POST HARVEST LIFE, QUALITY AND BIOCHEMICAL CONSTITUENTS OF CUT ROSES AS AFFECTED BY PRECOOLING AND STORAGE

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POST HARVEST LIFE, QUALITY AND BIOCHEMICAL CONSTITUENTS OF CUT ROSES AS AFFECTED BY PRECOOLING AND STORAGE

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CERTIFICATE

This is to certify that the thesis entitled **"Post Harvest Life, Quality and Biochemical Constituents of Cut Roses as Affected by Precooling and Storage"**, submitted to the Faculty of the Post Graduate School, Indian Agricultural Research Institute, New Delhi, in partial fulfilment of the requirements for the award of the degree of **Doctor of Philosophy in Horticulture** by **Ms. Mariam Mwangi** embodies the results of *bona fide* research work carried out by her under my supervision and guidance. No part of the thesis has been submitted by her for any other degree or diploma.

I further certify that any help or information received during the work on this thesis has been duly acknowledged.

19/1/2003

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1. INTRODUCTION

The provision of top quality flowers, which fully meet customer's requirements, is essential if the floriculture industry is to continue to develop profitably in an increasingly competitive market place. Certain flowers are inherently short-lived after harvest and pose unique problems in handling and marketing (Salunkhe *et al.*. 1990). It is known that 70 per cent of the potential lasting quality of cut flowers is predetermined at harvest, while postharvest factors influence 30 per cent of the effects. All along the market channel there is enormous loss in value of cut flowers which could be 50 per cent of the farm value (Bhattacharjee, 1999e).

The extension of vase life of cut flower and improved postharvest development and maintenance has now become commercially and economically important practice based on scientific principles. In postharvest technology, precooling and storage are considered most important. Quick removal of field heat from the harvested cut flowers through precooling reduces the respiration rate, prevents moisture from condensing on flowers, reduces *Botrytis* infection and reduces the amount of ethylene inside the package (Farnham *et al.*, 1978). The most common method of precooling is cold storage. However, cold storage facility is not available with the marginal grower as it is costly. Some inexpensive and easily available method of precooling has been worked out by Palanikumar *et al.* (2000a). Among the different precooling methods, ice-cold water spray for 45 min over the cut stems and buds and cold storage at 4^0C for 24 hours were reported to give maximum vase life and improved the flower quality of cut 'Raktagandha' roses (Palanikumar *et al.*, 2000a).

Further experimental evidences using the above two best precooling methods are essential to improve the quality of cut roses.

Pre-cooling is done before packaging and storage. It is a pre-requisite for storage and transport management whenever the flowers are held in dry pack (Goszcynska and Rudnicki, 1988). Different packaging or wrapping materials are in use in the flower market today. Packing in corrugated cardboard boxes (CCB) lined with polyethylene film (PEF) and wet newspaper was found to be better than packing in corrugated cardboard boxes alone (Ahn, 1997). The main principles of packaging towards long storage life and keeping quality are to lower the rate of respiration, transpiration and cell division during transportation. There is a need to investigate the effect of precooling on different packaging materials available today for different storage durations. Low temperature is the best storage treatment for retarding all physiological and pathological deteriorations. However, some of the problems encountered after low temperature storage are failure of the flower buds to open, short vase life, blueing of red rose petals, bent neck and infection with *Botrytis* (Mor *et al.*, 1989a). Prolonged storage also increases the sensitivity of flowers to endogenous and exogenous ethylene. Moreover, the senescence process of cut roses continue during cold storage resulting in shortened vase life. Several chemicals have been in use as 'pulsing', conditioning, and in holding solutions which can provide the possibility of extending the storage period and improving the quality and longevity of stored flowers. The chemicals including silver nitrate (Okhawa *et al.*, 1999), STS (Bhattacharjee and De, 1998), calcium chloride (Hong and Zhao, 1998), and dimethyl sulphoxide (Pritchard *et al.*, 1991) have been found to be beneficial

as pulsing treatments. A combination of sucrose and 8-HQC significantly improved the vase life of 'Sonia' roses (Ichimura *et al.*, 1999). STS (0.5 mM) pulsing for 45 min was found beneficial for improving postharvest life and quality of cut 'Raktagandha' roses (De *et al.*, 1996). Pulsing with DMSO (2 %) for 15 minutes and $CaCl_2$ (1 %) for 20 hours improved the vase life and quality of cut 'Raktagandha' roses (Sankar Vidhya and Bhattacharjee, 2002).

Storage of cut flowers involves wet and dry storage. In wet storage, the flowers are held in water or a preservative solution and is used for a short period of storage. Dry storage methods are without the use of water and are usually used for long periods of storage. Cut roses can be wet stored at 4^0C for upto maximum of five days and under 8^0C the cut roses can be stored maximum of two days without affecting their ultimate keeping quality in the vase at ambient temperature (Palanikumar and Bhattacharjee, 2001). Under dry storage, the cultivars can be stored dry at 4^0C for upto five days without affecting the ultimate vase life. Roses can also be dry stored in sealed polyethylene bags for about 7 days. The storage ability however, depends upon the cultivar and quality of the bloom. Pulsing of flowers before storage and holding the flowers in preservative solutions also improves the storage life and vase life of the cut flowers (Singh *et al.*, 2001). There is a need in ascertaining further the efficacy of chemicals before and after wet and dry storage. Information on the holding solution after storage is also very meagre.

Several ultrastructural, biochemical and metabolic changes are associated with the senescence of cut flowers (Halevy and Mayak, 1979). Respiration and enzymatic hydrolysis of cellular components are the two

major biochemical and metabolic events occurring in the senescing rose flowers. There is not much literature available on the biochemical changes occurring in cut rose especially in relation to precooling, packaging and refrigerated storage.

In cut roses, maintenance of a good water balance is important to prevent 'bent neck', which often terminates their vase life. Many factors have been reported to be involved in the decrease of water uptake. The decreased water uptake by the stem is mainly due to plugging of xylem vessels caused by bacteria (Van Doorn *et al.*, 1986; De Witte and Van doorn, 1988; Put and Jansen, 1989, 1990; Van Doorn and De Witte, 1997), fungi (De Stigter and Broekhuysen, 1986; Demmink *et al.*, 1987; Baayen *et al.*, 1988; Put, 1990; Van Doorn and Tijskens, 1991; De *et al.*, 1996) and other micro-organisms which grow in vase water or on the dipped portion of the stem. Not much research work is conducted on the isolation and identification of various microflora i.e. fungi, bacteria, etc. growing in the vase water as affected by precooling and packaging. Moreover, experimental work on the influence of precooling and packaging treatments on the gròwth of fungi and bacteria in the vase water at ambient temperature are also scarce.

Keeping these points in view and being aware of the gap in research, a series of experiments were carried out by using greenhouse grown roses with the following objectives :

1. To investigate the effect of precooling and pulsing, and precooling, pulsing and packaging on cut roses.
2. To determine the influence of dry and wet storage on the postharvest life and quality of cut roses.

3. To find out the efficacy of chemical solutions on postharvest life and quality of precooled and stored cut flowers.

4. To study the physio-biochemical changes occurring during the process of senescence of precooled and packed flowers.

5. To find out the influence of precooling and precooled and packed cut roses on the growth of microorganisms in vase water.

2. REVIEW OF LITERATURE

Post harvest handling of cut flowers is an important and interesting subject of study. Apart from the other aspects in postharvest technology, precooling and storage have been considered most important practice in postharvest handling of cut flowers. To reduce the field heat, flowers are precooled. Precooling the cut flowers immediately after harvest reduces the respiration rate and thus helps in enhancing the postharvest quality of cut flowers. Extensive research work has been carried out by several workers on post harvest handling of cut flowers but not much experimental evidences are there on precooling and storage. Particularly on precooling of flowers research work are very meagre. Recently, the subject of postharvest physiology and handling of cut flowers has attracted attention of many floriculturists, plant physiologists, biochemists, and plant pathologists due to its wide scope and importance in the domestic as well as international market. Storage of cut flowers is also a new area of research which has received attention along with the expansion of the floriculture industry. Storage methods are directed towards the increasing problems of appropriate preservation of large volumes of flowers and their transport and distribution to the consumers. Several review articles have been published on the post harvest longevity of cut flowers (Aarts, 1957; Coorts, 1973; Rogers, 1973; Halevy, 1976; Halevy and Mayak, 1979, 1981; Mayak and Halevy, 1980; Mayak, 1987; Goszcynska and Rudnicki, 1988; Borochov and Woodson, 1989; Zieslin, 1989; Nowak *et al.*, 1991; Van Doorn and De Witte, 1997; Bhat *et al.*, 1999a; Bhattacharjee, 1999a; De and Bhattacharjee, 2000).

Biochemical changes like breakdown of starch into sugars, proteins into amino acids and changes in phenol content are involved in the senescence process in cut flowers. These changes in turn are influenced by temperature, preservative solutions, and can be manipulated by low temperature, holding solutions and pulsing treatments.

In this chapter an attempt has been made to review the work done in India and abroad on the different aspects of post harvest technology under the following headings.

2.1 Influence of precooling on the post harvest life of cut flowers

Precooling is an important postharvest operation, which slows down the respiration rate from the harvested cut flowers and ultimately enhances the postharvest life and quality of cut flowers (Singh *et al.*, 2001). Reducing the temperature of unprecooled flowers is a very slow process requiring two or more days (Halevy *et al.*, 1978a), causing the risk of excessive moisture and the accumulation of harmful volatiles. Precooling flowers prior to transportation is necessary in order to maintain an optimal temperature in refrigerated containers or trucks for the duration of the transportation period. (Nowak and Rudnicki, 1990). The importance of precooling was well demonstrated in an experiment with roses carried out in the Netherlands in 1979 (78) (Nowak and Rudnicki, 1990). When roses were both precooled and transported in trucks with continuous refrigeration, their temperature decreased during the transportation period of 14 h to about 4^0C. These results showed the added benefit of precooling and continous refrigeration to maintain a low temperature during the flower transportation.

Several precooling techniques are in vogue such as room cooling, forced - air cooling, hydrocooling, vacuum cooling and the ice bank cooling (Hobson, 1994). Precooling has been widely practised in case of pot plants and bulbous plants for initiating flowering and enhancing the yield.

2.1.1 Precooling of bulbs

Yue and Imanishi (1990) exposed the bulbs of Dutch Iris 'Blue Magic' to ethylene treatment immediately before subjecting them to precooling (9^0C for 9 weeks). This resulted in a high percentage of flower bud formation.

Okhawa *et al.* (1990) found that long term frozen storage of bulbs was possible if bulbs were precooled for 4 weeks at 1^0C, but precooling must begin earlier for bulbs destined for cooler regions.

Lambrechts *et al.* (1994) studied the carbohydrate status of tulip bulbs during cold induced flower stalk elongation and flowering. The bulbs were stored dry for 12 weeks at 5^0C (precooled) or 17^0C (non precooled). Only the 5^0C treatment led to rapid flower stalk elongation and flowering following planting at high temperatures. Precooling enhanced the mobilization of starch, fructose and sucrose in the scales.

Kawa Miszczak (1997) investigated the effects on flowering and growth of bulbs of tulip cultivars 'Apeldoorn' and 'Gudoshnik' after treatment with ethylene for 3 days and after 6-8 weeks of precooling, the number of days to flowering was reduced. For 'Gudoshnik' bulbs, exposure to ethylene reduced the days to flowering after precooling for 8, 10 and 11 weeks and the greatest effect of ethylene was observed on bulbs after 8 weeks of precooling. Imanishi *et al.* (1997) observed that tulip cut flowers

cv. Gander of good quality were obtained when bulbs were precooled at 15^0C for 3 weeks from the outer perianth to gynoecium formation stages. Also precooling the bulbs at a more advanced stage of flower bud development resulted in plants with high percentage flowering and earlier flowering.

Botha *et al.* (1998) exposed the bulbs of Dutch Iris 'Sapphire Beauty' to ethylene prior to precooling. This resulted in stimulation of flowering in bulbs of various sizes. In large bulbs, exposure to ethylene followed by precooling resulted in 100% flowering over a 5-month period after planting compared to control, which gave 67% flowering.

2.1.2 Precooling of cut flowers

Gao *et al.* (1994) studied the water loss of cut rose during the process of vaccum precooling. This was the first published work in case of precooling of commercial cut flowers. Cut rose stems of the cv. Karolonal were either kept without water, stood in water or sprayed with water and precooled to a final temperature of 2, 5 or 10^0C. The vase life of cut roses stood in water was 6 to 7 days, similar to that of control. Without water the vase life was much reduced. The vase life of the cut rose also improved in precooled flowers, which varied from 4 to 9 days. Thus, they concluded that the vacuum cooling technique improve the cut flower longevity and maintains the high water potential.

Cheon Young *et al.* (1995) reported that vase life and fresh weight of cut chrysanthemums flower decreased with shipping duration. Pretreatment with STS or chrysal RVB before shipping extended the vase life by about 2 days compared with the control. Vase life was prolonged by precooling and shipping at low temperature (3^0C).

Bhattacharjee (1995) reported that the precooling temperature varies from flower to flower. *Alstroemeria* requires a precooling temperature of 4^0C, *Anthurium* 13^0C, *Cattleya* (orchid) needs 7 - 10^0C, *Chrysanthemum, Cymbidium* and *Paphiopedilum* orchids needs - 0.5 - 4^0C, *Dendrobium* orchids needs 5 - 7^0C, *Carnation* 1^0C, *Gerbera* 4^0C, *Gladiolus* 4-5^0C, *Rose* needs 1-3^0C and *Sterilitzia* needs 7-8^0C as their precooling temperature.

Hu-YuXiao *et al.* (1998) observed on cut rose cv. Bridal Pink flowers, which were precooled for 2 hours, and subjected to simulated transport for 0, 24, 48, 72 h at 20^0 or 5^0C that when flowers were transported wet in deionized water, they maintained their fresh weight thus prolonging vase life at 5^0C than 20^0C. Substituting 0.3 mM 8 - HQS and 0.1 M fructose for deionized water during the 72 hour transport period at 5^0 prolonged the vase life of cut roses more than 2 times than that of dry transported ones. The chrysanthemum cut flower quality was substantially improved by changing the precooling method. A small forced air cooling facility was constructed in which packed chrysanthemum flowers could be cooled down to 5^0C within 1 h (compared with > 10 h by traditional room cooling). The chrysanthemum flowers maintained good quality on the auction market in Japan even after being fumigated (Huang - chaochia *et al.,* 1998).

Palanikumar and Bhattacharjee (2000a) found that precooling of cut roses either by cold storage at 4^0C for 24 h, or ice cold water spray over the cut stems and buds for 45 min. gave maximum vase life and improved the flower quality.

Palanikumar *et al.* (2000b) observed a decrease in the respiration rate of the roses cv. 'Raktagandha' just after precooling treatment with cold storage at 4^0C for 24 h and ice cold water spray for 45 min. However,

at senescence, all the treatments including the control showed a marked reduction in their respiration rates.

2.2 Precooling and Packaging material

In chrysanthemum, using plastic mesh sleeves to protect individual blooms was beneficial. It reduced mechanical damage in comparison to the standard grower pack wherein the blooms are packed in boxes lined with polyethylene film. Precooling before packing was also beneficial which extended the acceptability of the flowers by 2-6 days (Krahn, 1978). Cut roses cv. 'Christian Dior' sealed in non-perforated polyethylene (PE) bags kept dry at 3 ± 1^0C had the best quality and longest storage life *viz.*, 12 days. These flowers did not differ significantly in vase life from freshly cut roses (Ketsa and Dadaung, 1989).

Vergano and Pertulit (1993) studied the effects of modified atmosphere packaging on the longevity of *Phalaenopsis* orchid florets. The packaging was in polymer films and stored at 21 - 27^0C for 76 days, such flowers showed a reduced incidence of discolouration than the control. Packaging tuberose florets cv. 'Single' in 300 guage Polyethylene bags with no ventilation under ambient conditions was the most effective treatment for extending shelf life upto 4-6 days compared with 1.3 days in the case of non-packed control and maintaining high quality (Madaiah and Reddy, 1994). In gladiolus cv. Adi, pulsing with sucrose (10%) +STS (0.4 mM) before dry storage at 2^0C for 14 days was given. After storage, the spikes were packed in polyethylene liners under modified atmosphere packaging (4 - 7% CO_2, 10 - 14% O_2). The subsequent vase life and quality were good (Meir *et al.*, 1995). Swam, *et al.* (1996) investigated the effects of package design and temperature treatment (cooling and rewarming) on

the quality of packed rose flowers cv. 'Sonia' with regard to *B. cinerea* infection. A significant increase in *Botrytis cinerea* spotting was observed on flowers experiencing both cooling and slow rewarming in the box. Package design (size and location of ventilation holes) had a significant effect on the proportion of flowers with spotting. Boxes with large ventilation holes and effective air ventilation around the buds resulted in 92% infected rewarmed flowers, whereas a commercially used box resulted in 2% infected rewarmed flowers, compared with 30% infection in untreated flowers.

Ahn (1997) studied the effects of pretreatment, packaging materials and transportation temperatures on quality of cut roses cv. 'Mary de Vor'. Packing in corrugated cardboard boxes (CCB) lined with polyethylene film (PEF) and wet newspaper (WNP) was better than packing in CCB alone. Compared with fresh control flowers, transported flowers had shorter vase life, decreased flower opening and increased incidence of bentneck. Transportation at 5^0C was better than that at 25^0C with regard to quality and vase life. Pretreatment with aluminium sulphate and sucrose was effective at maintaining the quality and vase life of transported and fresh flowers.

In *Chrysanthemum morifolium* cv. 'Mountaineer', it was found that the best packaging treatment was cold storage (4 ± 1^0C) for 24 h after wrapping in cellophane (Bhat *et al.*, 1999b). The rate of physiological loss in weight and cumulative PLW was least in 200 guage polyethylene bagged loose tuberose flowers compared to the unpacked control. Packing the flowers in unventilated polyethylene bags significantly decreased wilting but produced off odors. (Nagaraja *et al.*, 1999). Jothi and

Balakrishnamoorthy (1999) reported that cut rose cv. Happiness packed in cellophane sheet for 24 h gave the longest vase life (4.67 days), lowest percentage of wilting (6%) largest flower diameter (7.2 cm), lowest percentage of reflexed petals (35%) and the highest water uptake (58 ml).

Precooling effects either by cold storage at 4^0C for 24 h or ice cold water spray for 45 min was maintained only for 8 h under polyethylene packaging (Palanikumar *et al.,* 2000a). Telescopic boxes of corrugated fibreboard having compressive strength of 500 newton and puncture resistance of 197 oz/tear inch with two ventilation holes of 4.7 cm diameter on each side are highly suitable for bulk transport of cut roses (Singh *et al.,* 2001). Corrugated fibre board sheet and polyethylene bags of 150 gauge thickness were found to be beneficial as wrapping material for packing pulsed and precooled flowers in telescopic type CFB boxes, the packaging duration being 20 h and 22 h respectively resulting in enhanced longevity and flower quality as compared to the fresh cut flowers (Sankar, Vidhya 2001).

Out of the six packaging material i.e. newspaper, low guage polyfilm, brown paper, cellophane paper, butter paper, and corrugated thin sheet for 48 h, low guage poly film recorded the highest flower diameter, flower longevity, maximum bud opening and less colour fading in *Dendrobium* orchid (Dineshbabu *et al.,* 2002).

2.3 Effect of chemical treatments as pulsing on the postharvest life of cut roses

2.3.1 Influence of pulsing with sucrose

Pulsing is a short duration treatment (16 - 24 h) given before pre-shipment or pre-storage. Sugar (sucrose) is one of the main components

of the pulsing solution. The effect of such a treatment lasts throughout the entire vase life of the flower. The optimum concentration of sucrose for rose ranges from 2 to 5 per cent (Halevy *et al.*, 1978; Halevy and Mayak, 1974b). Pulsing with sucrose has been found to be of great value in prolonging life, promoting opening and improving the colour and size of petals in rose (Halevy and Mayak, 1974a,b; Halevy *et al.*, 1978). In roses, pulsing at high temperatures will cause excessive opening of the flower buds during the treatment. The recommended procedure is therefore, pulsing for 3 to 4 h at 20^0C followed by 12 to 16 hrs in the cool storage (Halevy *et al.*, 1978). In rose cv. 'Mary De Vor', sucrose made the flower colour brighter. There was a positive correlation between fresh weight increase and longevity (Cho and Lee, 1979). Pulsing cut 'Montezuma' rose with 2% sucrose for 3 hours effectively improved postharvest life by 3.0 days (Gowda, 1994).

Kuiper *et al.* (1995) reported that an aqueous solution of 45mM sucrose induced proper flower bud opening of 'Madelon' cut roses and that considerable amount of the added sucrose is used for osmoregulation. Singh (1995) reported that pulsing of cut 'Raktagandha' roses with 3 per cent for 24 hours increased the water uptake, gained fresh weight at all stages and dry weight at senescence and improved flower quality. This treatment also lengthened the vase life (9.4 days) as compared to the control (7.53 days). Yan *et al.* (1997) observed that in cut rose (*Rosa rugosa*) stems treated with a combination of 30 per cent sucrose and other preservatives, vase life was extended as compared to the control flowers. Ichimura (1998) investigated the effects of sucrose treatment on the vase life of several cut flowers. Pulse treatment was effective in improving the vase life of

these cut flowers whereas continuous treatment had the additional advantage of increasing anthocyanin concentrations in the petals.

In 'Super Star' cut roses pulsing with 3% sucrose for 18 hours at 20^0C significantly prolonged the vase life (Singh *et al.*, 2001). Bhat *et al.* (1999b) reported that the most effective pulsing solution on vase life of chrysanthemum cut flowers was BA (0.025 mM) + STS (0.4 mM) + 8 - hydroxyquinoline (250 ppm) + sucrose (5%). The vase life of cut roses cv Gladiator is considerably improved by pulsing them in the vase solution of sucrose 3% + aluminium sulphate (300 ppm). (Dhumbre-Patil *et al.* 2002). The tuberose spikes pretreated with 5% sucrose for 8 h recorded maximum vase life of 18 days and maximum percentage (71.2) of opened florets and minimum (28.8) of unopened florets per spike (Nagaraju *et al.*, 2002).

2.3.2 Influence of pulsing with D-fructose

Fructose is equally effective as sucrose in preservative formulations for cut flowers. It was observed that lactose and maltose were active only in low concentrations, while the non metabolic sugars like mannose and mannitol were inactive or harmful (Aarts 1957; Kofranek and Halevy 1972; Halevy and Mayak 1974b). Bhattacharjee (1999b) evaluated the different types of sugar such as sucrose, dextrose (glucose) monohydrate, glucose anhydrous, D-fructose, D-mannose, maltose, or lactose for improving post harvest life and quality of cut roses cv. 'Happiness'. The most effective treatment, which improved the vase life, and increased fresh and dry weight was D-fructose at 3%.

2.3.3 Influence of sucrose and hydroxyquinoline compounds

Since sugar solutions are seldom free of microbial contamination, it is usually combined with biocides before use. 8 - hydroxyquinoline citrate (8 - HQC) is very effective broad spectrum biocide. It acidifies water and also induces partial closure of stomatas. (Singh, *et al.*, 2001). Apart from being a broad spectrum biocide, 8 - HQC was shown to reduce physiological stem blockage in sterile tissues. This might be related to the chelating properties of the quinoline esters (Marousky, 1972). Quinoline esters 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). The chelating complex of HQ with divalent metals (mainly Fe and Cu) may be the basis for its antibacterial activity (Albert *et al.*, 1953). 'Better Times' roses held in 8 - HQC + sucrose were free of bent neck, heavier and lasted two to three times as long as roses held in tap water (Marousky, 1969, 1971). Flowers of cut 'Mercedes' roses pulsed in 3 per cent sucrose for 24 hours or in 1.5 per cent sucrose and different preservatives and held in cool boxes for 48 hours resulted in the longest vase life (13 - 15 days) compared to those stored at ambient temperatures after transporting at ambient temperature (El-Gamasy and Hashem, 1984). 200 ppm 8 - HQC along with 20 g sucrose/l was used as a preservative to lengthen the vase life of cut roses cv. 'Better Times' (Marousky and Carlyte, 1986). Ketsa and Treetaruyanondha (1988) observed that 250 mg/l HQS along with 5 per cent sucrose reduced blueing, bent neck and stem blockage, increased vase life, water uptake and fresh weight of cut rose. Cut 'Serena' roses pulsed with 80 g/l sucrose and 200 ppm 8 - HQS had longer vase life (14.28 days) than those pulsed with different concentrations of sucrose or

placed in distilled water from the beginning of the experiment (11.12 days) (Deambrogio and Garibaldi, 1991).

In cut flower stems of *Rosa hybrida* cv. 'Serena' the longest vase life and largest flower diameter were obtained with 80 g sucrose / litre + 200 ppm 8 - HQS + 3 days of dark storage at 2^0C. Accati *et al.* (1992). Bhattacharjee (1993) found 8 - HQC (250 ppm) to be the best concentration for 'Priyadarshini' roses. Pulsing of cut 'Montezuma' roses for 3 hours with 2 per cent sucrose prolonged the vase life by three days (Gowda, 1994). Pulsing with sucrose 3 per cent + 8 - HQC (150 ppm) for 24 hours prior to wet storage (3^0C) improved the vase life of Raktagandha roses (Sivasamy, 1998). Ichimura *et al.* (1999) reported that treatment with sucrose and 8 - HQS significantly improved the vase life of cut 'Sonia roses'. Flower diameter and fresh weight were markedly increased by the treatment. In chrysanthemum cut flowers cv. 'Mountaineer', the most effective pulsing solution was Benzyladenine (0.025 mM) + STS (0.4 mM) + 8 - hydroxyquinoline (250 ppm) + Sucrose (5%) (Bhat *et al.*, 1999b). Jothi and Balakrishnamoorthy (1999) found that a pulsing treatment of 3% sucrose + $Al_2(SO_4)_3$ (300 ppm) + 8 - HQC (200 ppm) for 24 h at 4 - 6^0C resulted in the longest vase life (7.6 days), lowest percentage of petal wilting (4.7%), highest water uptake (68 ml) and the largest flower diameter (9 cm) in cut rose cv. Happiness. Singh *et al.* (2000) reported that a pulsing for 20 h at 23 ± 2^0C was more effective in improving the postharvest quality of gladiolus than that at 5 ± 1^0C.

2.3.4 Influence of dimethyl sulphoxide (DMSO)

The use of dimethyl sulphoxide in the extraction of chlorophyll is well known. Not much literature is available on its use as a pulsing

chemical. Open Red Sim carnation flowers pulsed with 6% dimethyl sulphoxide (DMSO) + 20% sucrose and stored for 15 days at - 3^0C had a vase life of 5 - 7 days but when stored for 20 days the vase life was only one day (Wilkins 1983). Pulsing with 2.5% DMSO for 1 h before storage at 4^0C or 14^0C for 15 days failed to delay spathe blueing of anthurium flowers significantly (Pritchard *et al.*, 1991). Pulsing treatment with DMSO (2%) for 15 minutes improved the vase life and quality of 'Raktagandha' cut roses (Sankar Vidhya and Bhattacharjee, 2002).

2.3.5 Influence of silver thiosulphate (STS)

STS is a very effective inhibitor of ethylene synthesis (Veen 1979). Antibacterial property of silver was reduced when silver was supplied as STS in the holding solution (Van Doorn *et al.*, 1991c). Pretreatment of buds of cut 'Sonia' roses with anionic STS (silver thiosulphate) complex (0.2 mM STS to each stem) prevented inhibition of rose bud development by low concentration of ethylene 1 - 100 ppm) (Goszcynska and Reid, 1985). STS pretreatment at 4 mM for 80 minutes or 8 minutes increased the longevity of sweet pea and larkspur, respectively (Awad *et al.*, 1986; Lukaszewska *et al.*, 1990). Cut roses held in silver thiosulphate complex at various ratios of $AgNO_3$ + $Na_2S_2O_3$ i.e. Sodium thiosulphate (20 mg/l $AgNO_3$ + 1, 2, 4 and 6 mM $Na_2S_2O_3$) + 5 per cent sucrose lasted longer by 1.4 - 1.6 days over 3.5 days of the control flowers (Ketsa *et al.*, 1993). In cut roses cv. 'Raktagandha' pulsing with 0.5 mM STS for 45 min gave best results in terms of vase life i.e. 11.25 days compared to 7 days in the control (Bhattacharjee and De, 1998). Exogenous ethylene at low rates induces an inhibition or acceleration of flower bud opening as well as leaf/ flower abscission, depending on cultivar. These effects were overcome

by pretreatment with 0.5 mM silver thiosulphate which delivered 0.5 mol Ag + to each stem. (Seddiqi *et al.*, 1995). In cut rose cv. 'Asanic Red', pulsing the cut stems for 4 hours with STS before storage at 5^0C, resulted in a shorter vase life (8.3 days) compared to that in control (9.3 days) and also recorded an increased incidence of bent neck (Okhawa *et al.*, 1999).

2.3.6 Influence of calcium chloride

Calcium when applied to cut flowers of greenhouse roses 'Sonia', Celica, Samantha, and 'Mercedes' as $CaCl_2$ (calcium chloride) extended the longevity and flower opening (Michalczuk *et al.*, 1989). In cut roses cv. 'Queen Elizabeth', $CaCl_2$ at 2 mM when used alone in the holding solution extended the vase life (5.33 days) compared to the control (3.33 days). Use of calcium increased the flower fresh weight and water uptake (Nagarajaiah and Reddy, 1991). Pusling with 1 per cent $CaCl_2$ for 20 hours was useful for improving postharvest life and quality of cv. 'Raktagandha' roses. (De and Bhattacharjee, 1998). Hong and Zhao (1998) reported that spray application of 0.5 - 2.0 per cent $CaCl_2$ extended the vase life of cut roses by 2 to 4 days. $CaCl_2$ helped in maintaining membrane stability in petals during the vase life period. In 'Ariana' cut roses, the addition of calcium salts in postharvest chemical treatment significantly improved the vase life (Bolwar *et al.*, 1999). In cut roses cv. 'Mercedes' and 'Baroness' $CaCl_2$ treatment promoted bud opening and delayed senescence (Torre *et al.*, 1999). Baas *et al.* (2000) observed that in cut roses cv. First Red, Escada, and Mercedes calcium treatment resulted in better quality flowers. Pulsing with $CaCl_2$ (1%) for 20 hours improved the vase life and quality of rose cv. Raktagandha (Sankar Vidhya and Bhattacharjee, 2002).

2.3.7 Influence of Benzyl adenine (BA) / 6 - Benzylaminopurine

6 - Benzylaminopurine (BA) is one kind of cytokinins used for prolonging vase life of cut flowers. The beneficial effect of the exogenous application of cytokinins on the keeping quality of different cut flower species such as carnation, rose, iris, tulip, anthurium, gerbera, and chrysanthenum, has been reviewed by Goszczynska *et al.* (1985). The effect of cytokinins on the keeping quality of cut flowers was related to improved water uptake and maintenance of petal turgidity in rose (Mayak and Halevy 1974), reduced respiration rates in carnation, chrysanthemum, and anthurium (MacLean and Dedolph 1962; ShiraKawa *et al.*, 1964), and to inhibition of ethylene production and action (Eisigner 1977; Mor *et al.*, 1983). Heide and Oydvin (1969) reported that immersions of carnations in a BA solution was especially effective on stored flowers. The effect of BA on stored flowers could be due to increasing their resistance to water stress damage, as shown in rose (Mayak and Halevy 1974) and carnation (Paulin and Muloway 1979). Improvement of vase life was also obtained with 50 mg/l BA included in the pulsing solution plus packing stem bases wrapped in wet cotton during transit (Kesta *et al.*, 1987). Mayak and Halevy (1970) reported that pulsing cut roses in BA for 15 min is useful for delaying senescence. Del Rio *et al.* (1989) observed that cut roses cv. 'Sonia' kept in holding solutions containing BA (25-50 ppm) did not show benefit on vase life. Quality of potted rose cv. 'Meijikatar' 5 days after removal from storage was better with BA treatment at 50 or 100 mg/l than 0 mg/l (Clark *et al.*, 1991). BA at 5 ppm showed beneficial effects on vase life, flower diameter, water uptake and fresh weight of cv 'Eiffel Tower' cut roses (Bhattacharjee, 2000).

