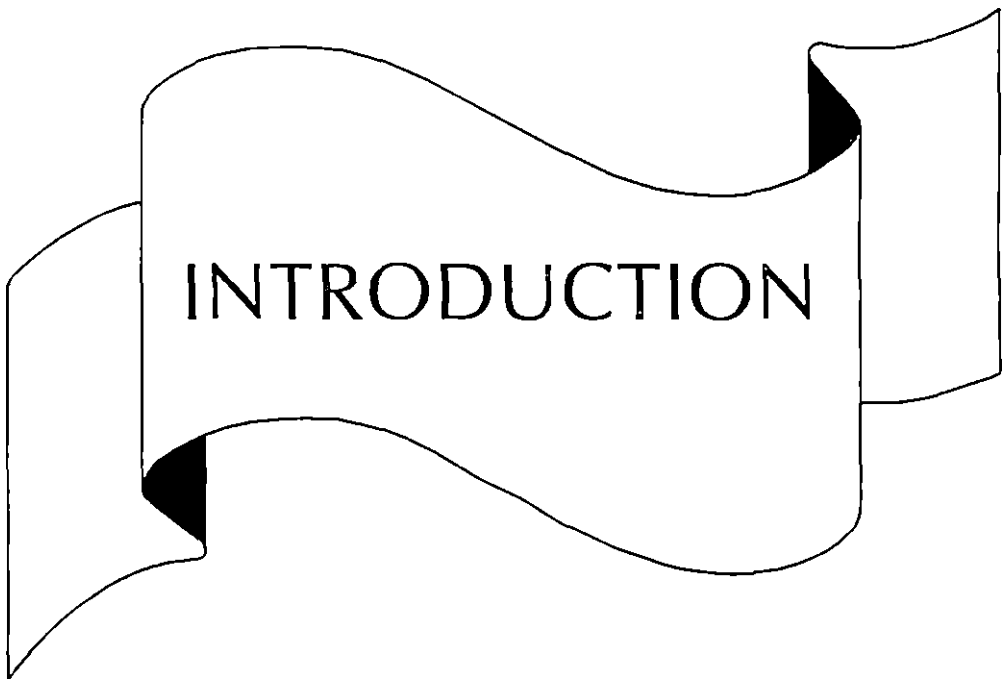

INTRODUCTION

INTRODUCTION

Floriculture is recognised today as a lucrative agri-business with a higher potential for returns per unit area. The Indian floriculture industry comprises of the production and marketing of flowers, nursery plants, potted plants, seeds, bulbs and essential oils from flowers.

The APEDA survey of 1988 had estimated the total returns from floricultural products as worth Rs. 2050 million which included Rs. 1050 million from traditional flori-products and Rs. 1000 million from modern florist trade. The floricultural export of India increased significantly from Rs. 14.55 crores in 1991-92 to Rs. 30.60 crores in 1994-95 and Rs. 57.80 crores in 1995-96 (Singh, 1997). The estimated area under flowers and production during 1994-95 were 53000 ha and four lakh tonnes respectively. India's share in the world trade was only 0.6 per cent till 1990 (Raghava, 1996).

Cut-flowers constitute 45 per cent share of the total world trade in floricultural products. Among them the cultivation and production of orchids is fast emerging as an absorbing and a rewarding vocation. The genera *Arachnis, Cattleya, Cymbidium, Dendrobium, Paphiopedilum* and *Phalaenopsis* command a high price for their cut-flowers and have

contributed immensely to the international trade in floriculture (Chadha and Bhattacharjee, 1995).

Kerala has been earmarked by the Government of India as a zone for intensification of orchid cultivation. *Dendrobium* hybrids are the most popular among the orchids commercially grown in Kerala. Some of the popular hybrids grown here are Sonia, Sabine, Ekapol, Kasem White, Walter Oumae, Mary Trowse and Candy Stripe. Among them, *Dendrobium* Sonia is the most free flowering and popularly grown.

The flowers grown in Kerala are chiefly marketed in the major cities of our country. The period of transport and transit involved until flowers reach consumers is 24 to 48 hours and the vase life under these conditions vary from 8 to 10 days while freshly cut flowers have a vase life of upto 14 days.

Commercial formulations of floral preservatives containing carbohydrates, germicides, inhibitors of ethylene, growth regulators and other chemicals are used extensively to retain freshness of flowers during transport and to enhance their subsequent vase life in developed countries. The composition of their constituent chemicals are closely guarded secrets and they are not produced or marketed in India. The use of chemicals which act as floral preservatives has not yet been standardised in orchids in our country.

To realize our aims of export oriented production, our growers are to be supplied with standardised techniques of handling and treatment of flowers. So also, for the end-users of the cut-flower orchids marketed in our country, the standardisation of an ideal preservative solution for enhancing vase life of blooms is essential.

With the above objectives, a study was undertaken to standardise postharvest chemical treatments to improve quality and vase life of *Dendrobium* cut flowers and to identify a combination of chemicals for maximising their vase life.


REVIEW OF
LITERATURE

REVIEW OF LITERATURE

Orchid flowers, in their diversity of form, colour and intricacy are among the natural treasures that stir human hearts (Dhiman and Vij, 1996). Among the different cut-flowers, orchids have a relatively greater postharvest life and their postharvest physiology has been investigated primarily to determine the regulatory factors of greater longevity. Research on prolonging the vase life of orchids especially the tropical *Dendrobium* using chemical treatments are very meagre. Hence studies on vase life of other cut-flower crops like gladiolus, carnations, chrysanthemum, rose, anthuriums, tuberose etc. have been reviewed here.

Postharvest life of cut flowers depends on several pre and post harvest factors, nutritional status of the growth medium, areal and root temperature, photoperiod and light intensity during the growth period in the green house, conditions during harvesting, grading, packaging, transportation and composition of 'pulsing' and 'bud opening' solutions (Salunkhe *et al.*, 1990). The 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 the second phase (Halevy and Mayak, 1979). The interaction between flowers, stems and leaves influences the water balance and postharvest quality of flowers

(Zieslin *et al.*, 1978; Halevy and Kofranek, 1977; Van Meeteren, 1978). Special care is thus needed in the development and postharvest handling of cut-flowers.

Since orchid flowers are the special occasion flower, the condition of the flower is very important. Further more, if a single flower in a consignment is beginning to fade or destined to fade soon, and if the ethylene liberated by it is not eliminated or inactivated, the whole consignment will fade in transit. Therefore, it is imperative that only sound flowers, (unfaded, unpollinated, with intact pollinia) are packaged in a clean atmosphere devoid of ethylene (Staby *et al.*, 1978).

The turgidity of the flower, the colour, the shape or the form of the labellum and other structures in the flower are more important in marketability of orchid flowers. In general, the flowers with a very special type of pigmentation or unusual form are in more demand in the international market. Undisturbed and unpollinated flowers last upto 3 weeks or more (Staby *et al.*, 1978).

As cut-flower is a complex organ composed of morphologically and physiologically different units, the regulatory factors and their inter-relationships determine postharvest longevity and quality. They are mainly water relations, carbohydrate levels and ethylene production. The most widely accepted theories on extending the vase life of cut-flowers are based on the improvement in water relations within the stem. A high level of turgidity is necessary for the development of cut-flower buds to

full bloom maturity (Bhattacharjee, 1994a). Water potential of intact gerbera flowers remain constant till senescence while in cut-flowers, the water potential drops creating a water deficit (Van Meeteren, 1980). He also reported that in water deficit flowers, the turgor of cells and loss in turgor, in turn, promotes leakage of water and ions from the cells.

Two major factors affecting water absorption through conducting vessels are air embolism and the occurrence of vascular occlusions in cut-flower stems. Vascular blockage begins at the cut end and moves upward in the stem with time (Durkin and Kue, 1966). Microbial occlusions localised at the base of the cut-flower stems (Linberger and Steponkus, 1976) and gummy exudates of cellular origin found inside the stems, usually above the solution levels, plug conducting vessels and obstruct waterflow. Buys (1979) also found that polyphenols which leach out of submerged leaves and stems of cut-flowers like roses get oxidised to orthoquinones, and poison cells at the base and impair water uptake. Ethylene induced clogging due to wounding of stem tissue is also believed to be a major factor limiting postharvest life by inducing water stress and senescence (Paull and Goo, 1985).

Postharvest treatments of cut-flowers

To preserve the quality of cut-flowers after harvest and to make them resistant to fluctuations in environmental conditions, treatment with floral preservatives is recommended. These may be applied to flowers during the entire marketing chain from growers to wholesalers, retail

florists and final purchasers. The different methods of postharvest treatments include conditioning or hardening, impregnation, pulsing or loading, bud opening etc. (Nowak and Rudnicki, 1990). Conditioning, pulsing and the use of floral preservatives in vase solutions tried in the present study are reviewed here.

Conditioning or hardening

While handling in the field or in grading rooms flowers suffer from water stress. Conditioning is necessary to hydrate the stems and overcome slight wilting before or during dry storage. Hydration is considerably promoted when water is de-aerated or acidified or when a wetting agent is added (Bhattacharjee, 1997). The conditioning period allows the stems to absorb water, so that the leaves and flowers regain turgidity. Marousky (1971a) reported that solution pH exerted a strong influence on water conduction and fresh weight of cut roses. Stems held in solutions at pH 3 and 4 for two days had greater ability to conduct water and weighed more than stems held at pH 5, 6 and 7. Pokorny and Kamp (1955) used HCl to acidify holding solutions and reported that pH 4 was optimum for extending vase life.

Pulsing treatments or loading

The method of pulsing or loading consists of placing the lower portion of flower stems in solutions containing sugar and germicides for a period ranging from several hours to as long as two days. It is effective

in extending vase life as well as quality of cut-flowers even when preservatives are not used subsequently at the wholesale or consumer level. The cut-flower may be pulsed with flower preservatives containing sugars, anti-microbial substances and antiethylene substances (Bhattacharjee, 1997). The main ingredient of pulsing solution is however, sugar, the percentage of which varies with species and cultivars. Sugar concentration used for pulsing is much higher than that used in flower preservatives for the continuous treatment of flowers in the vase. A strictly curtailed period of treatment is thus necessary in order to avoid the injuries to leaves and petals caused by high sugar concentrations. Sucrose replaces the depleted endogenous carbohydrates utilized during the postharvest life of flowers. It helps in continuation of the normal metabolic activities after harvest, and inhibition of the processes associated with senescence. Pulsing results in prolonged flower life in water, faster flower opening and better coloration of petals. This is especially beneficial for flowers destined for long periods of storage or long distance transportation (Hardenburg *et al.*, 1986).

Floral preservatives

Using floral preservative solutions throughout marketing channels reduces flower waste, improves flower longevity and general qualities and improves consumer satisfaction. Commercially available preservative materials usually contain a source of energy, such as sugar (sucrose), a biocide to inhibit the growth of micro-organisms ($AgNO_3$, 8-HQC, or quaternary ammonium compound) and an acidifying agent (often citric

acid) to reduce the pH to 3 to 5 (Reid and Kofranek, 1980)). Antiethylene compounds in the preservative solutions reduce action of ambient ethylene and suppress auto catalytic production of ethylene by fresh cut-flowers. Role of different components used for the present study are detailed here.

Role of sucrose

Carbohydrates are the main source of nutrition for flowers and the source of energy necessary for maintaining all biochemical and physiological processes after separation from the mother plant. A carbohydrate supply is required for both bud opening (Marousky, 1973; Ketsa and Amutiratana, 1986a; Ketsa and Teeracharoenpunya, 1986) and vase life (Ketsa, 1986a; Hew, 1987; Downs *et al.*, 1988). Sugars support the processes fundamental for prolonging vase life, such as maintaining mitochondrial structure and functions, improving water balance by regulating transpiration and increasing water uptake. Sucrose is the sugar most often used in floral preservatives, but in some formulations glucose and fructose may also be used (Nowak and Rudnicki, 1990).

They also reported that optimal concentrations of sugar (Sucrose) vary in preservatives designed for particular species of flowers and sometimes even for a particular cultivar of a flower. Excessive concentrations of sugar in floral preservatives may be harmful, especially for leaves and petals, whereas too low a concentration may not produce an

optimal response. All sugars present in floral preservatives make excellent media for the growth of micro organisms which plug water vessels in a stem. Therefore sugar is combined with germicides in the preservative mixture.

Two basic requirements for maintaining growth are carbohydrate supply and fully turgid tissues. Sucrose aids to fulfill these two requirements, the first by supplying the tissues with carbohydrates and the second by improving the water uptake of the stem (Kofranek and Halevy, 1976; Halevy, 1976 and Ketsa, 1986b). An exogenous supply of sugars delays the onset of excessive protein degradation and also serves as substrate for protein synthesis. Many earlier research workers have reported the use of sucrose and various chemical preservatives for extending the vase life and improving the quality of cut-flowers (Marousky, 1968, 1969a and 1973; Bravdo *et al.*, 1974 and Kofranek and Halevy, 1976).

Sucrose serves as a substrate for respiration and other metabolic activities and act as an osmoticum. Both sucrose and 8-hydroxyquinoline citrate (8-HQC) tend to close stomates, thereby reducing transpiration (Larsen and Scholes, 1966; Nichols, 1975 and Halevy and Mayak, 1979). Marousky (1969a) found that, though cut roses placed in sucrose solutions initially suppressed water absorption, it subsequently gained and sustained more fresh weight than roses which were held in water. He attributed this increase in fresh weight to stomatal closure. He suggested that one role of sucrose in floral preservative was to act as an anti-dessicant.

Blueing in cut roses which is essentially a proteolytic phenomenon, was also prevented by holding them in sucrose solutions (Bruszewski, 1968). Sucrose or glucose supplied either alone or with quinoline salts promoted normal development of cut-flowers, lengthened their vase life, diminished changes in petal colour and reduced proteolytic breakdown (Stoltz, 1956; Aarts, 1957; Borochov *et al.*, 1976; Larsen and Frolich, 1969; Larsen and Scholes, 1965).

Pulsing gladiolus stems with 20% sucrose in combination with $AgNO_3$ (silver nitrate) before storage for 7 or 10 days resulted in greater floret opening and size than those not pulsed (Kofranek and Halevy, 1976). Sucrose fulfilled the requirement for a carbohydrate source and osmoticum which was necessary for floret growth and development. Sucrose pulse in addition to increasing longevity also resulted in deep rich pink florets up to the time of senescence.

Increase in petal sucrose and reducing sugar content on treatment with sucrose solution have been reported in cut flowers (Acock and Nichols, 1979; Lukaszewska, 1980 and 1986; Chung *et al.*, 1986 and Khattab *et al.*, 1987). This increase in endogenous sugar content was found to help in growth and development of immature bud-cut flowers. Solutions containing 10% sugar or more, consistently improved opening and longevity (Mayak *et al.*, 1973). Anatomical studies by Steinitz (1982) revealed a strong postharvest cell wall thickening and lignification of phloem cells in sucrose treated flowers, resulting in irreversible changes in the cell wall

structure and composition rather than a temporary sugar dependent increase in turgor. Lukazewska (1986) reported that the presence of sugars in the holding solution prevented undesirable accumulation of free amino acids in the cut flowers.

Exogenous sugars maintained mitochondrial structure and function, thus controlling the decline in the respiratory control of mitochondria (Kaltaler and Steponkus, 1974). Fibre and lignin content of gerbera flowers was found to double when placed in sucrose solution (Steinitz, 1983). An increase in anthocyanin content and therefore, the colour intensity of flowers kept in sucrose solutions was reported by Belynskaya *et al.* (1985); Choi and Sang (1989) and Gao and Wu (1990).

Flowers held continuously in sugar solutions have been found to develop better and have longer vase life (Aarts, 1957; Marousky, 1972; Rogers, 1963). A short term pre treatment with sugar solutions improved the opening and size of the florets and increased longevity of the gladiolus flower spike (Mayak *et al.*, 1973).

Sabina *et al.* (1996) reported that the use of holding solutions containing sucrose and cobaltous chloride increased the vase life by more than four days in anthurium flowers.

Several workers have reported beneficial effects on vase life enhancement in orchids by the use of holding solutions containing sucrose, 8-HQ salts and silver nitrate. Ketsa and Boonrote (1990) also

reported prolonging of vase life with sucrose, glucose, 8-HQ and $AgNO_3$ in *Dendrobium* 'Youppadeewan' and recommended 4% glucose, 225 mg/l of 8-HQ sulphate and 30 mg/l of $AgNO_3$ as being the optimum concentration.

Role of 8-hydroxyquinoline (8-HQ)

Several workers have reported beneficial effects on vase life and quality of cut flowers by the use of sucrose and 8-hydroxyquinoline in holding solutions.

Nowak and Vacharotayan (1980) reported improvement in flower quality and vase life for upto 20 days with holding solutions containing 2 to 5% sucrose, 200 to 400 ppm 8-hydroxyquinoline citrate and 25 ppm silver nitrate in cultivars of *Arachnis, Aranthera, Dendrobium, Oncidium, Vanda* and *Vandopsis*. In *Dendrobium* 'Madam Pompadour' and *Dendrobium* 'Jacquelin Thomas', the combination of 2% sucrose and 200 ppm of 8-HQ citrate was found to be better.

Hew *et al.* (1987) observed enhancement of vase life in *Aranda* cultivars with sucrose and 8-HQ sulphate at varying concentrations. Yong and Ong (1979) obtained extension of vase life in *Oncidium* 'Goldiana' with 200 ppm 8-HQ, 2% sucrose and 100 ppm ascorbic acid. In the same cultivar, Hew (1987) reported that sucrose and 8-HQ were more beneficial.

The esters of 8-hydroxyquinoline are strong chelators of metal ions of certain enzymes; loss of essential metal, inactivates the enzyme system (Gershon *et al.*, 1969; Martell and Calvin, 1952). Larsen and Scholes (1965) recognised 8-HQC as a stomatal closing agent but concluded that prolonged cut-flower life was due to the bactericidal properties of quinoline compounds. Coorts *et al.* (1965) postulated that 8-HQS may have a beneficial effect on water uptake by reducing physiological plugging. They also concluded that the keeping quality of roses was enhanced by preservatives which increase respiration, rather than inhibit it. Stomatal closure by 8-HQC was responsible for reducing transpiration and increasing rose fresh weight. This is significant since cut-flower longevitiy is directly related to maintenance of fresh weight (Aarts, 1957). Larson and Cromarty (1967) suggested that 8-HQC may prolong flower life by inhibiting bacterial growth in holding solutions. They contended that cut flower stems in solutions free of microorganisms would be less prone to blockage.

Solutions of esters of 8-HQ plus sucrose sustained quality, increased weight and prolonged life in several cut-flowers (Larsen and Scholes, 1966, 1967). Bud-cut chrysanthemum flowers held in 8-HQC + sucrose increased more in fresh weight, absorbed more solution and developed into larger flowers than those held in water. Bud-cut chrysanthemums (50-60 mm dia) held in 200 ppm 8-HQC + 2% sucrose at 74°F developed into open flowers in 6 days (Marousky, 1969b, 1971b). The mixture of sucrose and 8-HQC partially fulfills Durkin and Kue's (1966) hypothesis for certain requirements for prolonging cut-flower life. They reduce vascular blockage

and transpiration, thus reducing moisture stress within the stem and retarding flower senescence.

The 8-HQS alone or with sucrose, dramatically maintains the potential xylem conductivity at very high levels throughout the entire vase life. 8-HQS without sucrose has little influence on the appearance of the cut-flowers, whereas sucrose by itself does not affect xylem conductivity and only slightly increases the appearance of the cut-flowers. Only the combination of the two resulted in enhanced appearance and increased xylem conductivity (Gilman and Steponkus, 1972).

Wang and Gu (1985) found that addition of 8-HQS to 5 % sucrose in the presence of $AgNO_3$ gave the highest percentage of open flowers, maximum fresh weight and vase life in gladiolus. Experiments on tuberose by Khondarkar and Mazumdar (1985) revealed delayed petal senescence, retarded abscission rate of petals and neck bending when held in sucrose plus 8-HQS. Vase life studies on roses conducted by Ketsa and Treeturuyanandha (1988) revealed that 8-HQC in combination with 5 % sucrose reduced blueing, bent neck and stem blockage and increased vase life, water uptake and fresh weight.

Preservative solution containing 300 ppm 8-HQ + 10,000 ppm sucrose was found to increase the vase life, water uptake, flower diameter and petal area in cut roses (Bhattacharjee, 1994b). Preservative solution containing 8-HQS (150 ppm) + sucrose (2%) 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).

Hwang and Kim (1995) reported that pretreatment of gladiolus for 30 min. in STS, followed by pulsing for 20 h in a solution containing sucrose (40%) + 8-HQS (200 ppm) + BA (20 ppm) extended vase life by 32% and improved flower quality in terms of flower diameter, percentage flower opening, fresh weight. water uptake and anthocyanin content. Hussein and Sass (1993) reported that in Chrysanthemum flowers, holding in 100 ppm 8-HQS resulted in the longest vase life. Combination of sucrose and 8-HQS extended vase life of gladiolus (1.5 to 1.6 times) (Song *et al.*, 1992).

The vase life of rose cultivars Dame de Cocur, Lady X and Shinsei were increased by the combination of 2% sucrose, 250 ppm 8-HQ, 500 ppm citric acid, 25 ppm $AgNO_3$ and 250 ppm $CoNO_3$. In Lady X and Dame de Cocur, treatment with a combination of sucrose, 8-HQ, citric acid and $AgNO_3$ increased respiration rate, soluble sugar and reducing sugar contents of petals and slightly increased the starch content of petals (Gao and Yang, 1992).

Suneeta (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 % sucrose plus 600 ppm 8-HQ. In the case of

Her Majesty, sucrose plus $AgNO_3$ (100 or 200 ppm) solutions were also equally effective.

Role of silver nitrate

Silver ion has been used for increasing the longevity of many cut-flowers (Aarts, 1957). Silver salts, usually at 20 to 50 ppm are included in several formulations of flower preservatives (Aarts, 1957, Deswal and Patil, 1982; Farnham *et al.*, 1971; Halevy and Mayak, 1974; Kofranek and Halevy, 1972; Mayak *et al.*, 1973; Rogers, 1973) or are used at high concentration (1000-1200 ppm) for very short term (seconds to minutes) stem basal dips (Kofranek and Paul, 1974). Since the silver ion is a potent bactericide, its flower preservative properties were attributed to reduced bacterial contamination of the flower stem. (Aarts, 1957; Rogers, 1973). Beyer (1976) reported that spray applied silver ion is a potent anti-ethylene agent in several plant processes. Silver nitrate and silver thiosulphate were reported to inhibit microbial growth in vase water and ethylene synthesis in tissues, resulting in extension of vase life (Halevy and Kofranek, 1977; Mayak *et al.*, 1977). Direct coating of flowers of carnation (*Dianthus caryophyllus* L.cv. White Sim) with Ag ions by spraying or momentarily dipping flower heads with $AgNO_3$ (50-100 ppm) extended cut flower longevity and counteracted the enhancing effect of ethephon on senescence (Halevy and Kofranek, 1977).

A stem impregnation with high concentration of $AgNO_3$ for several seconds was very effective in extending the longevity of cut-flowers

(Kofranek and Paul, 1972; 1974). Mayak *et al.* (1977) reported that such a stem treatment of carnation flowers reduced bacterial population in holding solution as well as a small reduction of microbial growth within the stem. Ag^+ was effective in counteracting with metabolites formed by the interaction of microorganisms with stems and to improve water relations in the petals. Ong and Lee (1983) found increased shelf life with 25 to 40 ppm silver nitrate along with 8-HQ in holding solutions for *Oncidium* 'Golden Shower'.

A combination of sucrose, 8-hydroxyquinoline citrate and silver nitrate was found to delay the senescence of tuberose cut-flowers (Khondarkar and Mazumdar, 1985). Pulsing gladiolus stems at 21°C with 20% sucrose in combination with $AgNO_3$ before storage for 7 or 10 days resulted in greater floret opening and size than those not pulsed. (Kofranek and Halevy, 1976). Treating the stem with $AgNO_3$ will extend the post harvest life of anthurium flowers. (Paull and Goo, 1985). A $AgNO_3$ pulse (4mM, 40 min) given immediately after harvest increased vase life of stored flowers of anthurium (Paull, 1987).

Solution containing sucrose (5%) + $AgNO_3$ (50 ppm) + 8-HQ (200 ppm) extended vase life of cut carnation flowers (Chung *et al.*, 1986). Ketsa (1989) recommended that the optimum holding solution for cut inflorescences of *Dendrobium* 'Pompadour' was 200 mg 8-HQS/litre + 50 mg $AgNO_3$/litre + 8% sucrose solution; this solution increased the percentage of bud opening and vase life and decreased the opening time.

Ketsa and Boonrote (1990) reported that optimum holding solution for increasing *Dendrobium* 'Youppadeewan' flowers was 4% glucose, 225 mg/l 8-HQS and 30 mg/l $AgNO_3$.

The vase life and the quality of gerbera flowers were considerably improved when they were pulsed in $AgNO_3$ (200 ppm) + 8-HQC (200 mg/l) + Sucrose (100 g/l) or in $AgNO_3$ (200 mg/l) + Sucrose (100 g/l) before transport, and when they were kept continuously after transport in preservative solution consisting of 8-HQC (200 mg/l) + Sucrose (30 g/l) (Nowak, 1989) Treatment of gladiolus with $AgNO_3$ at 3000 ppm considerably increased vase life and flower quality (Lal *et al.*, 1993). Vase life was found to be increased in cut roses when treated with $AgNO_3$ and sucrose (Rath *et al.*, 1991).

A holding solution of 2% sucrose + 150 ppm 8-hydroxyquinoline sulphate + 50 ppm $AgNO_3$ significantly extended vase life (by 2.8 times compared with controls) and improved cut flower quality in terms of percentage of flowering and fresh weight of Eustoma flowers (Song *et al.*, 1994).

Ketsa *et al.* (1995) reported that *Dendrobium* 'Pompadour' inflorescences held in HQS + $AgNo_3$ + glucose had the longest vase life (51.51 days), compared with 7.25 days in controls held in distilled water and had the highest percentage of buds which opened (89.46%, compared with 18.82% in controls) and lowest bacterial population. Their results

suggest that $AgNO_3$ in the holding solution may act as an antimicrobial agent, and not as an inhibitor of ethylene synthesis.

To extend the vase life of carnations, a 1:8 molar ratio of $AgNO_3$: $Na_2S_2O_3$ $5H_2O$ in the STS (silver thiosulphate solution) was recommended by Uda *et al.* (1995). Vase life of cut roses was increased by use of $AgNO_3$ (Ketsa *et al.*, 1993). Water uptake was enhanced and the bacterial count was greatly reduced by $AgNO_3$. They recommended an optimum concentration of 20 mg/l of $AgNO_3$. Water uptakewas enhanced and the bacterial count (colonies/ml of holding solution) was greatly reduced by $AgNO_3$.

In cut snapdragon, flowers pretreated with STS and held in a preservative solution (2% sucrose + 150 ppm 8-HQC + 25 ppm $AgNO_3$) recorded good flower quality and long vase life (Lee *et al.*, 1995). In *Arachnis* and *Cattleya*, longevity could be enhanced by a 10 minute treatment of $AgNO_3$ (100-200 ppm) (Sharma and Kaur, 1994). Application of $AgNO_3$ at 100-200 mg/l was useful in delaying senescence in *Cattleya, Dendrobium, Oncidium* and *Rhynchostylis* and thereby increasing their shelf life. (Pathak and Kaur, 1996).

Packaging of cut-flowers

Orchid flowers are wet packed either as groups of spikes or as individual flower. For wet packing cut ends of the individual spikes are placed in a plastic vial containing water or covered with moistened cotton.

Corrugated cardboard boxes of various sizes are reported to be used for different kinds of orchids (Bhattacharjee, 1997; Paull and Sewake, 1992).

In Kerala, grower's practice of postharvest handling consists of cutting inflorescences in the morning, conditioning them in tap water for one to two hours followed by packing in ventillated cardboard cartons and subsequently transporting by air to destinations. They do not follow any pulsing treatments. Most of them preferred wet packing to dry packing. Wet packing was done by wrapping moist cotton at the basal end of 3 to 5 inflorescences together and then inserting them in small polyethylene bags which were tied up using rubber bands. Normally 50 flower spikes of approximately 50 cm length are packed in a box of 75 cm x 25 cm x 17.5 cm size. (Personel communication; Mercy and Dale, 1997).

MATERIALS AND METHODS

MATERIALS AND METHODS

The study was conducted at the Department of Horticulture, College of Agriculture, Vellayani during the period from September 1996 to January 1997. Temperature and humidity in the laboratory during the experimental period ranged respectively from 23 to 32°C and 60 to 80 per cent.

The investigation envisaged a phased standardisation of various postharvest techniques to improve the quality and vase life of *Dendrobium* cut-flowers. The study comprised of four experiments. The materials used and methods adopted are described here under.

3.1. Orchid inflorescences and varieties

Cut-flowers of popular cultivated varieties of *Dendrobium* were used for experimentation. Inflorescences were obtained from a single grower. The varieties used were *Dendrobium*. Sonia, *D*. Walter Oumae, *D*. Mary Trowse, *D*. Candy Stripe. Inflorescences of length ranging from 25 to 60 cm harvested in the morning having six to seven flowers with all except the terminal bud in the fully opened stage were used.

3.1.1. Varietal description

3.1.1.1. *Dendrobium* Sonia

This is a hybrid of *Dendrobium* Caesar x *D.* Tomie Drake. Its flowers are large white and dark pink tipped. Flower length and width varied from 6.0 to 9.5 cm and 5.5 to 9.0 cm respectively (Plate I).

3.1.1.2. *D.* Walter Oumae

Flowers are white. Flower length and width varied from 4.0 to 6.0 cm and 4.0 to 5.5 cm respectively (Plate II).

3.1.1.3. *D.* Mary Trowse

Flowers are pink in colour. Flower length and width varied from 4.5 to 7.0 cm and 4.0 to 6.5 cm respectively (Plate III).

3.1.1.4. *D.* Candy stripe

Flowers are light pink with darker pink stripes. Flower length and width varied from 4.5 to 7.0 cm and 3.5 to 6.0 cm respectively (Plate IV).

3.2. Glass ware / containers

Conical flasks (100 ml) were used for keeping the orchid inflorescence in treatment solutions. Volume of the treatment solutions used was 100 ml.

Plate 1-IV- **Dendrobium cultivars selected for the experiments**

Plate I *Dendrobium* Sonia

Plate III *Dendrobium* Mary Trowse

3.3. Packing material

Standard cardboard cartons of size 75 x 20 x 15cm were used for packing the experimental material (Plate V). Wet packing was done by wrapping cotton moistened with distilled water at the basal end of each inflorescence and then inserting them in small polythene bags which were tied up using rubber bands (Plate VI.2).

3.4. Experimental details (Table 1)

3.4.1. Treatments (Tables 2, 3 and 4)

3.4.2. Treatment procedures

3.4.2.1. Experiment No. 1

Tap water was adjusted to the required pH using 1N HCl solution and inflorescences were placed in treatment solutions (T_1-T_7) for two hours immediately after harvesting. Subsequently the vase life of the conditioned inflorescences were assessed in distilled water.

3.4.2.2. Experiment No. 2

The freshly harvested inflorescences were initially subjected to the best conditioning treatment observed in experiment No. 1 for two hours. Then they were placed in the pulsing solutions (T_1-T_{12}) for 6 hours after which they were wet packed in cardboard cartons and subjected to simulation of transport and transit for 24 hours. Then vase life was assessed by placing in distilled water.

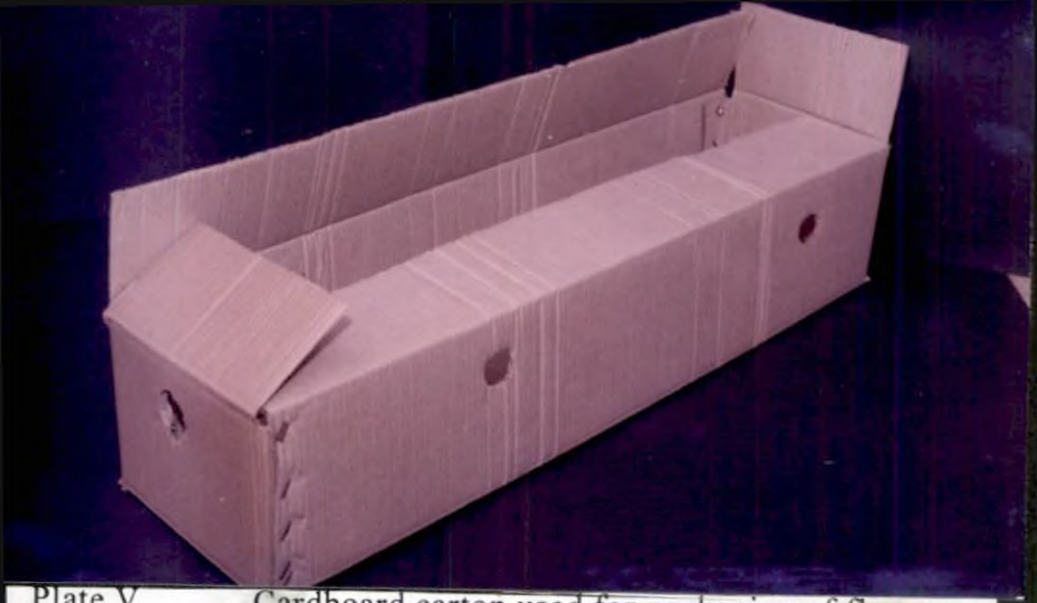


Plate V Cardboard carton used for packaging of flowers

Plate VI Wet packing methods followed for orchids

1. Using plastic vials containing holding solution

2. Using moist cotton covered with polythene

Table 1. Experimental details

Expt. No.	Title	Design	Replication	Dendrobium varieties used	No. of treatments
1.	Effect of conditioning of inflorescences in water of altered pH	CRD	3	Sonia	7
2.	Effect of pulsing solutions on vase life of inflorescences	CRD	3	Sonia	12
3. 1.	Effect of holding solutions on vase life of freshly harvested inflorescences	CRD	3	Sonia	29
2.	Effect of holding solutions on vase life of pulsed inflorescences	CRD	3	Sonia	29
4.*	---	Factorial CRD	3	Walter Oumae. Mary Trowse. Candy Stripe	5

* Best treatments of the above experiments were tried in three other varieties of Dendrobium

Table 2. Treatments of Experiment 1 and 2

Experiment No. 1. Effect of conditioning of inflorescences in water of altered pH

Treatments : 7

T_1 - Tap water with pH altered to 4.5

T_2 - Tap water with pH altered to 4.0

T_3 - Tap water with pH altered to 3.5

T_4 - Tap water with pH altered to 3.0

T_5 - Tap water with pH altered to 2.5

T_6 - Tap water of known pH (pH 4.8)

T_7 - Distilled water of known pH (pH 5.7)

Experiment No. 2. Effect of pulsing solutions on vase life of inflorescences

Treatments : 12

T_1 - Sucrose 2% + 8-HQ 200 ppm

T_2 - Sucrose 2% + 8-HQ 400 ppm

T_3 - Sucrose 2% + 8-HQ 600 ppm

T_4 - Sucrose 4% + 8-HQ 200 ppm

T_5 - Sucrose 4% + 8-HQ 400 ppm

T_6 - Sucrose 4% + 8-HQ 600 ppm

T_7 - Sucrose 6% + 8-HQ 200 ppm

T_8 - Sucrose 6% + 8-HQ 400 ppm

T_9 - Sucrose 6% + 8-HQ 600 ppm

T_{10} - Distilled water of known pH (pH 5.7)

T_{11} - Tap water of known pH (pH 4.8)

T_{12} - Absolute control (Grower's practice, without pulsing)

Table 3. Treatments of Experiments 3.1 and 3.2

Experiment No. 3.1. Effect of holding solutions on vase life of freshly harvested inflorescences