2.4 Effect of chemical treatments in holding solutions on the postharvest life of cut roses

2.4.1 Sugars

(i) Sucrose

The use of sucrose in preservative formulations is more common than the use of any other sugars like glucose, fructose, lactose, maltose, mannose etc. Extended vase life, lower incidence of bent neck and greater fresh weight of cut roses cv. Samantha occurred when sucrose (2 - 6%) and 1.5 mM cobaltous ion (Co^{2+}) were added to holding solutions. This improvement was attributed primarily to greater water retention when flowers were held in combined solution (Venkatarayappa *et al.*, 1981). Vase life of cut 'Queen Elizabeth' was extended by upto 4 days when sucrose (2 to 4%) was used alone, whereas when used in combination with cobalt sulphate (0.5 mM cobalt sulphate + 4% sucrose), vase life was extended upto 7 days. Vase life of control was 3.3 days. (Nagarajaiah *et al.*, 1989).

Remarkable increase in vase life was reported when sucrose (1 - 5%) was combined with other ingredients like germicides, salts, growth regulators etc. in the vase solution of cut rose (Ferreira and Swardt 1980b; Gherghi *et al.*, 1983; Lukaszewska 1986; Ketsa and Treetaruyanondha 1988; GoszczynsKa *et al.*, 1989; Shirai *et al.*, 1990; Nagarajaiah and Reddy 1991; Ahn and Um 1991; Bhattacharjee 1993).

A solution containing 3% sucrose + 150 ppm HQS + 50 ppm $AgNO_3$ significantly extended vase life of cut chrysanthemum flowers from 6.4 and 8.9 days for flowers pretreated with water or chrysal RVB, respectively, and held in distilled water to 29.4 and 32.9 days respectively, for flowers pretreated with distilled water and chrysal RVB respectively. The sucrose

+ HQS + $AgNO_3$ solution also improved the quality (fresh wt and flower diameter) of flowers. (Lee - JongSuk *et al.*, 1996). Addition of 5 mg chitosan/ litre and 3% sucrose to the holding solution prolonged the vase life of roses, cv. Cardinal, for 3 days as compared to the control, and improved the quality of cut roses in terms of flower diameter and fresh weight. The development of bent neck was delayed by the provision of 2 or 5 mg chitosan / litre and 3% sucrose at about 2 or 3 days. (Yoo-Yong Kweon *et al.*, 1999). Cut flowers of *Chrysanthemum morifolium,* kept in a holding solution of 8 - hydroxyquinoline (250 ppm) + sucrose (1.5%) had the longest vase life, the greatest flower diameter and the lowest fresh weight loss in storage (Bhat *et al.*, 1999b).

All the holding solutions exerted significant influence on floral characters and vase life of *Dendrobium* orchid hybrid Sonia - 17. The highest flower diameter displayed at cessation, greatest percentage of bud opening and exemplary display of vase life was recorded by 8 - HQS 100 ppm + sucrose 2%. (Jawaharlal *et al.*, 2002).

Maximum vase life (13.47 days) was recorded in the solution containing (200 ppm) 8 - HQC + (0.5 mM) STS + (2%) sucrose whereas minimum (6.78) days under distilled water control (Verma *et al.*, 2002).

Leaves on cut stems of commercially grown rose cv. Kardinal pretreated with abscisic acid for 24 h and transferred to preservative solution containing sucrose remained healthy. It is proposed that sucrose accumulates in the mesophyll cell wall, thus decreasing apoplastic osmotic potential, leading to cell collapse and tissue death. (Markhart and Harper, 1995).

2.4.2 Inorganic salts

(i) Sulphates

Aluminium sulphate ($Al_2(SO_4)_3$ has been used in many preservative formulations of roses at concentrations of 50 to 100 ppm of Aluminium (Weinstein and Laurencot 1963; Halevy *et al.*, 1978). Weinstein and Laurencot (1963) attributed the effect of Al to lowering the rose petal pH and stabilizing the anthocyanins. Halevy and Mayak (1979) reported that $Al_2(SO_4)_3$ also acidifies the holding water thus reducing bacterial growth and improving water uptake. A combination of 5% sucrose with 300 ppm aluminium sulphate gave cut rose 'Marina' a vase life of 5 days compared to 3 days for the control (tap water) (Ahn and Um 1991). $Al_2(SO_4)_3$ at 50 ppm in the holding solution was found useful in improving longevity and flower quality of cut rose cv. 'Priyadarshini' (Bhattacharjee 1999d). Cut rose 'Landora' placed in potassium, aluminium sulphate solution (50 mg/ l + 20 mg sucrose/l) had the longest vase life (9 days for flowers from both maturity stages) (Rath *et al.*, 1991). In gladiolus, $ZnSO_4$ (0.5 mM) + sucrose (4%) significantly prolonged vase life over control (Murali and Reddy 1993). Cut rose cv. Gladiator flowers were held in various vase solutions such as 5% sucrose, 300 ppm aluminium sulphate, 200 ppm 8 - HQC and 300 ppm citric acid under ambient conditions. The longest average vase life (7.23 days) was obtained with aluminium sulphate + sucrose + citric acid. The combination of aluminium sulphate + sucrose + 8 - HQC resulted in an average vase life of 7.20 days. Controls (held in water) had an average vase life of 5.33 days. (Patil and Singh, 1995).

Song *et al.* (1996) reported that preservative solutions containing HQS at 100 - 200 mg/l + sucrose at 1% increased vase life of cut hybrid

stock flower by about 4 days compared with the control and improved the quality of cut flowers judged by increased percentage of flowering and fresh weight. The use of water amendments such as sugar, 8 - HQC and silver nitrate in the vase solution was reported by Maxie *et al.* (1973). In preliminary studies with carnations, it was reported that the best holding solution for cultivar 'Arthur Sim' was 200 ppm 8 - HQC + 2.5% sucrose and that for 'Scania' it was 2 mM STS + 2.5% sucrose (Sandhu *et al.*, 1989). Mani (1992) reported that in chrysanthemum cv Shyama and Kundan, the vase solution 0.5 mM STS + 2% sugar gave maximum vase life (24.4 and 20.6 days respectively).

Cut roses held in silverthiosulphate complex at various ratios of $AgNO_3$ + $Na_2S_2O_3$ (20 mgl^{-1} : 1, 2, 4 and 6 mM $Na_2S_2O_3$) + 5% sucrose increased the vase life of cut roses significantly for additional 1.4 - 1.6 days over 3.5 days of control flowers (Ketsa *et al.*, 1993). The vase life of cv. Christian Dior roses was significantly increased by using 10 - 15 mg $AgNO_3$/litre and 5% sucrose as the holding solution instead of distilled water. A holding solution of 20 mg $AgNo_3$ and 5% sucrose also significantly increased vase life of cv. Eiffel Tower, Swartmore and Yankee. Water uptake was enhanced and the bacterial count (colonies/ml of holding solution) was greatly reduced by $AgNO_3$ (Ketsa *et al.*, 1993). Cut flowers of carnation harvested from greenhouse or open field production were placed in solutions containing 5% sucrose and 30 ppm $AgNO_3$, 200 ppm 8 - HQC or 50 ppm $NaNO_3$.

All holding solutions increased number of open florets and vase life. Vase life was longer for flowers raised in greenhouse (Lukaszewska, 1995). *Dendrobium* 'Pompadour' orchid flowers/

inflorescence held in 225 mg/l HQS + 30 mg/l $AgNO_3$ + 4% 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). After 10 days, bacterial populations were lowest in HQS + $AgNO_3$ + glucose, suggesting that $AgNO_3$ in the holding solution may act as an antimicrobial agent and not as an inhibitor of ethylene synthesis (Ketsa *et al.*, 1995).

(iii) Chlorides

Aluminium chloride as an ingredient in holding solution was reported in Orchid cut flowers. Vase life of cut Oncidium cv. Gloriana orchid was lengthened when inflorescence were placed in solution of aluminium chloride at 50 - 250 ppm (Tatt 1982).

Nickel chloride - $NiCl_2$ which is an anti-ethylene compound promoted vase life and increased the size of the cut capitula in chrysanthemum (Pardha Saradhi, 1985). A stem base treatment with $NiCl_2$ (1500 ppm for 10 min) was more effective than $AgNO_3$ in increasing longevity (Aharoni and Halevy, 1977) and promoting stem water conductance of *Phalaenopsis* orchid (Aharoni and Mayak 1977). Nickel may act as a germicide and as an inhibitor of ethylene production (Lau and Yang 1976). Sucrose in combination with $NiCl_2$ advanced the vase life of chrysanthemum upto 24 days as compared with 7-8 days in water. Murali and Reddy (1993) observed remarkable increase in the vase life (10 days) of gladiolus cv 'Friendship' when the cut flower spikes were held in 4% sucrose + 0.5 mM nickel chloride over the control flowers (7 days).

KCl at 0.02% was used together with K_2SO_4 at 0.1%, $Al_2(SO_4)_3$ at 0.1% and sucrose at 4% in the vase solution to lengthen the shelf life of roses (Gherghi *et al.*, 1983).

Cobalt chloride $CoCl_2$ (5×10^{-4} M) which is an antiethylene compound promoted the vase life of chrysanthemum cut flowers cv. Jyotsna to 12-14 days when $CoCl_2$ was used alone and to 24 days when $CoCl_2$ was combined with sucrose (0.1M) as compared to the average vase life of 7days in controls (Saradhi and Ram 1989).

Ketsa *et al.*, (2001) reported that all concentrations of $Al_2(SO_4)_3$ at 50, 100, 150 mg/l and 200 mg/l $CoCl_2$ in the holding solutions increased the vase life and bud opening of orchid flowers as effectively as the standard holding solution (225 mg HQS, 30 mg/l $AgNO_3$ and 4% glucose).

In whole cut flowers and in detached petals of rose cultivars Mercedes and Baroness, $CaCl_2$ treatment promoted bud opening and delayed senescence. It is suggested that Ca-induced delay in petal senescence involves the protection of membrane proteins and phospholipids from degradation, thus preserving the integrity of the membranes, reducing ethylene production and hence maintaining solute transport and tissue vitality (Torre *et al.*, 1999).

Cobalt chloride at 1.5 m mol/litre and 2% sucrose in the vase solution of greenhouse grown cut roses cv. Samantha (i) increased the water uptake by inhibiting the growth of microorganisms, particularly molds (ii) reduced bent neck disorder and delayed senescence by maintaining the integrity of the surface structure of the petal and the internal stem structure (Zhang- and Ma-Guori, 1998).

Bhattacharjee (1999c) investigated five different chloride salts ($Alcl_3$, $CoCl_2$, KCl, $MgCl_2$ and $NiCl_2$) in the holding solution at concentration of 100, 200, 300 and 400 ppm in cut rose cv. Sonia Meilland. All the chloride salts had beneficial effect compared with untreated control. Longest vase life, improved water uptake, increased flower diameter and fresh weight were obtained with 100 ppm $AlCl_3$, 200 ppm each of $CoCl_2$ and $MgCl_2$, 300 ppm $NiCl_2$ and 400 ppm KCl. Singh and Bhattacharjee (1999) found out that inorganic salts such as $MgSO_4$, $MnSO_4$, $Al_2(SO_4)_3$, $FeSO_4$, $NiCl_2$, $CoCl_2$, $CaCl_2$, $AlCl_3$, KCl, $MgCl_3$, KNO_3, $Ca(NO_3)_2$ and $AgNO_3$ lengthened the vase life of cut rose cv. Raktagandha, with $NiCl_2$ (250 ppm), $MgSO_4$ (100 ppm) and KNO_3 (500 ppm) giving the best results. The increased vase life was associated with a marked increase in water uptake, sustained fresh weight during senescence and better flower expansion.

2.4.3 Nitrates

Bhattacharjee and Palani Kumar (2002) reported that among the different holding solutions tested on rose cv. Raktagandha, calcium nitrate [$Ca(NO_3)_2$] (1000 and 2500 ppm) recorded maximum vase life (8.00 days), followed by aluminium sulphate (300 ppm) and sucrose (1.5%). These chemicals also gave maximum fresh and dry weights on 3rd day and at senescence.

Vase life of cut tuberose flowers can be extended (18.5 days) by keeping them in vase solution containing sucrose 2% and calcium nitrate 0.5 mM.

2.4.4 Others

Ahn (1996) observed that cut rose 'Mary de Vor' kept in a tap water for 2 h, then stems were recut in air and placed in 25% carbonated soft

drink + 10 ppm NaOCl developed less bent neck and produced less ethylene and thus prolonged vase life and maintained the flower quality than other treatments.

Seven biocides $Al_2(SO_4)_3$, $CoCl_2$, chlorine NaOCl, $AgNO_3$, citric acid and 8 - HQC in vase solution of gladiolus effectively controlled bacterial growth but did not increase vase life appreciably. Their efficacy increased only when used in combination with sucrose (2%) (Singh *et al.*, 2000).

Bang-changSeok *et al.* (1999a) investigated the effect of pretreatments and holding solutions water (control) or 200 ppm HQS + 2% sucrose + 0.1 mM ethionine (preservative) on quality and vase life of cut Saphir roses. Fresh weight, dry weight and flower diameter of flowers tended to be higher for flowers held in preservative solution, with the exception of flowers pretreated with STS + sucrose.

Son - Kicheol *et al.* (1997a) observed that the vase life of cut rose cv Red Sandra maintained in distilled water, Chrysal, BS (2% sucrose + 200 ppm 8 - HQS), SonKl solutions (BS + 0.1 mM ethionine) were 5.3, 6.1, 11.6 and 15.4 days respectively. Sonkl solution was very effective at maintaining fresh weight, solution uptake, water potential and petal colour compared with other treatments. SonKl and BS showed similar patterns in the temporal changes of pH and EC of cell sap of petals. It was suggested that ethionine indirectly influenced physiological changes of petal cells and had a synergistic effect with sucrose.

2.4.5 Growth regulators

Petal senescence of *Rosa damascena* flowers was delayed by Kinetin @ 10 mg/l in the holding solution better than other growth regulators like IAA and GA_3 at 10 mg /l (Rao 1982).

NAA along with BA promoted post-storage bud opening in carnation. Cytokinin play an important role in delaying senescence of many flowers. Dip treatment with BA is also reported to increase vase life of anthurium flowers. BA also accelerates opening of buds of rose and chrysanthemum and prolongs their vase life. (Singh *et al.*, 2001). GA_3 was reported to stimulate active sucrose uptake in GA_3 - sucrose dependent petals of rose cv 'Madelon' (Kuiper *et al.*, 1991). The presence of GA_3 (50 mg/l) in the holding solution stimulated pedicel elongation of cut *Nerine bowdenii*, thus increasing umbel diameter (Lukaszewska *et al.*, 1997). Adding GA_3 in the preservative solution 8 - HQC (200 ppm) + 4% sucrose, resulted in substantial growth of the pistil. Including ethephon and GA_3 in the preservative solution improved the cut flower quality of tulip (Lukaszewska, 1995).

Growth regulators like IAA, BA (benzyladenine) and kinetin in 1, 2.5, 5, 10 and 25 ppm of each and GA_3 at 50, 100, 150, 200 and 250 ppm were used in the vase solution individually. All the growth regulating chemicals showed beneficial effects on vase life, flower diameter, water uptake and fresh weight. Among the chemicals, Kinetin at 2.5 ppm was the best in terms of effectiveness in increasing the postharvest life of cut rose cv. 'Eiffel Tower', followed by GA_3 at 150 ppm, BA at 5 ppm and IAA at 2.5 ppm (Bhattacharjee, 2000). The best combination of chemicals for prolonging postharvest life and quality of Raktagandha roses was 3% D-Fructose, 500 ppm L - ascorbic acid and 2.5 ppm kinetin, followed by 3% D-Fructose, 300 ppm $NiCl_2$ and 2.5 ppm kinetin (Bhattacharjee, 1999d).

2.4.6 Streptomycin sulphate

Literature on the use of streptomycin sulphate in the holding solution of cut rose for lengthening shelf life is meagre. Mohan Ram and Ramanuja Rao (1977) and Rao and Mohan Ram (1982) reported that sucrose + streptomycin + 8-HQC in the holding solution lengthened the vase life of cut roses, chrysanthemums, gladioli, carnations, snapdragons, lupines and narcissus. Zagory and Reid (1986a) reported benefit of streptomycin sulphate in lengthening vase life of cut flowers.

2.4.7 Fungicides

Vascular blockage which causes water deficit in cut roses resulting in reduced vase life as reported earlier by Durkin and Kuc (1966) has also been attributed to fungal plugging as reported by Put (1986), Demmink *et al.* (1987), Baayen *et al.* (1988) and Van Doorn *et al.* (1991a). The predominant fungal genera identified from vase water are *Botrytis cineria, Fusarium oxysporum, Aspergillus niger, Mucor* sp., *Penicillium* sp., *Acremonium strictum* and *Rhizopus stolonifer* (De and Bhattacharjee, 2000). Use of benomyl in the holding solution of cut roses had been reported by Cho and Lee (1979). They observed that benomyl, when used alone was not very effective in extending vase life of cut rose cv. 'Mary de Vor'. Among different biocides used in vase water studied by various research workers were Streptomycin, $CuSO_4$, Kanamycin, Cycloheximide, Tetracyclin (Zagory and Reid, 1986b, De, 1995). $AgNO_3$, 8-HQC, DICA (Van Doorn *et al.*, 1989) and $Al_2(SO_4)_3$ (Hoogerwerf and Van Doorn, 1992).

The best treatment for inhibition of bent neck in cut *Rosa hybrida* cultivars Mary de Vor and Norena was 120 mg myclobutanil/litre for 4 h

at a stage when calyx were seperated from petals and petals beginning to open. (Kim - KiuWeon *et al.*, 1998). The best concentration of biocides on cut roses *Rosa hybrida* cv. Classy were 0.05 g/l sodium benzoate, cetylpyridinum chloride, Isocil and Physan-20, 0.05 and 0.2 g/l dichloroisocyanuric acid, and 0.2 and 0.8 g/litre HQC.

2.5 Effect of cool storage on the post harvest life of cut roses

Cool storage is the most common method of storing the cut flowers (Nowak and Rudnicki, 1990). Storage of cut flowers at low temperature is the best treatment for retarding all physiological and pathological deteriorations. Low temperature reduces the respiration and other metabolic activities, ethylene production and action of bacterial and fungal growth. Charles Fisher (1954) presented his valuable findings in terms of long term holding of cut flowers. According to him the cut rose cv. 'Better Times' which were stored at 31, 35 and 39^0F in cellophane containers did not show any mold symptom. But those flowers held at high temperature and those with the stems in water apparently aged in storage and they had a distinct blue colour in petals. Cut roses can be stored for a period of 4-5 days at 4^0C (Carra, 1959). Roses can be stored upto 2 weeks at normal refrigeration (NR) and still exhibit at least 61% of their non stored, original vase life. Recutting the stems under water upon removal from storage was found to be beneficial (Staby *et al.*, 1984). Faragher *et al.* (1986) found that extension of cold storage or increase in temperature from 3 to 8^0C, shortened the vase life of cut 'Mercedes' roses, which was accompanied by the rise in ethylene production and membrane permeability (ion leakage). Although storage at a relative humidity of 65% reduced the petal water content by 20% in comparison to 95% RH, it does not reduce

the vase life. Both the ethylene production and membrane permeability increased with increase in storage period both at 3^0C and 22^0C, but very slowly at 3^0C. From this, they concluded that the primary effect of cold storage on roses is to slow down senescence and that continued slow senescence leads to reduction of the vase life.

Rio *et al.* (1989) carried out their studies on 'Baccara' rose cultivars. There was basically no influence of storage method on vase life after 7 and 14 days. The maximum storage period under normal low pressure was 21 days. But roses could be stored upto 3 weeks under normal low pressure and retain 63 per cent of their original vase life, while those stored in normal refrigeration retained only 53 per cent of their original vase life. Roses cannot be stored satisfactorily under low oxygen, they became unacceptable due to *Botrytis* infection. During the storage of rose cv. Visa flowers at 4^0C the rate of ethylene production was maintained at very low levels and was unaffected by the length of the cold stroage period (Serrano *et al.*, 1992). De and Bhattacharjee, (1997) reported that the diameter of first and third florets, floret opening, fresh weight at senescence, longevity of first florets, increase in spike length and vase life of gladiolus cv. Dhanvantari were improved following storage at temperatures 0.55 - 1.66^0C and 12.2 - 13.3^0C compared with cut flowers kept at ambient temperatures. Storage at 0.55 - 1.66^0C was comparatively better than 12.2 - 13.3^0C. Deambrogio and Garibaldi (1991) found that cut 'Serena' roses stored at 2^0C for 3 days had a useful life of 10.56 days in distilled water, when compared to those stored in refrigerator for 6 and 9 days, which had a vase life of 7.79 and 4.60 days respectively.

Seddiqui *et al.* (1995) observed that cold storage of roses at 4^0C in polystyrene boxes (standard storage) gave better results than storage under plastic film at the same temperature. Cold storage for a longer period reduced vase life and flower opening and led to leaf / flower abscission. Cool chamber storage of tuberose florets whether packed or not, delayed the symptoms of wilting, maintained freshness and white colour for a long time, in addition to delay and reduction in rotting leading to increased storage life (Madaiah and Reddy, 1994).

Cushman *et al.* (1998) observed that the flowers of pot rose cvs. 'Meiji Katkar' and 'Meirutral' stored at 4^0C had the longest vase life, the best flower quality and the least leaf abscission. For flowers stored at 16^0C and 28^0C floral longevity decreased and leaf abscision increased, when the duration was longer than 4 and 2 days respectively. Wang, (1999) observed that storage at all temperatures, particularly at 4^0C, promoted discoloration of anthurium cut flowers. Changing the storage conditions (temperature) did not improve discoloration.

Effect of different storage conditions on cut gladiolus spikes resulted in less water uptake and transpirational loss of water (TLW) in cold storage conditions, and better maintenance of water relations which contributed to increased number of open florets and vase life for 22 days at cold storage, 17 days at cool chamber and 12 days at room temperature (Kanthi Rekha and Shankaraiah, 2002).

2.5.1 Influence of wet storage and its duration on subsequent vase life of cut roses

Storage methods of cutflowers involves both wet and dry storage. In case of wet storage, stem bases of the flowers are held in water or in floral preservative solution for a short period. During wet storage, flowers are usually stored at 3 to 4^0C, a temperature slightly higher than that used for dry storage (Halevy and Mayak, 1981). Wet storage methods is used for all flower species cut at the commercial stage and destined directly for sale within 1 to 2 days (Rudnicki *et al.*, 1991). Lenander (1957) observed that cut roses could be stored satisfactorily in water for at least ten days and still last for about five days at room temperature. The best results were obtained with a temperature of 1^0C. At 5^0C, the quality of some varieties was good, but there was some blueing with certain cultivars. Cut roses of cv. 'Dr. A.J.Verhage' held at 20^0C after storage for one night at 2^0C and 100 per cent RH, exhibited shortened vase life (Systema, 1969). Premarket storage of cut roses in water at a temperature range of 0 to 10^0C gave better results that dry storage. Within the range, a lower temperature made a longer storage possible (De Boer and Witmondt, 1975). Cut roses of cultivars 'Baccara' and 'Sonia' could be stored wet for four days and seven days, respectively at 0-10^0C. It was possible to store cv. 'Sonia' at 9 - 10^0C. for five days but not cv. 'Baccara' (De Boer and Hillhorst, 1979). Wet storage at 2^0C and 95 per cent RH reduced the vase life of cut 'Mercedes' roses (Faragher and Mayak, 1984). Lukaszewska and Gorin (1989) reported that wet storage of cut 'Sonia' roses resulted in slight opening of the corolla but with no subsequent petal abscission in the storage. Hence, flowers can be stored wet only for short period of time. Rajan (1993) reported that cut 'Super star' roses could be wet stored for

4 days at 4^0C without having any adverse effect on vase life and quality at ambient temperature. Cut roses can be stored for a maximum of two days without losing their ultimate keeping quality in the vase at ambient temperature. Cold storage at 4^0C increased water potential of the cut flowers. Flowers stored for 6 days at 4^0C recorded highest water potential. Flowers stored for 3 days at 4^0C gave maximum vase life compared with other treatment and freshly cut unstored flowers. (Palanikumar *et al.*, 1999). Bang-Chang Seok *et al.* (1999b) reported that storage of cut 'Red Sandra' roses in wet condition or low temperature, delayed bent neck, increased solution absorption, flower diameter and prolonged vase life compared with storage in dry or room temperature.

Cut 'Raktagandha' roses can be stored wet for 5 days at 3^0C and for 2 days at 8^0C without having any adverse effect on flower quality and vase life, when compared to unstored fresh flowers at ambient temperature. Storing of flowers at 3^0C was proved to be better in improving the quality and longevity of cut flowers over those stored at 8^0C. (Sivasamy and Bhattacharjee, 2000). Cut roses under 4^0C can be stored wet for a maximum of five days and under 8^0C can be stored for a maximum of two days without affecting their ultimate keeping quality in the vase at ambient temperature. Prolonged storage period reduced water uptake, flower diameter and vase life of the cut roses irrespective of the cultivars and storage temperatures in general (Palanikumar and Bhattacharjee., 2001). Cevallos and Reid, (2001) reported that there was no significant differences between the vase life of flower stored dry and flowers stored in water when storage temperatures were from 0 to 10^0C. The vase life after wet storage at temperatures of 12.5^0C and greater was significantly higher

than vase life after dry storage at those temperatures for carnation, daffodils, Iris, Killian daisies, narcissus, tulips and roses. Iris and carnation flowers survived storage at 15^0 and 20^0C only when stored in water. Cut roses of the cv. Raktagandha could be wet stored for upto 4 days at 4 ± 1^0C without any significant reduction in their subsequent vase life. (Sankar Vidhya and Bhattacharjee, 2002). Spikes of gladiolus can be wet stored for 7 days with minimum loss of vase life. (Singh *et al.*, 2002). Buds of carnation can be stored for upto 9 days in wet storage without any loss in vase life. However, in wet storage the buds showed hastening of opening as compared to dry storage (Singh *et al.*, 2002).

2.5.2 Influence of dry storage and its duration on subsequent vase life of cut roses

Dry storage methods are usually used for long term storage. In dry storage, flowers are sealed in plastic or polythene bags to prevent the loss of moisture. Dry storage is more laborious but can be used to hold the flower for longer duration. Lindemann and Buhr (1961) reported that storage at 2-3^{0}C for 17 days was too long for rose cut flowers stored dry. Jensen and Hansen (1972) reported that cold storage for more than 6 days reduced the subsequent vase life of cut roses markedly. In cut roses of cv. 'Baccara' and 'Sonia' vase life was suggested to decrease with increase in temperature and duration of storage (Amariutei and Burzo, 1982). Faragher and Mayak (1984) reported that senescence of cut 'Mercedes' rose flowers at 22^{0}C occurred earlier in flowers held at 2^{0}C for 10 days or 17 days than in fresh cut flowers. Faragher *et al.* (1984b) reported that in 'Mercedes' cut roses dry storage at 2^{0}C resulted in a shorter vase life compared to unstored flowers. Dry storage at 4^{0}C in closed refrigerated containers was beneficial

for cut roses cv. 'Sonia' in terms of subsequent vase life. (Van Beek, 1984). Cut spikes of gladiolus can be dry stored in sealed polyethylene sleeves at 4^0C upto 4 weeks without any reduction in vase life (Nowak and Rudnicki, 1984). Mor *et al.*, (1989a) observed that vase life of roses cv. 'Gabriella' stored dry at 1^0C for 3 weeks was 4 days shorter compared to fresh roses.

Low temperature during dry storage (5^0C) reduced the multiplication rate of bacteria in the stems of rose cv. 'Sonia' (Van-Doorn *et al.*, 1991a). Song *et al.* (1992) observed that when cut rose cv. 'Sonia' flowers were held in water after dry storage (20^0C, 60% RH and a 12 h photo period for 24, 36 or 48 h) the transpiration rate increased during the first 3 days and then declined. Transpiration and water uptake decreased with increasing length of the drying period. The number of stems with bent necks was correlated with water loss and with the water potential of the flower. Van-Doorn- and Hont (1994) reported that bacterial infection increased the level of flower opening inhibition and water relations of rose cv. 'Sonia' and 'Madelon' caused by dry storage at 8^0C for 24 h, when finally placed in vase water at 20^0C. Palani Kumar *et al.* (2000c) reported that under dry storage conditions at 4^0C cut roses cv. 'Folklore' and 'Queen Elizabeth' can be successfully stored for upto 6 days without loosing ultimate vase life and quality at ambient temperature compared with the controls. Cevallos and Reid, (2001) observed that there were no significant differences between the vase life of flowers viz. carnation, daffodils, narcissus, tulips and rose stored dry and flower stored in water when storage temperatures were from 0 to 10^0C. Bhatia *et al.* (2002) found that carnation flowers pretreated and stored dry at 2^0C for 24 hours gave subsequently longer vase life

(13.33 days and 9.83 days) for cv. Impala and Purple choppin respectively than those stored for 48, 72 and 128 hours.

Sang *et al.* (1998) investigated the effect of dry storage (25^0C, 40% RH for 0 - 96 h) on gerbera cvs. Beauty, Macho, First Love and Princessa. They observed that water absorption increased and fresh weight decreased with increasing period of dry storage. Stem curvature angle after dry storage increased with increasing storage period, the angle was largest in Macho and smallest in First Love. In Beauty, Macho and First Love vase life was increased after 24 h storage. In Princessa, vase life was increased after 48 h dry storage.

The flowers of carnation cv. Tasman can be dry stored in cool chamber at 4 ± 0.5^0C for upto 9 to 12 days without much loss in vase life. Thereafter, the vase life started decreasing but the flowers maintained good turgidity and did not show any visible damage till 18 days in storage (Singh *et al.*, 2002).

2.5.3 Influence of pulsing and low temperature storage on subsequent vase life of cut flowers

Flowers like gladiolus (Kofranek and Halevy, 1976) or bird of paradise (Halevy *et al.*, 1978) respond better to pulsing prior to storage. For successful storage, chemical treatment before or after storage and proper precooling is essential.

El-Gamasy and Hashem (1984) reported that pulsing cut rose flowers in 3 per cent sucrose before cool storage was beneficial for longer vase life. Mor *et al.* (1989b) reported that aminooxyacetic acid (AOA) as 10 mM pulse, applied either before or after cold storage extended by upto 2.7

days the longevity of roses cv. 'Gabriella' that had been stored for 3 weeks at 1^0C. Silver thiosulphate as a 0.5 h pulse at 0.5 mM extended the life of fresh and cold stored roses by 2 and 3 days, respectively. Cut flowers of cv. 'Sonia' were sprayed with or held in solutions containing Kinetin or BA, each at 25 or 50 ppm, prior to keeping in simulated conditions. The vase life ranged from 5.6 to 7.4 days (with 6.2 days in the control). Holding in a Kinetin or BA solution did not improve vase life and the best results were obtained by spraying especially with BA at 25 ppm. (Rio. *et al.*, 1989).

Cut 'Serena' roses pulsed with 80 and 100 g/l sucrose + 200 mg/ l 8 - HQS, stored for 3, 6 or 9 days at 2^0C had a longer vase life, than those held with 40 and 60 g/l sucrose + 200 mg/l 8 - HQS. However, flowers pulsed with 60 g/l sucrose + 200 mg/l HQS and kept for 9 days in a refrigerator, lost 50 per cent of their initial weight and had a vase life of only 3 days in distilled water. In all the pulse treatments used, 3 days storage recorded the largest flower diameter (Deambrigio and Garibaldi, 1991). Open carnation (*Dianthus caryophyllus* L.) flowers survived storage -3^0C for 15 days, after pulsing with 6% DMSO and still showed a vase life of 7.5 days (Wilkins, 1983). Pulsing anthurium cut spikes with 2.5 per cent DMSO for 1 hour before storage at 4^0C or 14^0C for 15 days failed to delay spathe blueing (Pritchard *et al.*, 1991). Pulsing the mini-gladiolus spikes cv. Adi with sucrose (10%) and silver thiosulphate (STS, 0.4 mM) prior to modified atmosphere packaging improved the flower quality and opening (Meir *et al.*, 1995). Pretreatment containing STS + sucrose or STS + sucrose + GA_3 extended vase life of cut hybrid stock by about 2 days compared with the control regardless of storage duration as method i.e. 1 or 2 weeks

dry or wet storage. (Song-Cheon Young *et al.*, 1996). Pretreatment with 4% sucrose + 4 mM silver thiosulphate for 30 min increased the vase life of cut Alstroemeria cv Ostara flowers and decreased weight loss and respiration rate compared with flowers which did not receive the pretreatment. With pretreatment, vase life following dry storage for 10 to 20 days (13.00 and 11.26 days, respectively) was greater than that of flowers not dry stored (10.60 days) and that of flowers dry stored for 30 days (vase life 8.93 days). In non-pretreated flowers, dry storage for 10 days resulted in the longest vase life (9.40 days) but 20 or 30 days of dry storage decreased vase life compared with no dry storage. (Menguc *et al.*, 1996). Pusling with STS and BA considerably delayed leaf yellowing in cut spikes of *Solidago canadensis* during vase life and the former treatment also inhibited flower senescence, combining STS and BA was beneficials to both leaf and flower survival. A range of concentrations suggested that the equivalent of 45 μM BA was optimal for both leaves and spikes even after simulated transport (dry storage for 2 days at 6^0C) (Philosoph *et.al.*, 1997). The longevity of cold stored roses cv. 'Serena' subjected to a pulsing treatment of sucrose and 8 - HQC were comparable to that of control flowers (i.e. kept in water). (Devecchi *et al.*, 1997). Pulsing with sucrose 3 per cent and 150 ppm 8 - HQC for 24 h prior to wet storage at 3^0C improved the keeping quality of cut rose cv. 'Raktagandha'. (Sivasamy and Bhattacharjee, 2000). Bang Chang Seok *et al.* (1999b) investigated the effects of pretreatments and storage conditions on quality and vase life of cut 'Red Sandra' roses. Flowers were harvested and pulsed with distilled water, 0.2 per cent Chrysal RVB or 200 ppm aluminium sulphate + 3 per cent sucrose + 50 ppm $AgNO_3$ + ethionine for 22 hours and then stored in wet or dry condition for 12, 24 or 48 hours at low or room temperature. Pulsing

with aluminium sulphate + sucrose + $AgNO_3$ + ethionine delayed bent neck, increased solution absorption and flower diameter and prolonged vase life compared with storage in dry or room temperature condition. Solution absorption, flower diameter and vase life decreased with increasing storage period, especially in distilled water pretreatment. Pulsing with aluminium sulphate + sucrose + $AgNO_3$ + ethionine prolonged vase life compared with other pretreatments regardless of storage conditions and shipping hours.

2.6 Changes in biochemical components associated with cut flower senescence

Several ultrastructural, biochemical and metabolic changes are associated with the senescence of cut flowers (Halevy and Mayak, 1979). The maintenance of carbohydrate pool in the corolla is an important factor for promoting the longevity of cut flowers. This is evident from the observations that corolla senescence is delayed by absorption of preservative solutions containing substantial amount of metabolic sugar (Rogers, 1973). The soluble carbohydrates contribute to the pool of respiratory substrates and to the osmotic potential of the petal cells. The final stages of flower development are characterized by a decline in the content of carbohydrates and dry weight of petals (Aarts, 1957; Coorts, 1973; Mayak and Halevy, 1974; Nichols, 1973, 1975).

2.6.1 Changes in total starch content during flower development and senescence

The starch content increased in all organs such as leaves, sepals and petals of rose cultivars but most of all in the petals (upto 30%) during bud formation. During flower opening starch content decreased in the petals,

sepals and leaves by 72-96, 56-80 and 40-60 per cent, respectively (Pankovetskii and Tyutyunnik, 1978). Leaves formed during the leafing out and flowering stages had lower sugar and starch contents than those formed during flower bud development. Starch synthesis was maximum in fully expanded (20-30 days old) leaves and then gradually decreased (Decheva and Koseva, 1978). A drastic decrease in the starch concentration was observed in the petals of roses cv. 'Sonia' during the first stage of senescence and a constant but slower decrease thereafter (Ferriera and Swardt, 1980a). Porgoralskaya *et al.* (1980) observed a decrease in starch content during corolla opening. In petals of cut 'Sonia' roses, starch content of the outermost whorl declined very rapidly on the second day (shortly before the onset of petal expansion) but that of the inner whorls remained constant (Evans and Reid, 1986).

2.6.1.1 Influence of chemical treatment on total starch content

Sacalis and Chin (1976) reported that the total starch content in flowers, leaves and stems of cut roses decreased when the flowers were held in water, but sucrose (2%) treatment resulted in maintenance of starch levels. In cut roses cv 'Forever Yours', Molnar and Parups (1977) observed a steady decrease in starch content when the stems were kept in water. On the fifth day in vase, there was no starch reaction. However, starch content in the stem tissues kept in a preservative solution (4% sucrose, 100 ppm sodium isoascorbate and 100 ppm 8-HQS), increased. In dahlia, starch levels declined during senescence and there was no gross difference among sucrose or fructose and 8-HQS treatments (Lukaszewska, 1980). During senescence of carnation flowers, the starch content of the petals declined gradually during senescence. The extent of this decline was

greatest in the cut flowers held in water, the least in attached flowers and intermediate in the cut flowers held in 2 per cent sucrose solution. (Tirosh and Mayak, 1988). Berkholst and Navarro-Gonzales (1989) studied the pattern of starch break down in petals of cut roses cv. 'Sonia'. Low amounts of petal starch were shown to be caused by insufficient synthesis due to premature cutting and breakdown after cutting. Low temperature did not arrest the break down, but at high temperature, starch disappearance was rapid. In cut 'Lady X' roses, treatment with a combination of 2 per cent sucrose, 250 ppm 8 - HQ, 500 ppm citric acid and 25 ppm $AgNO_3$, slightly increased the starch content of petals (Gao and Yang, 1992). Sivasamy (1998) reported that higher starch content during different stages after harvest was associated with longer vase life. The starch content declined gradually from harvest to senescence stage. Pulsing with sucrose 3 per cent D - fructose + 8 - HQC 150 ppm for 24 hours prior to wet storage significantly increased the starch content of petals and leaves in both stages i.e. after storage and at senescence.

Total starch content in petals of cut roses cv 'Raktagandha' had a tendency to increase on the third day in vase over that on the first day and there after decrease at senescence. Pulsing with DMSO (2%) for 15 minutes after storage, resulted in the highest content of starch in petals. The starch content at both the stages tended to decrease with increasing storage duration. In general, higher starch content in petals was associated with longer vase life (Sankar Vidhya, 2001). Pusling of cut rose with sucrose (3%) + 8 - HQC (150 ppm) for 24 h prior to wet storage (3^0C) significantly increased the total soluble sugar and total starch contents in petal and leaf tissues in both the stages i.e. immediately after storage and on senescence than those treated with distilled water (no pulsing) over 8 days of storage.

(Shiva *et al.*, 2002).

2.6.2 Changes in total soluble sugars during cut flower senescence

The dry matter and carbohydrate contents of intact and cut 'Sonia' corollas were compared from an immature bud to full expansion of the petals. Feeding with the sucrose solution maintained the soluble carbohydrate levels and retarded the hydrolysis of starch (Ho and Nichols, 1977). They studied the translocation of ^{14}C - Sucrose in relation to changes in carbohydrate content in the corollas cut at different stages of development. These findings were compared with the carbohydrate changes in the corollas of flowers cut at different stages and allowed to age with their stems either in water or in sucrose solution. For a few days after cutting, the carbohydrate metabolism of the cut flower roughly paralled that of intact flowers until starch hydrolysed to maintain the soluble carbohydrate pool. Feeding with sucrose solution maintained the soluble carbohydrate levels and retarded hydrolysis of starch. Active incorporation of ^{14}C into ethanol soluble carbohydrates, starch, ethanol insoluble material was found indicating that an active anabolic phase precedes the catabolic phase during senescence of the cut flower. Decheva Koseva (1978) reported that sugar synthesis increased with leaf development, reached a maximum in fully expanded (20-30 days old) leaves and then decreased. Leaves formed during flowering stage had lower sugar content than those formed during flower bud development. During flowering, sugar content increased rapidly in the petals (PanKovetskii and Tyutyunnik, 1978). Total soluble sugars accounted for approximately 50 per cent of the dry matter of ray florets from the outer whorls in freshly cut dahlias. At the moment wilting, their level fall to 20 per cent

(Lukaszewska, 1980). Sharma (1981) reported that in *Rosa damascena* flowers, there was first a decline in total sugars, then a sharp rise in the second phase followed by a sharp decline in the last phase. In cut carnations cv. Symphonie higher sugar content was associated with a longer vase life (Amariutei *et al.*, 1986). Periods of rapid expansion of cut rose petals were accompanied by decrease in starch and increase in soluble sugar in the petal but the total carbohydrate content of petals remained constant. (Evans and Reid, 1988). They suggested that starch hydrolysis during the petal growth was important for maintenance of cell size. 'Salmon Sim' carnation had higher sugar contents in the petals, a higher dry matter and longer vase life as compared to 'Astor' (Celikel and Karacali, 1991). Marissen (1991) recorded a competition between the inner and outer petals for sugars during flower development, as the area and sugar content increased when fewer outer petals were present during vase life. A progressive rise in the total soluble sugars content in the petal tissues of roses from harvest towards senescence was observed (Sivasamy, 1998). The precooled and packed flowers of rose cv. Raktagandha recorded higher total soluble sugars over unprecooled packed flowers. The treatment combination of precooling (either by cold storage at 4^0C for 24 hours or ice cold water spray for 45 min) and 8 hours packaging, registered highest TSS content at senescence and maximum vase life. (Palanikumar *et. al.*, 1999). Sankar Vidhya (2001) reported that the content of total soluble sugars in petals of rose were found to increase continously throughout the cut flower development and senescence.

2.6.2.1 Influence of pulsing and preservative chemicals on total soluble sugar contents during senescence

Total sugar contents of all three portions (flowers, leaves and stems) were maintained when cut roses were held in a sucrose (2%) solution, but decreased in water. Levels of sucrose, glucose and fructose in all the three portions decreased when kept in water, while holding in sucrose solution resulted in maintained or increased levels of individual sugars (Sacalis and Chin, 1976). The sugar content decreased in dahlia flowers held in water and 8-HQS but doubled in those held in sugar solutions (LukaszewsKa, 1980). In cut roses, treatment with a combination of 2 per cent sucrose, 250 ppm 8-HQ, 500 ppm citric acid, and 25 ppm $AgNO_3$ increased the soluble sugar and reducing sugar contents of petals (Gao and Yang, 1992). Carbohydrate levels remained significantly higher in cut 'Mercedes' rose flowers treated with 8 - HQC than those held in distilled water (Brena, 1994). Maximum amount of total soluble sugars was estimated in the petals and leaves of cut 'Superstar' roses treated with STS (0.2 mM) + 8 - HQC (300 ppm) + sucrose (2%) (De *et al.*, 1996b). Singh *et al.* (1996) reported that total soluble sugars in the corolla of cut rose cv Raktagandha increased gradually on 3rd day from harvest in the vase followed by sharp decrease on senescence. A foliar spray of 1000 ppm chlormequat which recorded the longest vase life significantly reduced TSS content in corolla, leaf and stem at harvest and on the 3rd day in the vase. Pulsing with 3% sucrose for 18 hours in 'Superstar' roses resulted in increased total soluble sugar content and reducing sugar content in corolla tissues over the control during flower senescence. (Bhattacharjee, 1998). Increased vase life of rose cultivar 'Raktagandha' with 0.5 mM STS pulsing for 45 min was associated with a rise in total soluble sugar content

in petal tissue throughout senescence (Bhattacharjee and De 1998). Singh and Bhattacharjee, (1999) investigated the influence of pre-harvest spray of micronutrients on the changes in total soluble sugars (TSS) and total free amino acids (TFAA) in petal leaf and stem tissues of cut roses cv. Raktagandha. The micronutrient sprays consisted of $ZnSO_4$ (0.5 or 1%), $FeSO_4$ (1 or 2%) or $CuSO_4$ (0.1 or 0.2%). The total soluble sugar content, in the corolla increased during senescence irrespective of micronutrient sprays. TSS in leaf and stem tissues were highest at harvest, and tended to decrease after harvesting and during senescence for most micronutrient treatments.

Ichimura *et al.* (1999) found that concentration of glucose, fructose and sucrose in the petals of 'Sonia' roses were increased by sucrose and HQS treatment. Correlation between sugar concentration in petals and maximum flower diameter on vase life were positive. Eason *et al.* (1997) working on the lilaceous cut flower *Sandersonia aurantiaca* observed that flower treated with sucrose contained greater quantity of carotenoids, soluble and storage carbohydrates and soluble protein than in control flowers.

A significant rise in total soluble sugar content in cut roses cv. 'Sonia Meilland' was observed with the use of chloride salts in holding solution and these were associated with an improved vase life. (Bhattacharjee, 1999c).

Bhattacharjee (2000) reported that among the growth regulating chemicals, Kinetin at 2.5 ppm was the best in terms of effectiveness in increasing postharvest life of cut rose cv. Eiffel flower followed by GA_3 at 150 ppm, BA at 5 ppm and IAA at 2.5 ppm. These treatments resulted in

significant increase in total soluble sugars and reducing sugars in petal tissues from harvest to senescence compared to the untreated control. The amount of soluble carbohydrates present in a single floret of cut gladiolus increased with florets opening and gradually decreased with senescence. Pulsing with 20% sucrose significantly increased the amount of soluble carbohydrates and soluble proteins (Hussain *et al.,* 2001). Pulsing with DMSO (2%) for 15 min and $CaCl_2$ (1%) for 20 hours tended to increase the total starch and total soluble sugars in the petal tissue of rose cv. Raktagandha. (Sankar Vidhya, 2001).

2.6.2.2 Influence of low temperature storage on sugar content

Lukaszewska *et al.* (1991) observed the pattern of changes in carbohydrates were similar among the cut roses placed at 20^0C or previously cold stored at 2^0C for different period of time upto 12 days. Smaller but significant decrease in soluble sugar contents were noticed during flower wilting. Longer the cold storage duration, smaller was the decrease in the sugar level by the end of subsequent vase life at 20^0C. The increase in the ratio of soluble sugars to starch was very small in ovaries as compared to corollas during 12 days of storage at 2^0C. From this, they concluded that only the ratio of soluble sugars to starch in rose corollas could have a potential value as a criterion for cold storage duration of cut roses.

The quality of gladiolus spikes stored for 2 weeks at 0^0C with sucrose treatment was as high as that of fresh flowers. It was suggested that decrease in sugar content of the spikes is a factor leading to poor ornamental quality of cut flowers, and the assessment of sugar content could provide an indication of keeping quality (Jiang *et al.,* 1989). Celikel and Karacali (1991) reported a reduction in sugar content in one week wet stored

(0-10^{0}C and 85-90% RH) carnation flowers. The mean value of reducing sugar contents of freshly harvested and wet stored flowers were 4.93 and 2.63 per cent, respectively. The content of reducing sugars (glucose + fructose) in the spathe of anthurium (*Anthurium andreanum*) generally decreased during storage, but storage at a chilling temperature of 4^{0}C tended to slow the loss of reducing sugars (Pritchard *et al.*, 1991). Total soluble sugar content in leaf tissues of *Leucadendron* declined during storage at 10^{0}C. This decline was significantly inhibited by a 20 per cent or higher sucrose pulse (pre storage) for 24 hours (Jones, 1995). Devecchi *et al.* (1997) studied the effect of pusling and cold storage at 2^{0}C for 3 days on longevity and carbohydrate content in petals of mini rose cv 'Serena'. Though the longevity of flowers pulsed with sucrose and 8-HQC was similar to that of flowers kept in water (control), there was difference regarding carbohydrates in the petals. The main carbohydrates in the petals were glucose, fructose and sucrose. In petal of flowers kept in water, the carbohydrate content decreased gradually with time. However, in pulsed flowers, carbohydrate content decreased during cold storage period and suddenly increased when the stems were immersed with water at ambient temperatures. The content of all the main carbohydrates was higher in pulsed flowers than in control flowers at all time suggesting uptake and hydrolysis of sucrose from the pulsing solution. The rise in soluble sugars which takes place at the end of the cold storage period may be a factor in preventing the longevity of cut roses from being reduced by cold storage. Pulsing 'Raktagandha' roses with 3 per cent sucrose + 150 ppm 8 - HQC for 24 hours prior to wet storage significantly increased the total soluble sugar content in petals and leaves both after storage and at senescence (Sivasamy, 1998). On the first day after low temperature as

well as at senescence the pulsing treatment with D-fructose (3%) + 8-HQC (150 ppm) for 24 hours recorded the highest TSS content in petals of rose cv 'Raktagandha'. Higher TSS content in petals was associated with longer vase life (Sankar Vidhya , 2001). Gladiolus spikes cold stored for 3 days showed higher content of carbohydrate and protein than those stored for 6 days (Hussain *et al.*, 2001).

2.6.3 Changes in total free amino acid (TFAA) during cut flower senescence

Senescence of cut roses in water was characterized by a decrease in concentration of anthocyanin, protein, N, asparagine, tannic acid and an increase in most amino acids and free ammonia in the petal tissue (Weinstein 1957). There appeared to be no direct correlation between senescence of cut flowers and accumulation of total free amino acids in corollas (Lukaszewska and Gorin, 1989). Gorin *et al.* (1989b) reported that there was no accumulation of total free amino acids in corollas of cut 'Sonia' roses. In fact, the TFAA decreased from reference level (100% day 0) to about 60 per cent (day 3) thereafter remaining almost constant. In cut roses of cultivars 'Dame de Couer' and 'Lady X' the concentrations of total and basic free amino acids increased throughout vase life while acidic free amino acids fluctuated at first and then increased sharply when petal senescence began (Gao, 1991, Gao and Wu, 1990). Sultan and Farooq (1996) observed an increase in free amino acids as day lily (*Hemerocallis fulva*) flowers developed, opened and senesced. Sivasamy (1998) observed that in rose cut flowers, TFAA contents in the petal tissues increased progressively from harvest towards senescence. A lower TFAA content was always correlated with a longer vase life. Similar result was also observed by (Sankar Vidhya , 2001).

2.6.3.1 Influence of pulsing and preservative solutions of TFAA content

Presence of glucose or fructose in the holding solution suppressed the accumulation of free amino acids in senescing cut dahlias (Lukaszewska, 1980). Addition of preservative containing 2% sucrose, 250 ppm 8 - HQC, 500 ppm citric acid and 25 ppm $AgNO_3$ reduced the level of increase in amino acid concentration in cut rose flowers (Gao and Wu 1990; Gao, 1991). De *et al.* (1996) observed minimum amount of TFAA in petals and leaves of cut 'Super star' roses treated with STS (0.2 mM) + 8 - HQC (300 ppm) + sucrose (2%). A foliar spray of chlormequat at 1000 ppm resulted in marked decrease of TFAA in leaf and corolla tissues at all the different stages of sencence when compared to controls (Singh *et al.*, 1996). De and *et al.*, (1996) reported that there was a progressive rise in contents of TFAA from less mature to more mature flower buds. After treatment with different holding solutions especially STS (0.2 mM) + 8 - HQC (300 ppm) + sucrose (2%), there was minimum amount of TFAA in petals and leaves of cut 'Superstar' roses. Bhattacharjee and De (1998) observed that increased vase life of cut rose cv Raktagandha was associated with lowest contents of TFAA in petal tissues throughout senescence process. Bhattacharjee (1999c) observed that use of chloride salts in the holding solutions of cut roses cv. 'Sonia Meilland' resulted in a significant fall in TFAA over the untreated control. The decrease in membrane properties in senescing cut roses in cultivars 'Mercedes' and 'Boroness' were delayed by $CaCl_2$ treatment (Torre *et al.*, 1999). Singh and Bhattacharjee, (1999) reported that irrespective of micronutrient sprays, TFAA tended to increase in all flower tissues after harvest, reaching a peak during senescence. Foliar application of $FeSO_4$ (2%) recorded the lowest TFAA content in corolla

and leaves compared with the other treatments and lowered TFAA in stems after harvest. Palanikumar (1999) observed maximum TFAA content in precooled and 24 hours packed flowers at senescence and thus ultimate vase life was reduced.

2.6.3.2 Influence of low temperature storage on TFAA content

Gorin *et al.* (1989a) found that there was an accumulation of total free amino acids in corollas from cut roses stored at 2^0C. In cold stored flowers, senescence was retarded as indicated by only slight opening of the corolla and no subsequent petal abscission. They also observed that changes in the corollas of all free amino acids except alanine and lysine were affected by cold storage. Velasco *et al.* (1992) suggested that an asparagine concentration of less than 70 m mol/kg D W in the calyces or a glutamic acid concentration of less than 15 m mol/kg DW in the corollas or less than 10 m mol/kg DW in the leaves, could be taken as evidence that the roses had been cold stored. Pusling treatment of cut 'Raktagandha' roses with 3 per cent sucrose + 150 ppm 8 - HQC for 24 hours prior to wet storage at 3^0C decreased the increase in TFAA content after storage and on senescence (Sivasamy, 1998). With increasing storage duration in the content of total amino acids in cut rose cv. Raktagandha showed a steady increase (Sankar, Vidhya 2001). Gorin *et al.* (1989b) observed no correlation between senescence of cut roses and accumulation of total free amino acids in the corollas of the individual free amino acids, only leucine content was affected by ethylene treatment. Cold storage, however, did affect the contents of leucine, histidine, glutamic acid, valine, proline, aspartic acid, phenylalanine, asparagine, tyrosine, isoleucine and glycine in the rose corollas.

2.6.4 Role of phenolic compounds during senescence of cut flowers

Plants cotain a large number of aromatic compounds with hydroxyl groups which are collectively referred to as phenolics or phenols. Phenols have an important role as antioxidants in plant systems. Also phenolic derivates play an active role in plant resistance and defence against microbial infections. Tsujimoto *et al.* (1993) suggested that the antioxidative properties of phenols may be due to rapid reaction with primary produced oxygen radicals such as superoxide and hydroxide.

Thus, in senescing plant tissue they play a role of scavenging superoxide, peroxyl and hydroxyl radicals. Because of the widespread occurrence of phenolics in plants, many plant physiologists are of the opinion that they function as regulatory substances. Varieties differ in their response with regard to phenolic changes, initially an increase in the susceptible and resistant varieties but with the symptom development, phenols decrease in the susceptible varieties while in the resistant varieties phenols accumulate. During and after infection de novo synthesis of phenols as well as phenol oxidizing enzymes (Phenol oxidases, peroxidases) have been observed (Elstner *et al.*, 1994).

Paull *et al.* (1985) observed that in cut anthurium flowers the concentration of tissue phenolic increased during senescence and intensified colour change by copigmentation. Newman *et al.* (1990) investigating leaf blackening in proteas observed that addition of silver thiosulphate (STS) in the vase solution prevents oxidation of phenolics. Mc Conchie *et al.* (1994) suggested that in protea, the rapid rate of leaf starch hydrolysis imposed an osmotic stress resulting in cleavage of glycosylated phenolic compounds to release glucose for carbohydrate metabolism and

third day and then a small rise towards the end of useful life of cut 'Priyadarshini' roses. The ethylene production and respiration of florets detached from the spikes of gladiolus flowers vary between cultivars (Serek *et al.*, 1995). The respiration rate of cut rose cv. Lady X and Dame de Coeur, increased in a preservative combination of 2% sucrose + 250 ppm 8-hydroxy quinoline + 500 ppm citric acid + 25 ppm silver nitrate (Gao and Yang, 1992). Jones *et al.* (1995) concluded that despite the lack of a respiratory climacteric and ethylene production, petal wilting in tulips was associated with a rapid increase in de novo synthesis of lipoxygenase (LOX), an enzyme thought to be associated with membrane degradation. Highest respiration rate in cut rose was associated with the shortest vase life and lowest respiration with the longest vase life (Sivasamy, 1998).

Wang, (1999) reported that sugar content of cut flowers of *Anthurium andraeanum* stored at 14^0C for 10-15 days was lower than that of flowers stored at 4^0C. Sugar content decreased with increasing rates of respiration. Respiration rate was lower at 4^0C than at 14^0C. Storage of cut spray type chrysanthemum by modified atmosphere packaging (MAP) using polyethylene (PE) and (PP) film resulted in 2% oxygen atmosphere which reduced the respiration rate of cut chrysanthemum by 50% (Yamashita *et al.*, 1999).

Son-Kicheol *et al.* (1997b) investigated the effects of preservative solutions (Distilled water), BS (2% sucrose + 200 ppm 8-HQS), chrysal (0.5%) or Sonkl (BS + 0.1 mM ethionine) on the senescence of leaves of cut flowers of rose cv. Red Sandra. BS and Sonkl solutions reduced photosynthesis rate and chlorophyll content but stimulated respiration rate of leaves compared with the control. Chrysal solution rapidly reduced

photosynthesis rate and maintained the highest respiration rate of all treatments leaves abscised after 6 days.

Bhattacharjee and Pal (1999) reported that irrespective of cultivar, respiration rates increased sharply during flower development and petal expansion stages and declined markedly at senescence after the full expansion of flowers. In cultivars, with longer vase life, the rate of respiration during the flower development and ageing were comparatively lower than that of cultivars with short vase life. The respiration rate decreased during senescence of cut flowers and was increased by keeping them in the preservative solution (Pascale S-de *et al.*, 1998).

Yan *et al.* (2000) observed that during the change of respiratory rate, ethylene declines during the early period, then increase and decline again. Soluble protein increased constantly and thereafter declined. The peroxidase activity increased throughout the period of measurement. Petals in different positions all showed the same physiological characteristics and gradually degenerated from the outer to the inner. Nitrogen at the rate of 500 kg N/ha gave the lowest respiration rate for rose cv. Arjun (Sankar Vidhya and Bhattacharjee, 2000). During spring or summer, flower respiration rate appears to be a good indicator of potential metabolic rate and flowers with low respiration rates lasts longer (Monteiro *et al.*, 2001).

2.7.2 Influence of cool storage on respiration rate.

Serrano *et al.* (1992) studied the physiological alternations of *Rosa hybrida* cv. 'Visa' during cold storage. The cut flowers were stored at 4^0C. They observed that the rate of ethylene production was maintained at very low levels and it was unaffected by the time of cold storage. Respiration, in contrast, decreases during storage. The respirtory activity

of the roses not stored at a low temperature ranges from 250 to 450 mg CO_2/kg/hr. But the respiratory activity during senescence at room temperature was lower in those flowers stored at 4^0C for longer period ranging from 100-200 mg CO_2/kg/hr in the roses stored for 7 weeks. The content of reducing sugars (in case of fructose) in the spathe of cut anthurium flowers decreased during storage corresponding with sudden increase in respiration rate. Storage at 4^0C slowed down the loss of reducing sugars, probably due to slower respiration rate (Pritchard *et al.*, 1991).

Cold stored alstroemeria cv. 'Ostara' cut flowers were pretreated with 4% sucrose + 4 mM STS. Then they were dry stored at 0 ± 0.5^0C for 10 days in plastic bags. The pretreatment with 4% sucrose + 4 mM STS increased the vase life and decreased the respiration rate of the flowers. The weight loss was also minimized (Menguc *et al.*, 1996).

2.8 Microorganisms and their role in post harvest losses in cut roses

The action of microorganisms against cut flower includes bacterial plugging of flower vessel elements (Van Meeteren, 1978), enzymatic action (Durkin, 1967) or possible endogenous production of ethylene (Van Doorn *et al.*, 1989). Aarts (1957) was the first to demonstrate that microorganisms growth in the vase water resulted in low hydraulic conductance of the stems especially in the basal stem segment. At the concentration of 3×10^9 bacteria per ml of water, the roses wilted within an hour (Van Doorn *et al.*, 1986). Bent neck was also observed only at this high bacterial number. The development of occlusions in the stems of cut rose flowers has been correlated with an increase in the number of bacteria in the stems. The main blockage developed in the lower most stem segment in which many more bacteria were found than in more distal segments. When vascular

blockage developed, the bacterial population in the basal 5 cm stem segments was about 10^6 colony forming units (cfu) per gram fresh weight. Whenever, the number of bacteria exceeded this number, the blockage was found, be it after 3 days in pure water or after a long period in the presence of an antimicrobial compound (Van Doorn *et al.*, 1989). High bacterial counts in stem were also correlated with vascular occlusion in the petioles of fronds from the fern *Adiantum raddianum* (Van Doorn *et al.*, 1991a). Bacterial suspensions containing *Pseudomonas aeruginosa* isolated from *Rosa hybrida* cv. Sonia stems significantly reduced water uptake and hydrolytic conductance of the stems compared with control stems (De Witte and Van Doorn, 1991).

The number of bacteria in the stems are correlated with the blockage, such a correlation does not always exist between numbers in the stems and in the vase water. After a few days of vase life, no bacteria can sometimes be found in the vase water containing cut rose flowers, but a considerable number of bacteria high enough to result in vascular occlusion were present in the stems (Van Doorn and Perik, 1990). A population of bacteria is also present on the outside of the stems. These bacteria may rapidly multiply in the water, the freshly cut stem and the xylem vessels (Van Doorn and Tijs Kens, 1991).

The bacterial concentration found in the vase water at consumer sites was about 10^7 - 10^8 c.f.u per ml a few days after placing the stems in water (Jones and Hill, 1993). Toxic microbial compound may also be excreted into the vase water which accelerates senescence (Put and Klop, 1990).

During vase life, the number of bacteria in the vase water of several cut flower species have been measured. Bacterial counts reach a maximum of about 10^7 cfu/ml of water after a few days of vase life in roses, carnations, tulips and chrysanthemums. Such bacterial counts correspond with symptoms of water deficit in roses and some chrysanthemum cultivars, but not in carnation and tulips. Bacteria in the vase water at concentration 108-1010 c.f.u ml of cut *Gerbera jamesonii* resulted in an increase in scape curvature depending on the concentration of bacteria in the water, cultivar and season (Van-Doorn and De Witte, 1994). High bacterial counts in the vase water can shorten flower longevity of cut carnation flowers cv. 'Scania' and 'White Sim'. The reduction in flower longevity were related to inhibition of water uptake (Van-Doorn *et al.*, 1995). The possible sources of bacteria contributing to premature wilting of cut rose flowers cv Sonia was tap water containing *Pseudomonads and Enterobacter* sp. It was observed that bacteria rapidly developed on the cut surface and inside the water conducting elements when rose stems were placed in tap water, even when the stems had been surface sterlized (Van-Doorn and De Witte, 1997).