Treatments : 29

T_1 - Sucrose 2% + 8-HQ 200 ppm + $AgNO_3$ 20 ppm
T_2 - Sucrose 2% + 8-HQ 200 ppm + $AgNO_3$ 30 ppm
T_3 - Sucrose 2% + 8-HQ 200 ppm + $AgNO_3$ 40 ppm
T_4 - Sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 20 ppm
T_5 - Sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 30 ppm
T_6 - Sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 40 ppm
T_7 - Sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 20 ppm
T_8 - Sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm
T_9 - Sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 40 ppm
T_{10} - Sucrose 4% + 8-HQ 200 ppm + $AgNO_3$ 20 ppm
T_{11} - Sucrose 4% + 8-HQ 200 ppm + $AgNO_3$ 30 ppm
T_{12} - Sucrose 4% + 8-HQ 200 ppm + $AgNO_3$ 40 ppm
T_{13} - Sucrose 4% + 8-HQ 300 ppm + $AgNO_3$ 20 ppm
T_{14} - Sucrose 4% + 8-HQ 300 ppm + $AgNO_3$ 30 ppm
T_{15} - Sucrose 4% + 8-HQ 300 ppm + $AgNO_3$ 40 ppm
T_{16} - Sucrose 4% + 8-HQ 400 ppm + $AgNO_3$ 20 ppm
T_{17} - Sucrose 4% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm
T_{18} - Sucrose 4% + 8-HQ 400 ppm + $AgNO_3$ 40 ppm
T_{19} - Sucrose 6% + 8-HQ 200 ppm + $AgNO_3$ 20 ppm
T_{20} - Sucrose 6% + 8-HQ 200 ppm + $AgNO_3$ 30 ppm
T_{21} - Sucrose 6% + 8-HQ 200 ppm + $AgNO_3$ 40 ppm
T_{22} - Sucrose 6% + 8-HQ 300 ppm + $AgNO_3$ 20 ppm
T_{23} - Sucrose 6% + 8-HQ 300 ppm + $AgNO_3$ 30 ppm
T_{24} - Sucrose 6% + 8-HQ 300 ppm + $AgNO_3$ 40 ppm
T_{25} - Sucrose 6% + 8-HQ 400 ppm + $AgNO_3$ 20 ppm
T_{26} - Sucrose 6% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm
T_{27} - Sucrose 6% + 8-HQ 400 ppm + $AgNO_3$ 40 ppm
T_{28} - Distilled water of known pH (5.8)
T_{29} - Tap water of known pH (4.8)

Experiment No. 3.2 Effect of holding solutions on vase life of pulsed inflorescences

Treatments : 29

T_1-T_{29} Same as that of Experiment 3.1

Table 4. Treatments of Experiment 4

Varieties - 3

V_1 - Walter Oumae V_2 - Mary Trowse V_3 - Candy Stripe

Treatments : 5

T_1 - Best conditioning treatment[(i)] + holding in distilled water

T_2 - Best conditioning + best pulsing[(ii)] + holding in distilled water

T_3 - Best conditioning + best pulsing + best holding treatments of experiment 3.1[(iii)]

T_4 - Best conditioning + best pulsing + best holding treatments of experiment 3.2[(iv)]

T_5 - Control - holding in tap water of known pH (4.8)

Treatment combinations - 15

i. Tap water with altered pH 3.0 (T_4 of Expt. 1)

ii. Sucrose 4% + 8-HQ 400 ppm (T_5 of Expt. 2)

iii. Sucrose 6% + 8-HQ 300 ppm + $AgNO_3$ 20 ppm (T_{22} of Expt. 3.1)

iv. Sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm (T_8 of Expt. 3.2)

3.4.2.3. Experiment No. 3

This experiment included two parts. In the first part (3.1), the freshly harvested inflorescences were immediately subjected to the best conditioning treatment after which they were kept in the different treatment solutions (T_1-T_{29}) and vase life was assessed.

In the second part of the experiment (3.2), the freshly cut inflorescences were subjected to the best conditioning treatment followed by best pulsing treatment observed in experiment NO. 2 for 6 hours and were then wet packed in cartons. After 24 hours of simulation of transport and transit, the inflorescences were placed in treatment solutions (T_1-T_{29}) for assessment of vase life.

3.4.2.4. Experiment No. 4

The best treatments obtained from the other three experiments were tried in three *Dendrobium* varieties viz., Walter Oumae, Mary Trowse and Candy Stripe and compared with the control.

3.4.3. Observations

The following observations were recorded in all the experiments.

3.4.3.1. Fresh weight of the inflorescences

Fresh weight of the inflorescences were recorded at different periods

during the vase life ie., on first day (P_1), 4th day (P_2), 7th day (P_3) and at cessation of vase life (P_4) and expressed in grams.

3.4.3.2. Dry weight of the inflorescences

At cessation of vase life inflorescences were dried in a hot air oven at 70°C and weight of dried samples were recorded and expressed in grams.

3.4.3.3. Water content of the inflorescences

Difference in weight of fresh and oven dried inflorescences at cessation of vase life were recorded and its ratio to fresh weight was taken as water content which was expressed in percentage.

$$\text{Water content} = \frac{\text{Fresh weight} - \text{Dry weight}}{\text{Fresh weight}} \times 100$$

3.4.3.4. Vase life of the inflorescences

Number of days taken for the appearance of symptoms of senescence in the first flower was recorded as vase life. The vase solution was replaced on alternate days after cutting 0.5 cm of the stalk base. This process was repeated until the cessation of vase life. Vase life was expressed in days.

3.4.3.5. Sugar content of the flowers and stalk

Total sugar was determined by the copper reduction method using Fehlings solution, after HCl digestion of the dried and powdered sample (Chopra and Kanwar, 1986). It was expressed as percentage of glucose equivalent on dry weight basis.

3.4.3.6. Size of the flower

The maximum length and width of each flower in the inflorescences was taken at different periods ie., on first day (P_1), 7th day (P_2) and at cessation of vase life (P_3) and expressed in centimeters.

3.4.3.7. Colour fading / deepening of the blooms

Visual observations on the change occurring in the colour of lateral petals with advancement of flower senescence was recorded and compared with the help of a colour chart (Anonymous, 1966).

3.4.3.8. Electrical conductivity of vase solutions

Electrical conductivity of vase solutions were recorded by using conductivity bridge at different periods during the vase life.

3.4.3.9. Bending of the spikes

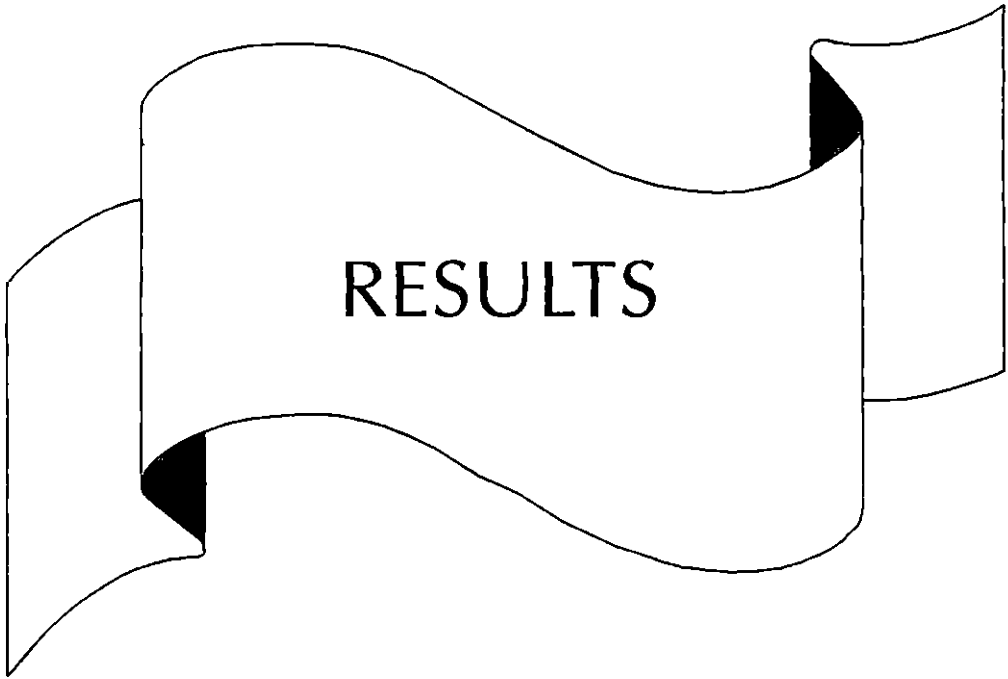
It was observed during the period of vase life.

3.4.3.10. Temperature and humidity variation in the experimental environment

This was recorded throughout the experimental period.

Analysis and interpretation of data

The data generated from the study was subjected to analysis of variance using the methods suggested by Panse and Sukhatme (1985) and interpreted.


RESULTS

RESULTS

4.1. Experiment 1

4.1.1. Fresh weight of the inflorescences

The fresh weight of the inflorescences were not influenced by the conditioning treatments during different periods of their vase life. However, the mean fresh weight of the inflorescences differed between the different periods of their vase life. The mean fresh weight recorded on the fourth day (P_2) was on par with that recorded on the first day (P_1). Thereafter a significant reduction was observed until the cessation of vase life (Table 5) when the weight recorded was 20.94 g.

4.1.2. Dry weight of the inflorescences

The dry weight of the inflorescences at cessation of vase life was not influenced by the conditioning treatments (Table 6).

4.1.3. Water content of the inflorescence

There was no significant difference due to the treatments in the water content of the inflorescences at cessation of vase life (Table 6).

Table 5. Experiment 1. Fresh weight of inflorescences at different periods of vaselife

Treatments (T)	Weight of inflorescences at different periods (P)				Mean (g)
	P_1 (First day)	P_2 (Fourth day)	P_3 (Seventh day)	P_4 (at cessation)	
T_1	22.48	22.78	22.71	20.20	22.04
T_2	28.21	28.51	28.13	26.25	27.78
T_3	20.42	20.36	19.98	18.20	19.74
T_4	21.57	21.77	21.76	20.02	21.28
T_5	20.39	20.46	19.32	17.69	19.47
T_6	22.90	23.19	23.01	21.48	22.64
T_7	27.30	27.51	25.17	22.76	25.68
Mean (g)	23.32	23.51	22.87	20.94	

	F	CD	SE
$T_{(6,14)}$	1.31^{NS}	—	2.672
$P_{(3,42)}$	34.92^{**}	0.569	0.199
$TP_{(18,42)}$	1.13^{NS}	—	0.527

** - Significant at 1% level NS - Not significant

Table 6. Experiment 1. Dry weight, water content, vase life and sugar content of inflorescences

Treatments	Dry weight (g)	Water content (%)	Vase life (days)	Sugar content (%)	
				Flowers	Stalks
T_1	1.72	91.52	13.33	27.13	14.08
T_2	2.31	91.12	12.67	24.08	12.00
T_3	1.64	90.98	19.67	22.26	9.20
T_4	1.91	90.77	20.67	31.10	15.68
T_5	1.61	90.95	14.00	24.78	11.56
T_6	1.92	91.13	9.67	22.82	10.72
T_7	2.26	89.78	8.67	23.02	14.92
$F_{(6,14)}$	0.930^{NS}	0.420^{NS}	4.498^{*}	2.608^{NS}	2.660^{NS}
CD	—	—	6.553	—	—
SE	0.302	0.832	2.160	1.938	1.451

* - Significant at 5% level NS - Not significant

4.1.4. Vase life of the inflorescences

Vase life of the inflorescences differed significantly due to the conditioning treatments (Table 6, Plates VII & VIII). The spikes conditioned in tap water of pH 3.0 (T_4) was found to have the greatest vase life among the treatments, followed by those conditioned in T_3 (Tap water altered to pH 3.5). T_4 and T_3 recorded a vase life of 20.67 and 19.67 days respectively. These two treatments were superior to the controls T_6 and T_7, which recorded 9.67 and 8.67 days respectively. The treatments T_2, T_1 and T_5 were on par.

4.1.5. Sugar content of the flowers and stalks

The sugar content of the inflorescences (flowers and stalks) at cessation of vase life did not differ significantly due to the different treatments (Table 6).

4.1.6. Size of the flowers

The mean length and width of flowers differed significantly between the different periods of observation. The mean length and width on the 4^{th} day of the vase life (P_2) were 7.84 cm and 7.58 cm respectively which was on par with that on the first day (P_1). The mean length and width were reduced significantly at the cessation of vase life (by 0.56 cm and 0.57 cm respectively) (Table 7).

Plate VII Experiment 1. Conditioned inflorescences of *Dendrobium* Sonia on the first day of vase life

Plate VIII Experiment 1. Conditioned inflorescences of *Dendrobium* Sonia during second week of their vase life

Table 7. Experiment 1. Size of the flowers at different periods of vase life

Treatments (T)	Length at different periods (P) (cm)			Mean length (cm)	Width at different periods (P) (cm)			Mean width (cm)
	P_1 (First day)	P_2 (Seventh day)	P_3 (at cessation)		P_1 (First day)	P_2 (Seventh day)	P_3 (at cessation)	
T_1	7.46	7.46	6.87	7.26	7.48	7.48	6.87	7.28
T_2	8.21	8.23	7.58	8.01	7.82	7.79	7.12	7.58
T_3	8.29	8.32	7.67	8.09	7.64	7.95	7.08	7.56
T_4	7.43	7.42	6.87	7.24	7.53	7.53	7.02	7.36
T_5	8.02	8.00	7.54	7.85	7.91	7.89	7.28	7.69
T_6	7.64	7.63	7.17	7.48	7.06	7.05	6.69	6.94
T_7	7.83	7.83	7.26	7.64	7.43	7.41	7.00	7.28
Mean (cm)	7.84	7.84	7.28	—	7.55	7.58	7.01	—

	F	CD	SE		F	CD	SE
$T_{(6,14)}$	1.56^{NS}	—	0.276	T	1.070^{NS}	—	0.244
$P_{(2,28)}$	347.18^{**}	0.050	0.017	P	124.31^{**}	0.084	0.029
$TP_{(12,28)}$	0.85^{NS}	—	0.046	TP	0.220^{NS}	—	0.077

** - Significant at 1% level NS - Not significant

4.2. Experiment 2

4.2.1. Fresh weight of inflorescences

The pulsing treatments did not significantly influence the fresh weight of the conditioned inflorescences observed during four different periods of their vase life. However, the mean fresh weight recorded on 4th day (28.42 g) was found to be significantly superior than that recorded during the other three periods. The lowest mean fresh weight (23.60 g) was recorded at cessation of vase life (Table 8).

4.2.2. Dry weight of the inflorescences

Dry weight of the inflorescences did not differ significantly among the treatments (Table 9).

4.2.3. Water content of the inflorescences

There was no significant difference in the water content of the inflorescences subjected to the various treatments (Table 9).

4.2.4. Vase life of the inflorescences

The different pulsing treatments had a significant effect on the vase life of the inflorescences. The spikes pulsed with T_5 (Sucrose 4% + 8-HQ 400 ppm) recorded the highest vase life of 21.33 days. The lowest vase life of 10 days was recorded by the spikes pulsed in distilled water followed by T_{12}, T_{11}, T_7, T_2, T_4, T_8 and T_3 all of which were on par (Table 9).

Table 8. Experiment 2. Fresh weight of the inflorescences at different periods of vase life

Treatments (T)	Different periods (P)				Mean (g)
	P_1 (First day)	P_2 (Fourth day)	P_3 (Seventh day)	P_4 (at cessation)	
T_1	30.03	32.70	28.62	26.75	29.52
T_2	26.94	29.01	26.24	23.87	26.52
T_3	32.43	33.79	32.08	28.89	31.80
T_4	23.07	24.19	22.99	20.16	22.60
T_5	24.44	27.41	24.54	21.58	24.49
T_6	24.41	26.61	23.58	21.12	23.93
T_7	28.51	29.73	26.50	25.09	27.46
T_8	28.34	29.82	28.11	24.79	27.77
T_9	29.36	31.56	27.89	26.10	28.73
T_{10}	24.05	24.37	23.76	20.94	23.28
T_{11}	23.25	24.22	23.40	20.32	22.80
T_{12}	27.09	27.56	25.99	23.55	26.05
Mean (g)	26.83	28.42	26.14	23.60	—

	F	CD	SE
$T_{(11,24)}$	0.320^{NS}	—	5.205
$P_{(3,72)}$	253.30^{**}	0.356	0.126
$TP_{(33,72)}$	1.57^{NS}	—	0.436

** - Significant at 1% level NS - Not significant

Table 9. Experiment 2. Dry weight, water content, vase life and sugar content of inflorescences

Treatments	Dry weight (g)	Water content (%)	Vase life (days)	Sugar content (%)	
				Flowers	Stalks
T_1	2.67	90.03	18.67	19.25	10.89
T_2	2.32	91.75	12.33	16.22	7.52
T_3	2.84	90.01	13.67	13.08	9.51
T_4	2.00	89.98	12.67	16.05	9.93
T_5	1.59	90.08	21.33	24.09	8.90
T_6	2.01	90.45	14.00	15.82	7.37
T_7	2.30	90.81	10.67	19.63	8.62
T_8	2.37	90.52	13.00	27.64	9.97
T_9	2.08	89.69	14.00	14.22	8.20
T_{10}	2.71	89.64	10.00	18.38	10.53
T_{11}	2.16	89.77	10.67	18.42	7.35
T_{12}	2.32	90.30	10.33	20.06	10.27
$F_{(11,24)}$	0.36^{NS}	0.72^{NS}	6.44^{**}	2.49^{*}	0.66^{NS}
CD	—	—	3.942	7.590	—
SE	0.582	0.692	1.350	2.600	1.570

** - Significant at 1% level * - Significant at 5% level NS - Not significant

4.2.5. Sugar content of the flowers and stalks

The pulsing treatments influenced the sugar content of flowers. Inflorescences pulsed with sucrose 6% + 8-HQ 400 ppm (T_8) recorded the highest sugar content (27.64 %) in the flowers, which was on par with T_5 (24.09%) and T_{12} (20.06%). The lowest (13.08 per cent) was obtained with T_3 (sucrose 2% + 8-HQ 600 ppm) which was on par with T_1, T_2, T_4, T_6, T_7, T_9, T_{10} and T_{11}.

The treatments recorded no significant effect on the sugar content of the stalks (Table 9).

4.2.6. Size of the flower

The length and width of flowers did not differ significantly among the treatments, but at different periods during experimentation significant differences in flower size was observed. On the first and the seventh day the mean flower length was greatest in the treatments and at cessation of vase life, the length was reduced to 7.70 cm.

The mean width of flowers was the highest and on par on the first and the seventh day (7.75 cm) and then it was reduced to 7.29 cm at the cessation of vase life. The interaction of treatments and periods of observation were found significant for width of flowers. The flowers treated with T_3 recorded the maximum width on the first (8.03 cm) and the seventh day (8.00 cm) of vase life. The flower width was the lowest for T_4 (7.17 cm) followed by T_{10}, T_5, T_7 and T_{12} at P_3 (Table 10).

Table 10. Experiment 2. Size of the flowers at different periods of vase life

Treatments (T)	Length (cm)			Mean length (cm)	Width (cm)			Mean width (cm)
	P_1 (First day)	P_2 (Seventh day)	P_3 (at cessation)		P_1 (First day)	P_2 (Seventh day)	P_3 (at cessation)	
T_1	7.58	7.59	7.30	7.49	7.51	7.47	7.43	7.43
T_2	8.03	8.06	7.61	7.90	7.80	7.81	7.25	7.62
T_3	8.49	8.47	7.98	8.31	8.03	8.00	7.50	7.84
T_4	7.93	7.94	7.52	7.80	7.68	7.68	7.17	7.51
T_5	7.8	7.89	7.46	7.74	7.73	7.74	7.21	7.56
T_6	8.07	8.07	7.64	7.93	7.70	7.71	7.28	7.56
T_7	8.44	8.44	8.09	8.32	7.61	7.63	7.21	7.48
T_8	8.31	8.31	7.86	8.16	7.95	7.96	7.46	7.79
T_9	8.03	8.02	7.6.	7.90	7.79	7.78	7.29	7.62
T_{10}	8.04	8.05	7.59	7.89	7.70	7.62	7.18	7.50
T_{11}	8.20	8.20	7.72	8.04	7.83	7.83	7.37	7.68
T_{12}	8.10	8.10	7.62	7.94	7.62	7.63	7.27	7.50
Mean (cm)	8.09	8.10	7.70		7.75	7.74	7.29	

	F	CD	SE	F	CD	SE
$T_{(11,24)}$	0.794^{NS}	—	0.263	0.458^{NS}	—	0.184
$P_{(2,48)}$	367.889^{**}	0.036	0.012	601.074^{**}	0.030	0.010
$TP_{(22,48)}$	0.600^{NS}	—	0.044	2.757^{**}	0.104	0.036

** - Significant at 1% level NS - Not significant

4.3.1. Experiment 3.1

4.3.1.1. Fresh weight of the inflorescences

The treatments did not influence the fresh weight of the spikes during their vase life but there was significant difference in fresh weight between different periods of the vase life. The mean fresh weight of the spikes was found to be the highest during the fourth day of the vase life (P_2) and the lowest at cessation of vase life (P_4). The mean fresh weight of 22.22 g on the first day (P_1) increased to 24.41 g by the fourth day (P_2) and thereafter it reduced to 20.10 g at the cessation of vase life (P_4).

The interaction between the treatments and different periods of the vase life were found to be non significant.

4.3.1.2. Dry weight of the inflorescences

The treatment effects on dry weight of the inflorescences was not significant (Table 12).

4.3.1.3. Water content of the inflorescences

There was no significant difference in the water content of the inflorescences at cessation of vase life due to the treatments (Table 12).

Table 11. Experiment 3.1. Fresh weight of the inflorescences at different periods of vase life

Treatments (T)	Different periods (P)				Mean (g)
	P_1 (First day)	P_2 (Fourth day)	P_3 (Seventh day)	P_4 (at cessation)	
T_1	17.11	19.86	17.79	14.58	17.33
T_2	19.33	21.85	20.32	17.57	19.76
T_3	22.90	25.02	23.68	20.19	22.95
T_4	19.66	22.21	20.43	17.03	19.83
T_5	21.33	23.88	22.66	18.73	21.65
T_6	21.74	23.89	22.55	18.84	21.75
T_7	21.60	23.66	22.72	18.55	21.63
T_8	25.12	27.60	26.18	23.17	25.52
T_9	20.33	22.31	19.66	18.14	20.11
T_{10}	24.37	25.92	25.36	21.33	24.24
T_{11}	24.23	22.54	21.96	18.83	21.14
T_{12}	30.83	31.66	30.96	28.09	30.38
T_{13}	19.20	21.15	19.12	16.99	19.11
T_{14}	20.38	23.20	21.31	18.11	20.75
T_{15}	23.72	26.37	25.39	21.07	24.14
T_{16}	19.04	19.79	19.09	16.57	18.62
T_{17}	24.18	27.10	25.79	21.53	24.65
T_{18}	25.24	28.06	26.60	23.97	25.97
T_{19}	22.83	25.32	23.53	20.64	23.08
T_{20}	22.55	24.33	22.82	20.34	22.51
T_{21}	21.97	24.59	24.05	20.81	22.86
T_{22}	19.02	22.56	21.45	17.81	20.21
T_{23}	21.23	23.16	22.46	19.72	21.64
T_{24}	20.95	22.33	21.87	19.54	21.17
T_{25}	34.06	37.08	35.96	33.24	35.08
T_{26}	19.65	21.69	20.99	18.53	20.21
T_{27}	19.15	21.88	21.04	18.08	20.04
T_{28}	23.98	25.48	23.62	21.44	23.63
T_{29}	21.57	23.54	22.43	19.40	21.73
Mean (g)	22.22	24.41	23.16	20.10	—

	F	CD	SE
$T_{(28,28)}$	0.49^{NS}	—	5.100
$P_{(3,174)}$	1073.78^{**}	0.15	0.055
$TP_{(4,174)}$	2.50^{NS}	—	0.299

** - Significant at 1% level NS - Not significant

Table 12. Experiment 3.1. Dry weight, water content, vase life and sugar content of the inflorescences

Treatments (T)	Dry weight (g)	Water content (%)	Vase life (days)	Sugar content (%)	
				Flowers	Stalks
T_1	1.45	90.04	17.67	17.30	10.02
T_2	1.87	89.44	19.00	16.54	8.78
T_3	2.02	90.31	15.00	15.48	7.45
T_4	1.58	90.71	13.00	17.29	7.90
T_5	1.66	91.16	22.67	22.42	11.00
T_6	1.78	90.44	14.33	26.69	10.12
T_7	1.87	89.51	16.67	17.97	9.51
T_8	2.03	91.03	21.00	20.29	10.11
T_9	1.81	89.99	19.67	17.19	8.19
T_{10}	2.21	89.85	9.00	16.10	7.87
T_{11}	1.80	90.61	12.67	18.91	9.98
T_{12}	2.82	90.02	9.67	15.03	6.84
T_{13}	1.57	90.92	17.00	17.31	10.53
T_{14}	1.90	89.44	19.33	14.32	7.57
T_{15}	2.06	90.19	23.00	18.29	10.38
T_{16}	1.51	90.68	15.33	12.32	6.92
T_{17}	2.05	90.55	25.33	9.56	4.60
T_{18}	2.17	90.78	17.00	13.22	6.45
T_{19}	2.14	89.61	16.33	12.64	7.10
T_{20}	1.91	90.35	18.00	17.26	9.52
T_{21}	1.94	91.56	25.00	10.94	5.16
T_{22}	1.68	90.07	26.00	13.99	7.92
T_{23}	1.78	90.42	23.33	17.60	9.86
T_{24}	1.90	90.67	15.00	19.10	9.97
T_{25}	3.49	90.01	20.33	12.31	6.89
T_{26}	1.92	89.21	22.00	10.61	5.75
T_{27}	1.86	89.72	25.33	10.91	6.53
T_{28}	2.14	89.09	8.33	20.73	10.67
T_{29}	1.96	89.98	9.33	15.01	8.29
$F_{(28,58)}$	0.567^{NS}	1.022^{NS}	8.074^{**}	2.369^{**}	2.134^{*}
CD	—	—	5.181	7.043	3.447
SE	0.524	0.110	1.832	2.490	1.218

** - Significant at 1% level * - Significant at 5% level NS - Not significant

4.3.1.4. Vase life of the inflorescences

The influence of different holding solution treatments on the vase life of the inflorescences was significant. The vase life was the greatest with T_{22} (26 days) followed by T_{27} and T_{17} (25.33 days), T_{21} (25 days), T_{23} (23.33 days), T_{15} (23 days), T_5 (22.67 days), T_{26} (22 days) and T_8 (21 days) which were on par. The lowest vase life of 8.33 days was observed in T_{28} (Distilled water) followed by T_{10} (9 days), T_{29} (9.33 days), T_{12} (9.67 days) T_{11} (12.67 days) and T_4 (13.00 days) which were on par (Table 12).

4.3.1.5. Sugar content of the flowers and stalks

The sugar content of the flowers and stalks at cessation of vase life was significantly influenced by the treatments. The sugar content of the flowers was the highest (26.69%) in the inflorescences treated with T_6 followed by T_5, T_{28} (Distilled water control) and T_8 which were on par. The lowest content of 9.56% was recorded by T_{17} which was on par with T_2, T_3, T_{10}, T_{12}, T_{16}, T_{18}, T_{19}, T_{21}, T_{22}, T_{25}, T_{26}, T_{27} and T_{29} (Tap water control).

The sugar content of the stalks was found to be the highest (11 %) for T_5 (Sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 30 ppm) which was on par with T_1, T_2, T_4, T_6, T_7, T_8, T_9, T_{10}, T_{11}, T_{13}, T_{14}, T_{15}, T_{20}, T_{22}, T_{23}, T_{24}, T_{28} and T_{29}.

The lowest content 4.60% was recorded by T_{17} which was on par with T_3, T_4, T_{10}, T_{12}, T_{14}, T_{16}, T_{18}, T_{19}, T_{21}, T_{22}, T_{25}, T_{26} and T_{27} (Table 12).

4.3.1.6. Size of the flower

The treatments did not significantly influence the length and width of flowers. But at different periods during their vase life, the mean length and width of the flowers differed significantly (Table 13).

The mean length was the highest (7.86 cm) on the first day (P_1) and was reduced to 7.82 cm by the fourth day (P_2). It was further reduced to 7.37 cm at the cessation of vase life (P_3).

The mean width was the highest (7.41 cm) on the first day which was on par with that on the fourth day (P_2). It was reduced significantly to 6.95 cm at the cessation of vase life (Table 13).

Interaction between the treatments and the different periods of the vase life did not significantly influence the length and width of the flowers.

Table 13. Experiment 3.1. Size of the flower at different periods of vase life

Treatments (T)	Length (cm)			Mean (cm)	Width (cm)			Mean (cm)
	P_1	P_2	P_3		P_1	P_2	P_3	
T_1	7.14	7.09	8.87	7.04	6.71	6.70	6.36	6.59
T_2	7.93	7.97	7.77	7.89	7.11	7.26	6.97	7.11
T_3	8.26	8.25	7.85	8.12	7.90	7.93	7.40	7.74
T_4	8.12	8.12	7.68	7.97	7.75	7.74	7.38	7.62
T_5	7.89	7.93	7.48	7.77	7.06	7.09	6.74	6.96
T_6	7.68	7.65	7.25	7.53	7.14	7.04	6.86	7.01
T_7	8.65	8.50	8.31	8.49	7.80	7.80	7.44	7.68
T_8	8.09	8.05	7.67	7.94	7.51	7.53	7.00	7.35
T_9	7.61	7.53	7.07	7.40	7.51	7.47	7.15	7.37
T_{10}	7.65	7.72	7.24	7.57	7.44	7.42	6.92	7.26
T_{11}	7.81	7.80	7.00	7.54	7.43	7.40	6.95	7.26
T_{12}	7.84	7.74	7.19	7.59	7.35	7.34	6.79	7.16
T_{13}	7.40	7.31	6.91	7.20	7.62	7.57	7.01	7.40
T_{14}	7.88	7.80	7.37	7.71	7.01	7.04	6.53	6.86
T_{15}	8.10	8.09	7.51	7.90	7.76	7.77	7.41	7.65
T_{16}	7.91	7.83	7.37	7.71	7.66	7.59	7.33	7.53
T_{17}	7.77	7.81	7.29	7.62	7.24	7.26	6.72	7.07
T_{18}	7.51	7.45	6.89	7.28	6.87	6.90	6.45	6.74
T_{19}	7.76	7.70	7.29	7.59	7.43	7.34	6.79	7.19
T_{20}	7.82	7.76	7.20	7.59	7.55	7.42	7.00	7.32
T_{21}	7.58	7.56	7.01	7.38	7.06	7.03	6.60	6.90
T_{22}	7.88	7.78	7.45	7.70	7.59	7.54	6.96	7.36
T_{23}	8.29	8.15	7.84	8.09	7.91	7.76	7.39	7.69
T_{24}	7.37	7.29	6.77	7.14	7.10	7.03	6.61	6.91
T_{25}	7.96	7.90	7.36	7.74	7.59	7.50	7.13	7.41
T_{26}	7.95	7.84	7.56	7.78	7.67	7.64	7.04	7.45
T_{27}	7.81	7.84	7.32	7.66	7.63	7.65	6.91	7.40
T_{28}	8.24	8.23	7.74	8.07	7.57	7.57	7.08	7.41
T_{29}	8.01	7.92	7.55	7.83	6.96	6.89	6.49	6.78
Mean (cm)	7.86	7.82	7.37		7.41	7.39	6.95	

	F	CD	SE	F	CD	SE
$T_{(28,58)}$	0.747^{NS}	—	0.365	0.566^{NS}	—	0.410
$P_{(2,116)}$	503.218^{**}	0.033	0.012	442.195^{**}	0.034	0.012
$TP_{(56,116)}$	1.381^{NS}	—	0.065	1.255^{NS}	—	0.067

** - Significant at 1% level NS - Not significant

4.3.2. Experiment 3.2

4.3.2.1. Fresh weight of the inflorescences

Fresh weight of the inflorescences was not influenced by the different treatments but significant changes in fresh weight was observed during the different periods of the vase life. The initial mean fresh weight of 21.50 g on the first day (P_1) increased significantly to the highest value of 23.42 g on the fourth day of the vase life (P_2). Thereafter a gradual reduction was observed and the lowest mean fresh weight was recorded at cessation of the vase life (P_4) (Table 14).

Interaction of the treatments with the different periods was significant. All the treatments on fourth day (P_2) recorded a significantly greater fresh weight than their initial fresh weight (P_1). Interaction effects resulted in inflorescences treated with T_{15} (Sucrose 4% + 8-HQ 300 ppm + $AgNO_3$ 40 ppm) recording the highest fresh weight of 30.18 g on the fourth day of the vase life and those treated with T_5 (sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 30 ppm) recording the lowest, at cessation of vase life. (P_4)

4.3.2.2. Dry weight of the inflorescences

There was no significant difference in dry weight of the pulsed spikes due to the treatments (Table 15).

Table 14. Experiment 3.2. Fresh weight of the inflorescences at different periods of vase life

Treatments (T)	Different periods (P)				Mean (g)
	P_1 (First day)	P_2 (Fourth day)	P_3 (Seventh day)	P_4 (at cessation)	
T_1	23.45	24.90	23.16	21.07	23.14
T_2	22.83	24.11	23.16	20.00	22.53
T_3	19.53	21.23	20.00	17.11	19.47
T_4	19.26	21.33	19.50	16.88	19.24
T_5	17.42	18.68	17.44	14.91	17.11
T_6	23.76	25.88	24.22	20.95	23.70
T_7	22.35	23.74	22.30	19.27	21.91
T_8	23.77	27.85	25.36	21.79	24.69
T_9	24.30	26.87	24.98	20.49	24.16
T_{10}	22.90	24.39	22.89	20.18	22.59
T_{11}	21.54	24.28	22.91	17.65	21.60
T_{12}	24.46	26.78	24.90	21.60	24.44
T_{13}	21.39	22.75	21.34	18.16	20.91
T_{14}	22.21	24.42	23.38	19.29	22.32
T_{15}	26.51	30.18	28.00	22.95	26.91
T_{16}	20.17	21.72	20.29	17.21	19.85
T_{17}	21.48	24.64	22.18	17.86	21.54
T_{18}	22.70	24.58	23.32	20.16	22.69
T_{19}	19.98	21.26	19.80	16.86	19.50
T_{20}	21.78	23.57	21.46	18.35	21.30
T_{21}	19.93	22.53	20.60	16.28	19.84
T_{22}	19.83	21.32	20.14	16.34	19.41
T_{23}	20.31	21.76	20.22	17.07	19.84
T_{24}	21.21	22.98	21.79	18.26	21.06
T_{25}	20.19	21.45	20.36	18.41	20.10
T_{26}	19.88	20.77	18.44	17.00	19.02
T_{27}	21.54	24.33	22.74	19.24	21.96
T_{28}	20.00	21.28	20.24	16.87	19.60
T_{29}	18.86	19.54	17.60	15.80	17.95
Mean (g)	21.50	23.42	21.82	18.55	

	F	CD	SE
$T_{(28,58)}$	0.255^{NS}	—	4.372
$P_{(3,174)}$	926.44^{**}	0.184	0.066
$TP_{(84,174)}$	2.23^{**}	0.994	0.358

** - Significant at 1% level NS - Not significant

Table 15. Experiment 3.2. Dry weight, water content, vase life and sugar content of the inflorescences

Treatment	Dry weight (g)	Water content (%)	Vase life (days)	Sugar content (%)	
				Flowers	Stalks
T_1	2.24	89.73	12.00	24.96	12.31
T_2	2.31	88.06	8.33	24.78	12.22
T_3	1.71	89.80	18.00	25.21	10.50
T_4	1.90	88.50	18.67	27.64	11.90
T_5	1.47	90.08	11.67	16.61	9.36
T_6	2.01	90.45	14.00	25.88	12.95
T_7	1.83	90.37	12.33	25.92	12.35
T_8	2.17	90.26	22.00	21.61	11.04
T_9	2.29	88.27	21.67	25.48	14.26
T_{10}	2.26	89.25	14.33	22.02	10.04
T_{11}	2.07	88.11	21.67	14.32	8.48
T_{12}	2.01	90.35	18.67	19.65	10.27
T_{13}	1.89	89.46	12.00	24.52	12.40
T_{14}	1.99	89.72	18.00	22.71	12.77
T_{15}	2.14	90.22	20.67	20.97	13.73
T_{16}	2.01	88.30	13.00	24.97	12.46
T_{17}	1.76	90.19	20.00	20.60	11.84
T_{18}	2.17	89.31	15.33	22.79	13.14
T_{19}	1.57	90.52	9.67	22.03	12.31
T_{20}	1.79	90.11	17.33	18.38	10.53
T_{21}	2.00	88.19	16.00	20.53	11.54
T_{22}	1.70	89.62	18.33	24.32	14.11
T_{23}	1.94	88.82	14.33	26.12	12.45
T_{24}	1.76	89.43	15.33	21.28	11.08
T_{25}	1.68	90.85	13.67	19.74	9.79
T_{26}	2.14	89.02	12.33	19.83	10.87
T_{27}	1.66	90.17	17.67	13.70	7.94
T_{28}	1.88	89.89	9.67	21.77	11.04
T_{29}	1.01	89.32	8.33	20.92	11.72
$F_{(28,58)}$	0.440^{NS}	1.050^{NS}	14.139^{**}	3.729^{**}	2.436^{**}
CD	—	—	3.042	5.045	2.803
SE	0.430	0.150	1.075	1.784	0.991

** - Significant at 1% level NS - Not significant

4.3.2.3. Water content of the inflorescences

Water content of the spikes did not significantly differ among the treatments (Table 15).