Ultra structural investigations of cut roses placed in water also led to the conclusion that the region close to the cut surface contained bacteria, presence of a population of bacteria at the cut surface and inside the water conducting elements preceded the onset of measurable occlusion (Lineberger and Steponkus 1976, De Stigter and Broekhuysen, 1986, Van Doorn *et al.*, 1991c).

When the vase water was held at neutral pH there was usually no development of yeast population in the vase solution and only a few

filamentous fungi were found. When, however, the pH is kept at a low level, for e.g. by using citric acid, bacterial growth is initially suppressed but a population of yeasts rapidly develops and many filamentous fungi were found (Van Doorn, 1997). Both yeasts and filamentous fungi may lead to vascular blockage (Put and Clerkx, 1988). Vase water held at pH higher than about 4.0 may contain a few fungi and yeasts, but no yeasts were observed at the cut surface or inside the xylem of rose stems held in such water. In vase water of pH 4.0-7.0 the role of yeasts in vascular occlusion is therefore, apparently minimal. Within 3-4 days of vase life at such pH, a few fungal hyphae were found at the cut surface. Because the development of fungi occurs after the development of the occlusion of cut roses was also apparently minimal. At pH 4.0-7.0 population of bacteria rapidly develops at the cut surface and inside the xylem conduits (Van Doorn *et al.*, 1991b).

The bacteria that was predominant in the vase water of cut roses and other cut flowers has been isolated and identified by various research workers (De Witte and Van Doorn, 1988; Zagory and Reid, 1986b; Put and Jansen, 1989; Van Doorn *et al.*, 1991; De Witte and Van Doorn, 1991). They belong to the genera namely *Pseudomonas, Alcaligenes faecalis, Enterobacter, Aeromonas, Bacillus, Flavobacterium, Acetinobacter* sp., *Achromobacter* sp. *Erwinia* sp. *Corynebacteria.*

Fungal plugging of xylem vessel elements of cut flowers was reported by De Stigter and Broekhuysen (1986); Put (1990); Van Doorn *et al.* (1991). The predominant fungal species isolated and identified from vase water are *Botrytis cineria, Fusarium oxysporum, Mucor, Penicillium* sp. and *Rhizopus stolonifer.* In cut roses cv. Norena bacteria which cause

vascular blockage were observed in the xylem vessels of stem ends after 10 days in distilled water. These bacteria were identified as *Pseudomonas fluorescens, Klebseilla oxytoca* and *Aeromonas hydrophila* (Kim *et al.*, 1997).

2.8.1 Influence of baceria and dry storage

The number of bacteria in the basal 5 cm of the stems of cut rose flowers cv. Sonia stored in water for 1 to 4 days was positively correlated with the number of bacteria in the water. Subsequent dry storage of the flowering rose stems resulted in an increase in the number of bacteria in the stems, similar to that occuring in stems that were held in water. Low temperature during dry storage (5^0C) reduced the multiplication rate of baceria in the stems (Van-Doorn and De Witte, 1991).

Cut flowers of rose cvs. Sonia, Madelon, Jacaranda and Frisco stems were placed in acqueous, mixed bacterial suspensions (104 and 108 cfu/ ml) for 24 h at 5^0C, controls were placed in water containing < 102 c.f.u/ ml. Stems were then placed in water or were dry stored for 24 h at 8^0C, and were finally placed in vase water at 20^0C. Flower opening and water relations in Sonia and Madelon were negatively affected by treatment with 108 c.f.u/ml and by dry storage. At 104 c.f.u/ml a negative effect occurred only in combination with dry storage. It was concluded that, in general, bacterial infection increased the level of flower opening inhibition caused by dry storage (Van-Doorn and D'Hont, 1994).

2.8.2 Control of microbial population

Different biocides used in vase water studied by various research workers were streptomycin sulphate, $CuSO_4$, Kanamycin, Cycloheximide, Chloramphenicol (Zagory and Reid, 1986b); $AgNO_3$, benzalkene, HQC,

DICA (Van Doorn *et al.,* 1989), HQC and low pH (3.0) (Van Doorn and Perik, 1990); Chlorine (Hoogerwerf and Van Doorn, 1992); $Al_2 (SO_4)_3$ (Hoogerwerf and Van Doorn, 1992), Van Doorn and De Witte, 1991; Put *et al.,* 1992), DICA and HQC (Van Doorn *et al.,* 1990; Jones and Hill, 1993).

Aluminium sulphate showed weak biocidal activity towards *Bacillus subtilis* at pH 4 as the $Al_2(SO_4)_3$ was hydrolysed to give a colloidal Al $(OH)_3$ solution. *B. subtilis* cells were co-precipitated with $Al(OH)_3$ on the open surface of cut xylen vessels of rose cv 'Sonia' and acted as a bacterial filter (Put *et al.* 1992). Use of aluminium sulphate solution (0.8 g/litre) during the rehydration period before dry storage limited the number of bacteria in the stems of rose cv. Sonia and prevented their subsequent increase during dry storage (Van-Doorn *et al.,* 1991). Analyses of microbial concentrations showed that proliferation was effectively controlled by DICA (Sodium dichloroisocyanurate) and BCDMH, but not by HQC (hydroxyquinoline citrate) (Jones and Hill, 1993). Silver nitrate in holding solution enhanced the water uptake and greatly reduced the bacterial count (colonies/ml of holding solution) (Ketsa *et al.,* 1993). Ketsa *et al.* (1995) reported that bacterial populations were lowest in holding solution of HQS + $AgNO_3$ + glucose. *Bacillus sp* was found in vase water from all treatments except that containing $AgNO_3$ + HQS + glucose. The peptides cecropin B, hordothionin and tachyplesin I were tested for their ability to control bacterial growth in the keeping solutions of cut roses. Dilution experiments showed that tachyplesin I was the most effective agent in controlling bacterial populations in vase water (Florack *et al.,* 1996). The best treatment for inhibition of bent neck in cut *Rosa hybrida* cultivars Mary de Vor and Norena was 120 mg myclobutanil/litre for 4 h at a stage

when calyx was separated from petals and petals beginning to open of bud development (Kim *et al.,* 1998). The effects of a multi-component pulsing solution MPS-STS (2 mM) + Sucrose 10% + BA (Benzyladenine) 20 ppm + 8-HQS (300 ppm) in prolonging vase life of cut freesia are attributed to the inhibition of lipoxygenase activity and microorganism growth. 8-HQS showed an antibacterial activity and STS inhibited the action of ethylene, leading to a decrease in lipoxygenase activity as well as an antibacterial components (Kwon *et al.,* 2000).

3. MATERIALS AND METHODS

The present investigation was carried out at the Division of Floriculture and Landscaping, Indian Agricultural Research Institute, New Delhi-110 012 during the period from January 2000 to August 2002. The investigation consisted of different experiments under the following aspects :

1. To study the effect of precooling and pulsing on the postharvest life and quality of rose cut flowers.

2. To investigate the effect of precooling and pulsing on packaging and storage for different durations

   (a) Effect of half covered cut stems with different packaging material and duration of storage under packing.

   (b) Effect of full covered cut stems with packaging materials and duration of storage under packing.

3. Effect of pulsing and holding solution on postharvest life and quality of wet stored cut flowers.

   (a) Influence of pulsing and wet storage days on vase life of cut roses.

   (b) Influence of holding solution on wet stored and pulsed cut roses.

4. Effect of pulsing and holding solution on the postharvest life and quality of dry stored cut flowers

(a) Influence of pulsing and dry storage days on vase life of cut roses.

(b) Influence of holding solutions on dry stored and pulsed cut roses.

5. Effect of pulsing, conditioning and holding solutions on the vase life of dry stored cut flowers.

6. To study the changes in biochemical constituents like starch, total soluble sugars (TSS), total free amino acids (TFAA) and phenols in Golden Gate cut roses as affected by pulsing, precooling and packaging.

7. Rate of respiration of cut roses during the course of senescence as affected by the chemical treatments and cold storage.

8. Influence of precooling, pulsing and packaging duration on the growth of microorganisms in the vase water of the cut roses.

Description of the rose cut flower varieties and the cultivation practices followed

For the various experiments following cultivars of roses were taken.

'First Red' : It is a Hybrid Tea variety, having tall and upright stem of 80 cm length. Large red coloured buds are produced on long strong stems. Average yield of flowers is 190 per sq.m. per year (Plate 3).

'Noblesse' : It is a Hybrid Tea variety. Large light pink coloured buds are borne on erect thorny stems. The stem length is 60 cm. Average yield of flowers is 260 per sq.m. per year (Plate 4).

Plate 1. View of greenhouse in I.A.R.I.

Plate 2. Cool storage chamber in the division

Plate 3. A greenhouse view of the rose cultivar 'First Red'

Plate 4. A greenhouse view of the rose cultivar 'Noblesse'

'Golden Gate' : It is a Floribunda type rose variety. Medium sized buds of golden yellow colour are borne on stems whose length varies from 50-60 cm. Average yield of flowers is 210 per sq.m. per year (Plate 5).

'Mercedes' : It is a Floribunda type (sweet heart) variety. It has small, orange coloured buds with dark green foliage. Stem length is 45 cm and average yield of flowers is 300 per sq.m. per year (Plate 6).

The cut flowers of the above four varieties were collected from polyhouse grown roses of Indo-Israel Project of IARI, New Delhi. The flowers were cut randomly from the beds in the morning. While growing, these plants were given uniform treatment of fertilization, irrigation, spraying of insecticide and fungicide as per the schedule under the fan and pad system polyhouse.

3.1 Effect of precooling and pulsing on the postharvest life and quality of cut rose cultivars viz., 'First Red', 'Golden Gate' 'Noblesse' and 'Mercedes'

Two methods of precooling and two pulsing chemicals were used in the experiment. These were

Methods of precooling used

(1) Ice-cold water spray (2 ± 1^0C) for 45 min at an interval of 3 minutes, total 15 sprayings were given in 45 minutes.

(2) Cool storage at 4^0C for 24 hours.

Pulsing chemicals for pretreatment

(1) Dimethyl sulphoxide (DMSO) 2 % for 15 min.

(2) D-fructose (3%) + 8-hydroxyquinoline citrate (HQC) (150 ppm) for 24 h.

Plate 5. A greenhouse view of the rose cultivar 'Golden Gate'

Plate 6. A greenhouse view of the rose cultivar 'Mercedes'

The experimental treatments employed were :

(a) No pulsing and no precooling

(b) Precooling with ice cold water spray for 45 min and no pulsing

(c) Precooling with ice cold water spray for 45 min and pulsing with D-fructose (3%) + 8-HQC (150 ppm) for 24 h.

(d) Precooling with ice cold water spray for 45 min and pulsing with DMSO 2% for 15 min.

(e) Precooling with cool storage at 4^0C for 24 h and no pulsing.

(f) Precooling with cool storage at 4^0C for 24 h and pulsing with D-fructose 3 % + 8-HQC (150 ppm) for 24 h.

(g) Precooling with cold storage at 4^0C for 24 h and pulsing with DMSO 2 % for 15 min.

The flowers of cut rose cvs. 'First Red', 'Noblesse', 'Mercedes' and 'Golden Gate' were collected from three year old polyhouse grown rose plants (Plate 1). The flowers were harvested with 35 cm long stems in the morning with the help of a clean and sharp secateur at a stage when the flower buds were fully mature and completely developed and all sepals were well spread and furled down. The stem ends of the harvested flowers were immediately dipped in the tap water collected fresh at the bottom of a clean bucket. They were then shifted to the laboratory. The harvested stems were again recut to a uniform length of 30 cm by retaining only the four uppermost compound leaves.

After recording the fresh weight of each cut stem, the flowers were kept in a plastic bucket containing tap water and precooled with two different methods (i) spraying of ice-cold water of temperature (2 ± 1^0C) over the cut flowers for 45 min. With a small hand sprayer, ice-cold water was sprayed over the buds and flower stems at a regular interval of 3 min, and a total of 15 sprays, (ii) cool storage at 4^0C for 24 h. The pre-cooled cut flowers with ice-cold water spray were then pulsed with two chemicals viz. (a) DMSO (2%) for 15 min. and (b) D-fructose (3%) + 8-HQC (150 ppm) for 24 h.

For cool storage treatment, the flowers were pulsed in the cool storage simultaneously with the above two pulsing chemicals. One set of treatments served as control which were neither precooled nor pulsed. The precooled and pulsed cut flowers were then transferred to a clean test tube (25 mm x 200 mm) containing a known amount of tap water. These tubes were kept at ambient temperature of 25^0C (maximum), 12^0C (minimum) and 75-80 % relative humidity in the laboratory and their postharvest life and quality was studied. There were altogether seven treatments including control and for each treatment five flowers were kept and replicated three times. The experiment was laid out in Completely Randomized Design (CRD).

Observations taken

1. Fresh weight of cut flower (g)

- at harvest
- on the 3rd day in vase
- at the end of vase life

The fresh weight (FW) of flowers was recorded using a digital weighing balance. Care was taken that the cut end of the roses were dipped in water during the weighing operation.

2. Dry weight of cut flower (g)

- at harvest
- on the 3rd day in vase
- at the end of vase life

The dry weight of the cut flowers were recorded by drying the cut flower in a hot oven at 70^0C and then weighing using digital weighing balance.

3. Flower diameter (cm)

This was measured by scale at the maximum expansion of the flower on two perpendicular axis and the average of the two values were taken.

4. Water uptake (ml)

- on the 3rd day in vase
- at the end of vase life

The difference in the amount of water in the test tube from initial amount to final amount during 3rd day in vase and at senescence.

5. Vase life (days)

Vase life was recorded since the time the cut flowers were kept in vase after precooling treatments till senescence. The end of useful vase life or senescence symptoms was marked either by appearance of bent

neck, blueing of petals in case of red roses, wilting, blackening or drying of outer petals or opening at center, petal drop and colour fading etc.

3.2 Studies on the effect of precooling and pulsing on packaging and storage for different durations

The best treatment from Experiment 3.1 (one through ice-cold water spray and pulsing with DMSO (2%); and another through cool storage at 4^0C and pulsing with DMSO (2%) for pre-cooling) were used for this investigation. The experiment was conducted in one variety 'Golden Gate'.

Five different packaging materials viz., (i) Butter paper, (ii) Brown paper, (iii) Polythene (80 gauge), (iv) Newspaper and (v) Single layer corrugated fibre board sheet, and three storage durations i.e. 6 h, 20 h and 24 h were used for this investigation.

The experiment was conducted in two sets :

(1) Covering the entire cut stem with packaging material.

(2) Covering only the half portion of the cut flowers i.e. towards the floral portion.

3.2.1 Effect of half covered cut stems with different packaging material and duration of storage under packing

The experimental treatments for this experiment were as follows :

(a) Butter paper packed for 6h, 20h and 24 h.

(b) Polythene (80 gauge) packed for 6 h, 20 h and 24 h.

(c) Brown paper packed for 6 h, 20 h and 24 h.

(d) Single layer corrugated fibre board sheet packed for 6 h, 20 h and 24 h.

(e) Newspaper packed for 6 h, 20 h and 24 h.

The plant material was obtained from the polyhouse and prepared uniformly by recutting the stem to 35 cm length and retaining four compound leaves. Precooling treatments with ice-cold water spray on cut flowers for 45 minutes and cool storage at 4^0C for 24 h were given to remove the field heat and then pulsed with DMSO (2%) for 15 min. Immediately after each precooling and pulsing treatment, the cut rose stems were half covered i.e. towards the floral portion with five different packaging material mentioned above and were kept in the corrugated fibre board boxes at ambient temperature for 6 h, 20 h and 24 hours (Plate 12). After the packaging duration was over they were cut to 30 cm length and transferred to test tube (20 mm x 200 mm) containing 70 ml of tap water to study the vase life and quality of precooled and packed cut flowers at ambient temperature. One set of flowers were neither precooled nor packed which served as the control. For each treatment five flowers were kept which were replicated three times. The experiment was laid out in Completely Randomized Design (two factorial).

Observations taken were similar to Experiment 3.1.

3.2.2 Effect of full covered cut stems with packaging materials and duration of storage under packing

Out of five packaging materials and three duration of storage from the Experiment 3.2.1, only four packaging materials and two storage duration were chosen for this experiment.

The experimental treatments were as follows :

(a) Butter paper packed for 6 h and 20 h.

(b) Polythene (80 guage) packed for 6 h and 20 h.

(c) Brown paper packed for 6 h and 20 h.

(d) Single layer corrugated fibre board sheet packed for 6 h and 20 h.

The experiment was laid out in Completely Randomized Design (CRD) (two factorial) replicated three times and five flowers kept for each treatment (with two different precooling treatments). Observations taken were similar to Experiment 3.1.

3.3.1 Influence of pulsing and wet storage days on vase life of cut roses

Three pulsing chemicals were used and pulsed cut flowers were wet stored for 0, 1, 2, 3 and 4 days in the cool storage at 4^0C. The experiment was conducted in one variety i.e. 'Golden Gate'.

Pulsing chemical used

(1) Silver thiosulphate (STS) 0.5 mM for 45 min.

(2) Calcium chloride ($CaCl_2$) 1 % for 20 h.

(3) Benzyl adenine (BA) 25 ppm for 45 min.

The experimental treatments were as follows :

(a) No pulsing and no storage.

(b) STS pulsing + wet storage (0, 1, 2, 3, 4) days + vase water.

(c) $CaCl_2$ pulsing + wet storage (0, 1, 2, 3, 4) days + vase water.

(d) BA pulsing + wet storage (0, 1, 2, 3, 4) days + vase water.

Observations taken

(a) No pulsing and no storage (Observations recorded similar to Experiment 3.1).

(b) STS or $CaCl_2$ or BA pulsing + wet storage (0, 1, 2, 3, 4) days + vase water.

1. Fresh weight of cut flower (g)

- at harvest
- after storage
- on the 3rd day in vase
- at the end of vase life.

2. Dry weight of cut flower (g)

- at harvest
- after storage
- on the 3rd day in vase
- at the end of vase life.

3. Flower diameter (cm)

- after complete opening of the flower.

4. Water uptake (ml)

- on the 3rd day in vase
- at the end of vase life.

5. Vase life (days)

Vase life was recorded since the time when the cut flowers were kept in vase after the storage duration till senescence. The end of

useful life or senescence symptoms were marked either by appearance of bent neck, blueing of petals in case of red roses, wilting, blackening, drying of outer petals or opening at center, petal drop, colour fading etc.

The 'Golden Gate' cultivars were harvested in the morning and were taken to the laboratory to be prepared uniformly (30 cm long stem and retaining only four compound leaves) before going to storage (Plate 10). The cut stems were pulsed with three different pulsing chemicals mentioned above and then taken to the cold storage to be wet stored for 1, 2, 3 or 4 days. One set of flowers was neither pulsed nor stored and served as control. The cut ends of the stem were dipped in water and were taken to cold storage. The temperature of the storage room was maintained at 4 ± 1^0C and the humidity was around 90 %. The effect of wet storage for different storage duration was studied. Each treatment was replicated four times and five flowers were taken for each treatment. The experiment was laid out in Completely Randomized Design (CRD).

3.3.2 Influence of holding solution on wet stored and pulsed cut roses

The best two pulsing chemical (STS 0.5 mM for 45 min and BA 25 ppm for 45 min) and optimum storage duration (3 days) was chosen from experiment 3.3.1. Seven different holding solutions used were :

(1) D-fructose 3 % + Kinetin 2.5 ppm

(2) D-fructose 3 % + Silver nitrate 25 ppm

(3) D-fructose 3 % + Nickel chloride 300 ppm

(4) Sucrose 3 % + 8-HQC 200 ppm

(5) Sucrose 2 % + Captan 200 ppm

(6) Sucrose 2 % + Streptomycin sulphate 250 ppm

(7) Control - Tap water.

The experimental treatments were as follows :

(a) No pulsing and no storage

(b) Pulsing (STS 0.5 mM) + wet storage (3 days) + seven different holding solutions.

Observations taken were similar to Experiment 3.3.1.

Each treatment was replicated three times and five flowers were taken for each treatment. The experiment was laid out in Completely Randomized Design (CRD).

3.4.1 Influence of pulsing and dry storage days on vase life of cut roses

Two best pulsing chemicals similar to experiment 3.3.1 were used and the pulsed cut flowers were dry stored for 0, 4, 5, 6, 7 days. The experiment was conducted in one variety 'Noblesse'.

The experimental treatments were as follows :

(a) No pulsing and no storage.

(b) STS pulsing + Dry storage (0, 4, 5, 6, 7) days + vase water.

(c) BA pulsing + Dry storage (0, 4, 5, 6, 7) days + vase water.

The 'Noblesse' flowers were harvested in the morning and were brought to the laboratory to be prepared uniformly (35 cm long stem and retaining uppermost four compound leaves) and fresh weight of each cut stem was taken by a digital weighing balance (Plate 19). The cut stems were then pulsed with two best chemicals mentioned above for certain duration and then packed in polythene (80 guage) wrapping material and

dry stored for 4, 5, 6 and 7 days at 4^0C. One set of flowers were neither pulsed nor dry stored which served as control. The effect of dry storage for different duration on the vase life of cut roses was studied. Each treatment was replicated four times and five flowers were kept for each treatment. The experiment was laid out in Completely Ranmdomized Design.

3.4.2 Influence of holding solutions on dry stored and pulsed cut roses

The best pulsing chemical (STS 0.5 mM for 45 min) and optimum storage duration (6 days) was chosen from experiment 3.4.1.

Seven different holding solutions used were :

(1) D-fructose 3 % + Kinetin 2.5 ppm

(2) D-fructose 3 % + Silver nitrate 25 ppm

(3) D-fructose 3 % + Nickel chloride 300 ppm

(4) Sucrose 3% + 8-HQC 200 ppm

(5) Sucrose 2 % + Captan 200 ppm

(6) Sucrose 2 % + Streptomycin sulphate 250 ppm

(7) Control (Tap water).

The experimental treatments were as follows :

(a) No pulsing and no storage.

(b) Pulsing (STS 0.5 mM) + dry storage (6 days) + seven different holding solutions.

Observations taken were similar to experiment 3.3.1. Each treatment was replicated three times and five flowers were kept for each treatment. The experiment was laid out in Completely Randomized Design.

3.5 Effect of pulsing, conditioning and holding solutions on the vase life of dry stored cut roses

The best one pulsing chemical (STS 0.5 mM for 45 min), optimum dry storage day (6 days) and best holding solution (D-fructose 3% + Nickel chloride 300 ppm) from experiment 3.4.2 was used.

The experimental treatments were as follows :

a) Dry store + conditioning in water for 1 h + vase water

b) Dry store + conditioning in 500 ppm Citric acid for 1 h + vase water

c) Pulsing + dry store + vase water

d) Pulsing + dry store + holding solution

e) No pulsing + No storage + No holding solution (control)

Observations taken are similar to experiment 3.3.1. Each treatment was replicted four times, five flowers were taken for each experiment. The experiment was laid out in Completely Randomized Design.

3.6 Biochemical constituents of cut roses as affected by pulsing, precooling and packaging duration

To study the changes in biochemical constituents like total soluble sugars, starch, total free amino acids and phenols in the cut roses, dried powdered petal samples from experiment 3.1 and 3.2 were used.

The following protocols were used for the analysis.

3.6.1 Changes in total starch content in petals as affected by pulsing, pre-cooling and packaging materials

The method used was Mc Cready *et al.* (1950).

Principle

The sample is treated with 80 per cent ethanol to remove soluble sugars and then starch is extracted with perchloric acid. In hot acidic medium, starch is hydrolysed to glucose and dehydrated to hydroxy methylfurfural. This compound forms a green coloured product with anthrone.

Reagents

(i) Anthrone sulphuric acid

200 g of anthrone was dissolved in 100 ml of ice cold 95 percent sulphuric acid and stored near 0^0C. Fresh reagent was prepared for every two days.

(ii) 52 per cent perchloric acid

It was prepared by adding 347 ml of 60 per cent perchloric acid to 53 ml of distilled water and stored in a glass stoppered container.

Extraction of sugars and starch

0.2 g of finely powdered, dried petal samples were homogenized with 10 ml of 80 per cent ethanol by stirring thoroughly and centrifuged at 5000 rpm for 15 minutes after 5 minutes standing. The residue was retained after removing the alcoholic solution (to remove sugars). To the residue 10 ml of fresh hot 80 per cent ethanol was added by stirring, centrifuged and the residue retained as before by discarding the alcoholic solution.

The washing treatment was repeated twice more for a total of four washings or till a test with anthrone reagent was negative. The residue

was dried over a water bath after final centrifugation. To the dried residue, 5 ml of water was added and the tubes were cooled in ice. 6.5 ml of 52 per cent perchloric acid was added to the ice cold test tubes by constant stirring for 15 minutes and occasionally thereafter for 15 min. The tubes were centrifuged at 5000 rpm for 15 minutes and the acqueous starch solution was poured into a 100 ml volumetric flask. The extraction was repeated as before and the starch solution was pooled. The volume was made upto 100 ml with distilled water and filtered through Whatman No. 1 filter paper.

Extraction of starch

0.2 ml of the filtrate was pipetted out in a test tube and the volume made upto 1 ml with distilled water. 4 ml of fresh anthrone reagent were added to each tube by keeping the tubes in ice. The tubes were mixed thoroughly and heated in a waterbath for 8 minutes at 100^0C. The solution in the tubes was cooled rapidly to room temperature and the intensity of green to dark green colour was read at 630 nm in Digital Spectrophotometer (Systronics, Model UV-VIS Spectrophotometer 117) after proper setting and calibration using a blank. The glucose content of the flower sample was calculated by referring to a standard graph of glucose. Total starch content was worked out by multiplying the value of glucose content found out, by the factor 0.90 and expressed in mg/g of dry weight.

Preparation of glucose standard curve

A stock solution of glucose was prepared by dissolving 100 mg of glucose in 100 ml of water. 10 ml of stock solution was diluted to 100 ml

with water to prepare the working standard 0, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6 and 0.7 ml of the working standard solution was made upto 1 ml with water to obtain standard glucose concentrations of 0, 10, 20, 30, 40, 50, 60 and 70 µg/ml. To each 1 ml of glucose at different concentrations, 4 ml of fresh anthrone reagent was added after cooling the tubes in ice. After thorough mixing of the reagents contained in a test tube, the tubes was immediately heated in a water bath at 100^0C for 8 min. The solution in the tubes were cooled rapidly to room temperature and intensity of green to dark green colour was read at 630 nm in digital spectrophotometer for the different glucose standards. A standard curve of glucose was prepared against OD readings of the respective glucose concentrations.

3.6.2 Changes in total soluble sugar content in petals as affected by pulsing, precooling and packaging materials

The method used by Dubois *et al.* (1956) was followed.

0.2 g of finely powdered dried petal samples were homogenized in 10 ml of 80 per cent ethanol by stirring it and keeping overnight and centrifuging at 2000 rpm for 20 minutes. 0.04 ml of this aliquot was pipetted into a test tube. To this 1 ml of 5 per cent phenol and 5 ml of concentrated H_2SO_4 were added. Immediately after adding each reagent, a proper mixing was done by giving a slight shaking to each tube. The solution in the tube was left at room temperature for 15 minutes. A golden yellow colour developed at the end of the cooling. Absorbance of each sample was read in a Digital Spectrophotometer (Systronics, Model UV VIS spectrophotometer 117) at 490 nm after proper setting and

calibration of the instrument using a blank. Total sugar content in the flower sample was worked out by referring to a standard curve of sugar (glucose) and was expressed in mg/g of dry weight.

Preparation of glucose standard curve

A 0.2 per cent stock solution of glucose was prepared by dissolving 100 mg of glucose in 50 ml of 80 per cent ethanol. Standard solution of glucose of strength 0, 20, 40, 60, 80 µg/ml were prepared by taking 0.01, 0.02, 0.03 and 0.04 ml of the stock solution together with 0.04, 0.03, 0.02, 0.01 and 0 ml of 80 per cent ethanol respectively so that the volume of the aliquot was made upto 0.04 ml equivalent to the volume of the aliquot taken from the alcoholic extract of each powdered flower sample. To each 0.04 ml of different glucose concentration, 1 ml of 5 per cent phenol was added, followed by the addition of 5 ml concentration of H_2SO_4 taking care so as to mix each reagent added each time. The solution was kept at room temperature for 15 minutes for colour development. OD was recorded for each glucose standard solution in a Digital Spectrophotometer at 490 nm wavelength. A standard curve of glucose was prepared by plotting OD values.

3.6.3 Changes in total free amino acid (TFAA) content in petals as affected by pulsing, precooling and packaging materials

The method used by Rosen (1957) was followed

Principle

Ninhydrin, a powerful oxidizing agent deoxycarboxylates the alpha-aminoacid and yields an intensely coloured blueish purple product which

is colorimetrically measured at 570 nm.

Reagents

(i) Stock NaCN of 0.01 M

It was prepared by dissolivng 49 mg of NaCN in 100 ml of distilled water.

(ii) Acetate buffer of pH 5.34.

To 270 g of sodium acetate trihydrate, 500 ml of distilled water and 50 ml of glacial acetic acid were added with constant stirring. The final volume was made upto 750 ml with distilled water and pH adjusted to 5.34.

(iii) Acetate cyanide

10 ml of solution (i) (0.01 M NaCN) was made upto 500 ml with solution (ii) (acetate buffer of pH 5.34)

(iv) Ninhydrin 3 per cent in methyl cellosolve

7.5 g of ninhydrin was dissolved in 250 ml of methyl cellosolve.

(v) Isopropyl alcohol : Water (1:1) diluent

It was prepared by mixing 500 ml of isopropyl alcohol with 500 ml of distilled water.

Extraction

0.2 g of oven dried, finely powdered petal samples were homogenized in 5 ml of 80 per cent ethanol by soaking it overnight and centrifuging at 2000 rpm for 20 minutes. The centrifugation was repeated

thrice and the extracts made upto 25 ml with 80 per cent ethanol.

Procedure

5 ml of the alcoholic extract was diluted with 20 ml of distilled water. 0.5 ml of the alcoholic extracts of the samples, was pipetted into test tubes and made upto 1 ml with acetate buffer (0.5 ml). To this 0.5 ml of acetate cyanide buffer was added followed by 0.5 ml of ninhydrin 3 per cent, shaking the tubes for proper mixing each time. The contents in the tubes were heated in a waterbath for 15 minutes at 100^0C. 5 ml or 12 ml of isopropyl alcohol : water diluent were added to each tube immediately after removing from the water bath. This was followed by vigorous shaking using an electrically operated mixer (Jay Vortex Mixer). The tubes were allowed to cool down to room temperature and OD reading at 570 nm taken in a Digital Spectrophotometer after proper setting up and calibration of the instrument using a blank.