4.3.2.4. Vase life of the inflorescences

The treatments had a significant influence on the vase life of the pulsed orchid spikes (Table 15). Inflorescences treated with T_8 (sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm) recorded the highest vase life of 22 days which was on par with T_9, T_{11}, T_{15} and T_{17}. All the treatments were superior to the tap water control (T_{29}) and T_2 which recorded the lowest vase life of 8.33 days.

4.3.2.5. Sugar content of the flowers and stalks

The holding solution treatments significantly influenced the sugar content of the flowers. It was found to be the highest (27.64%) with T_4 (sucrose 2% + 8-HQ 300 ppm + $AgNO_3$ 20 ppm) which was on par with T_1, T_2, T_3, T_6, T_7, T_9, T_{13}, T_{14}, T_{18}, T_{22} and T_{23}. The lowest sugar content was observed with T_{27} (13.7%) which was on par with T_5, T_{11} and T_{20}.

Spikes treated with T_9 (sucrose 2% + 8-HQ 400 ppm + $AgNO_3$ 40 ppm) recorded the highest sugar content of 14.26% in their stalks which was on par with T_1, T_2, T_4, T_6, T_7, T_{13}, T_{14}, T_{15}, T_{16}, T_{17}, T_{18}, T_{19} T_{21}, T_{22}, T_{23} and T_{29}. The lowest sugar content of 7.94% was recorded by

those treated with T_{27} which was on par with T_3, T_5, T_{10}, T_{11}, T_{12}, T_{20} and T_{25} (Table 15).

4.3.2.6. Size of the flowers

Flower size was not influenced by the treatments. However, the length and the width of the flowers differed significantly at the different periods of the vase life (Table 16).

The mean length was highest (7.60 cm) on the first day of vase life (P_1) which was on par with (P_2). Then it was significantly reduced to 7.06 at cessation of vase life (P_3).

The mean width also followed the same pattern. The greatest mean width of 7.09 cm was recorded on the first day (P_1) which was on par with P_2 and the lowest width (6.47 cm) was recorded at cessation of vase life.

4.4. Experiment 4

4.4.1. Fresh weight of the inflorescences

The treatments did not affect the fresh weight of the inflorescences of the three varieties. However the mean fresh weight was significantly different at different periods of the vase life. The interaction between treatments, varieties and periods as well as that between treatments and varieties was not significant; whereas interaction between treatments and periods and that between varieties and periods was significant (Table 17 and 18).

Table 16. Experiment 3.2. Size of the flower at different periods of vase life

Treatments (T)	Length (cm)			Mean (cm)	Width (cm)			Mean (cm)
	P_1	P_2	P_3		P_1	P_2	P_3	
T_1	7.78	7.79	7.48	7.68	7.36	7.35	6.86	7.19
T_2	7.42	7.39	6.82	7.21	6.55	6.54	6.01	6.37
T_3	7.25	7.22	6.77	7.08	6.39	6.38	5.59	6.12
T_4	7.64	7.62	6.90	7.38	7.20	7.14	5.98	6.77
T_5	7.74	7.71	6.84	7.43	7.23	7.21	6.30	6.91
T_6	7.32	7.31	6.25	6.96	6.98	7.02	6.22	6.74
T_7	8.16	8.15	7.57	7.96	7.38	7.35	6.85	7.19
T_8	7.46	7.48	6.82	7.25	7.04	7.03	6.14	6.74
T_9	7.52	7.46	7.19	7.39	7.16	7.07	6.70	6.98
T_{10}	7.79	7.83	7.33	7.65	7.21	7.21	6.77	7.06
T_{11}	7.10	7.10	6.71	6.97	6.48	6.48	5.83	6.26
T_{12}	8.18	8.13	7.60	7.97	7.58	7.51	7.21	7.43
T_{13}	7.96	7.95	7.45	7.79	7.59	7.56	6.96	7.37
T_{14}	7.13	7.13	6.76	7.01	6.57	6.63	5.67	6.29
T_{15}	7.73	7.69	7.30	7.57	7.28	7.23	6.73	7.08
T_{16}	7.89	7.90	7.50	7.76	7.24	7.26	6.91	7.14
T_{17}	7.22	7.22	6.81	7.08	6.49	6.49	5.85	6.28
T_{18}	7.00	6.98	6.42	6.80	6.86	6.82	6.27	6.65
T_{19}	6.82	6.83	6.00	6.95	6.60	6.61	5.46	6.22
T_{20}	7.55	7.55	6.93	7.34	7.14	7.13	6.48	6.92
T_{21}	7.12	7.11	6.48	6.90	6.44	6.45	5.86	6.25
T_{22}	7.88	7.89	7.25	7.67	7.52	7.49	7.07	7.36
T_{23}	7.88	7.88	7.37	7.71	7.17	7.17	6.88	7.67
T_{24}	7.83	7.80	7.54	7.72	7.33	7.32	6.85	7.17
T_{25}	8.16	8.04	7.63	7.94	7.54	7.44	6.88	7.28
T_{26}	7.84	7.84	7.53	7.74	7.32	7.34	6.92	7.19
T_{27}	7.68	7.69	7.32	7.57	7.17	7.18	6.61	6.99
T_{28}	7.23	7.25	6.71	7.06	6.81	6.80	6.19	6.60
T_{29}	7.97	7.74	7.49	7.73	8.05	7.94	7.55	7.85
Mean (cm)	7.60	7.58	7.06		7.09	7.07	6.47	

	F	CD	SE	F	CD	SE
$T_{(28,58)}$	0.504^{NS}	—	0.541	0.613^{NS}	—	0.560
$P_{(2,116)}$	308.212^{**}	0.047	0.017	260.106^{**}	0.060	0.021
$TP_{(56,116)}$	1.387^{NS}	—	0.092	1.244^{NS}	—	0.118

** - Significant at 1% level NS - Not significant

Table 17. Experiment 4. Mean fresh weight of inflorescences at different periods of vase life

Varieties (V) and different periods (P) of vase life		Treatments (T) T_1	T_2	T_3	T_4	T_5	Mean varieties (g)
	P_1	18.44	25.58	18.09	17.63	19.68	
	P_2	19.76	27.27	20.70	19.28	20.28	
V_1	P_3	17.74	23.26	16.75	17.81	17.74	19.28
	P_4	14.90	22.34	15.30	15.30	17.74	
	P_1	20.39	16.95	17.39	14.51	19.20	
	P_2	21.79	17.97	20.04	16.69	19.94	
V_2	P_3	20.00	14.92	17.54	13.87	18.12	17.35
	P_4	17.66	14.08	15.29	13.14	17.77	
	P_1	17.10	16.27	16.69	19.35	20.12	
	P_2	18.42	18.42	19.40	21.79	21.50	
V_3	P_3	17.74	16.21	17.16	19.29	20.28	17.92
	P_4	14.61	13.31	15.33	16.88	18.73	
Mean of treatments		18.21	18.88	17.47	17.12	19.24	
		P_1	P_2	P_3	P_4		
Mean of different periods		18.49	20.19	17.90	16.16		

	F	CD	SE		F	CD	SE
$T_{(4,30)}$	0.393^{NS}	—	1.436	$TP_{(12,90)}$	1.790^{**}	0.744	0.264
$V_{(2,30)}$	0.794^{NS}	—	1.112	$VP_{(6,90)}$	2.914^{*}	0.576	0.205
$P_{(3,90)}$	197.955^{**}	0.333	0.118	$TVP_{(24,90)}$	0.701^{NS}	—	0.458
$TV_{(8,90)}$	1.156^{NS}	—	2.487				

** - Significant at 1% level * - Significant at 5% level NS - Not significant

Table 18. Experiment 4. Interaction effects on fresh weight of inflorescences

		Treatments (T)					Mean	Varieties (V)		
		T_1	T_2	T_3	T_4	T_5		V_1	V_2	V_3
Different periods (P)	P_1	18.65	19.60	17.39	17.16	19.66	18.49	19.88	17.69	17.91
	P_2	19.99	21.22	20.05	19.21	20.48	20.19	21.46	19.23	19.88
	P_3	18.49	18.13	17.15	16.99	18.71	17.90	18.66	16.89	18.13
	P_4	15.72	16.58	15.31	15.11	18.08	16.16	17.12	15.59	15.77
Mean		18.21	18.88	17.47	17.11	19.24		19.28	17.38	17.92
	V_1	17.71	24.61	17.71	17.51	18.86				
	V_2	19.96	15.98	17.57	14.55	18.69				
	V_3	16.97	16.05	17.15	19.29	20.16				

	F	CD	SE
$T_{(4,30)}$	0.393^{NS}	—	1.436
$V_{(2,30)}$	0.794^{NS}	—	1.112
$P_{(3,90)}$	197.955^{**}	0.333	0.118
$TV_{(8,90)}$	1.156^{NS}	—	2.487
$TP_{(12,90)}$	1.790^{**}	0.744	0.264
$VP_{(6,90)}$	2.914^{*}	0.576	0.205
$TVP_{(24,90)}$	0.701^{NS}	—	0.458

** - Significant at 1% level * - Significant at 5% level NS - Not significant

4.4.1.1. Walter Oumae (V_1)

The mean fresh weight of the spikes of this variety (Table 18) increased from 19.88 g on the first day to 21.46 g on the fourth day (highest) and this was maintained until the seventh day (P_3). It was then decreased to 17.12 g (the lowest) at the cessation of vase life (P_4).

The spikes treated with T_2 (conditioned at pH 3 and pulsed with sucrose 4% + 8-HQ 400 ppm) recorded the maximum mean fresh weight on the first (25.58 g) and the fourth day (27.27 g). The lowest mean fresh weight of this variety was found in the spikes treated with T_1, T_3 or T_4 on the first day, T_1, T_3, T_4 and T_5 on the seventh day and T_3, T_4 and T_5 at cessation of vase life (Table 17).

4.4.1.2. Mary Trowse (V_2)

The mean fresh weight (Table 18) of this variety increased from 17.69 g on the first day (P_1) to 19.23 g on the fourth day (P_2) which was on par with P_3. Then it decreased gradually to 15.59 at the cessation of vase life (P_4).

The spikes treated with T_1 (conditioning at pH 3.0) on the fourth day of vase life (P_2) recorded the highest mean fresh weight of 21.79 g which was on par with T_1P_1, T_1P_3, T_3P_2, T_5P_1, T_5P_2 and T_5P_3. The lowest mean fresh weight of 13.14 g was recorded by spikes treated with T_4 (conditioning at pH 3.0 + pulsing with sucrose 4% + 8-HQ 400 ppm)

and holding solution with sucrose 4% + 8-HQ 400 ppm + $AgNO_3$ 30 ppm) at the cessation of vase life (P_4) which was on par with T_4P_3.

4.4.1.3. Candy Stripe (V_3)

The highest mean fresh weight (Table 18) of 19.88 g was recorded on the fourth day of the vase life (P_2). The lowest mean fresh weight of 15.77 g was recorded at the cessation of vase life (P_4).

Among the different treatments (Table 17), T_4 recorded the highest mean fresh weight of 21.79 g on the fourth day of the vase life (P_2) followed by T_5P_2 which were on par. The lowest mean fresh weight of 13.31 g was recorded by T_2 at the cessation of vase life (P_4) which was significantly lower than those in all other treatments during all periods.

4.4.2. Dry weight of the inflorescences

The dry weight of the spikes did not differ significantly among the different treatments and varieties. Data are presented in Table 19.

4.4.3. Water content of the inflorescences

No significant difference among treatments and varieties were observed in the water content of the spikes (Table 19).

Table 19. Experiment 4. Interaction effects on the dry weight and water content of the inflorescences

Treatment (T)	Dry weight (g)				Water content (%)			
	Varieties (V)			Mean	Varieties (V)			Mean
	V_1	V_2	V_3		V_1	V_2	V_3	
T_1	1.55	1.85	1.69	1.70	89.39	89.42	88.39	89.07
T_2	1.92	1.86	1.44	1.74	91.42	87.33	89.20	89.32
T_3	1.56	1.71	1.49	1.59	89.79	88.88	90.29	89.65
T_4	1.57	1.16	1.72	1.48	89.78	91.16	89.82	90.25
T_5	1.65	1.76	1.61	1.68	90.75	90.06	91.40	90.74
Mean	1.65	1.67	1.59	—	90.23	89.37	89.82	—

	F	SE	F	SE
$T_{(4,30)}$	0.386^{NS}	0.163	1.994^{NS}	0.484
$V_{(2,30)}$	0.104^{NS}	0.126	1.307^{NS}	0.375
$TV_{(14,30)}$	0.456^{NS}	0.282	1.808^{NS}	0.839

NS - Not significant

4.4.4. Vase life of the inflorescences

The three cultivars did not differ in the total duration of their vase life. Among the treatments, T_3 was found superior with a vase life of 11.33 days which was on par with all the treatments except the control. Control treatment (T_5) recorded the lowest mean vase life of 7.00 days (Table 20) for all the three varieties.

4.4.4.1. Walter Oumae (V_1)

Maximum vase life of 11 days of this variety was recorded by T_4 followed by T_3 and T_2 which were on par. The lowest vase life of 6 days was recorded by the control (T_5).

4.4.4.2. Mary Trowse

In this variety, T_4 resulted in the highest vase life of 11 days followed by T_3 and T_2 which were on par. The lowest vase life was recorded by the control (6.33 days).

4.4.4.3. Candy Stripe

The highest vase life of 13 days was observed with T_3 which was on par with T_1, T_2 and T_4. The lowest of 8.67 days was recorded by T_5 (control).

Table 20. Experiment 4. Interaction effect on the vase life of the inflorescences (days)

Variety (V)	Treatments (T)					Mean
	T_1	T_2	T_3	T_4	T_5	
V_1	8.00	9.33	10.67	11.00	6.00	9.00
V_2	9.00	9.33	10.33	11.00	6.33	9.20
V_3	12.00	11.33	13.00	11.67	8.67	11.33
Mean	9.67	10.00	11.33	11.22	7.00	

	F	CD	SE
$T_{(4,30)}$	7.302*	1.870	0.647
$V_{(2,30)}$	6.641	—	0.501
$TV_{(14,30)}$	3.225*	3.240	1.122

* - Significant at 5% level

The interaction between treatments and varieties influenced the vase life. Variety Candy Stripe treated with T_3 was found to have the highest vase life which was on par with T_1V_3, T_2V_3, T_3V_1, T_3V_2, T_4V_1, T_4V_2 and T_4V_3. The lowest vase life of 6 days was observed with Walter Oumae treated with T_5 (control) followed by T_5V_2, T_1V_1, T_5V_3 and T_1V_2 which were on par.

4.4.5. Sugar content of the flowers and stalks

There was significant difference in the sugar content of the flowers due to the treatments. Varietal differences in sugar content was not significant. However, interaction between treatments and varieties influenced the sugar content. T_2 recorded the highest sugar content of 29.37%. The lowest was recorded by T_3 (21.28 %) which was on par with T_1 (23.34 %). Control treatment (T_5) resulted in 25.61 per cent sugar in the flowers (Table 21).

As a result of interaction T_2V_2 (Var. Mary Trowse receiving the treatment T_2) recorded the highest sugar content of 33.74% and T_2V_3 recorded a content of 30.21 per cent and were on par. The lowest content (19.53%) was recorded with T_3V_2 which was on par with T_1V_1, T_1V_2, T_3V_1, T_3V_3, T_4V_1, T_4V_2 and T_5V_3.

Sugar content of the inflorescence stalks did not differ significantly due to the treatments and among the varieties.

Table 21. Experiment 4. Interaction effects on the sugar content (%) of flowers and stalks

Treatment (T)	Flowers				Stalks			
	Varieties (V)			Mean	Varieties (V)			Mean
	V_1	V_2	V_3		V_1	V_2	V_3	
T_1	23.28	21.66	25.09	23.34	7.71	11.56	11.13	10.13
T_2	24.16	33.74	30.21	29.37	8.80	16.06	12.62	12.49
T_3	23.66	19.53	20.67	21.28	12.28	10.82	10.71	11.27
T_4	22.20	21.56	27.98	23.91	13.40	11.95	14.01	13.12
T_5	28.07	25.67	23.09	25.61	16.17	16.13	12.58	14.96
Mean	24.27	24.43	25.41		11.67	13.30	12.21	

	F	CD	SE	F	CD	SE
$T_{(4,30)}$	12.515^{*}	2.474	0.856	4.864^{NS}	—	0.832
$V_{(2,30)}$	0.854^{NS}	—	0.663	1.662^{NS}	—	0.644
$TV_{(14,30)}$	6.797^{**}	4.286	1.484	3.023^{*}	4.163	1.441

** - Significant at 1% level * - Significant at 5% level NS - Not significant

However, their interaction was found to be significant. The highest value of 16.17% was obtained for Walter Oumae treated with T_5 which was found to be on par with T_2V_2, T_2V_3, T_3V_1, T_4V_1, T_4V_3, T_5V_2 and T_5V_3. The lowest was recorded with T_1V_1, (7.71%) which was on par with T_1V_2, T_1V_3, T_2V_1, T_3V_2 and T_3V_3.

4.4.6. Size of the flower

The flower length was not influenced by the treatments, varieties and their interaction. However, the mean length differed significantly at the different periods of the vase life. Interaction between these periods and the treatments were also significant (Tables 22 and 23).

A gradual reduction in length was observed from period 1 to period 3. P_1 was superior to P_2 and P_3. On the first day (P_1) the mean flower length was 5.92 cm while on the seventh day (P_2) and at cessation of vase life (P_3) it was reduced to 5.79 cm and 5.49 cm respectively.