Preparation of leucine standard curve

10 mg of leucine was dissolved in 10 ml of acetate buffer of pH 5.34. From this solution 1 ml was made upto 100 ml with acetate buffer to give a stock solution with concentration 50 µg/ml. 0 .1, 0.2, 0.3, 0.4, 0.5 and 0.6 ml of the stock solution (50 µg/ml) were made upto 1 ml with acetate buffer, to obtain standard leucine concentration of 0, 5, 10, 15, 20, 25 and 30 µg/ml. To each 1 ml of leucine of different concentrtations 0.5 ml of acetate cyanide and 0.5 ml of 3 per cent ninhydrin solution were added. After thorough mixing of the reagents, the tubes were immediately immersed in hot water bath at 100^0C for 15 min. During heating the solution gradually turned into blueish purple. Immediately after removing

the tubes from the hot water bath 5 ml of the isopropyl alcohol : water diluent were added to each test tube. This was followed by vortexing and then the tubes were allowed to cool to room temperature. Then OD of the standard were read at 570 nm and standard curve of leucine prepared by plotting OD against the concentrations.

3.6.4 Changes in total phenol content in petals as affected by pulsing, precooling and packaging materials

The method used by Malick and Singh (1980) was followed.

Principle

Phenols react with phosphomolybdic acid in folin cioculteau reagent in alkaline medium and produce a blue coloured complex molybdenum blue.

Reagents

80 per cent ethanol

Folin Ciocaltau reagent

Na_2CO_3 20 per cent

Standard (100 mg catechol in 100 ml of water)

Dilute 10 times for a working standard

Procedure

0.5 g of dried finely powdered petal samples were homogenized in 5 ml of 80 per cent ethanol. The homogenate was centrifuged at 10000 rpm for 20 minutes. The supernatant was saved. The residue was re-extracted with 2.5 ml of 80 per cent ethanol. Centrifugation was repeated and the supernatant pooled. The supernatant was evaporated to dryness

over a boiling water bath.

The residue was dissolved in 25 ml of distilled water. 0.1 ml aliquot was pipetted into test tubes. The volume in each tube was made by upto 3 ml with water. Add 0.5 ml of folin ciocalteau reagent. After 3 min, 2 ml of 20 per cent Na_2CO_3 solution were added in each tube. The contents were mixed thoroughly. The tubes were placed in a boiling water bath for exactly one minute, cooled and measured the absorbance at 650 nm against a reagent blank. A digital spectrophotometer 117 was used (Plate 7). A standard curve was prepared using different concentrations of catechol. From the standard curve, the concentration of phenols in the samples was found out and expressed as mg phenols/g dry weight.

3.7 Rate of respiration of cut roses during the course of senescence as affected by the chemical treatments and cold storage

For this experiment, cut flower samples from experiment 3.3.2 and 3.4.2 were used for this study.

The respiration rate of cut roses (in cc of CO_2/g d.w/ hr) as affected by the holding solution and wet and dry storage during different stages (at harvest, after storage, on the third day in vase and at the end of vase life) was measured. An infra red gas analyser (IRGA) model LI-6200 (Plate 8) was used for this purpose.

IRGA LI-6200 consists of a CO_2 analyser, a system console and a sensor housing with interchangeable chambers. The LI-6200 CO_2 analyser is a non dispersive infra red type (NDIR) calibrated for measurement of 0-2000 ppm of CO_2. A pump in the analyser circulates air from the measurement chamber to the analyser, where CO_2 concentration is

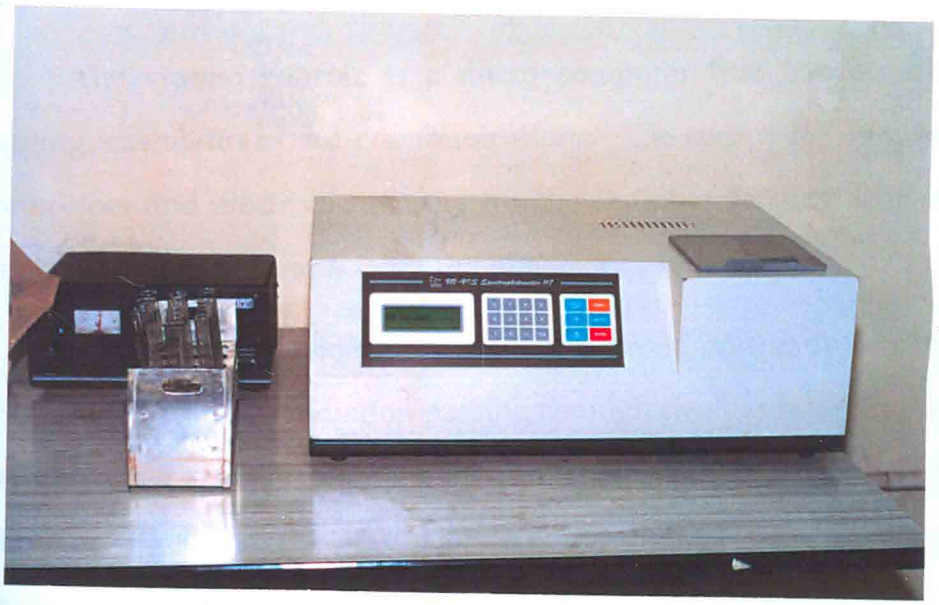


Plate 7. Systronics model UV VIS Spectrophotometer-117

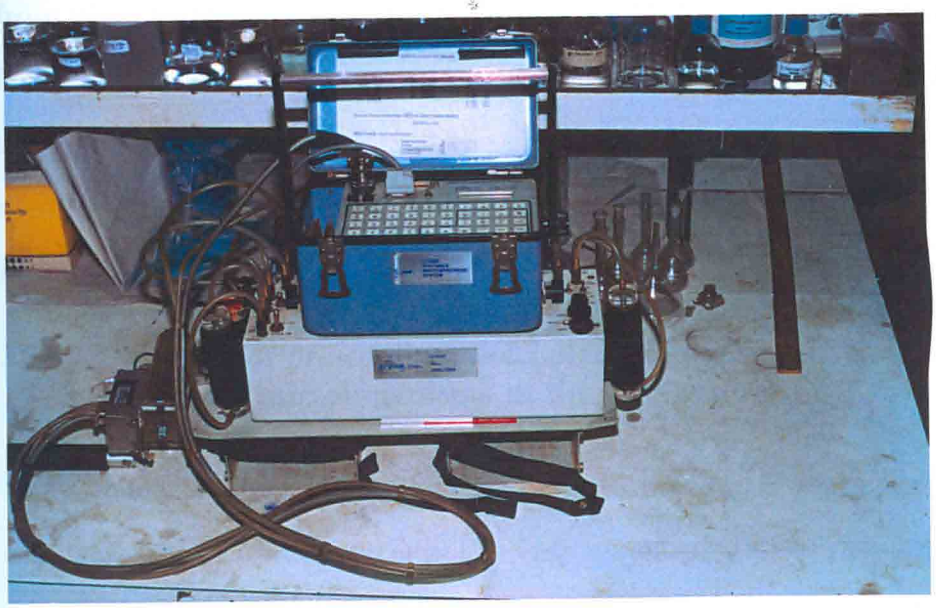


Plate 8. IRGA model LI-6200

measured and returns it to the chambers.

The system console is a micro computer that handles the data logging, calculations and communications. The sensor housing contains connectors and electronic sensors for the chamber sensors, fans and the intake and exhaust parts from the analyser.

The carbon dioxide measurement is based on the difference in the intensity of infra red radiation passing through two gas sampling cells, the reference cell contains either a zero or known concentration of CO_2 and the sample cell contains an unknown concentration. Infra red radiation is transmitted through both cell paths and the output of the analyser is proportional to the difference in absorption between the two. Measurements were made placing the flowers in the chambers of volume 250 ml and activating the log button on the console, when regular rise in carbon dioxide concentration is observed in the console window. The data from the measurement are automatically logged into the systems memory. Data logging continues for 30 seconds during which time the instrument records 3 observations. Using the data thus obtained as well as the dry weight of the samples, respiration rate was calculated in cc of CO_2/g d.w/ hr.

3.8 Influence of pre-cooling, precooled and packed cut flowers on the growth of microorganisms in the vase water of cut roses

The investigation was carried out to find out the microorganisms, especially fungi and bacteria in the vase water which were responsible for post harvest spoilage of cut roses and also to find out the influence of precooling and precooled and packed cut flowers on the growth of microorganisms in the vase water of cut roses. Hence, this investigation

constituted of three parts i.e. isolation, pure culture and identification.

Experimental materials

The cut rose stems cv. Noblesse of 30 cm length with four compound leaves were used for this investigation.

For isolating fungi, potato dextrose agar (PDA) and for bacteria, nutrient agar (NA) were used. The vase water of different days after the precooling and packaging treatment were given, was utilized for culturing the microbes in PDA and NA media. At senescence, the basal stem portion of the cut flower was sliced into thin sections and placed on the PDA medium to observe any growth of microorganisms at the basal portion of the cut stem.

The pre-cooling treatments were as follows:

(a) No pulsing and no precooling

(b) Precooling with ice-cold water spray for 45 min and no pulsing

(c) Precooling with ice-cold water spray for 45 min and pulsing with D-fructose (3%) + 8 HQC (150 ppm) for 24 h.

(d) Precooling with ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min.

(e) Precooling with cool storage at 4^0C for 24 h and no pulsing

(f) Precooling with cool storage at 4^0C for 24 h and pulsing with D-fructose (3%) + 8 HQC (150 ppm) for 24 h.

(g) Precooling with cool storage at 4^0C for 24 h and pulsing with

DMSO (2%) for 15 min.

The precooled flowers, one with ice-cold water spray for 45 min and another one with cool storage at 4^0C were packed with butterpaper packaging material for two different durations i.e. 6 h and 20 h and placed in CFB boxes at room temperature. In total, there were 7 treatments including control which was neither precooled nor packed.

The precooling and packaging treatments were as follows:

(a) No pre-cooling and no packaging

(b) Ice-cold water spray for 45 min, pulsed with DMSO (2%) and no packaging.

(c) Ice-cold water spray for 45 min, pulsed with DMSO (2%) and packed with butter paper for 6 h.

(d) Ice-cold water spray for 45 min, pulsed with DMSO (2%) and packed with butter paper for 20 h.

(e) Cool storage at 4^0C for 24 hr, pulsed with DMSO (2%) and packed with butter paper for 6 h.

(f) Cool storage at 4^0C for 24 h, pulsed with DMSO (2%) and packed with butterpaper for 20 h.

Preparation of media

A. Potato Dextrose Agar (PDA)

This was prepared with peeled potatoes (250 g), dextrose (20g), agar (20g) and distilled water (1000 ml). The skin of potatoes was removed, cut into small pieces and boiled in 1 litre of water in a vessel for

10-15 min, till the potatoes became soft and were easily penetrated by a glass rod. Then the extract was filtered through a muslin cloth into another vessel and the volume made upto 1 litre. To this, 20 g of agar was added and was boiled for 2-3 min with constant stirring. The medium is cooled and 20 g of dextrose was added with constant stirring. The medium prepared was filled into the test tubes and flasks and autoclaved at 15 lbs pressure at 121^{0}C for 15 min.

B. Nutrient Agar (NA)

Bacterial peptone	5 g
Yeast extract	3 g
Agar	20 g
Distilled water	1000 ml

pH of the mixture was maintained at 6.8 - 7.0 before sterilization in autoclave.

Isolation

The purpose of isolation is to separate mixed populations of microorganisms into individual species. Sterilized PDA medium was used for growth of fungal populations and sterilized NA medium for bacterial growth and petriplates were used for growth of the above microorganisms in the incubator at 28^{0}C.

Individual fungal colonies were isolated from petriplates containing PDA medium by inoculation needle in the laminar flow chamber. Similarly, bacterial colonies were isolated from petriplates containing NA medium.

Pure culture

A culture containing a single unadulterated species of cells is called a pure culture.

Individual fungal colonies were developed in the PDA slants by following single hyphal tip culture. Similarly, for bacteria colony counting, serial dilution technique was used for the establishment of pure culture. All these operations were done under sterilized conditions.

Identification

The fungal colonies of pure culture were subjected for identification under microscope. The bacterial colonies per ml of vase water for different days of vase life were counted by serial dilution techniques. The morphological informations, especially the different shapes of bacteria were observed microscopically using gram staining procedure.

Serial dilution technique

Suspend 1 ml of vase water sample of different days of vase life of cut rose in a tube of 10 ml distilled water, from which a clear sterile pipette was used to transfer an aliquot (1 ml) of this to a tube with 9 ml distilled water. This was continued for as many dilutions as required. For e.g. 10^{-1} is denoted as the first dilution and from this 1 ml aliquot was transferred to 9 ml distilled water in another tube which becomes the second dilution (10^{-2}) and so on. One drop of this suspension was placed on the melted and cooled nutrient agar medium on petriplates inside a Laminar flow chamber. Immediately the drop is spread evenly with a spreader until it dries in the agar medium.

The petriplates were placed upside down and marked. Then they were placed in a plastic cover and tied with a rubber band and transferred to the incubation room at temperature 28^0C. After 24 h or one day, the petriplates were observed for the bacterial colonies and were counted. The total colony counts, referred as colony forming units (cfu) were calculated as below:

$$cfu = \frac{y}{dx}$$

Where, y = Number of colonies formed

d = dilution

x = volume of the sample taken

Gram staining of bacteria

The method of gram staining to identify bacteria and classify them into two major groups, the gram-positive '+' and 'gram negative '-', was developed by Dr. Hans Christian Gram, a Danish physician in 1884. In this process the fixed bacteria smear is subjected to four reagents viz. crystal violet (primary stain), iodine solution (mordant), alcohol (decolorizing agent) and safranin (counter stain). The bacteria which retain the primary stain appear dark blue or violet are called gram positive, whereas that lose the crystal violet and counterstained by safranin (appear red) and referred to as gram negative.

The procedure followed is as follows:

(a) The smears of bacterial colonies were made on separate glass slides and

(b) The smears were allowed to dry and heated.

Then each smear was covered with crystal violet for 30 seconds and each slide was washed with distilled water for a few seconds. After that, the smear was covered with iodine solution with 95% ethyl alcohol. Then the slides were washed with distilled water and drained. Then smears were covered with safranin for 30 seconds and washed with distilled water and blot dried and air dried subsequently and examined using oil-immersion under microscope.

4. RESULTS

4.1 Studies on the effect of precooling and pulsing on the postharvest life and quality of cut rose cultivars viz. 'First Red', 'Golden Gate', 'Noblesse' and 'Mercedes'.

4.1.1 Changes in fresh and dry weight of 'Noblesse' cut roses as affected by precooling and pulsing

With reference to Table 1, precooling and pulsing treatments significantly affected the changes in fresh and dry weight during the development of cut flower cv. Noblesse. On 3rd day in vase, there was increase in fresh and dry weight of cut flower irrespective of the treatments. Maximum fresh weight on 3rd day was recorded with the treatment of ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min and the second highest fresh weight was recorded with cool storage at 4^0C and pulsed with DMSO (2%). The same trend was observed with the changes in dry weight of Noblesse cut roses. During senescence, however, there was decrease in fresh and dry weight over the initial weight of cut flower and 3rd day. Maximum decrease in the fresh weight at senescence was recorded with the treatment by ice cold water spray for 45 min and no pulsing, minimum decrease with cool storage at 4^0C and pulsing with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. In dry weight, however, the maximum decrease was recorded with the treatment of cool storage at 4^0C and not pulsed. Minimum decrease was observed with ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min. The vase life was associated with the changes in fresh and dry weight in the cv 'Noblesse'. Maximum vase life was recorded with treatment of ice cold

Table 1. Effect of precooling and pulsing on changes in fresh and dry weight of 'Noblesse' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Ice cold water spray for 45 min and not pulsed	+0.69	-0.91	+0.05	-0.35	12.00
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.99	-0.64	+0.08	-0.91	12.53
Ice cold water spray for 45 min and pulsed with DMSO (2%)	+1.78	-0.79	+0.31	-0.14	13.80
Cool storage at 4^0C for 24 h and not pulsed	+0.99	-0.87	+0.22	-1.37	11.40
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+1.47	-0.22	+0.18	-1.19	12.60
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	+1.73	-0.75	+0.27	-0.17	13.00
No precooling and no pulsing (Control)	+0.91	-0.41	+0.05	-0.45	10.00
'F' test	**	**	**	**	**
S.Em. ±	0.01	0.01	0.01	0.01	0.12
CD at 5%	0.03	0.03	0.03	0.03	0.36

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

water spray for 45 min and pulsing with DMSO (2%), where highest fresh and dry weight was observed on 3rd day and minimum loss in dry weight at senescence. Second highest post harvest life was recorded with cool storage at 4^0C and pulsing with DMSO (2%) for 15 min. There was also pronounced increase in the fresh weight on 3rd day and little decrease on the dry weight at senescence.

4.1.2 Postharvest life and flower quality of 'Noblesse' cut rose as affected by precooling and pulsing

Water uptake, flower diameter and vase life was significantly affected by the different precooling and pulsing treatments in rose cv. Noblesse (Table 2). Maximum water uptake was observed with the treatment of cool storage at 4^0C and pulsing with DMSO (2%) for 15 min, and the next highest water uptake with ice cold water spray for 45 min and pulsing with DMSO (2%). However, there was no significant difference between these treatments in the water uptake on 3rd day. Measurement of water uptake at senescence, showed almost the same trend.

Flower diameter was also influenced by the different treatments. There was significant improvement in the flower diameter by all the treatments over the control. Maximum flower diameter was recorded in the three treatments viz. ice-cold water spray with no pulsing, cool storage at 4^0C and pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h and ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. There was no significant difference between the above three treatments with the treatment of ice-cold water spray for 45 min and pulsing with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. Maximum vase life was recorded with ice-cold water spray for 45 min and pulsing with DMSO

Table 2. Effect of precooling and pulsing on postharvest life and quality of 'Noblesse' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Ice cold water spray for 45 min and not pulsed	9.40	36.80	7.0	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	8.70	37.40	6.9	12.5
Ice cold water spray for 45 min and pulsed with DMSO (2%)	9.50	38.80	7.0	13.8
Cool storage at 4^0C for 24 h and not pulsed	8.20	33.60	5.9	11.4
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	8.80	39.00	7.0	12.6
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	9.80	40.00	6.5	13.0
No precooling and no pulsing (Control)	7.50	32.50	5.3	10.0
'F' test	**	**	**	**
S.Em. ±	0.19	0.16	0.17	0.12
CD at 5%	0.58	0.49	0.52	0.36

(2%) and second maximum vase life with cool storage at 4^0C and pulsed with DMSO (2%). Minimum vase life was recorded with the untreated control. It has been observed, in general, that there was significant increase in the vase life of rose cv. Noblesse over control. Thus, it may be concluded that the increased water uptake at different stages of flower senescence and the improved flower diameter was associated with increased vase life.

4.1.3 Changes in fresh and dry weight of 'Mercedes' cut roses as affected by precooling and pulsing

It is evident from Table 3 that the changes in fresh and dry weight and vase life of precooled and pulsed 'Mercedes' cut flowers significantly varied with the control. All the treatments recorded significantly higher increase in fresh weight on the third day compared to the untreated control flowers. The highest increase in fresh weight on the third day was recorded with the treatment of ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min and the second highest gain in fresh weight with cool storage at 4^0C and pulsed with DMSO (2%) for 15 min. The minimum increase in fresh weight on the third day was recorded by the untreated control flowers.

At senescence, however, there was decrease in fresh and dry weight over the initial weight of cut flower and 3rd day. Maximum decrease in the fresh weight at senescence was recorded with two treatments viz. ice cold water spray for 45 min and no pulsing, and cool storage at 4^0C for 24 h and pulsing with D-fructose (3%) + 8 HQC (150 ppm) for 24 h. While minimum decrease in fresh weight was recorded with ice-cold water spray for 45 min and pulsing with D-fructose (3%) + 8 HQC (150 ppm).

Table 3. Effect of precooling and pulsing on changes in fresh and dry weight of 'Mercedes' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Ice cold water spray for 45 min and not pulsed	+0.85	-1.62	+1.04	-0.96	11.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.73	-0.06	+1.21	-0.72	11.4
Ice cold water spray for 45 min and pulsed with DMSO (2%)	+1.46	-1.01	+1.59	-1.13	12.3
Cool storage at 4^0C for 24 h and not pulsed	+0.35	-0.42	+0.39	-0.28	11.9
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.85	-1.62	+1.38	-1.68	11.5
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	+1.00	-0.46	+1.21	-0.77	12.0
No precooling and no pulsing (Control)	+0.28	-0.90	+0.59	-0.96	9.6
'F' test	**	**	**	**	**
S.Em. ±	0.01	0.01	0.01	0.01	0.08
CD at 5%	0.03	0.03	0.03	0.03	0.24

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

In the case of dry weight, there was significantly higher increase in dry weight on third day over the initial weight in all the treatments as compared to the untreated control. Maximum increase in dry weight on 3rd day was recorded with ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. Maximum decrease in dry weight at senescence was observed with cool storage at 4^0C and not pulsed flowers. The loss in dry weight at senescence was same with two treatments, ice cold water spray for 45 min and no pulsing and the untreated control which did not differ significantly with each other.

The vase life was associated with the changes in fresh and dry weight in the cv. Mercedes. The longest vase life was recorded with ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min followed by cool storage at 4^0C and pulsed with DMSO (2%) for 15 min, though these two treatments did not differ significantly with each other. In general, the longer vase life had highest increase in fresh and dry weight on the 3rd day over other treatments.

4.1.4 Post harvest life and flower quality of 'Mercedes' cut rose as affected by precooling and pulsing

Water uptake, flower diameter and vase life were influenced by the precooling and pulsing treatments in 'Mercedes' cut roses (Table 4 and Plate 9). On 3rd day, maximum water uptake was observed with ice cold water spray for 45 min and pulsing with DMSO (2%) for 15 min and second highest water uptake was with the treatment of ice cold water spray for 45 min and not pulsed. These two treatments also differed significantly from all the other treatments. At senescence, maximum water uptake was recorded with the treatment of ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. Maximum flower

Table 4. Effect of precooling and pulsing on postharvest life and quality of 'Mercedes' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senes-cence		
Ice cold water spray for 45 min and not pulsed	10.10	23.00	6.4	11.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	9.50	28.00	7.0	11.4
Ice cold water spray for 45 min and pulsed with DMSO (2%)	10.50	31.00	7.9	12.3
Cool storage at 4^0C for 24 h and not pulsed	9.70	26.90	6.9	11.9
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	9.20	29.80	6.5	11.5
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	9.00	29.67	7.7	12.0
No precooling and no pulsing (Control)	7.50	22.30	6.2	9.6
'F' test	**	**	**	**
S.Em. ±	0.07	0.18	0.09	0.08
CD at 5%	0.21	0.55	0.27	0.24

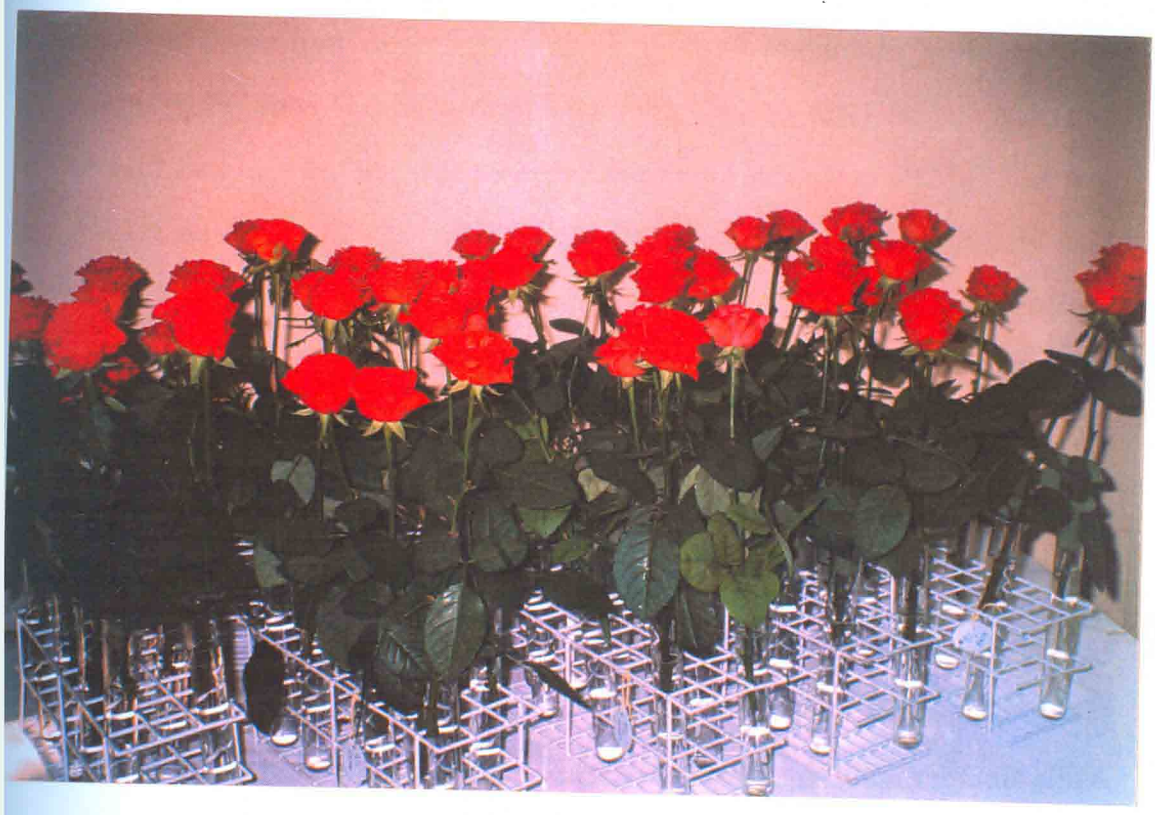


Plate 9. A view of the laboratory experiment with 'Mercedes' cut roses for vase life evaluation

diameter was recorded with the treatment of ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. and second highest flower diameter was observed with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min. However, there was no significant difference between these two treatments. Vase life was maximum with ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min and second longest vase life was recorded with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min. Minimum vase life was recorded with the untreated control. In general, longer vase life was associated with maximum water uptake and largest flower diameter when fully open in rose cv. Mercedes.

4.1.5 Changes in fresh and dry weight of 'Golden Gate' cut roses as affected by precooling and pulsing

It has been observed from the Table 5 that the precooling and pulsing treatments significantly affected the changes in fresh and dry weight during the development of rose cut flower cv. Golden Gate (Plate 11). On 3rd day in vase, there was increase in fresh and dry weight of cut flower in all the treatments. Maximum fresh weight on 3rd day was recorded with the treatment cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min and the second highest fresh weight was recorded with two treatments viz. ice cold water spray for 45 min. and pulsed with DMSO (2%) for 15 min and cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm). Maximum increase in dry weight was observed with treatment of cool storage at 4^0C for 24 h and not pulsed, followed by cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min. However, there was no significant difference between these two treatments.

Table 5. Effect of precooling and pulsing on changes in fresh and dry weight of 'Golden Gate' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Ice cold water spray for 45 min and not pulsed	+0.23	-1.09	+0.64	-1.48	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.15	-1.66	+0.69	-0.81	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	+0.82	-0.85	+0.69	-0.10	13.0
Cool storage at 4^0C for 24 h and not pulsed	+0.67	-0.60	+0.84	-0.44	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.82	-1.40	+0.75	-0.19	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	+1.13	-0.77	+0.83	-0.24	13.5
No precooling and no pulsing (Control)	+0.27	-1.05	+0.66	-1.02	11.0
'F' test	**	**	**	**	**
S.Em. ±	0.01	0.01	0.01	0.01	0.12
CD at 5%	0.03	0.03	0.03	0.03	0.36

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

Plate 10. Harvesting stage of 'Golden Gate' cut roses

Plate 11. Effect of precooling (cool storage at 4^0C for 24 h) and pulsing (DMSO 2% for 15 min) on the cut rose cv. 'Golden Gate' on 7^{th} day of vase life

During senescence, there was decrease in fresh and dry weight over the initial weight of the cut flower and 3rd day. Maximum decrease in the fresh weight at senescence was observed with ice-cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. In dry weight, maximum decrease in dry weight was observed with ice cold water spray for 45 min and not pulsed, whereas minimum decrease in dry weight was observed with ice cold water spray for 45 min and pulsing with DMSO (2%) for 15 min.

The vase life was associated with the changes in fresh and dry weight in the rose cv. Golden Gate. Maximum vase life was recorded with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min, where highest fresh and dry weight was observed on 3rd day and less loss in dry weight at senescence. Second highest post harvest life was recorded with two treatments viz. ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min and cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. However, there was no significant difference between these two treatments on the vase life. These two treatments showed marked increase in the fresh and dry weight on 3rd day and minimum decrease in the dry weight at senescence.

4.1.6 Post harvest life and flower quality of 'Golden Gate' cut rose as affected by precooling and pulsing

Water uptake, flower diameter and vase life was significantly affected by the different precooling and pulsing treatments in cv. Golden Gate (Table 6). Maximum water uptake on the 3rd day in vase was observed with the treatment of cool storage at 4^0C for 24 h and pulsing with DMSO (2%) for 15 min and the next best treatment in water uptake

Table 6. Effect of precooling and pulsing on postharvest life and quality of 'Golden Gate' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Ice cold water spray for 45 min and not pulsed	7.20	22.00	6.7	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	6.40	24.40	7.7	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	9.30	27.60	7.9	13.0
Cool storage at 4^0C for 24 h and not pulsed	9.00	25.50	7.0	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	9.60	28.00	7.3	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	10.30	29.40	6.9	13.5
No precooling and no pulsing (Control)	6.70	19.90	5.5	11.0
'F' test	**	**	**	**
S.Em. ±	0.07	0.10	0.07	0.12
CD at 5%	0.21	0.30	0.21	0.36

was observed with cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. Water uptake at senescence showed the same trend by these two treatments, i.e. significant over all the other treatments.

Flower diameter was also influenced by the different precooling and pulsing treatments. There was significant improvement in the flower diameter by all the treatments over the control. Highest flower diameter was observed with the treatment of ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min and the second highest was observed with the treatment of ice-cold water spray for 45 min and pulsing with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. However, there was no significant difference between these two treatments on the flower diameter of cv. Golden Gate. Maximum vase life was recorded with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min, while minimum vase life was observed with the untreated control. There was significant increase in the vase life of cv. Golden Gate over the control. Longest vase life was associated with maximum water uptake and improvement in the flower diameter at senescence of cv. Golden Gate.

4.1.7 Changes in fresh and dry weight of 'First Red' cut roses as affected by precooling and pulsing

From Table 7, it is clear that the changes in the fresh, dry weight and vase life of the cut rose cv. 'First Red' was significantly affected by the precooling and pulsing treatments. The fresh weight was increased on the third day in all the treatments over the initial weight of the cut flower at harvest. Maximum fresh weight on 3rd day was recorded with the treatment of ice cold water spray for 45 min and pulsing with DMSO (2%)

Table 7. Effect of precooling and pulsing on changes in fresh and dry weight of 'First Red' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Ice cold water spray for 45 min and not pulsed	+0.72	-0.44	+0.27	-0.30	8.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.93	-0.30	+0.74	-0.99	8.5
Ice cold water spray for 45 min and pulsed with DMSO (2%)	+1.29	-0.66	+0.96	-0.54	9.5
Cool storage at 4^0C for 24 h and not pulsed	+0.75	-0.59	+0.52	-0.09	7.5
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	+0.67	-0.50	+0.35	-0.46	8.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	+0.79	-0.43	+0.75	-0.27	8.5
No precooling and no pulsing (Control)	+0.50	-0.45	+0.12	-0.10	7.0
'F' test	**	**	**	**	**
S.Em. ±	0.01	0.01	0.01	0.01	0.08
CD at 5%	0.03	0.03	0.03	0.03	0.24

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

for 15 min, and second highest with ice-cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. At senescence, the fresh weight showed a declining trend when compared to third day. Minimum loss in fresh weight on 3rd day was recorded with ice-cold water spray for 45 min and pulsing with D-fructose (3%) + 8-HQC (150 ppm) for 24 h. The dry weight of the cut flowers also increased on third day and decreased at senescence in case of both treated and untreated control flowers over the initial weight of the cut flower at harvest. Minimum loss in dry weight was recorded with the treatment of cool storage at 4^0C for 24 h and not pulsed. Thus, precooling with ice cold water spray for 45 min and pulsing with DMSO (2%) for 15 min significantly increased the fresh weight and dry weight over untreated control, which also resulted in maximum vase life.

4.1.8 Post harvest life and flower quality of 'First Red' cut rose as affected by precooling and pulsing

Treatment with precooling and pulsing showed significant increase in water uptake and flower diameter of cut rose cv. First Red in vase (Table 8). Maximum water uptake on 3rd day and at senescence was observed with ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min, which also resulted in maximum flower diameter after the flower was completely opened. Second maximum flower diameter was recorded with two treatments and these are cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min and cool storage at 4^0C for 24 h and not pulsed. However, there was no significant difference between these two treatments on the flower diameter of the cut rose cv. First Red. Maximum vase life was observed with the treatment of ice-cold water

Table 8. Effect of precooling and pulsing on postharvest life and quality of 'First Red' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Ice cold water spray for 45 min and not pulsed	6.30	15.50	7.8	8.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	6.70	16.00	8.0	8.5
Ice cold water spray for 45 min and pulsed with DMSO (2%)	6.70	18.00	9.4	9.5
Cool storage at 4^0C for 24 h and not pulsed	5.70	14.00	8.8	7.5
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	6.30	15.60	8.7	8.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	6.20	17.00	8.8	8.5
No precooling and no pulsing (Control)	5.00	13.00	7.5	7.0
'F' test	**	**	**	**
S.Em. ±	0.07	0.10	0.06	0.08
CD at 5%	0.21	0.30	0.18	0.24

spray for 45 min and pulsing with DMSO (2%) which also resulted in increased water uptake on 3rd day and senescence and maximum flower diameter. Thus, it may be concluded that longest vase life was associated with increased water uptake and maximum flower diameter during different stages of flower development till senescence of rose cv. First Red.

4.2 Studies on the effect of precooling and pulsing on packaging and storage for different durations

4.2.1.1 Influence of precooling (ice-cold water spray for 45 min) pulsing and packaging material (half covered) on the changes in fresh and dry weight of 'Golden Gate' cut roses

The data presented in Table 9 shows that changes in fresh and dry weight of precooled, pulsed and packed cut flowers of 'Golden Gate' on 3rd day and at senescence differed significantly over untreated control. On 3rd day, irrespective of treatments fresh and dry weight of cut flowers increased. Maximum increase in fresh weight was recorded with flowers precooled, pulsed and packed with butterpaper for 6 h (Plate 13) and second highest increase in fresh weight was with single layer corrugated fibre board sheet packed for 6 h (Plate 14). Maximum increase in dry weight on 3rd day was observed with single layer corrugated fibre board sheet packed for 20 h followed by single layer corrugated fibre board sheet packed for 24 h. At senescence, fresh and dry weight decreased in all the treatments. Maximum decrease in fresh weight was recorded with brown paper packed for 24 h, followed by single layer corrugated fibre board sheet packed for 24 h. However, maximum decrease in dry weight was observed with two treatments i.e. single layer corrugated fibre board packed for 24 h and brown paper packed for 20 h. However, there was

Table 9. Effect of ice-cold water spray, pulsing and packaging material (half covered) on the changes in fresh and dry weight of 'Golden Gate' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Butter paper 6 h	+1.88	-1.31	+1.03	-0.15	10.5
Butter paper 20 h	+0.30	-1.30	+0.90	-0.88	9.5
Butter paper 24 h	+0.38	-1.00	+0.70	-0.40	9.0
CFB 6 h	+1.35	-0.65	+0.95	-0.81	11.0
CFB 20 h	+0.88	-1.26	+1.27	-0.58	9.5
CFB 24 h	+0.52	-1.42	+1.22	-0.98	9.5
Brown paper 6 h	+0.76	-0.22	+0.42	-0.63	9.5
Brown paper 20 h	+0.52	-0.49	+0.85	-0.98	8.3
Brown paper 24 h	+0.24	-1.54	+0.08	-0.67	7.8
Polythene 6 h	+0.75	-0.76	+0.21	-0.03	9.5
Polythene 20 h	+0.62	-0.75	+0.82	-0.49	8.0
Polythene 24 h	+0.38	-0.57	+0.47	-0.97	7.8
Newspaper 6 h	+0.95	-0.67	+0.47	-0.24	9.0
Newspaper 20 h	+0.96	-0.83	+0.42	-0.24	8.0
Newspaper 24 h	+0.50	-0.82	+0.58	-0.20	7.5
Control	+0.28	-0.16	+0.31	-0.48	7.2
'F' test	**	**	**	**	**
S.Em. ±					
Packaging (P)	0.0043	0.0033	0.0036	0.0668	0.0470
Duration (D)	0.0038	0.0029	0.0032	0.0598	0.0420
P x D	0.0086	0.0066	0.0072	0.1336	0.0940
CD at 5%					
Packaging (P)	0.012	0.009	0.010	0.191	0.134
Duration (D)	0.011	0.008	0.009	0.171	0.120
P x D	0.025	0.019	0.021	0.382	0.269

** Highly significant

(+) Denotes gain in weight over the initial weight taken at harvest

(-) Denotes loss in weight over the initial weight taken at harvest.

Plate 12. Precooled and pulsed cut roses cv. 'Golden Gate' wrapped (half covered) in different packaging materials

Plate 13. Precooled and pulsed cut roses wrapped in butter paper packaging material in CFB box

no significant difference between these two treatments on the change in dry weight at senescence.

Vase life showed a declining trend, when the packaging duration increased from 6 to 24 h. Maximum vase life was recorded with single layer corrugated fibre board sheet packed for 6 h and second longest vase life was recorded with butterpaper packed for 6 h. Thus, it may be concluded that six hour packaging of precooled and pulsed flowers gave significantly more vase life compared to untreated control.

4.2.1.2 Influence of precooling (ice-cold water spray for 45 min), pulsing and packaging material (half covered) on postharvest life and quality of 'Golden Gate' cut roses

It is evident from Table 10 that precooled, pulsed and packaging material (half covered) for different duration significantly affected water uptake, flower diameter and vase life of the cut flowers. The water uptake increased as the duration of packing increased from 6 h to 20 h and then decreased in 24 h packing duration, except for polythene and newspaper packaging material where water uptake reduced in 20 h duration. Maximum water uptake on 3rd day in vase was recorded by the flowers wrapped with brown paper for 20 h (Plate 15) and single layer of corrugated fibre board sheet for 20 h which were at par with each other. Minimum water uptake on 3rd day was observed with flowers wrapped with polythene bags (80 guage) for 24 h and newspaper for 24 h. At senescence maximum water uptake was recorded with the treatment of brown paper packed for 6 h followed by butterpaper packed for 6 h and single layer corrugated fibre board sheet packed for 20 h. The flower diameter of precooled, pulsed and wrapped with brown paper for 6 h and

Table 10. Effect of ice-cold water spray, pulsing and packaging material (half covered) on the quality and vase life of 'Golden Gate' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Butter paper 6 h	8.0	29.0	8.3	10.5
Butter paper 20 h	9.6	25.0	7.9	9.5
Butter paper 24 h	7.8	24.8	7.3	9.0
CFB 6 h	8.8	26.8	8.0	11.0
CFB 20 h	10.4	28.8	7.6	9.5
CFB 24 h	7.8	23.0	7.2	9.5
Brown paper 6 h	8.8	29.3	8.5	9.5
Brown paper 20 h	10.6	26.0	7.7	8.3
Brown paper 24 h	8.6	25.0	7.9	7.8
Polythene 6 h	7.2	26.3	8.1	9.5
Polythene 20 h	6.8	27.0	7.2	8.0
Polythene 24 h	6.6	25.8	7.1	7.8
Newspaper 6 h	8.2	28.3	7.8	9.0
Newspaper 20 h	7.2	25.8	7.4	8.0
Newspaper 24 h	6.6	24.8	6.3	7.5
Control	7.4	23.0	7.8	7.2
'F' test	**	**	**	**
S.Em. ±				
Packaging (P)	0.0382	0.0483	0.0329	0.0470
Duration (D)	0.0342	0.0432	0.0294	0.0420
P x D	0.0764	0.0966	0.0658	0.0940
CD at 5%				
Packaging (P)	0.109	0.138	0.094	0.134
Duration (D)	0.098	0.123	0.084	0.120
P x D	0.218	0.276	0.188	0.269

Plate 14. Precooled and pulsed cut roses wrapped in single layer corrugated fibreboard sheet in CFB box

Plate 15. Precooled and pulsed cut roses wrapped in brown paper packaging material in CFB box

butter paper for 6 h recorded the maximum, while minimum flower diameter was recorded with flowers wrapped with newspaper for 24 h. There was significant decrease in vase life as the packaging duration increased from 20 to 24 h. Maximum vase life was recorded with flowers kept in CFB boxes and wrapped (half covered) with single layer corrugated fibre board sheet for 6 h followed by butter paper packed for 6 h. Increased vase life was associated with improved water uptake and flower diameter during the course of development of cut roses cv. Golden Gate.

4.2.1.3 Influence of precooling (cool storage at 4^0C for 24 h), pulsing and packaging material (half covered) on the changes in fresh and dry weight of Golden Gate cut roses

The changes in fresh and dry weight of precooled, pulsed and packaging material (half covered) of 'Golden Gate' cut roses differed significantly over the untreated control (Table 11). On 3rd day, irrespective of treatments fresh and dry weight of cut flowers increased. At senescence, both fresh and dry weight decreased. Maximum fresh weight was recorded in flowers precooled, pulsed and packed in newspaper for 6 h, followed by butterpaper packed for 6 h on 3rd day in vase. Dry weight was maximum on 3rd day in flowers precooled, pulsed and half covered with polythene bags (80 guage) for 24 h. Minimum loss at senescence in fresh weight and dry weight was recorded in treatment with brown paper packed for 24 h and single layer corrugated fibre board sheet for 24 h respectively. The vase life of precooled, pulsed and half covered with different packaging material was significantly reduced as the storage duration increased. The maximum vase life was recorded with precooled pulsed, and packed with brown paper for 6 h or polythene bags for 6 h.

Table 11. Effect of cool storage (4^0C), pulsing and packaging material (half covered) on the changes in fresh and dry weight of 'Golden Gate' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Butter paper 6 h	+1.62	-0.65	+0.40	-0.21	7.5
Butter paper 20 h	+0.29	-0.15	+0.42	-0.54	6.8
Butter paper 24 h	+0.32	-0.22	+0.45	-0.78	6.3
CFB 6 h	+0.26	-0.20	+0.06	-0.22	7.0
CFB 20 h	+0.14	-0.49	+0.50	-0.20	6.8
CFB 24 h	+0.71	-1.32	+0.10	-0.08	6.5
Brown paper 6 h	+1.27	-0.75	+0.98	-0.45	7.8
Brown paper 20 h	+0.96	-1.07	+0.76	-0.54	7.0
Brown paper 24 h	+0.09	-0.05	+0.66	-0.29	6.5
Polythene 6 h	+1.03	-0.83	+0.55	-0.39	7.8
Polythene 20 h	+0.88	-0.28	+0.42	-0.45	7.3
Polythene 24 h	+0.91	-0.95	+1.27	-0.42	7.0
Newspaper 6 h	+1.76	-1.53	+0.46	-0.36	7.5
Newspaper 20 h	+1.12	-0.16	+0.90	-1.22	7.5
Newspaper 24 h	+0.69	-0.62	+0.59	-0.50	7.0
Control	+0.11	-0.71	+0.55	-0.19	6.5
'F' test	**	**	**	**	**
S.Em. ±					
Packaging (P)	0.0029	0.0029	0.0029	0.0029	0.0365
Duration (D)	0.0026	0.0026	0.0026	0.0026	0.0327
P x D	0.0058	0.0058	0.0058	0.0058	0.0730
CD at 5%					
Packaging (P)	0.008	0.008	0.008	0.008	0.104
Duration (D)	0.007	0.007	0.007	0.007	0.093
P x D	0.017	0.017	0.017	0.017	0.209

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

4.2.1.4 Influence of precooling (cool storage at 4^0C), pulsing and packaging material (half covered) on post harvest life and quality of 'Golden Gate' cut roses

From Table 12, it is clear that maximum water uptake on 3rd day was recorded with flowers precooled, pulsed and packed (half covered) with polythene bags (80 guage) for 20 h followed by polythene bags packed for 24 h and untreated control. Water uptake was maximum at senescence with flowers precooled, pulsed and wrapped with brown paper for 6 h. However, maximum flower diameter was recorded with butterpaper packed for 6 h or brown paper packed for 6 h followed by corrugated fibre board sheet packed for 6 h and corrugated fibre board sheet packed for 20 h. However, there was no significant difference in these treatments on the flower diameter of cut rose cv. Golden Gate. Maximum vase life was recorded with cut flowers precooled, pulsed and wrapped with brownpaper for 6 h and polythene bags (80 guage) for 6 h. The vase life of the flowers precooled, pulsed and wrapped in packaging material for 6 h was better than those packed for 24 h duration. Minimum vase life was observed with flowers precooled, pulsed and packed with butterpaper for 24 h.

4.2.2 Effect of full covered cut stems with packaging materials and duration of storage under packing

4.2.2.1 Influence of precooling (ice-cold water spray for 45 min) pulsing and packaging material (full covered) on the changes in fresh and dry weight of cut rose cv. Golden Gate

All the packaging treatments resulted in gain in fresh and dry weight on 3rd day in vase over the initial weight at harvest (Table 13). The highest gain in fresh weight was recorded in the flowers precooled, pulsed and wrapped with butterpaper for 6 h followed by single layer

Table 12. Effect of cool storage (4^0C), pulsing and packaging material (half covered) on the quality and vase life of 'Golden Gate' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Butter paper 6 h	7.8	25.0	7.9	7.5
Butter paper 20 h	7.8	24.8	7.4	6.8
Butter paper 24 h	7.4	22.8	7.6	6.3
CFB 6 h	7.2	24.3	7.8	7.0
CFB 20 h	8.8	25.8	7.7	6.8
CFB 24 h	7.8	19.8	7.5	6.5
Brown paper 6 h	8.8	28.3	7.3	7.8
Brown paper 20 h	8.8	23.0	7.9	7.0
Brown paper 24 h	8.0	22.0	6.9	6.5
Polythene 6 h	9.0	24.8	6.5	7.8
Polythene 20 h	11.2	24.8	6.2	7.3
Polythene 24 h	10.8	22.3	6.0	7.0
Newspaper 6 h	7.2	24.3	6.7	7.5
Newspaper 20 h	9.4	21.0	6.9	7.5
Newspaper 24 h	9.6	20.0	5.8	7.0
Control	10.8	20.0	6.0	6.5
'F' test	**	**	**	**
S.Em. ±				
Packaging (P)	0.0365	0.0470	0.0398	0.0365
Duration (D)	0.0327	0.0420	0.0356	0.0327
P x D	0.0730	0.0940	0.0796	0.0730
CD at 5%				
Packaging (P)	0.104	0.134	0.114	0.104
Duration (D)	0.093	0.120	0.102	0.093
P x D	0.209	0.269	0.227	0.209

Table 13. Effect of ice-cold water spray, pulsing and packaging material (full covered) on the changes in fresh and dry weight of 'Golden Gate' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Butter paper 6 h	+1.45	-0.21	+1.33	-1.05	7.3
Butter paper 20 h	+1.07	-0.15	+0.72	-1.06	7.0
CFB 6 h	+1.37	-1.05	+1.30	-1.21	7.0
CFB 20 h	+1.30	-0.71	+1.13	-0.62	6.8
Brown paper 6 h	+1.25	-0.68	+0.64	-0.40	6.5
Brown paper 20 h	+0.94	-0.62	+0.86	-0.32	6.0
Polythene 6 h	+0.82	-0.08	+0.71	-0.78	6.8
Polythene 20 h	+0.89	-0.72	+1.37	-1.13	6.0
Control	+0.55	-0.54	+0.57	-0.41	5.8
'F' test	**	**	**	**	**
S.Em. ±					
Packaging (P)	0.0033	0.0043	0.0062	0.0033	0.0593
Duration (D)	0.0029	0.0037	0.0054	0.0029	0.0514
P x D	0.0058	0.0075	0.0108	0.0058	0.1027
CD at 5%					
Packaging (P)	0.010	0.013	0.018	0.010	0.173
Duration (D)	0.008	0.011	0.016	0.008	0.150
P x D	0.017	0.022	0.032	0.017	0.300

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

corrugated fibre board sheet packed for 6 h. Higher gain in fresh weight on the third day in vase was associated with maximum vase life. Highest gain in dry weight on 3rd day was recorded with flowers wrapped in polythene bags (80 guage) for 20 h followed by butterpaper packed for 6 h. However, these two treatments did not differ significantly. At senescence, both fresh weight and dry weight decreased. Minimum loss in fresh weight at senescence was recorded with polythene bags packed for 6 h while minimum loss in dry weight at senescence was recorded with brownpaper packed for 20 h. In all the packaging treatments employed, vase life was reduced in the 20 h packaging treatment. The maximum vase life was recorded with flowers precooled, pulsed and wrapped with butterpaper for 6 h followed by butterpaper packed for 20 h and single layer corrugated fibre board sheet packed for 6 h. However, these treatments did not differ significantly in vase life. Minimum vase life was recorded with untreated control.

4.2.2.2 Influence of precooling (ice cold water spray for 45 min), pulsing and packaging material (full covered) on post harvest life and quality of 'Golden Gate' cut roses

It is evident from Table 14, that water uptake, flower diameter and flower longevity was significantly influenced by precooling, pulsing, and packaging material (full covered) in cut roses cv. Golden Gate. Maximum water uptake on 3rd day in vase was recorded with control followed by precooled and pulsed flowers wrapped in single layer corrugated fibre board sheet for 6 h. At senescence, flowers precooled, pulsed and wrapped with butterpaper for 6 h showed maximum water uptake followed by butterpaper packed for 20 h. Maximum flower diameter was recorded with three treatments i.e. butterpaper packed for 6 h, single layer corrugated

Table 14. Effect of ice-cold water spray, pulsing and packaging material (full covered) on the quality and vase life of 'Golden Gate' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Butter paper 6 h	10.6	29.3	7.4	7.3
Butter paper 20 h	9.4	28.3	6.9	7.0
CFB 6 h	11.4	26.0	7.4	7.0
CFB 20 h	9.6	24.5	6.7	6.8
Brown paper 6 h	9.4	24.5	7.4	6.5
Brown paper 20 h	9.2	22.0	6.8	6.0
Polythene 6 h	11.0	27.8	7.3	6.8
Polythene 20 h	10.2	23.0	7.0	6.0
Control	12.6	24.3	7.0	5.8
'F' test	**	**	**	**
S.Em. ±				
Packaging (P)	0.0527	0.0408	0.0333	0.0593
Duration (D)	0.0456	0.0354	0.0289	0.0514
P x D	0.0913	0.0707	0.0577	0.1027
CD at 5%				
Packaging (P)	0.154	0.119	0.097	0.173
Duration (D)	0.133	0.103	0.084	0.150
P x D	0.266	0.206	0.168	0.300

fibre board sheet for 6 h and brown paper for 6 h. Polythene packed for 6 h was at par with the above treatments in flower diameter. The vase life of packaging treatments was significantly different from the untreated control. Maximum vase life was registered with flowers precooled, pulsed and wrapped with butterpaper packed for 6 h followed by butterpaper packed for 20 h and single layer corrugated fibre board sheet packd for 6 h and 20 h. However, these treatments did not differ significantly from each other.

4.2.2.3 Influence of precooling (cool storage at 4^0C), pulsing, and packaging material (full covered) on changes in fresh and dry weight of cv. Golden Gate cut roses

With reference to Table 15, the packaging materials (full covered) significantly affected the changes in fresh and dry weight of cv. Golden Gate cut roses. Irrespective of the treatments there was increase in both fresh and dry weight of the flowers on 3rd day in vase. Maximum increase in fresh weight was recorded with flowers precooled, pulsed and wrapped with butter paper for 6 h followed by single layer corrugated fibre board sheet packed for 6 h. Minimum loss in fresh weight was registered with butterpaper packed for 20 h at senescence. Maximum increase in dry weight was observed with flowers precooled, pulsed and wrapped with butterpaper for 6 h. Minimum loss in dry weight at senescence was recorded with brownpaper packed for 20 h followed by polythene bags (80 guage) packed for 20 h. The vase life showed a decrease from 6 h and 20 h packaging duration. Maximum vase life was recorded with flowers precooled, pulsed and wrapped in butterpaper for 6 h while minimum vase life was recorded with untreated control. Longest vase life was

Table 15. Effect of cool storage (4^0C), pulsing and packaging material (full covered) on the changes in fresh and dry weight of 'Golden Gate' cut roses

Treatments	Change in fresh weight (g)		Change in dry weight (g)		Vase life (days)
	On 3rd day	At senes-cence	On 3rd day	At senes cence	
Butter paper 6 h	+2.63	-1.75	+0.95	-0.44	7.8
Butter paper 20 h	+1.00	-0.23	+0.08	-0.45	6.3
CFB 6 h	+1.46	-0.88	+0.56	-0.23	6.5
CFB 20 h	+0.49	-0.95	+0.81	-0.54	6.0
Brown paper 6 h	+0.83	-1.62	+0.48	-0.44	6.9
Brown paper 20 h	+0.40	-0.30	+0.13	-0.15	6.0
Polythene 6 h	+1.13	-1.24	+0.56	-0.64	6.8
Polythene 20 h	+1.08	-1.09	+0.03	-0.18	6.5
Control	+0.91	-0.74	+0.25	-0.90	5.5
'F' test	**	**	**	**	**
S.Em. ±					
Packaging (P)	0.0033	0.0033	0.0037	0.0053	0.0333
Duration (D)	0.0029	0.0029	0.0032	0.0046	0.0289
P x D	0.0058	0.0058	0.0065	0.0091	0.0577
CD at 5%					
Packaging (P)	0.010	0.010	0.011	0.015	0.097
Duration (D)	0.008	0.008	0.009	0.013	0.084
P x D	0.017	0.017	0.019	0.027	0.168

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

associated with maximum gain in fresh and dry weight on 3rd day in cv. Golden Gate.

4.2.2.4 Influence of precooling (cool storage at 4^0C) pulsing and packaging material (full covered) on post harvest life and quality of 'Golden Gate' cut roses

It is clear from Table 16, that the water uptake, flower diameter and flower longevity differed significantly over the control. Maximum water uptake on 3rd day was recorded with flowers precooled, pulsed and wrapped with brownpaper for 6 h followed by single layer corrugated fibre board sheet packed for 20 h and polythene bags packed for 20 h. At senescence, maximum water uptake was recorded with butterpaper packed for 6 h. Flower diameter was largest with flowers precooled, pulsed and wrapped with butterpaper packed for 20 h followed by polythene bags packed for 6 h and butterpaper packed for 6 h which were at par with each other. There was significant difference in the vase life of the treated cut flowers over the untreated control. Maximum vase life was recorded with cut flowers precooled, pulsed and wrapped with butterpaper for 6 h followed by the treatment of brownpaper packed for 6 h. The vase life of 6 h packaging duration was better than 20 h packaging duration.

4.3.1 Influence of pulsing and wet storage days on the vase life of cut roses

4.3.1.1 Changes in fresh and dry weight of cut roses cv. Golden Gate as influenced by pulsing (STS 0.5 mM for 45 min) and wet storage at 4^0C

It is evident from Table 17, that the pulsing and wet storage at 4^0C for different days in the cool storage chamber (Plate 16) significantly affected the keeping quality of cut rose cv Golden Gate in the vase. There

Table 16. Effect of cool storage (4^0C), pulsing and packaging material (full covered) on the quality and vase life of 'Golden Gate' cut roses

Treatments	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Butter paper 6 h	12.5	24.8	6.6	7.8
Butter paper 20 h	12.0	21.8	7.0	6.3
CFB 6 h	10.8	23.5	6.3	6.5
CFB 20 h	13.4	23.3	6.3	6.0
Brown paper 6 h	15.6	23.0	6.4	6.9
Brown paper 20 h	12.2	22.0	6.0	6.0
Polythene 6 h	11.4	11.5	6.7	6.8
Polythene 20 h	13.4	13.5	6.2	6.5
Control	9.6	19.0	6.5	5.5
'F' test	**	**	**	
S.Em. ±				
Packaging (P)	0.0408	0.0500	0.0408	0.0333
Duration (D)	0.0354	0.0433	0.0354	0.0289
P x D	0.0707	0.0866	0.0707	0.0577
CD at 5%				
Packaging (P)	0.119	0.146	0.119	0.097
Duration (D)	0.103	0.126	0.103	0.084
P x D	0.206	0.253	0.206	0.168

Table 17. Changes in the fresh and dry weight of cut roses cv. Golden Gate as influenced by pulsing (STS 0.5 mM) and wet storage at 4^0C

Treatments (Storage duration)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
0 days	-	+1.18	-0.34	-	+0.25	-0.01	12.0
1 days	+0.48	+1.53	-0.12	+0.15	+0.25	-0.02	11.8
2 days	+0.74	+1.54	+0.94	+0.10	+0.25	-0.01	12.4
3 days	+0.43	+2.24	+1.75	+0.50	+0.66	-0.01	13.0
4 days	+0.86	+2.12	+1.61	+0.40	+0.25	-0.03	12.6
Control (No pulsing and no storage)	-	+0.64	-0.53	-	+0.24	-0.04	10.0
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.005	0.006	0.006	0.081	0.006	0.006	0.065
C.D. at 5 %	0.016	0.019	0.019	0.238	0.019	0.019	0.190

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

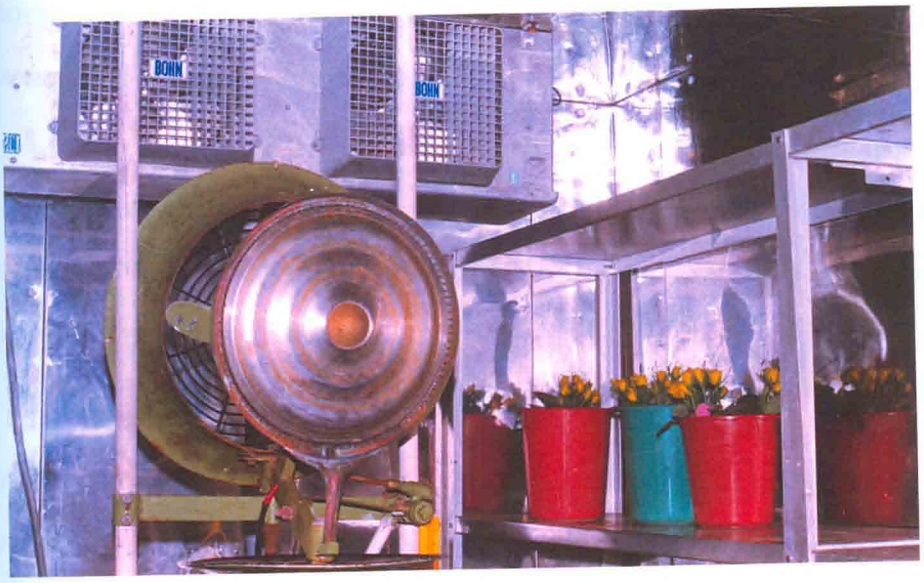


Plate 16. Cut rose cv. 'Golden Gate' being wet stored at 4^0C for different days in the cool storage chamber

was an increase in both fresh and dry weight of cv Golden Gate after the storage period. Maximum rise in fresh weight was observed with 4 days wet stored cut flowers after the storage. On 3rd day in vase fresh weight was maximum in 3 days stored flowers. While maximum rise in dry weight after storage and 3rd day in vase was with the 3 days wet stored cut flowers. However, there was no significant difference between 3 days and 4 days storage treatments.

At senescence, there was decrease in fresh weight of 0 days, 1 days and control, whereas 2, 3 and 4 days wet stored flowers showed gain in weight over the initial weight. There was a decrease in dry weight at senescence in all the storage period including control. Maximum loss in dry weight was registered with the control and second maximum loss was with 4 days stored cut flowers. However, they did not differ significantly. There was successive rise in vase life with increase in storage period upto 3 days, but on 4th day the vase life decreased when compared with 3 days storage. The vase life of 3 days stored flowers at 4^0C was maximum.

4.3.1.2 Post harvest life and quality of cut rose cv Golden Gate as influenced by pulsing (STS 0.5 mM) and wet storage at 4^0C

It is clear from Table 18, that water upake, flower diameter and vase life of cv. Golden Gate cut flowers differed significantly with the days of wet storage. Maximum water uptake on 3rd day was recorded by 3 days stored flowers, while minimum with pulsed and not stored (0 days flowers). The same trend was observed at senescence when total water uptake in vase was measured. The water uptake increased as the storage duration increased, but on 4 days there was a decline in water uptake when compared with 3 days stored flowers. Flower diameter was

Table 18. **Postharvest life and quality of cut roses cv. Golden Gate as influenced by pulsing (STS 0.5 mM) and wet storage at 4^0C**

Treatments (Storage duration)	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
0 days	8.0	18.8	7.0	12.0
1 days	9.6	19.5	7.2	11.8
2 days	10.4	22.0	7.1	12.4
3 days	13.6	30.1	7.5	13.0
4 days	12.7	27.6	7.4	12.6
Control (No pulsing and no storage)	9.2	23.0	6.9	10.0
'F' test	**	**	**	**
S.Em. ±	0.065	0.065	0.065	0.065
CD at 5%	0.190	0.190	0.190	0.190

maximum with 3 days stored flowers and second highest flower diameter was with 4 days. However, there was no significant difference between them. 3 days stored flowers gave significantly better vase life over other treatments and control. Thus it can be inferred that the cut roses can be wet stored upto 3 days without affecting its ultimate vase life and quality. Pulsed flowers was better than unpulsed and unstored control.

4.3.1.3 Changes in fresh and dry weight of cut roses cv Golden Gate as influenced by pulsing ($CaCl_2$ 1% for 20 h) and wet storage at 4^0C

Pulsing with $CaCl_2$ 1% for 20 h and wet storing the flowers at 4^0C showed a gain in both fresh and dry weight of cv. Golden Gate after storage (Table 19). The wet storage of 4 days at 4^0C, gained the maximum fresh weight followed by 2 days stored flowers. On 3rd day in vase, fresh weight was maximum with 4 days stored flowers and second maximum gain was observed in both 1 day and 2 days stored cut flowers. At senescence, there was decrease in fresh weight, but 1 day and 4 day storage showed gain in fresh weight over the initial weight. Change in dry weight after storage was maximum with 3 days stored flowers, while on 3rd day in vase, maximum gain in dry weight was observed with 2 days stored flowers. At senescence, maximum loss in dry weight was recorded with 3 days stored flowers whereas 0 days gained maximum dry weight. The 4 days stored flowers gave the maximum vase life over other treatments and untreated control.