The mean flower width was significantly influenced by the different treatments and their interaction with varieties. The varieties and different periods of the vase life did not influence the mean flower width. Their mutual interaction and that with the treatments were not significant (Tables 24 and 25).

Table 22. Experiment 4. Interaction effects on the length of flower at different periods of vase life

Varieties (V) and different periods (P) of vase life		Treatments (T) T_1	T_2	T_3	T_4	T_5	Mean varieties
V_1	P_1	5.71	5.57	5.93	5.59	5.59	5.42
	P_2	5.60	5.24	5.76	5.59	4.87	
	P_3	5.32	5.16	5.47	5.09	4.87	
V_2	P_1	6.84	6.52	5.66	6.26	6.42	6.17
	P_2	6.68	6.34	5.69	6.23	6.16	
	P_3	6.49	6.24	5.14	5.75	6.10	
V_3	P_1	6.47	5.53	5.27	5.51	5.92	5.61
	P_2	6.40	5.53	5.27	5.50	5.92	
	P_3	6.24	5.04	4.94	5.03	5.51	
Mean of treatments		6.19	5.68	5.46	5.62	5.71	
		P_1		P_2		P_3	
Mean of different periods		5.92		5.79		5.49	

	F	CD	SE
$T_{(4,30)}$	2.049^{NS}	—	0.193
$V_{(2,30)}$	6.758^{NS}	—	0.149
$TV_{(8,30)}$	1.107^{NS}	—	0.334
$P_{(2,60)}$	144.548^{**}	0.052	0.018
$TP_{(8,60)}$	3.974^{*}	0.115	0.041
$VP_{(4,60)}$	4.113^{NS}	—	0.032
$TVP_{(16,60)}$	2.075^{NS}	—	0.071

** - Significant at 1% level * - Significant at 5% level NS - Not significant

Table 23. Experiment 4. Mean length of flowers

		Treatments (T)					Mean	Varieties (V)		
		T_1	T_2	T_3	T_4	T_5		V_1	V_2	V_3
Different periods (P)	P_1	6.34	5.87	5.62	5.79	5.98	5.92	5.68	6.34	5.74
	P_2	6.22	5.70	5.57	5.78	5.65	5.79	5.41	6.22	5.72
	P_3	6.02	5.48	5.18	5.29	5.49	5.49	5.18	5.94	5.35
Mean		6.19	5.68	5.46	5.62	5.71		5.42	6.17	5.61
	V_1	5.54	5.32	5.72	5.42	5.11				
	V_2	5.67	6.37	5.50	6.08	6.23				
	V_3	6.37	5.37	5.16	5.34	5.78				

	F	CD	SE
$T_{(4,30)}$	2.049^{NS}	—	0.193
$V_{(2,30)}$	6.758^{NS}	—	0.149
$TV_{(8,30)}$	1.107^{NS}	—	0.334
$P_{(2,60)}$	144.548^{**}	0.052	0.018
$TP_{(8,60)}$	3.974^{*}	0.115	0.041
$VP_{(4,60)}$	4.113^{NS}	—	0.032
$TVP_{(16,60)}$	2.075^{NS}	—	0.071

** - Significant at 1% level * - Significant at 5% level NS - Not significant

Table 24. Experiment 4. Interaction effects on the width of the flowers at different periods of vase life

Varieties (V) and different periods (P) of vase life		Treatments (T) T_1	T_2	T_3	T_4	T_5	Mean varieties
V_1	P_1	5.14	5.05	5.35	5.01	5.06	4.91
	P_2	4.91	4.78	5.28	5.18	4.51	
	P_3	4.68	4.58	4.98	4.54	4.66	
V_2	P_1	6.29	6.04	4.76	5.79	5.06	5.36
	P_2	5.95	5.72	4.69	5.57	4.97	
	P_3	5.79	5.52	4.31	5.37	4.59	
V_3	P_1	5.74	4.32	4.87	5.06	4.88	4.71
	P_2	5.60	4.32	4.89	5.04	3.06	
	P_3	5.32	3.62	4.51	4.70	4.65	
Mean of treatments		5.49	4.88	4.85	5.14	4.60	—
Mean of different periods		P_1 5.23	P_2 4.96	P_3 4.79			

	F	CD	SE
$T_{(4,30)}$	6.425^{*}	0.384	0.133
$V_{(2,30)}$	10.587^{NS}	—	0.103
$TV_{(8,30)}$	3.875^{*}	0.665	0.230
$P_{(2,60)}$	6.833^{NS}	—	0.085
$TP_{(8,60)}$	1.101^{NS}	—	0.190
$VP_{(4,60)}$	0.246^{NS}	—	0.147
$TVP_{(16,60)}$	0.744^{NS}	—	0.328

* - Significant at 5% level NS - Not significant

Table 25. Experiment 4. Mean width of flowers

		Treatments (T)					Mean	Varieties (V)		
		T_1	T_2	T_3	T_4	T_5		V_1	V_2	V_3
Different periods (P)	P_1	5.72	5.14	4.99	5.29	5.00	5.23	5.12	5.59	4.97
	P_2	5.49	4.94	4.95	5.26	4.18	4.96	4.93	5.38	4.58
	P_3	5.26	4.58	4.60	4.87	4.63	4.79	4.69	5.11	4.56
Mean		5.49	4.88	4.85	5.14	4.60	—	4.91	5.36	4.71
V_1		4.91	4.81	5.20	4.91	4.74				
V_2		6.90	5.76	4.59	5.58	4.87				
V_3		5.55	4.09	4.76	4.93	4.20				

	F	CD	SE
$T_{(4,30)}$	6.425^{*}	0.384	0.133
$V_{(2,30)}$	10.587^{NS}	—	0.103
$TV_{(8,30)}$	3.875^{*}	0.665	0.230
$P_{(2,60)}$	6.833^{NS}	—	0.085
$TP_{(8,60)}$	1.101^{NS}	—	0.190
$VP_{(4,60)}$	0.246^{NS}	—	0.147
$TVP_{(16,60)}$	0.744^{NS}	—	0.328

* - Significant at 5% level NS - Not significant

Among the treatments, T_1 recorded the highest mean width of 5.49 cm which was on par with T_4 (5.14 cm). The lowest value of 4.60 cm was recorded by T_5 which was on par with T_2 and T_3.

4.4.6.1. Walter Oumae (V_1)

4.4.6.1.1. Mean length of flowers

The mean flower length of 5.68 cm observed on the first day (P_1) was reduced significantly to 5.41 cm on the seventh day (P_2) and then to 5.18 cm at the cessation of vase life (P_3) (Table 23).

Interaction between treatments and the periods of the vase life of Walter Oumae was significant (Table 22). T_3P_1 recorded the highest mean flower length of 5.93 cm. The lowest value (4.87 cm) was recorded by T_5 on the seventh day (P_2) and at the cessation of vase life (P_3).

4.4.6.1.2. Mean width of flowers

The mean flower width (Table 25) was the highest (5.20 cm) in the inflorescences treated with T_3 which was on par with T_1 and T_4. The lowest mean width was observed with T_5 (4.74 cm).

4.4.6.2. Mary Trowse (V_2)

4.4.6.2.1. Mean length of flowers

The mean flower length (Table 23) of 6.34 cm on the first day (P_1) was significantly reduced to 6.22 cm on the seventh day (P_2) and then to 5.94 cm at cessation of vase life (P_3).

As a result of interaction between treatments and the periods of the vase life, inflorescences treated with T_1 on the first day (P_1) recorded

the highest mean flower length of 6.84 cm (Table 22). The lowest was recorded with T_3P_1 (5.14 cm).

4.4.6.2.2. Mean width of flowers

The mean flower width of Mary Trowse was found to be the highest in the inflorescences treated with T_1 (6.90 cm). The lowest width of 4.59 cm was recorded by T_3 which was on par with T_5 (Table 25).

4.4.6.3. Candy Stripe

4.4.6.3.1. Mean length of flowers

The mean flower length (Table 23) was found to be the highest (5.74 cm) on the first day (P_1) which was on par with (P_2). The lowest value of 5.35 cm was recorded at the cessation of vase life (P_3).

As a result of interaction between treatments and the different periods of the vase life, inflorescences treated with T_1 on the first day (P_1) and on the seventh day (P_2) were found to be superior to others with a mean flower length of 6.47 cm and 6.40 cm respectively (Table 22). The lowest mean flower length of 4.94 cm was recorded at the cessation of vase life (P_3) in the inflorescences treated with T_3 which was on par with T_2P_3 and T_4P_3.

4.4.6.3.2. Mean width of flowers

The mean flower width was the highest in the inflorescences treated with T_1 (5.55 cm). The lowest was recorded by T_2 (4.09 cm) which was on par with T_5 (Table 25).

4.5. Electrical conductivity of the holding solution

The electrical conductivity of the holding solution treatments was observed to be in traces, beyond the detectable range at different periods during the vase life.

4.6. Spike bending

Bending of the spikes was not observed during the vase life.

4.7. Colour fading of the petals

The treatments were not found to influence the change in colour of the petals. However, the original petal colour was found to change gradually towards cessation of vase life. The observations were recorded and based on these, a colour chart was developed for the four cutivars, depicting the variations in petal colour observed during their vase life periods (Fig. 1, Plate IX to XII).

In *Dendrobium* Sonia, the colour changed from violet-purple (77B) to amethyst-violet (81C) and then to various shades of brown (182B to 177D) and finally to brown (165B). In Mary Trowse, the change was from violet-purple (77C) to purple (80C and 80D), and then to shades of brown (182B) and finally to brown (165B). In Candy Stripe, the change was from phlox-purple (75B) to shades of pink (62B) and then to pinkish brown (182D and 182C) and finally to brown (165B). In Walter Oumae,

Plate IX-XII.Colour changes of flowers during vase life period

Plate IX *Dendrobium* Sonia

Plate X *Dendrobium* Walter Oumae

Plate XII *Dendrobium* Candy Stripe

the flowers changed from white gradually to off-white (159B) and then to pale brown (173D) and finally to a darker brown (177D).

4.8. Temperature and humidity

Temperature and humidity variations in the experimental environment (laboratory) were recorded throughout the experimental period (Table 26). The lowest mean maximum temperature was recorded during October 1996 and the lowest mean minimum was recorded during December 1996. The highest mean maximum and mean minimum temperature were recorded during January 1997.

Table 26. Temperature and humidity variations in the experimental environment

Month		Temperature (°C)		Relative humidity (%)
		Mean Maximum	Mean Minimum	
September	1996	29.7	26.3	80.5
October	1996	28.1	25.4	79.7
November	1996	28.3	25.8	80.1
December	1996	30.3	24.7	75.3
January	1997	30.7	28.9	72.7

DISCUSSION

DISCUSSION

To evolve recommendations for postharvest treatment of *Dendrobium* cut flowers, investigations on the effect of conditioning, pulsing and the use of holding solutions for maximising vase life and flower quality were carried out. The cultivar selected for detailed study was *Dendrobium* Sonia and the favourable results of Experiments 1, 2, 3.1 and 3.2 were tried in *Dendrobium* Walter Oumae, D. Mary Trowse and D. Candy Stripe to assess their applicability to these popular cultivars.

The postharvest life of cut-flowers depends on pre-harvest and postharvest factors (Halevy and Mayak, 1979; 1981; Anonymous, 1980). About one-third of the postharvest life is estimated to be influenced by the pre-harvest conditions and two-third by the postharvest environment and handling techniques (Holley, 1963). Continuing the supply of water and carbohydrates to cut-flowers and retardation of the onset of senescence help to prolong their life (Halevy and Mayak, 1979). To preserve the quality of cut-flowers and to make them resistant to fluctuations in the postharvest environment, conditioning or hardening of the flowers and the use of floral preservatives have been widely recommended. Most of the preservatives contain carbohydrates, germicides, ethylene inhibitors, growth

regulators and certain mineral compounds. In the present study, combinations of a sugar (sucrose), a germicide (8-hydroxyquinoline) and an ethylene inhibitor (Ag^+) in the form of silver nitrate were tried.

Conditioning of the inflorescences immediately after harvest for two hours in tap water of altered pH (Exp. 1) was found to influence the vase life in *Dendrobium* Sonia (Table 6, Fig. 2). The best conditioning treatment was tap water altered to pH 3.0 (T_4), followed by T_3 (pH 3.5) which gave a vase life of 20.67 and 19.67 days respectively (Fig. 2). These results are in agreement with that reported by Aarts (1957), Marousky (1971a) and Pokorny and Kamp (1955) that roses held at low pH lasted longer than those held at high pH. Better water conductance, was observed to be the cause of longer life at pH 3.0 when compared to pH 5 to 7 (Marousky, 1971a). In this experiment, the advantage of conditioning in pH 3.0 or 3.5 on vase life may be due to the enhancement of water uptake and limiting of microbial growth at the lowered pH which are effects reported by Nowak and Rudnicki (1990) in many cut-flowers.

The fresh weight, dry weight, water content, sugar content and flower size were not influenced by the conditioning treatments. However, irrespective of the treatments, the flowers absorbed water from the vase solutions and gained in fresh weight upto the fourth day (P_2) during the vase life period. Thereafter, the fresh weight declined towards the cessation of vase life (Table 5).

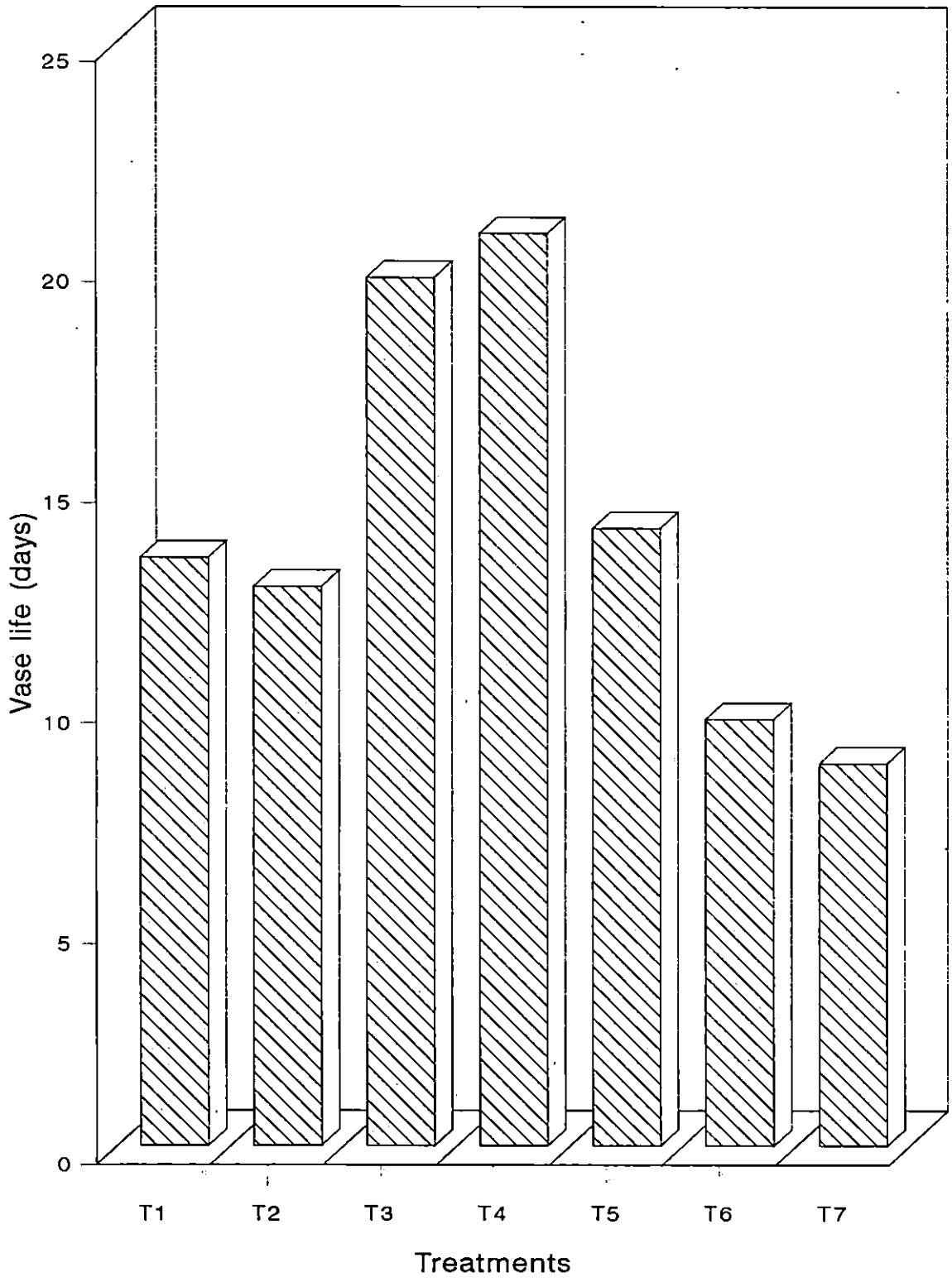


Fig. 2. Experiment 1 - Vase life of inflorescences

The maximum length and width of the flowers taken as a measure of size was not influenced by the conditioning treatments (Table 7). Even so, changes in flower size were observed during the vase life period irrespective of the conditioning given. The maximum length and width were maintained in the flowers upto the fourth day, on par with that on the first day. Thereafter, structural changes leading to reduction in length and width was observed towards the cessation of vase life. Ketsa and Amutiratana (1986b) observed a similar positive correlation between the vase life and the length and width of the flowers in *Dendrobium* Pompadour.