4.3.1.4 Post harvest life and quality of cut roses cv Golden Gate as influenced by pulsing ($CaCl_2$ 1% for 20 h) and wet storage at 4^0C

There was significant water uptake with 2 days wet stored flowers at 4^0C over 4 days stored flowers on 3rd day in vase (Table 20). At

Table 19. **Changes in the fresh and dry weight of cut roses cv. Golden Gate as influenced by pulsing ($CaCl_2$ 1%) and wet storage at 4^0C**

Treatments (Storage duration)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
0 days	-	+0.81	-0.57	-	+0.27	+0.31	9.0
1 days	+0.69	+1.88	+1.01	+0.18	+0.29	+0.06	8.3
2 days	+1.42	+1.82	-1.18	+0.76	+0.90	-0.08	8.5
3 days	+0.33	+1.73	-0.19	+0.79	+0.88	-0.17	9.8
4 days	+1.88	+2.00	+0.57	+0.43	+0.73	+0.20	10.6
Control (No pulsing and no storage)	-	+0.64	-0.53	-	+0.28	-0.04	10.0
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.006	0.021	0.007	0.005	0.006	0.004	0.074
C.D. at 5 %	0.018	0.062	0.020	0.016	0.019	0.016	0.216

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

Table 20. **Postharvest life and quality of cut roses cv. Golden Gate as influenced by pulsing ($CaCl_2$ 1%) and wet storage at 4^0C**

Treatments (Storage duration)	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
0 days	8.1	20.7	7.5	9.0
1 days	7.5	20.6	7.5	8.3
2 days	13.0	23.0	7.3	8.5
3 days	9.8	16.8	7.4	9.8
4 days	10.5	22.0	8.0	10.6
Control (No pulsing and no storage)	9.2	23.0	6.9	10.0
'F' test	**	**	**	**
S.Em. ±	0.068	0.076	0.068	0.074
CD at 5%	0.201	0.223	0.201	0.216

senescence, both 2 days and control recorded maximum water uptake. Flower diameter was maximum with 4 days wet stored flowers followed by 0 days and 1 days stored flowers. There was increase in vase life as the storage period increased, with the 4 days stored flowers recording maximum vase life over 3 days and control. In general, longest vase life was associated with increased water uptake and maximum flower diameter when the cut flowers were pulsed with $CaCl_2$ 1 % for 20 h and wet stored for 4 days at 4^0C.

4.3.1.5 Changes in fresh and dry weight of cut roses cv. Golden Gate as influenced by pulsing (BA 25 ppm for 45 min) and wet storage at 4^0C

It is clear from Table 21, that the changes in fresh and dry weight and flower longevity significantly varied with the cool storage treatment. There was gain in both fresh and dry weight after storage at 4^0C of the cut rose cv. Golden Gate. Maximum gain in fresh weight was registered with 4 days stored flowers after storage. On 3rd day in vase, fresh weight was maximum with 3 days stored flowers. At senescence, maximum loss in fresh weight was with control. Change in dry weight was maximum after storage with 1 day stored flowers. On 3rd day in vase all the treatments showed gain in dry weight except untreated control which showed loss in dry weight. Maximum gain in dry weight on 3rd day was with 3 days stored flowers and 1 days stored flowers which did not differ significantly. However, at senescence, the dry weight declined from the initial weight of the cut flower, except for 3 days wet stored flowers which showed gain in dry weight at senescence. Maximum vase life was observed with 3 days wet stored flowers at 4^0C. There was increase in vase life as the

Table 21. Changes in the fresh and dry weight of cut roses cv. Golden Gate as influenced by pulsing (BA 25 ppm) and wet storage at 4^0C

Treatments (Storage duration)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
0 days	-	+0.97	+0.90	-	+0.25	-0.49	9.9
1 days	+0.36	+1.69	+0.59	+0.16	+0.27	-0.28	10.7
2 days	+0.15	+0.91	-0.40	+0.05	+0.25	-0.34	10.9
3 days	+0.30	+2.03	+1.10	+0.12	+0.29	+0.08	12.4
4 days	+1.44	+1.25	+0.32	+0.13	+0.25	-0.18	11.7
Control (No pulsing and no storage)	-	+0.65	-0.52	-	-0.63	-0.04	10.0
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.006	0.006	0.006	0.005	0.007	0.007	0.065
C.D. at 5 %	0.017	0.019	0.019	0.016	0.020	0.020	0.190

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

storage period increased upto 3 days, but from 4 days onward, the vase life decreased. The minimum vase life was observed with 0 days and control.

4.3.1.6 Post harvest life and quality of cut roses cv. Golden Gate as influenced by pulsing (BA 25 ppm for 45 min) and wet storage at 4^0C

It can be seen from Table 22, water uptake, flower diameter and flower longevity was significantly affected by the pulsing and wet storage duration at 4^0C. Maximum water uptake on 3rd day in vase was recorded with 4 days stored flowers and second highest with 3 days wet stored flowers at 4^0C. However, at senescence, i.e. after the complete opening and development of the cut flower, water uptake measurement showed maximum with control. Flower diameter was highest with 3 days stored flowers followed by 4 days stored flowers, but they did not differ significantly. The vase life was found best in 3 days stored cut flowers over control and other treatments of storage after which the vase life decreased. It may be concluded that 'Golden Gate' cut flowers can be pulsed (BA 25 ppm for 45 min) and wet stored for 3 days at 4^0C without hampering its ultimate vase life and quality.

4.3.2 Influence of holding solution on wet stored and pulsed cut roses

4.3.2.1 Changes in fresh and dry weight of cut roses cv. Golden Gate as affected by pulsing (STS 0.5 mM for 45 min) wet storage (3 days at 4^0C) and holding solutions

It is apparent from Table 23 that cut roses cv. Golden Gate held in different holding solutions had a significant effect on the changes in fresh and dry weight during the flower development and senescence. After

Table 22. **Postharvest life and quality of cut roses cv. Golden Gate as influenced by pulsing (BA 25 ppm) and wet storage at 4^0C**

Treatments (Storage duration)	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
0 days	11.5	15.2	6.7	9.9
1 days	8.6	16.5	6.8	10.7
2 days	9.2	19.5	7.0	10.9
3 days	11.8	18.2	7.3	12.4
4 days	13.4	9.3	7.2	11.7
Control (No pulsing and no storage)	9.2	23.0	6.9	10.0
'F' test	**	**	**	**
S.Em. ±	0.072	0.068	0.065	0.065
CD at 5%	0.212	0.201	0.190	0.190

Table 23. Effect of pulsing (STS 0.5 mM), wet storage (4^0C for 3 days) and holding solution on the changes in fresh and dry weight of cv. Golden Gate cut roses

Treatments (Holding solution)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senescence	After storage	On 3rd day	At senescence	
D-fructose 3% + Kinetin 2.5 ppm	+0.57	+1.84	+1.93	+0.88	+1.00	+1.33	15.8
D-fructose 3% + $AgNO_3$ 25 ppm	+0.66	+1.50	+0.36	+0.36	+0.66	+1.27	16.8
D-fructose 3% + Nickel chloride 300 ppm	+1.22	+2.00	+4.55	+0.50	+0.71	+1.67	18.5
Sucrose 3% + 8-HQC 200 ppm	+0.65	+2.52	+3.17	+0.52	+0.81	+1.68	20.5
Sucrose 2%+ Captan 200 ppm	+0.84	+1.93	+0.21	+0.85	+1.00	+1.51	15.3
Sucrose 2% + Streptomycin sulphate 250 ppm	+0.64	+1.74	+1.43	+0.97	+1.22	+1.21	17.8
Control	-0.05	+1.15	-0.20	+0.50	-0.51	-0.43	13.3
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.006	0.006	0.006	0.006	0.006	0.006	0.068
C.D. at 5 %	0.018	0.019	0.019	0.019	0.019	0.019	0.200

** Highly significant

(+) Denotes gain in weight over the initial weight taken at harvest

(-) Denotes loss in weight over the initial weight taken at harvest.

pulsing with STS 0.5 mM for 45 min and wet storage for 3 days at 4^0C, the cut flowers recorded both gain in fresh and dry weight after storage. It is observed that maximum gain in fresh weight after storage was with the treatment D-fructose (3%) + nickel chloride (300 ppm) and second highest gain with sucrose (2%) + captan (200 ppm). All the holding solution treatments recorded significantly higher increase in fresh weight on the third day compared to the untreated control flowers. The highest increase in fresh weight on the third day over the initial weight was recorded with the treatment of sucrose (3%) + 8-HQC (200 ppm) followed by that of D-fructose (3%) + nickel chloride (300 ppm). The minimum increase in fresh weight on the third day was recorded by the untreated flowers i.e. control. At senescence, only the untreated control showed a decrease in fresh weight while all the other treatments showed gain in fresh weight over the initial weight. Highest gain in fresh weight at senescence was recorded with D-fructose (3%) + nickel chloride (300 ppm) followed by sucrose (3%) + 8-HQC (200 ppm). In the case of dry weight, maximum gain in dry weight after storage was recorded with sucrose (2%) + streptomycin sulphate (250 ppm), while minimum gain was observed with treatment D-fructose (3%) + $AgNO_3$ (25 ppm). On 3rd day in vase, there was increase in dry weight over the initial weight, except for the control treatment which registered a loss in dry weight. Maximum dry weight on 3rd day was observed with sucrose 2% + streptomycin sulphate (250 ppm) followed by both D-fructose (3%) + kinetin (2.5 ppm) and sucrose (2%) + captan (200 ppm). At senescence, the dry weight gained in all the holding solution treatments and control showed loss in dry weight. Maximum gain in dry weight at senescence was with sucrose (3%) + 8-HQC (200 ppm) and with D-fructose 3% + nickel chloride (300 ppm). All the six

holding solution employed gave significantly higher vase life of cut roses compared to the untreated control. The longest vase life (20.5 days) was recorded with the holding solution treatments of sucrose (3%) + 8-HQC (200 ppm) (Plate 17), followed by D-fructose (3%) + nickel chloride (300 ppm) and sucrose (2%) + streptomycin sulphate (250 ppm) (Plate 18).

4.3.2.2 Post harvest life and quality of cut roses cv. Golden Gate as influenced by pulsing (STS 0.5 mM for 45 min) wet storage (3 days at 4^0C) and holding solutions

It is evident from Table 24, that all the holding solutions treatments had a significant effect on the total solution uptake, flower diameter and flower longevity of cut roses cv. Golden Gate. Cut roses held in holding solution containing sucrose (2%) + streptomycin sulphate (250 ppm) recorded highest solution uptake on 3rd day in vase till senescence and was significantly higher than the water uptake of cut roses held in tap water (control) and D-fructose (3%) + nickel chloride (300 ppm). Second maximum holding solution uptake after the complete opening of the flower at senescence was recorded with sucrose (3%) + 8-HQC (200 ppm). Cut roses held in a combination of sucrose (3%) + 8-HQC (200 ppm) showed the maximum flower diameter which was significantly greater than that of cut roses held in D-fructose (3%) + nickel chloride (300 ppm) and also over tap water (control). Minimum flower diameter was recorded with cut roses held in D-fructose (3%) + $AgNO_3$ (25 ppm). Among the different combinations of holding solution treatments, sucrose (3%) + 8-HQC (200 ppm) recorded maximum vase life (20.5 days), followed by D-fructose (3%) + nickel chloride (300 ppm) (18.5 days) and sucrose (2%) + streptomycin sulphate (250 ppm) (17.8 days). Thus it may be concluded that Golden Gate cut roses when pulsed with STS 0.5 mM for 45 min and

Table 24. **Effect of pulsing (STS 0.5 mM), wet storage (4^0C for 3 days) and holding solution on the postharvest life and quality of cv. Golden Gate cut roses**

Treatments (Holding solution)	Solution uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
D-fructose 3% + Kinetin 2.5 ppm	13.0	31.5	7.1	15.8
D-fructose 3% + $AgNO_3$ 25 ppm	14.4	29.0	6.9	16.8
D-fructose 3% + Nickel chloride 300 ppm	16.0	40.5	7.9	18.5
Sucrose 3% + 8-HQC 200 ppm	13.4	48.5	8.3	20.5
Sucrose 2% + Captan 200 ppm	15.4	36.5	7.1	15.3
Sucrose 2% + Streptomycin sulphate 250 ppm	18.4	50.0	7.4	17.8
Control	13.8	22.5	7.4	13.3
'F' test	**	**	**	**
S.Em. ±	0.065	0.076	0.074	0.068
CD at 5%	0.190	0.223	0.218	0.200

Plate 17. Effect of sucrose (3%) + 8-HQC (200 ppm) as holding solution on pulsed and wet stored cut roses cv. 'Golden Gate' on 15th day of vase life

Plate 18. Effect of sucrose (2%) + streptomycin sulphate (250 ppm) as holding solution on pulsed and wet stored cut roses cv. 'Golden Gate' on 13th day of vase life

wet stored at 4^0C for 3 days and held in chemical solution (holding solution) containing sucrose (3%) + 8-HQC (200 ppm) extended its vase life by 7.2 days more than the control, and this treatment was found most beneficial for the improvement of postharvest life and quality of the cut flowers.

4.4.1 Influence of pulsing and dry storage days on the vase life of cut roses

4.4.1.1 Changes in fresh and dry weight of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM for 45 min) and dry storage at 4^0C

The data presented in Table 25, revealed that the pulsing and dry storage (4^0C) days significantly affected the keeping quality of cut rose cv. Noblesse in the vase. There was a decrease in fresh weight of cv. Noblesse after the dry storage period. Maximum decrease in fresh weight was observed with 4 days dry stored flowers and minimum decrease with 5 days and 6 days dry stored flowers which were at par with each other. On 3rd day in vase, fresh weight increased in all the treatments including control. Maximum increase in fresh weight on 3rd day was recorded with 4 days dry stored flowers followed by 6 days stored flowers. However, at senescence, all the treatments showed increase in fresh weight from the initial weight except the 7 days and control treatments. Change in dry weight after storage also showed a declining trend in dry weight from the initial weight, except the 6 days dry stored flowers which gained minimum increase in dry weight. Maximum loss in dry weight after storage was recorded with 4 days dry stored flowers followed by 5 days dry stored flowers. On 3rd day in vase, there was increase in dry weight which was at par in all the treatments, except for control which showed a significant

Table 25. Changes in the fresh and dry weight of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM) and dry storage at 4^0C

Treatments (Storage duration)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
0 days	-	+1.37	+2.28	-	+0.05	+0.03	12.0
4 days	-0.93	+1.68	+1.18	-1.89	+0.04	+0.20	11.8
5 days	-0.13	+1.15	+0.55	-1.80	+0.05	+0.03	12.0
6 days	-0.15	+1.57	+0.53	+0.02	+0.07	+0.02	12.0
7 days	-0.30	+0.57	-0.27	-0.82	+0.06	+0.03	11.5
Control (No pulsing and no storage)	-	+1.03	-0.48	-	-1.91	-2.25	11.2
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.006	0.008	0.009	0.007	0.009	0.007	0.098
C.D. at 5 %	0.019	0.024	0.027	0.022	0.026	0.022	0.288

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

loss in dry weight. At senescence, the increase in dry weight was maintained and the increase was at par in all the treatments except control which recorded maximum decrease in dry weight. The vase life of 'Noblesse' cut roses was greatly influenced by dry storage periods. Maximum vase life was recorded in three storage duration treatments i.e. 0 days, 5 days and 6 days dry stored flowers followed by 4 days stored flowers which was at par with all the above storage duration.

4.4.1.2 Post harvest life and quality of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM for 45 min) and dry storage at 4^0C

It is evident from Table 26, that the water uptake, flower diameter and vase life of cut rose cv. Noblesse differed significantly during the dry storage at 4^0C. Maximum water uptake on 3rd day in vase was recorded with unpulsed and unstored flowers followed by 0 days stored cut flowers. The same trend was also observed at senescence after the flower had completely opened. However, maximum flower diameter was recorded with 6 days stored flowers followed by 0 days. The vase life of the dry stored flowers was more over control. Five and six days storage of cut flowers recorded maximum vase life which was same as that of pulsed and not stored cut flowers. The 7 days dry stored flowers recorded a vase life of 11.5 days and control showed a minimum vase life of 11.2 days. The vase life of cut rose cv. Noblesse decreased from the 6th day storage duration. Hence, it may be concluded that 'Noblesse' cut roses can be stored dry at 4^0C upto 6 days after pulsing with STS 0.5 mM for 45 minutes without affecting its vase life at ambient temperature.

Table 26. **Postharvest life and quality of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM) and dry storage at 4^0C**

Treatments (Storage duration)	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
0 days	12.7	26.6	7.0	12.0
4 days	9.8	20.0	6.0	11.8
5 days	10.2	24.3	6.4	12.0
6 days	9.6	24.8	7.5	12.0
7 days	10.5	22.8	6.5	11.5
Control (No pulsing and no storage)	17.5	28.2	6.0	11.2
'F' test				
S.Em. ±	0.098	0.255	0.091	0.098
CD at 5%	0.288	0.749	0.267	0.288

4.4.1.3 Changes in fresh and dry weight of cut roses cv. Noblesse as influenced by pulsing (BA 25 ppm for 45 min) and dry storage at 4^0C

It reveals from the Table 27 that pulsing with BA 25 ppm for 45 min and dry storage at 4^0C significantly affected the changes in fresh and dry weight during the development of cut flower cv. Noblesse. There was decrease in both fresh and dry weight of cut rose cv. Noblesse after the storage duration. Maximum loss in fresh weight after storage was recorded with 5 days stored cut flowers followed by 4 days dry stored flowers. Minimum loss in fresh weight was observed with 6 days dry stored flowers. On 3rd day in vase, maximum gain in fresh weight was with 0 days, followed by 6 days stored flowers. At senescence, there was a decrease in fresh weight of the dry stored flowers. Maximum decrease was recorded with 7 days stored flowers followed by 5 days stored cut flowers. However, there was gain in fresh weight over the initial weight in 0 days and control treatments at senescence. Maximum decrease in dry weight after the storage period was recorded in 4 days dry stored flowers while minimum in 6 days dry stored flowers. On 3rd day in vase, there was little gain in dry weight over the initial weight of the cut flower, with 6 days stored flowers recording maximum gain followed by 5 days stored flowers. However, 0 days and untreated flowers (control) showed a decrease in the change in dry weight over the initial weight of the cut flower. At senescence, there was decrease in the dry weight irrespective of the treatments. Maximum decrease was observed with untreated flowers (control) followed by 0 days. While minimum decrease in dry weight was observed with 6 days stored flowers.

Table 27. Changes in the fresh and dry weight of cut roses cv. Noblesse as influenced by pulsing (BA 25 ppm) and dry storage at 4^0C

Treatments (Storage duration)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
0 days	-	+3.52	+1.34	-	-1.07	-1.79	11.5
4 days	-0.30	+1.35	-0.80	-1.61	+0.05	-1.41	10.5
5 days	-1.22	+0.66	-2.17	-1.20	+0.06	-1.08	12.2
6 days	-0.11	+2.17	-1.47	-0.07	+0.07	-0.44	13.0
7 days	-0.14	+0.86	-2.59	-0.17	+0.04	-0.50	12.0
Control (No pulsing and no storage)	-	+1.03	+1.52	-	-2.25	-1.91	11.2
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.008	0.009	0.008	0.007	0.009	0.009	0.105
C.D. at 5 %	0.023	0.025	0.024	0.022	0.027	0.027	0.308

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest

There was a successive rise in vase life with increase in storage duration upto 6 days, but on 7th day the vase life decreased. Maximum vase life was recorded with 6 days dry stored flowers followed by 5 days stored flowers which was at par with 7 days stored flowers. Minimum vase life was observed with 4 days stored flowers. It can be inferred that pulsing of cut flower 'Noblesse' with BA 25 ppm for 45 min. resulted in significant increase in cut flower longevity from the control. Dry storage for 6 days gave highest vase life, and minimum loss in both fresh and dry weight after the storage duration. Hence, cut roses pulsed with BA 25 ppm for 45 min. and dry stored for 6 days at 4^0C can give a vase life of 1.8 days more than the control and maintain the fresh and dry weight of the cut roses after storage.

4.4.1.4 Post harvest life and quality of cut roses cv. Noblesse as influenced by pulsing (BA 25 ppm for 45 min.) and dry storage at 4^0C

It can be seen from Table 28, that the water uptake, flower diameter and flower longevity was significantly affected by the pulsing and dry storage at 4^0C. Maximum water uptake on 3rd day in vase was observed with 6 days stored flowers followed by control. At senescence, after the flower was completely opened, maximum water uptake was observed with 6 days stored flowers and second highest with 7 days stored flowers. Highest flower diameter was recorded with 6 days dry stored flowers which differed significantly from 0 days and control (Plate 20). The vase life was longest with 6 days stored flowers followed by 5 days and 7 days which were at par with each other. The vase life increased progressively from 4 days to 6 days dry stored flowers but reduced in 7 days dry stored

Table 28. **Postharvest life and quality of cut roses cv. Noblesse as influenced by pulsing (BA 25 ppm) and dry storage at 4^0C**

Treatments (Storage duration)	Water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
0 days	14.6	20.5	6.4	11.5
4 days	9.0	29.3	5.1	10.5
5 days	10.5	33.6	5.7	12.2
6 days	20.4	46.5	7.8	13.0
7 days	16.2	41.0	5.5	12.0
Control (No pulsing and no storage)	17.5	28.2	6.0	11.2
'F' test	**	**	**	**
S.Em. ±	0.098	0.074	0.091	0.105
CD at 5%	0.288	0.218	0.267	0.308

Plate 19. Harvesting stage of 'Noblesse' cut roses

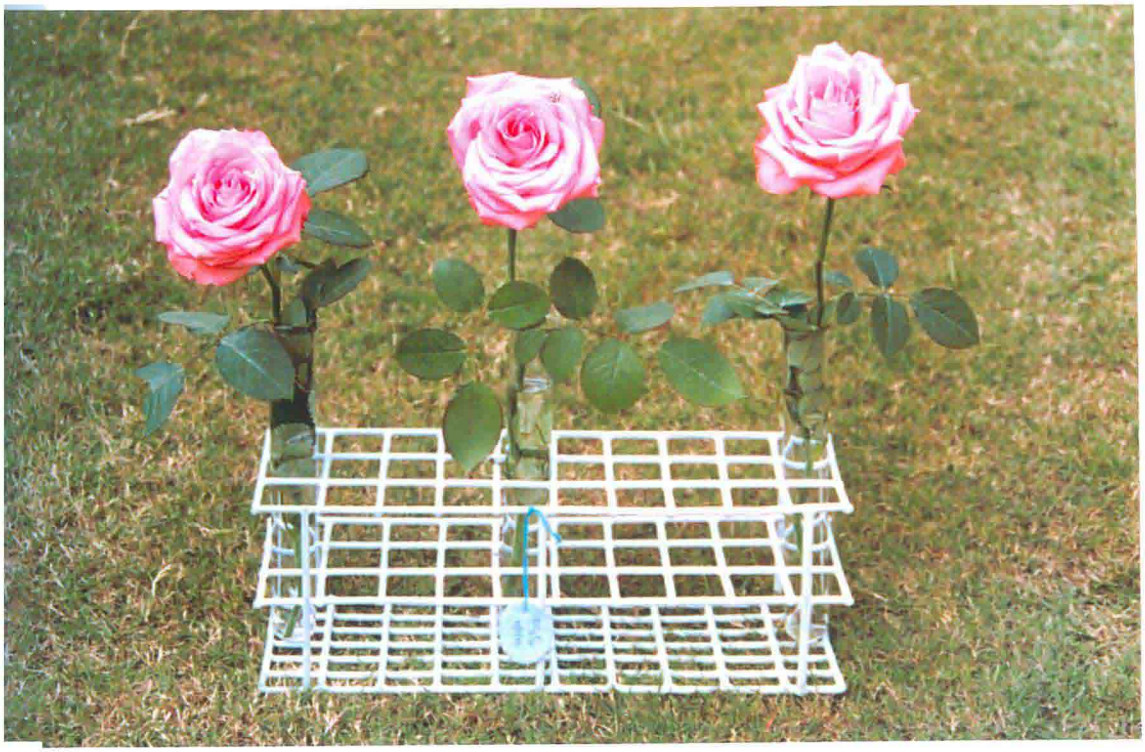


Plate 20. Effect of pulsing (BA 25 ppm for 45 min) on the opening of dry stored cut rose cv. 'Noblesse'

flowers. Thus, the longest vase life was associated with maximum water uptake and highest flower diameter in the cut rose cv. Noblesse.

4.4.2 Influence of holding solutions on dry stored and pulsed cut roses

4.4.2.1 Changes in fresh and dry weight of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM for 45 min), dry storage (4^0C for 6 days) and holding solutions

It is evident from Table 29 that pulsed dry stored cut roses significantly affected the changes in fresh and dry weight of cv. Noblesse. There was decrease in both fresh and dry weight after the dry storage period. Maximum loss in fresh weight after storage was observed with treatment combination of sucrose (2%) + streptomycin sulphate (250 ppm) followed by sucrose (3%) + 8-HQC (200 ppm). Maximum gain in fresh weight on 3rd day in vase was noticed in treatment D-fructose (3%) + nickel chloride (300 ppm) which was significantly higher than the gain in fresh weight recorded with the rest of the treatments except for D-fructose (3%) + kinetin (2.5 ppm).

Decrease in fresh weight from the initial weight taken at harvest of the cut roses were found maximum in sucrose (2%) + streptomycin sulphate (250 ppm) followed by control at senescence which showed significantly higher decrease in fresh weight over the other treatments. Maximum decrease in dry weight after dry storage was observed in control, followed by treatments D-fructose (3%) + kinetin (2.5 ppm) and sucrose (2%) + streptomycin sulphate (250 ppm). On 3rd day in vase, there was gain in dry weight for all the treatments except control and D-fructose (3%) + kinetin (2.5 ppm) which showed loss in dry weight. Maximum gain in dry weight on 3rd day was with sucrose (3%) + 8-HQC

Table 29. **Effect of pulsing (STS 0.5 mM), dry storage (4^0C for 6 days) and holding solution on the changes in fresh and dry weight of cv. Noblesse cut roses**

Treatments (Holding solution)	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senescence	After storage	On 3rd day	At senescence	
D-fructose 3% + Kinetin 2.5 ppm	-0.47	-0.21	-2.44	-0.63	-1.32	-0.24	13.0
D-fructose 3% + $AgNO_3$ 25 ppm	-0.27	+0.13	-2.38	-0.20	+0.03	-0.26	12.3
D-fructose 3% + Nickel chloride 300 ppm	-0.37	+1.65	-3.22	-0.43	+0.04	-0.25	13.5
Sucrose 3% + 8-HQC 200 ppm	-0.54	+0.73	-4.18	-0.40	+0.05	-0.32	12.8
Sucrose 2%+ Captan 200 ppm	-0.21	+1.23	-2.20	-0.35	+0.02	-0.18	10.0
Sucrose 2% + Streptomycin sulphate 250 ppm	-0.90	+1.26	-4.68	-0.63	+0.02	-0.52	10.5
Control	-0.31	+0.64	-4.50	-0.91	-0.70	-0.70	10.5
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.006	0.006	0.012	0.006	0.006	0.006	0.100
C.D. at 5 %	0.019	0.019	0.036	0.019	0.019	0.019	0.294

** Highly significant

(+) Denotes gain in weight over the initial weight taken at harvest

(-) Denotes loss in weight over the initial weight taken at harvest.

(200 ppm) and D-fructose (3%) + nickel chloride (300 ppm) which were at par with each other. However, at senescence control treatment registered maximum loss followed by sucrose (2%) + streptomycin sulphate (250 ppm).

Cut roses cv. Noblesse held in different holding solutions recorded significantly longer vase life than the vase life of cut roses held in tap water (control) and sucrose (2%) + captan (200 ppm). Maximum vase life was observed with D-fructose (3%) + nickel chloride (300 ppm) 13.5 days followed by D-fructose (3%) + kinetin (2.5 ppm) 13 days and sucrose (3%) + 8-HQC 200 ppm 12.3 days which did not differ significantly from each other. Minimum vase life of 10 days was observed with sucrose (2%) + captan (200 ppm).

4.4.2.2 Post harvest life and quality of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM for 45 min.), dry storage (6 days at 4^0C) and holding solutions

It reveals from the Table 30, that maximum solution uptake on 3rd day was with cut roses held in sucrose (2%) + streptomycin sulphate (250 ppm). However, D-fructose (3%) + nickel chloride (300 ppm) recorded maximum solution uptake at senescence. Maximum flower diameter was recorded with D-fructose (3%) + nickel chloride (300 ppm) followed by D-fructose (3%) + kinetin (2.5 ppm). There was significant increase in vase life of cut roses held in D-fructose (3%) + nickel chloride (300 ppm) which also showed maximum solution uptake at senescence and largest flower diameter. Thus it may be concluded that holding solution D-fructose (3%) + nickel chloride (300 ppm) gave maximum vase life of 13.8 days and was found beneficial for the improvement of post harvest life and quality of pulsed and dry stored cut flowers.

Table 30. **Effect of pulsing (STS 0.5 mM), dry storage (4^0C for 6 days) and holding solution on the postharvest life and quality of cv. Noblesse cut roses**

Treatments (Holding solution)	Solution uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
D-fructose 3% + Kinetin 2.5 ppm	11.2	37.8	7.1	13.0
D-fructose 3% + $AgNO_3$ 25 ppm	10.2	24.3	6.8	12.3
D-fructose 3% + Nickel chloride 300 ppm	13.8	40.5	7.5	13.5
Sucrose 3% + 8-HQC 200 ppm	13.2	25.3	6.2	12.8
Sucrose 2% + Captan 200 ppm	10.6	28.0	5.8	10.0
Sucrose 2% + Streptomycin sulphate 250 ppm	14.2	24.0	5.0	10.5
Control	12.5	39.0	5.5	10.5
'F' test	**	**	**	**
S.Em. ±	0.094	0.073	0.073	0.100
CD at 5%	0.276	0.215	0.215	0.294

4.5 Effect of pulsing, conditioning and holding solution on the vase life of dry stored cut roses

4.5.1 Changes in fresh and dry weight of dry stored (at 4^0C for 6 days) 'Noblesse' cut roses as affected by pulsing (STS 0.5 mM for 45 min.), conditioning and holding solutions

The data presented in Table 31 reveals that the pulsing, conditioning and holding solutions significantly influenced the change in fresh and dry weight of cut rose cv. Noblesse. Maximum gain in fresh and dry weight after the dry storage period was recorded with dry stored + conditioning in citric acid + vase (tap) water. On 3rd day in vase, there was increase in fresh weight in all treatments except pulsing + dry store + vase (tap) water, which showed loss in fresh weight. Maximum gain in fresh weight was observed with pulsing + drystore + holding solution in D-fructose (3%) + nickel chloride (300 ppm). At senescence, both fresh and dry weight decreased irrespective of the treatments. Minimum loss in both fresh and dry weight was observed with pulsed + dry stored + D-fructose (3%) + nickel chloride. (300 ppm) The vase life was also increased significantly in all the treatments, when compared with control. Pulsing + dry store + holding solution in D-fructose (3%) + nickel chloride (300 ppm) gave the maximum vase life followed by dry store + conditioning in water (1 hr) + tap water and dry store + conditioning in citric acid (1 hr) + vase (tap) water.

4.5.2 Post harvest life and quality of cut roses cv. Noblesse as influenced by pulsing (STS 0.5 mM for 45 min.), conditioning and holding solutions

It is evident from the Table 32, that the holding solution uptake, flower diameter and vase life was improved significantly over the control.