Pulsing of the conditioned inflorescences in various concentrations of sucrose and 8-HQ prior to wet packing and simulation of transport and transit for 24 hours (Exp. 2) was found to influence the vase life. The flowers pulsed with 4% sucrose + 400 ppm 8-HQ (T_5) recorded the highest vase life of 21.33 days followed by T_1 (2% sucrose + 200 ppm 8-HQ) with 18.67 days (Table 9, Fig. 3). Short-term pre treatment with sugar solutions has been reported to increase the longevity of gladiolus spikes (Mayak *et al.*, 1973). The combination of esters of 8-HQ and sucrose was reported to sustain quality and prolong cut-flower life by many workers (Coorts *et al.*, 1965; Larsen and Scholes, 1965; 1966; 1967). A synergistic effect of 8-HQS with either glucose or sucrose on extending the vase life of *Dendrobium* 'Youppadeewan' flowers was observed by Ketsa and Boonrote (1990). In the present study, the effect of the pulsing treatments T_5 and

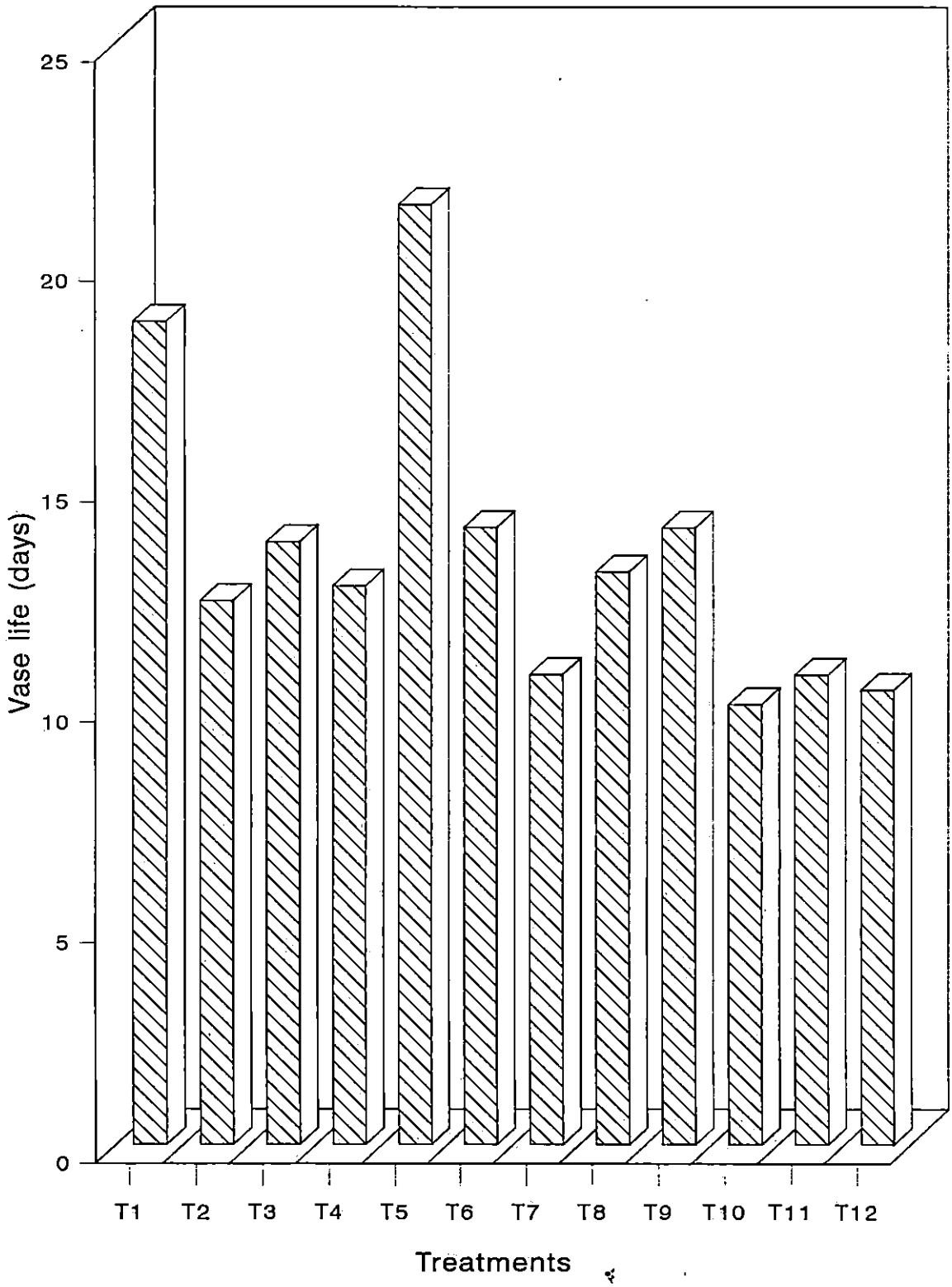


Fig. 3. Experiment 2 - Vase life of inflorescences

T_1 indicate a similar activity at the particular concentrations of sucrose and 8-HQ.

Pulsing with treatments other than T_5 or T_1 resulted in a low vase life similar to that observed under no pulsing (T_{12}) which was 10.33 days. Vase life was minimum in flowers pulsed with T_4 and T_6 (8.66 days and 7.33 days respectively) when compared to those pulsed with T_5 all of which had the same concentration of sucrose (4%), but different concentrations of 8-HQ indicating that the dosage of 8-HQ in combination with sucrose was critical and endorse the probability of their synergistic activity.

The manifold role of sucrose in combination with chemical preservatives on improving the vase life of cut flowers has been elucidated by many workers (Marousky, 1970; Mayak *et al.*, 1973; Choi and Roh, 1980; Rao and Ram, 1981; Wang and Gu, 1985 and Garibaldi and Deambrogio, 1989). 8-HQ has been formed by many workers to be the most effective preservative that can be used in combination with sucrose for increasing the post harvest quality of cut-flowers (Marousky, 1973; Marousky and Woltz, 1975; Wang and Gu, 1985; Khondarkar and Mazumdar, 1985 and Gao and Wu, 1990), which endorse the present findings on pulsing.

Pulsing was not found to directly influence the length and width of the flowers during their vase life (Table 10). However flower width was

influenced by the interaction between pulsing treatments and the different periods of the vase life.

Flower width was greater in the flowers pulsed with T_3 at cessation of vase life. Though T_8 and T_1 were on par with T_3, greater width was maintained by T_3 treated flowers for upto 18 days at which cessation of vase life took place while the same was maintained by the T_1 and T_8 treated flowers for upto 13 days only.

The vase life of the freshly harvested inflorescences subjected to conditioning in tap water of pH 3.0 was influenced by the holding solution treatments (Exp. 3.1, Fig. 4). The lowest vase life was for T_{28} (8.33 days) which was on par with T_4 (13.00 days), T_{10} (9.00 days), T_{11} (12.67 days) and T_{29} (9.33 days). The vase life was the highest in the flowers held in T_{22} (26 days), T_{17} and T_{27} (25.33 days), T_{21} (25 days), T_{23} (23.33 days), T_{15} (23.00 days) and T_5 (22.67 days). Among these, T_{17}, T_{21}, T_{22} and T_{27} resulted in three times the vase life obtained in distilled water (T_{28}). T_{22} and T_{23} contained 6% sucrose and 300 ppm 8-HQ with 20 or 30 ppm $AgNO_3$ and T_{21} and T_{27} had the same concentration of sucrose with 40 ppm silver nitrate and 200 or 400 ppm 8-HQ (Table 12).

Several holding solutions have been reported by workers to be beneficial for various cut-flowers. 10,000 ppm sucrose + 300 ppm 8-HQ was found to increase water uptake (Bhattacharjee, 1994a; 1994b) while Wang and Gu (1985) found 8-HQS and silver nitrate with 5% sucrose to give maximum fresh weight and vase life in gladiolus. In *Eustoma* flowers,

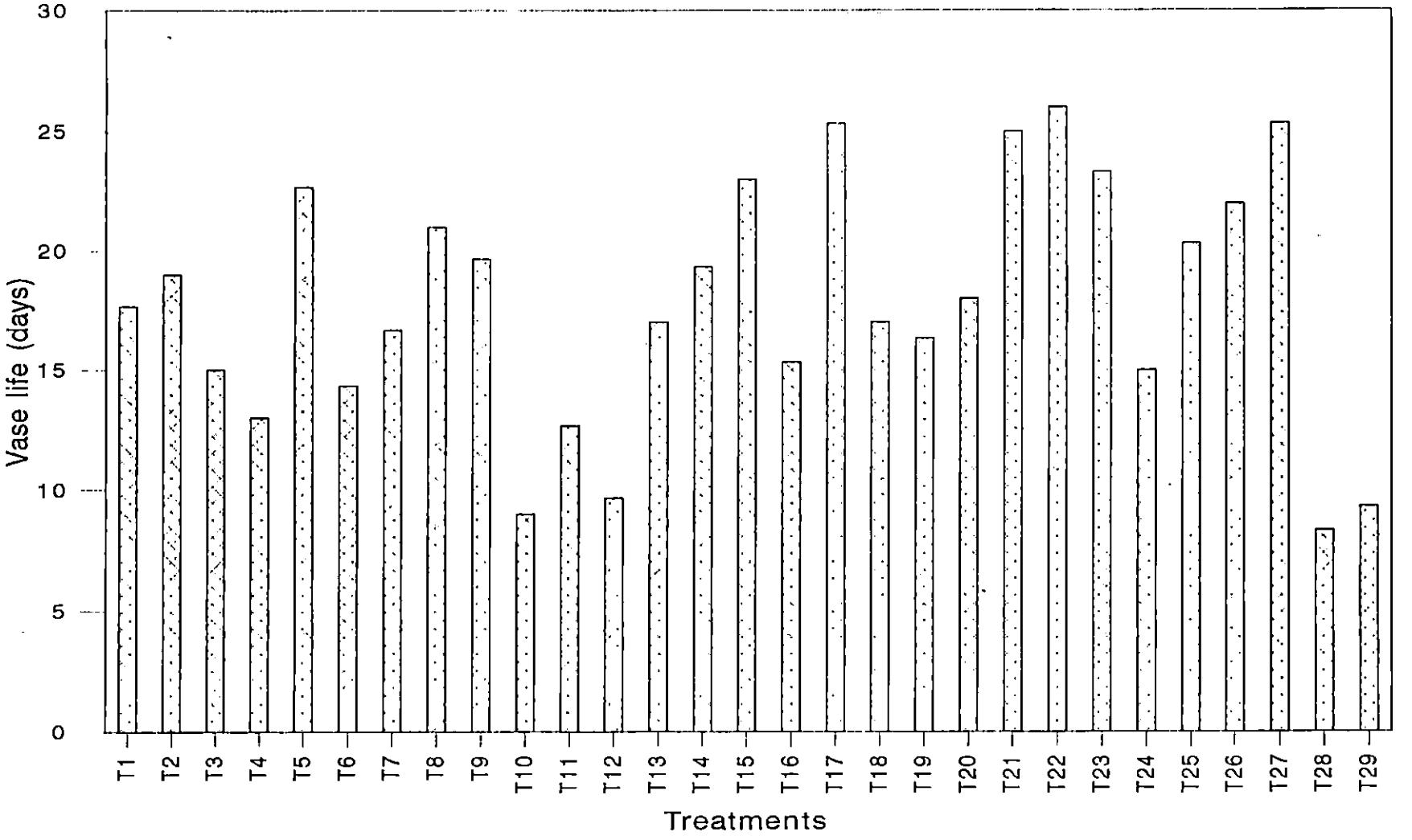


Fig. 4. Experiment 3.1 - Vase life of inflorescences

Song *et al.* (1994) reported 2% sucrose + 150 ppm 8-HQS + 50 ppm $AgNO_3$ to be beneficial and in cut roses, treatment with 20 mg/l of $AgNO_3$ or silver-thio sulphate was found to be beneficial (Ketsa *et al.*, 1993). The vase life observed in T_6 (14.33 days) and T_4 (13.00 days) which had the same concentration of sucrose and 8-HQ and a difference of ± 10 ppm $AgNO_3$ with T_5 (22.67 days) suggest that the concentration of components in the holding solutions are critical.

Several workers have reported beneficial effects on vase life enhancement in orchids by the use of holding solutions containing sucrose, 8-HQ salts and $AgNO_3$. Ketsa and Boonrote (1990) recommended 4% glucose with 225 mg/l of 8-HQS and 30 mg/l of $AgNO_3$ as being optimum for *Dendrobium* 'Youppadeewan'. Nowak and Vacharotayan (1980) found improvement in flower quality and vase life of *Arachnis, Aranthera, Dendrobium, Oncidium, Vanda* and *Vandopsis* cultivars for upto 20 days, in holding solutions containing 2 to 5% sucrose, 200 to 400 ppm 8-HQC and 25 ppm silver nitrate. In *Dendrobium* 'Pompadour' and D. 'Jacquelin Thomas', the combination of 2% sucrose and 200 ppm 8-HQC was found to be better while Ketsa *et al.* (1995) reported that the combination of glucose, 8-HQS and silver nitrate was better for enhancing the vase life of *Dendrobium* 'Pompadour' flowers.

At cessation of vase life, the sugar content of the flowers and stalks was found to be influenced by the holding solution treatments (Table 12). The content was generally low in the flowers which had a greater

vase life due to the treatments solutions (T_{17}, T_{21}, T_{22} and T_{27}) except for T_5 and T_8 which had a high content even after 20 days of the vase life period. An initial high sugar level in these flowers may have resulted in this accumulation. Flowers with the highest sugar content at harvest have been observed to keep the longest (Knappenberger *et al.*, 1955). The low sugar content in the stalks of the flowers treated with T_{17}, T_{21} and T_{27} indicate that active mobilization from the stalks was probable.

Changes in fresh weight and water content of the inflorescence were not influenced by the holding solution treatments. However, the fresh weight of the flowers increased upto the fourth day of the vase life and by the seventh day a decline was observed which progressed towards the cessation of vase life (Table 11).

The vase life of the conditioned and pulsed inflorescences were also influenced by the holding solution treatments (Exp. 3.2). The flowers held in T_8, T_9, T_{11}, T_{15} and T_{17} had a vase life of 20 days or more. The concentration of sucrose was 2% in T_8 and T_9 and 4% in the rest and that of silver nitrate was 30 ppm in T_8 and T_{17} and 40 ppm in the others. The concentration of 8-HQ was 400 ppm in T_8, T_9 and T_{17} and 200 ppm in T_{11} and 300 ppm in T_{15} (Table 15, Fig. 5). The relatively low sucrose concentration of these effective holding solution treatments when compared to those of the non-pulsed flowers of Exp. 3.1 indicate that pulsed flowers responded to lower sugar concentrations probably due to their being already loaded with sugar. In holding solutions of high sugar concentration,

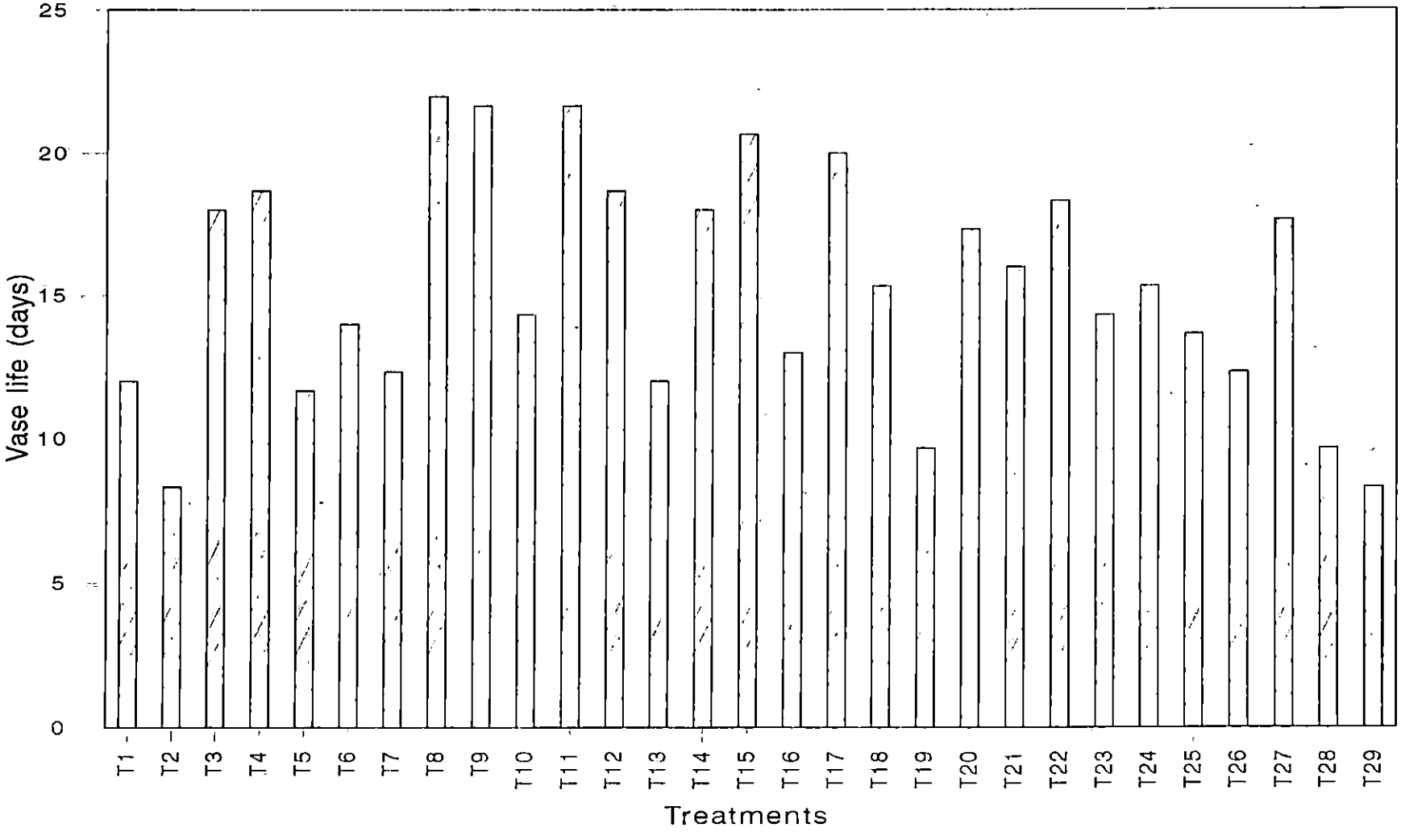


Fig. 5. Experiment 3.2 - Vase life of inflorescences

reduction of water absorption due to increase in osmotic potential has been reported (Borochov *et al.*, 1976). In the pulsed flowers, a reduction in vase life observed in holding solutions having high sugar concentrations may be attributed to a similar effect.

The general reduction in vase life observed in the conditioned and pulsed flowers when compared to the conditioned and non-pulsed flowers, may be due to the postharvest conditions to which the former were subjected. Postharvest conditions have been reported to effect in loss of turgidity (Wongkaew and Techapinyawat, 1992) and to trigger autocatalytic ethylene production leading to the onset of senescence (Arditti, 1979; Nair, 1984) in orchid flowers.

As in the non-pulsed flowers, in the pulsed flowers too fresh weight at the cessation of vase life was not influenced by the holding solution treatments and similar changes in fresh weight of the flowers was observed during the vase life period, irrespective of the treatments. The results indicate that in both the groups, flowers having a greater vase life could maintain a greater fresh weight for longer periods (Table 14).

In the freshly harvested inflorescences subjected to conditioning alone (Exp. 3.1) and the conditioned and pulsed inflorescences subjected to simulation of transport and transit (Exp. 3.2) the holding solution treatments did not influence flower size. However, changes in the length

and width of the flowers was noticed during the vase life period, irrespective of the treatments.

In the freshly harvested inflorescence, the length was maximum (7.86 cm) on the first day of the vase life period and was significantly reduced by the fourth day with further reduction to 7.37 cm at the cessation of vase life (Table 13). The maximum flower width (7.41 cm) was maintained to the fourth day of the vase life period and was thereafter reduced at the cessation of vase life to 6.95 cm. These results indicated that structural changes in the lip and dorsal sepal leading to a reduction in the length of the displayed flower surface took place earlier than structural changes of the lateral sepals leading to reduction in the width of the flowers.

In the conditioned and pulsed flower of Exp. 3.2, changes in flower size during the vase life period were different (Table 16). Structural changes in the length and width of the flowers followed a similar pattern during the vase life period. The maximum length and width were maintained from the first to the fourth day and reduction took place thereafter. The pulsing given to these flowers may have acted to retard structural changes leading to earlier reduction in flower length which was observed in the non-pulsed flowers.

In the fourth experiment, where the best treatment of Experiment 1 (T_4), Experiment 2 (T_5) and the best holding solution treatment of Experiment 3.1 (T_{22}) and 3.2 (T_8) were tried in *Dendrobium* Walter Oumae,

Mary Trowse and Candy Stripe, the vase life and sugar content at cessation of vase life were influenced by the treatments (Table 20 and 21). The treatments T_1 to T_4 resulted in a greater vase life in all the cultivar when compared to tap water (T_5). Varietal differences in vase life were not observed. However, interaction effects between the treatments and varieties showed that T_2, T_3 or T_4 in Walter Oumae and T_3 or T_4 in Mary Trowse and T_1 or T_3 in Candy Stripe resulted in a greater vase life when compared to the control of the respective varieties. This points to the need for standardisation of conditioning and holding solution treatments for the fresh as well as the pulsed and packed flowers specifically for each cultivar as varietal characters interact with the treatments (Fig. 6).

The sugar content of Mary Trowse and Candy Stripe flowers at cessation of vase life was greater under pulsing (T_2) than under no-pulsing (T_1). T_3 resulted in more or less the same sugar level in all the cultivars at cessation of vase life while T_4 resulted in a greater content in Candy Stripe when compared to Walter Oumae and Mary Trowse.

The dry weight and water content of the flowers were not influenced by the treatments (Table 19). However significant differences in fresh weight at different periods of the vase life was observed (Table 17). Interaction between the periods and the varieties was also found to influence fresh weight (Table 18). In Walter Oumae and Mary Trowse, the fresh weight was increased from the first day (P_1) to the fourth day (P_2), and this was maintained upto the seventh day (P_3). Whereas in the Candy

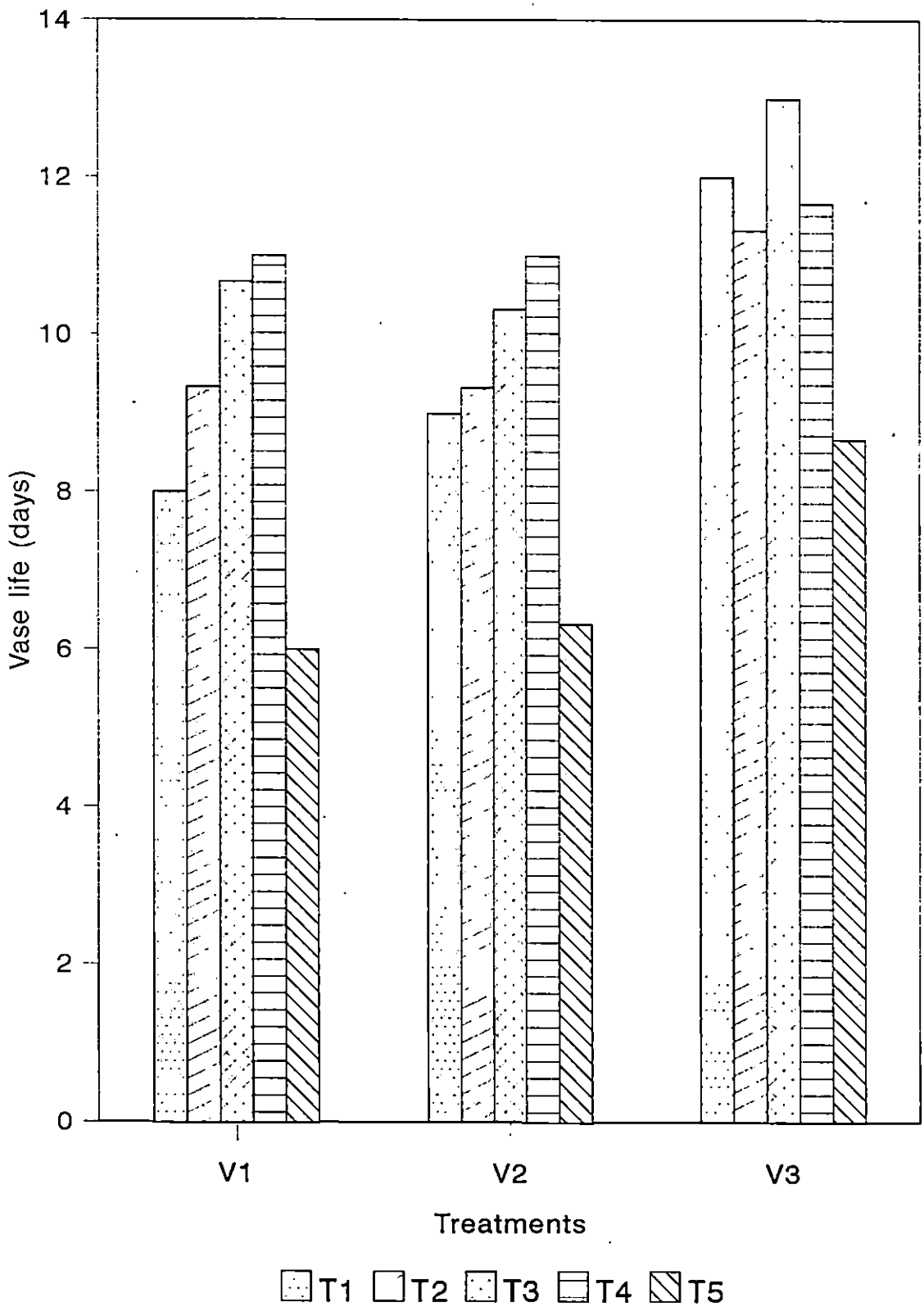


Fig. 6. Experiment 4 - Vase life of inflorescences

Stripe fresh weight increase was not observed during the vase life period unlike in the other varieties. The initial fresh weight was maintained in this variety until the seventh day and decline occurred thereafter.

The electrical conductivity of the holding solutions observed during the different periods of the vase life was beyond the detectable range. This suggests that solute concentration was not an influential factor effecting the uptake of the solutions.

Spike bending was not observed during the vase life period, in the different cultivars. Dendrobium orchid inflorescences are generally sturdy and for the present study, the flowers were harvested at the mature stage with all but the topmost bud in the fully opened state. The unopened bud was found to open fully in all the varieties, without bending of the inflorescence stalk.

Though the treatment did not influence the changes in petal colour during the vase life period, the colour variations observed from the start to the cessation of vase life were recorded (Fig. 1, Plate IX & XII). In *Dendrobium* Sonia, the colour changed from violet-purple (77B) to amethyst-violet (81C) and then to various shades of brown (182B to 177D) and finally to brown (165B). In Mary Trowse, the change was from violet-purple (77C) to purple (80C and 80D), and then to shades of brown (182B) and finally to brown (165B). In Candy Stripe, the change was from phlox-purple (75B) to shades of pink (62B) and then to pinkish brown (182D

and 182C) and finally to brown (165B). In Walter Oumae, the flowers changed from white gradually to off-white (159B) and then to pale brown (173D) and finally to a darker brown (177D).

In the coloured varieties Sonia, Mary Trowse and Candy Stripe, flower colour deepened before the onset of browning while in Walter Oumae, in the absence of colouring pigments, the loss of white colour and the onset of browning was gradual.

SUMMARY

SUMMARY

A study was conducted at the Department of Horticulture, College of Agriculture, Vellayani from September 1996 to January 1997 to find the effects of various postharvest chemical treatments on improving quality and vase life of *Dendrobium* cut-flowers and to identify the best combination of chemicals for maximising vase life.

The study comprised of four experiments. The Experiments 1, 2, 3.1 and 3.2 were conducted in Completely Randomised Design and Experiment 4 was carried out in factorial CRD. The results are summarised below.

The first experiment was aimed to study the effect of conditioning of freshly harvested inflorescences for two hours in tap water of altered pH. Conditioning significantly influenced the vase life of the flowers. The best conditioning treatments were tap water altered to pH 3.0 (T_4) and 3.5 (T_3) which recorded a vase life of 20.67 days and 19.67 days respectively.

Changes in the fresh weight, dry weight, water content, sugar and flower size during the vase life period were not influenced by the

conditioning treatments. Irrespective of the treatments, the fresh weight of the inflorescences increased upto the fourth day and by the seventh day a decline preceeded upto the cessation of vase life. So also the flowers were found to maintain their maximum length and width upto the seventh day of the vase life period.

The second experiment was aimed at investigating the influence of pulsing with various concentration of sucrose and 8-hydroxy quinoline (8-HQ) on the vase life and quality of the conditioned flowers. Pulsing with a combination of 4% sucrose and 400 ppm 8-HQ for six hours was found to result in the highest vase life of 21.33 days in packed inflorescences subjected to a period of transport and transit (simulated) for 24 hours.

Fresh weight changes and changes in flowers structure observed in these flowers followed the same pattern as in the freshly harvested and conditioned inflorescences of Experiment-1, irrespective of the pulsing treatments.

The third experiment was aimed at standardising a holding solution for obtaining the maximum vase life in freshly harvested and pulsed inflorescences. Combinations of sucrose (2, 4 and 6%), 8-HQ (200, 300 and 400 ppm) and silver nitrate (20, 30 and 40 ppm) formed the treatments. The freshly harvested flowers conditioned for two hours in tap water of pH 3.0 were subjected to the holding solution treatments in Experiment

3.1. Vase life was the highest (26.00 days) in T_{22} (6% sucrose + 300 ppm 8-HQ + 20 ppm $AgNO_3$) followed by T_{27} (25.33 days) (6% sucrose + 400 ppm 8-HQ + 40 ppm $AgNO_3$), T_{17} (25.33 days) (4% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$) and T_{21} (25.00 days) (6% sucrose + 200 ppm 8-HQ + 40 ppm $AgNO_3$).

In the conditioned and pulsed flowers subjected to the simulation of transit and transport for 24 hours followed by treatment in holding solutions (Exp. 3.2), the vase life was the highest (22.00 days) in T_8 (2% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$), T_9 (2% sucrose + 400 ppm 8-HQ + 40 ppm $AgNO_3$), T_{11} (4% sucrose + 200 ppm 8-HQ + 30 ppm $AgNO_3$), T_{15} (4% sucrose + 300 ppm 8-HQ + 40 ppm $AgNO_3$), T_{17} (4% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$).

The sucrose concentration of the treatments which resulted in a high vase life was generally lower for the pulsed flowers when compared to the non-pulsed flowers of Experiment 3.1. In both the groups, irrespective of the treatments, changes in flower structure measured as changes in the maximum length and width of the flowers, were noticed during the vase life period.

While these changes started simultaneously by the seventh day in the pulsed flowers, in the non-pulsed flowers of Experiment 3.1, structural changes in the lip and dorsal sepal leading to a reduction in length took place by the fourth day itself while changes in the width started by the seventh day only. Thus, pulsing was found to delay the onset of structural changes leading to reduction in length of the flowers.

The fourth experiment was carried out to test the applicability of the results of the Experiments 1, 2, 3.1 and 3.2 in three other popular cultivars namely *Dendrobium* Mary Trowse, *Dendrobium* Candy Stripe and *Dendrobium* Walter Oumae.

The vase life of all the varieties were increased by the treatments T_1 to T_4 when compared to the control (T_5). Interaction between the treatments and the varieties was observed.

A greater vase life was observed in *Dendrobium* Walter Oumae flowers subjected to conditioning followed by pulsing (T_2), conditioning, pulsing and holding in 6% sucrose + 300 ppm 8-HQ + 20 ppm $AgNO_3$ (T_3) and conditioning, pulsing and holding in 2% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$ (T_4) than the control (T_5). In *Dendrobium* Mary Trowse, T_3 and T_4 recorded a greater vase life and in *Dendrobium* Candy Stripe, conditioning alone (T_1) and T_3 were observed to result in a greater vase life.

The sugar content of the flowers observed at the cessation of vase life was also influenced by the treatments. Conditioning followed by pulsing (T_2) resulted in a greater sugar content than conditioning alone (T_1) in Mary Trowse and Candy Stripe. T_3 resulted in a similar sugar content in all cultivars while T_4 resulted in a greater content in Candy Stripe than in Walter Oumae and Mary Trowse.

The differences in the responses of the cultivars to the treatments point to the need for standardisation of post harvest treatments for each of them.

The electrical conductivity of the vase/holding solutions was not observed to be in the detectable range during the vase life period. Spike bending was not observed in *Dendrobium* Sonia and the other varieties. The terminal unopened flower bud was found to open fully, irrespective of the treatments.

The changes in petal colour observed during the vase life were not influenced by the treatments. Petal colour variations, irrespective of the treatments recorded from the start to the cessation of vase life showed that in the coloured cultivars namely *D.* Sonia, *D.* Mary Trowse and *D.* Candy Stripe, the petal colour deepened before browning.

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* Originals not seen

ENHANCEMENT OF POSTHARVEST LIFE OF *DENDROBIUM* FLOWER

By

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ABSTRACT OF A THESIS

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ABSTRACT

A study was conducted at the Department of Horticulture, College of Agriculture, Vellayani from September 1996 to January 1997 to find the effects of various postharvest chemical treatments in improving quality and vase life of Dendrobium cut-flowers and to identify the best combination of chemicals for maximising vase life. The study comprised of four experiments. All of them were laid out in Completely Randomised Design except the fourth which was in factorial CRD.

The conditioning treatments, pulsing and use of holding solutions were significantly influence the vase life of *Dendrobium* varieties. The best conditioning treatments observed in Expt.1 were tap water altered to pH 3.0 (T_4) and 3.5 (T_3) which recorded a vase life of 20.67 days and 19.67 days respectively. Changes in the fresh weight, dry weight, water content, sugar content and flower size during vase life period were not influenced by the conditioning treatments. Irrespective of the treatments the fresh weight of the inflorescences increased upto the fourth day and by the seventh day a decline proceeded upto the cessation of vase life. So also the flowers were found to maintain their maximum length and width upto the seventh day of the vase life period. In experiment 2, pulsing with a combination of 4% sucrose and 400 ppm 8-HQ for six hours was found

to result in the highest vase life of 21.33 days in packed inflorescences subjected to a period of transport and transit (simulated) for 24 hours. Irrespective of the pulsing treatments, changes in fresh weight and flower structure followed the same pattern as in the conditioned inflorescences of experiment 1.

In experiment 3.1, the freshly harvested inflorescences conditioned for two hours in tap water of pH 3.0 were subjected to the holding solution treatments. Vase life was the highest (26 days) in T_{22} (6% sucrose + 300 ppm 8-HQ + 20 ppm $AgNO_3$ followed by T_{27}, T_{17} and T_{21}. In the conditioned and pulsed inflorescences subjected to the simulation of transit and transport for 24 hours followed by treatment in holding solutions (Expt. 3.2), the vase life was the highest in T_8 (2% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$), T_9 (2% sucrose + 400 ppm 8-HQ + 40 ppm $AgNO_3$), T_{11} (4% sucrose + 200 ppm 8-HQ + 30 ppm $AgNO_3$), T_{15} (4% sucrose + 300 ppm 8-HQ + 40 ppm $AgNO_3$), and T_{17} (4% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$). The sucrose concentration of the treatments which resulted in a high vase life was generally lower for the pulsed flowers when compared to the non-pulsed flowers of experiment 3.1. In both the groups, irrespective of the treatments, changes in flower structure measured as changes in the maximum length and width of the flowers, were noticed during the vase life period.

The fourth experiment was carried out to test the applicability of the results of the experiments 1, 2, 3.1 and 3.2 in three other popular

cultivars namely, *Dendrobium* Mary Trowse, *D.* Candy Stripe and *D.* Walter Oumae. The vase life of all the varieties were increased by the treatments T_1 to T_4 when compared to the control (T_5). In *D.* Walter Oumae a greater vase life was observed in flowers subjected to conditioning followed by pulsing (T_2), conditioning, pulsing and holding in 6% sucrose + 300 ppm 8-HQ + 20 ppm $AgNO_3$ (T_3) and conditioning, pulsing and holding in 2% sucrose + 400 ppm 8-HQ + 30 ppm $AgNO_3$ (T_4) than the control (T_5). In *Dendrobium* Mary Trowse, T_3, and T_4 recorded a greater vase life and in *D.* Candy Stripe, conditioning alone (T_1) and T_3 were observed to result in a greater vase life. The sugar content of the flowers observed at the cessation of vase life was also influenced by the treatments.

The electrical conductivity of the holding solutions was not observed to be in the detectable range during the vase life period. Spike bending was not observed in *Dendrobium* Sonia and other varieties. The petal colour variations irrespective of the treatments recorded from the start to the cessation of vase life showed that in the coloured cultivars namely *Dendrobium* Sonia, *Dendrobium* Mary Trowse and *Dendrobium* Candy Stripe, the petal colour deepened before browning, while in the *Dendrobium* Walter Oumae, in the absence of colouring pigments, the loss of white colour and the onset of browning was gradual.