Table 31. Effect of pulsing (STS 0.5 mM), conditioning, holding solution on the changes in fresh and dry weight of cv. Noblesse cut roses

Treatments	Changes in fresh weight (g)			Changes in dry weight (g)			Vase life (days)
	After storage	On 3rd day	At senes-cence	After storage	On 3rd day	At senes-cence	
Dry store + Conditioning + Vase water	-0.35	+0.74	-2.56	+0.24	+0.27	-0.02	8.0
Dry store + Citric acid + Vase water	+0.74	+1.69	-3.41	+0.36	+0.62	-0.03	8.0
Pulsing + Dry store + Nickel chloride	-0.02	+2.82	-0.69	-0.05	+0.08	-0.01	10.7
Pulsing + Dry Store + Vase Water	-0.39	-1.06	-3.03	-0.04	+0.04	-0.02	7.5
Control	-	+1.10	-0.76	-	+0.10	-0.03	6.3
'F' test	**	**	**	**	**	**	**
S.Em. ±	0.029	0.009	0.009	0.007	0.010	0.008	0.065
C.D. at 5 %	0.086	0.025	0.025	0.021	0.028	0.022	0.190

** Highly significant
(+) Denotes gain in weight over the initial weight taken at harvest
(-) Denotes loss in weight over the initial weight taken at harvest.

Table 32. **Effect of pulsing (STS 0.5 mM), conditioning, holding solutions on the post harvest life and quality of dry stored 'Noblesse' cut roses**

Treatments	Solution/water uptake (ml)		Flower diameter (cm)	Vase life (days)
	On 3rd day	At senescence		
Dry store + Conditioning + Vase water	15.5	25.0	6.0	8.0
Dry store + Citric acid + Vase water	27.8	32.6	5.8	8.0
Pulsing + Dry store + D-fructose (3%) + Nickel chloride (300 ppm)	22.8	39.0	6.3	10.7
Pulsing + Dry store + Vase water	29.0	31.7	5.6	7.5
Control (No pulsing, no storage and no holding solution)	23.3	22.0	4.8	6.3
'F' test	**	**	**	**
S.Em. ±	0.178	1.033	0.086	0.065
CD at 5%	0.523	3.039	0.253	0.190

Maximum solution uptake on 3rd day in vase was observed with pulsing + dry store + vase (tap) water. While at senescence, maximum solution uptake was observed with pulsing + dry store + holding solution in D-fructose (3%) and nickel chloride (300 ppm) followed by dry store + conditioning in citric acid (1 h) + vase (tap) water. Flower diameter was significantly improved with maximum recorded in pulsing + dry store + holding solution in D-fructose (3%) + nickel chloride (300 ppm) followed by dry store + conditioning in water (1 h) + vase (tap) water. Maximum vase life was recorded with pulsing + dry store + holding solution in D-fructose (3%) + nickel chloride (300 ppm) and minimum vase life with untreated control. Longest vase life was associated with maximum holding solution uptake and largest flower diameter.

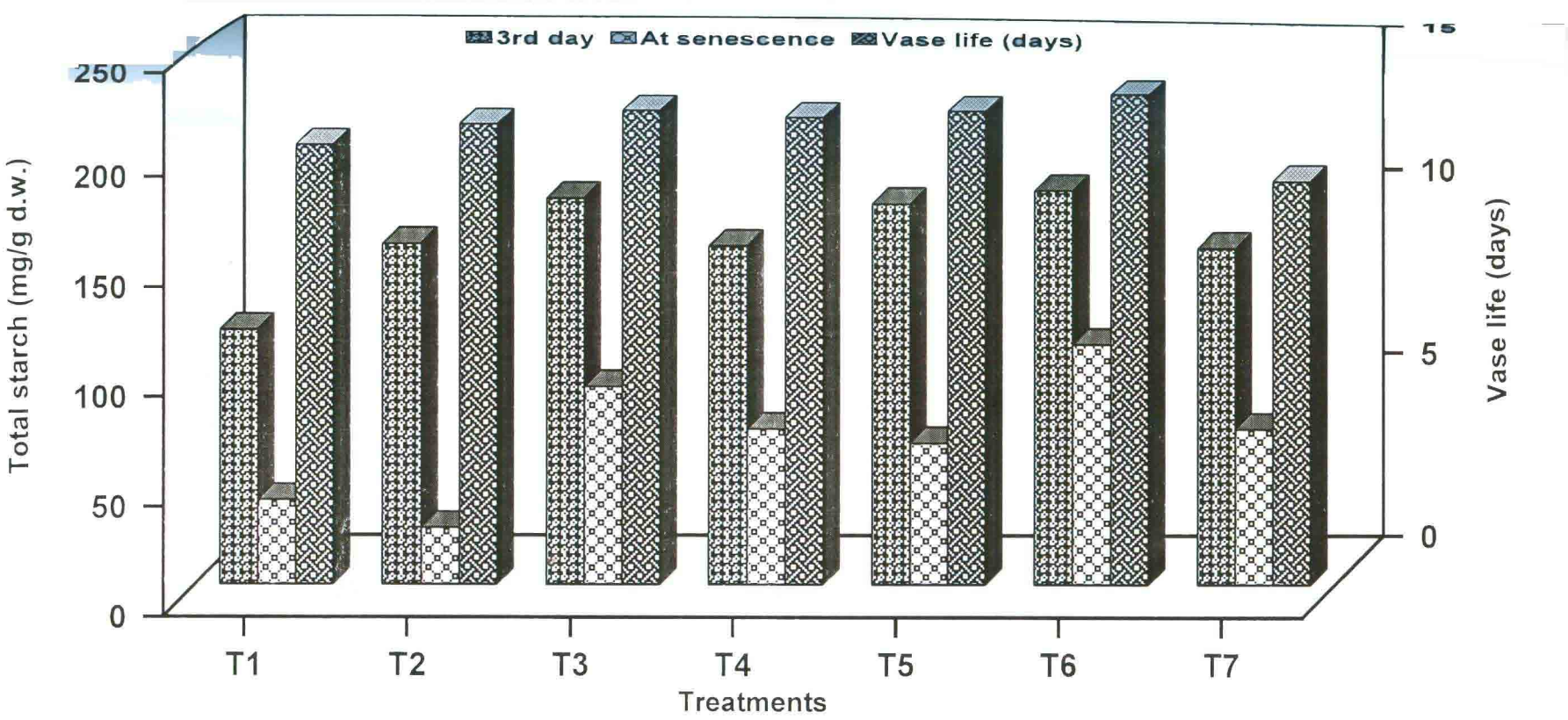
4.6 Changes in biochemical constituents like total starch, total soluble sugars, total free amino acids and total phenols in 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

4.6.1 Total starch content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing

It is evident from the Table 33 that the total starch content in petals of 'Golden Gate' cut roses showed a continuous decrease on the third day in vase and at senescence over that at harvest. In all the precooling and pulsing treatments except that of ice cold water spray for 45 min and not pulsed, there was significantly higher starch content in petals than the untreated control. On the third day in vase, the highest total starch content was observed in the flowers treated with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 minutes (179.20 mg/g d.w) followed by ice-cold water spray for 45 min and pulsed with DMSO (2%)

Table 33. **Total starch content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing**

Treatments	Total starch (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Ice cold water spray for 45 min and not pulsed	115.71	38.57	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	154.93	25.74	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	175.50	90.00	13.0
Cool storage at 4^0C for 24 h and not pulsed	153.92	70.74	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	173.14	64.31	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	179.20	109.31	13.5
No precooling and no pulsing (Control)	153.00	70.70	11.0
	*Total starch at harvest is 393.42 mg/g d.w.		
'F' test	**	**	**
S.Em. ±	0.07	0.04	0.12
CD at 5 %	0.21	0.12	0.36



T1 = Ice cold water spray for 45 min and not pulsed
T2 = Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T3 = Ice cold water spray for 45 min and pulsed with DMSO(2%)
T4 = Cool storage at 4°C for 24 h and not pulsed
T5 = Cool storage at 4°C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T6 = Cool storage at 4°C for 24 h and pulsed with DMSO (2%)
T7 = No precooling and no pulsing (Control)

Fig. 1. Total starch content in petals of 'Golden gate' cut roses as affected by precooling and pulsing

for 15 minutes (175.50 mg/g d.w) (Fig. 1). At senescence, similar trend was observed. High starch content during different stages of flower development and senescence was associated with increased vase life.

4.6.2 Total starch content in petals of 'Golden Gate' cut roses as affected by ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials

With reference to Table 34, the total starch content in the petals of 'Golden Gate' cut roses showed a decrease on 3rd day in vase and at senescence when compared to the harvest. On the 3rd day in vase, as the packaging duration increased from 6 h to 20 h, the starch content decreased in all the treatments. Maximum starch content on 3rd day in vase was observed with precooled and pulsed flowers packed with single layer of corrugated fibre board sheet for 6 h followed by pre-cooled, pulsed cut flowers packed with butterpaper for 6 h (Fig. 2). However, at senescence, maximum starch content in the petals was observed with pre-cooled pulsed flowers packed with butterpaper for 20 h followed by pre-cooled and pulsed flowers packed with corrugated fibre board sheet for 20 h.

4.6.3 Total starch content in petals of 'Golden Gate' cut roses as affected by cool storage at 4^0C for 24 h, pulsing (DMSO 2%) and different packaging materials

Precooling with cool storage at 4^0C for 24 h, pulsing with DMSO (2%) for 15 min and packing with different packaging materials significantly affected the total starch content in petals of 'Golden Gate' cut roses (Table 35). There was a decrease in the total starch content of petals from harvest, on 3rd day in vase and at senescence. On the 3rd day in vase, 6 h duration packed flowers had more starch content than 20 h duration in all the treatments except single layer corrugated fibre board sheet where

Table 34. **Total starch content in petals of 'Golden Gate' cut roses as affected by ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials**

Treatments	Total starch (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	230.78	84.90	7.3
Butter paper 20 h	229.86	101.60	7.0
Brown paper 6 h	114.43	93.24	6.5
Brown paper 20 h	104.14	77.20	6.0
Polythene 6 h	156.85	46.31	6.8
Polythene 20 h	146.57	61.74	6.0
CFB 6 h	234.64	58.50	7.0
CFB 20 h	154.28	95.22	6.8
Control	196.07	89.37	5.8

* Total starch at harvest is 393.42 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0771	0.0140	0.0471
Duration (D)	0.0667	0.0122	0.0408
P x D	0.1355	0.0243	0.0816
CD at 5 %			
Packaging (P)	0.225	0.041	0.137
Duration (D)	0.195	0.036	0.119
P x D	0.390	0.071	0.238

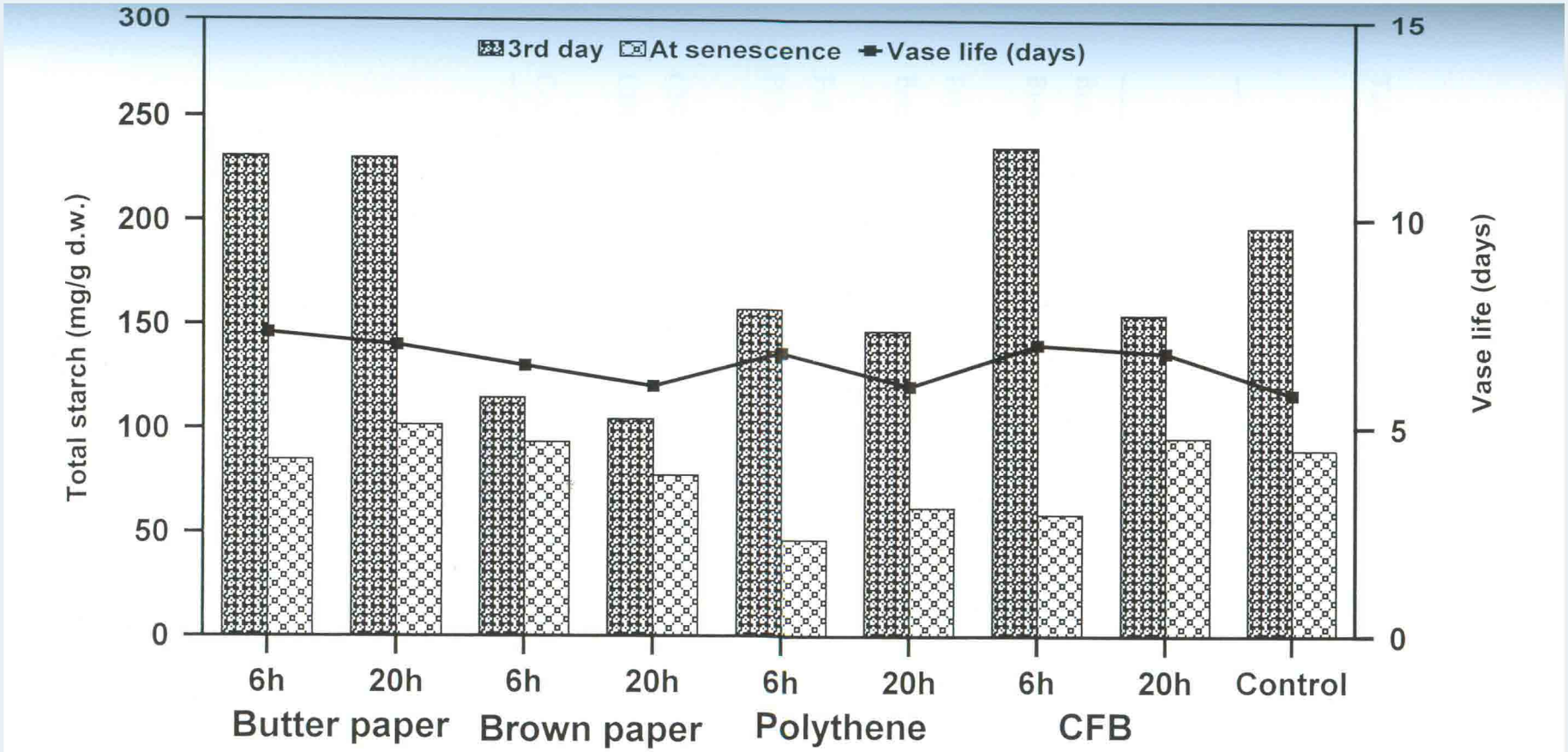


Fig. 2. Total starch content in petals of Golden gate' cut roses as affected by ice-cold water spray for 45 min., pulsing (DMSO 2%) and different packaging materials

Table 35. **Total starch content in petals of 'Golden Gate' cut roses as affected by cool storage (4^0C) for 24 h, pulsing (DMSO 2%) and different packaging materials**

Treatments	Total starch (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	176.78	95.24	7.8
Butter paper 20 h	176.78	88.74	6.3
Brown paper 6 h	174.85	56.60	6.9
Brown paper 20 h	141.43	82.31	6.0
Polythene 6 h	169.71	81.00	6.8
Polythene 20 h	104.14	92.61	6.5
CFB 6 h	91.28	81.68	6.5
CFB 20 h	142.71	89.37	6.0
Control	144.00	36.86	5.5

* Total starch at harvest is 393.42 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0393	0.0220	0.0527
Duration (D)	0.0340	0.0190	0.0456
P x D	0.0681	0.0381	0.0913
CD at 5 %			
Packaging (P)	0.115	0.064	0.154
Duration (D)	0.099	0.055	0.133
P x D	0.199	0.111	0.266

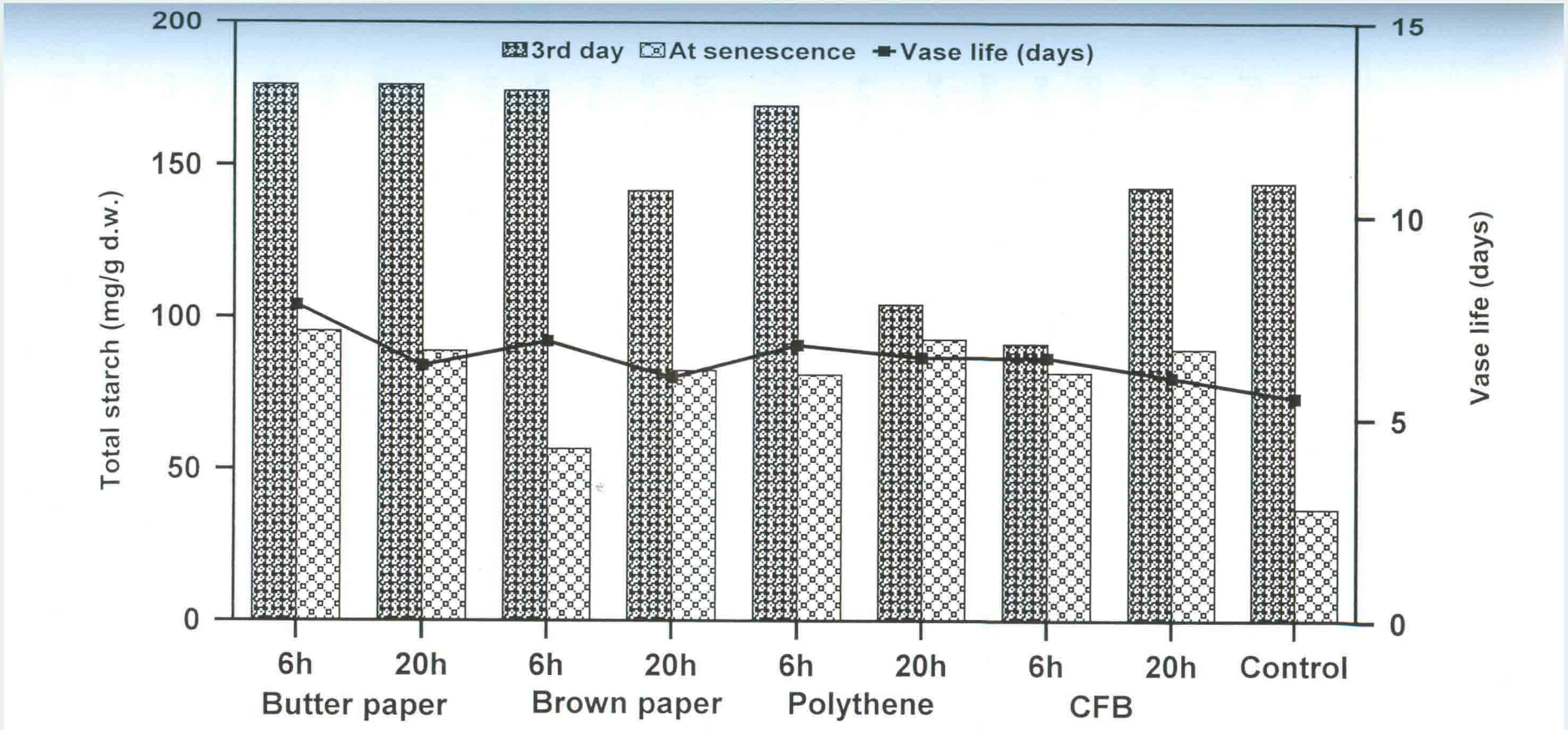


Fig. 3. Total starch content in petals of Golden gate' cut roses as affected by cool storage (4^{O}C) for 24h, pulsing (DMSO 2%) and different packaging materials

20 h duration recorded more starch content than 6 h packed flowers. The highest content of total starch on 3rd day in vase was recorded with precooled and pulsed flowers packed with butterpaper for 6 h and 20 h followed by pre-cooled and pulsed flowers packed with brownpaper for 6 h. At senescence, the highest content of starch was recorded with precooled and pulsed flowers packed with butterpaper for 6 h which also recorded maximum vase life (Fig. 3). In general, maximum vase life was associated with high starch content during the flower development and senescence.

4.6.4 Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing

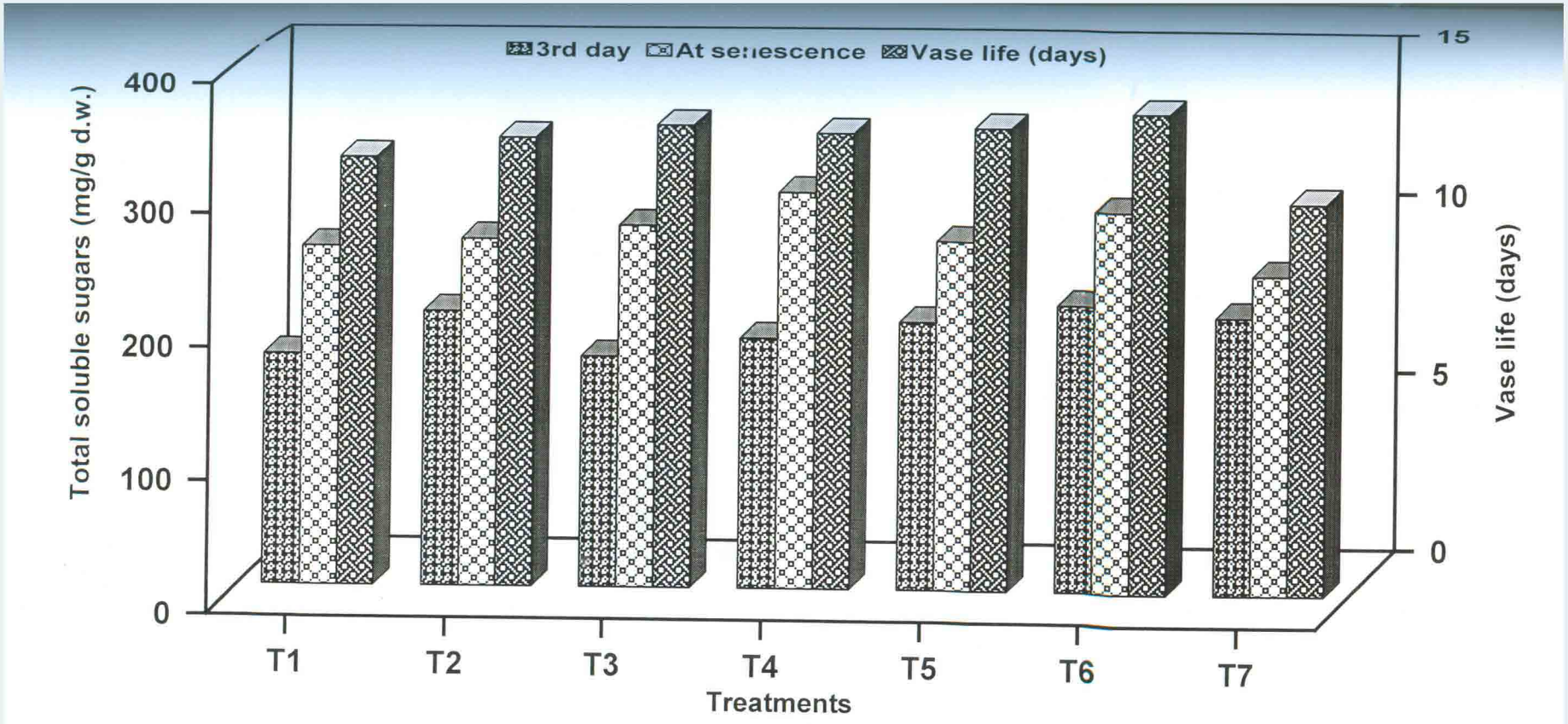
It reveals from Table 36 that the total soluble sugars content (TSS) in petals of cut 'Golden Gate' roses showed an increase on the third day in vase except in treatments with ice-cold water spray for 45 min and not pulsed, cool storage at 4^0C for 24 h and not pulsed and ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. At senescence, the total soluble sugars content increased from 3rd day in vase and also from harvest. The highest TSS content on the third day in vase was recorded with the precooling treatment with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 minutes (Fig. 4). At senescence, precooling with cool storage at 4^0C for 24 h and not pulsed recorded the highest petal TSS content (296.50 mg/g d.w) followed by precooling with cool storage at 4^0C for 24 h and pulsing with DMSO (2%) (286.00 mg/g d.w) and precooling with ice cold water spray for 45 min and pulsing with DMSO at 2% (271.00 mg/g d.w). The lowest petal TSS content at senescence was recorded with the untreated control. Maximum vase life

Table 36. **Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing**

Treatments	TSS (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Ice cold water spray for 45 min and not pulsed	172.50	253.50	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	205.70	260.00	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	172.80	271.00	13.0
Cool storage at 4^0C for 24 h and not pulsed	187.50	296.50	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	200.80	261.50	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	215.00	286.00	13.5
No precooling and no pulsing (Control)	208.20	239.50	11.0

* Total soluble sugars content (TSS) at harvest is 201.90 mg/g d.w.

'F' test	**	**	**
S.Em. ±	0.09	0.09	0.12
CD at 5 %	0.27	0.27	0.36



T1 = Ice cold water spray for 45 min and not pulsed
T2 = Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T3 = Ice cold water spray for 45 min and pulsed with DMSO(2%)
T4 = Cool storage at 4°C for 24 h and not pulsed
T5 = Cool storage at 4°C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T6 = Cool storage at 4°C for 24 h and pulsed with DMSO (2%)
T7 = No precooling and no pulsing (Control)

Fig. 4. Total soluble sugars content in petals of 'Golden gate' cut roses as affected by precooling and pulsing

was associated with the increase in the TSS content in the petal tissues of 'Golden Gate' cut roses.

4.6.5 Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by precooling with ice cold water spray for 45 min, pulsing (DMSO 2%) and packaging materials

The data presented in Table 37 shows that the total soluble sugars content in petals of cut Golden Gate roses showed an increase on the third day in vase over that at harvest and then decreased at senescence except in flowers precooled, pulsed and packed with polythene bags (80 guage) for 20 h. The maximum increase in TSS content in the petal tissues on 3rd day was recorded with flowers precooled, pulsed and packed with single layer corrugated fibre board sheet for 6 h followed by single layer corrugated fibre board sheet packed for 20 h. However, at senescence, the TSS content decreased from 3rd day (Fig. 5). Maximum content of total soluble sugar at senescence was found with flowers precooled, pulsed and packed with polythene for 20 h, followed by brownpaper packed for 20 h. Minimum content of TSS in the petals at senescence was found with the untreated control which resulted in the minimum vase life.

4.6.6 Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by precooling with cool storage at 4^0C for 24 h, pulsing DMSO (2%) and different packaging materials

It reveals from the Table 38 that the TSS content in the petal tisues of Golden Gate cut roses significantly increased on the third day in vase in all the treatments and thereafter decreased at senescence. The highest total soluble sugars content on 3rd day in vase was recorded with flowers precooled, pulsed and packed with butterpaper for 6 h, followed by precooled, pulsed flowers packed with Brownpaper for 6 h. The minimum

Table 37. **Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials**

Treatments	TSS (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	246.07	189.00	7.3
Butter paper 20 h	240.78	238.50	7.0
Brown paper 6 h	230.71	200.00	6.5
Brown paper 20 h	297.85	247.00	6.0
Polythene 6 h	247.50	213.50	6.8
Polythene 20 h	252.85	275.50	6.0
CFB 6 h	348.56	245.00	7.0
CFB 20 h	304.28	216.00	6.8
Control	235.42	180.00	5.8

* Total soluble sugars content (TSS) at harvest is 201.90 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0657	0.0577	0.0441
Duration (D)	0.0569	0.0500	0.0382
P x D	0.1137	0.1000	0.0764
CD at 5 %			
Packaging (P)	0.192	0.168	0.129
Duration (D)	0.166	0.146	0.111
P x D	0.332	0.292	0.223

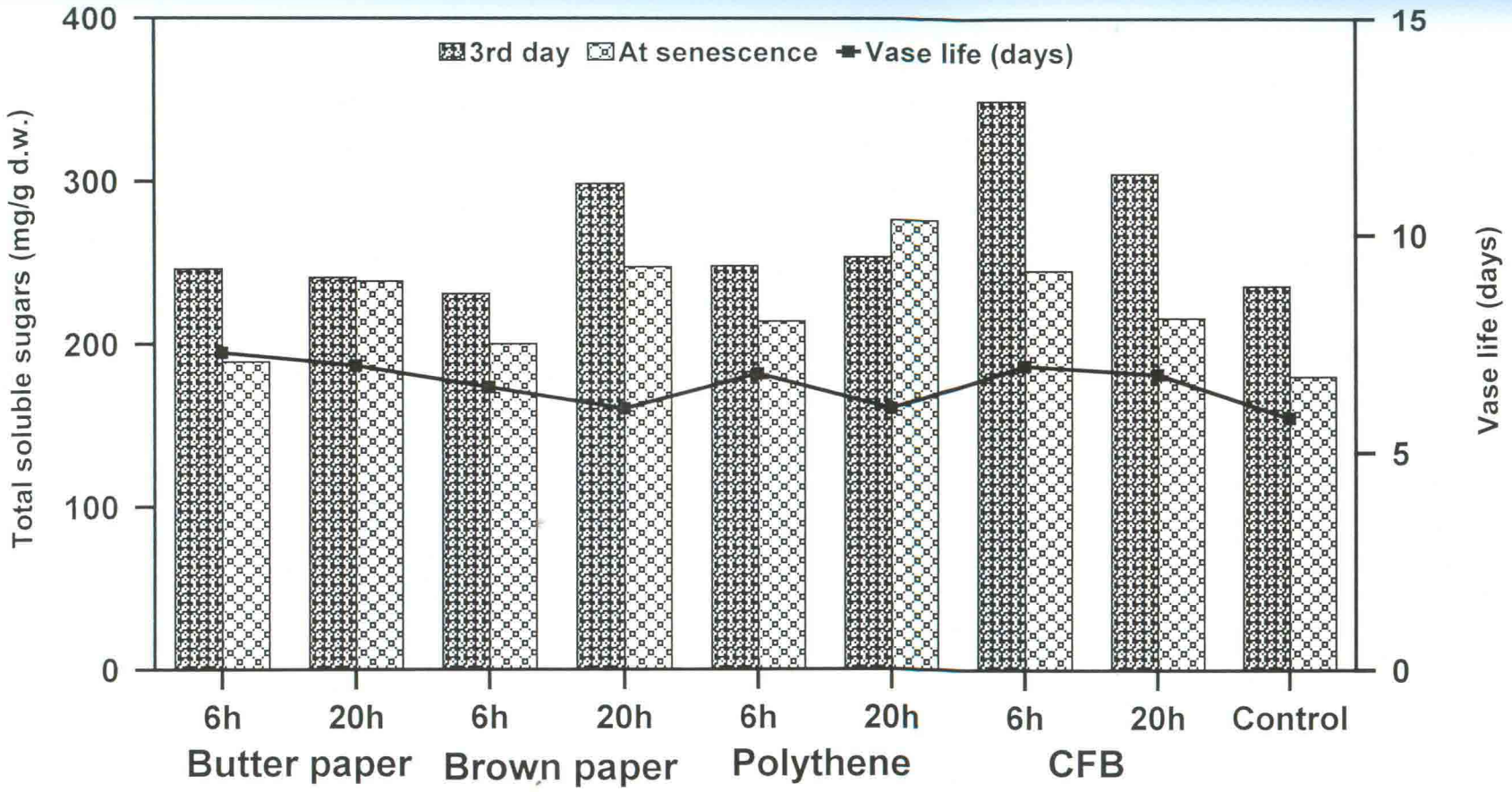


Fig. 5. Total soluble sugars content in petals of Golden gate' cut roses as affected by ice-cold water spray for 45 min., pulsing (DMSO 2%) and different packaging materials

Table 38. Total soluble sugars content in petals of 'Golden Gate' cut roses as affected by cool storage (4^0C) for 24 h, pulsing (DMSO 2%) and different packaging materials

Treatments	TSS (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	361.00	242.20	7.8
Butter paper 20 h	341.42	296.50	6.3
Brown paper 6 h	351.42	247.90	6.9
Brown paper 20 h	264.80	212.10	6.0
Polythene 6 h	255.71	181.45	6.8
Polythene 20 h	288.57	197.50	6.5
CFB 6 h	255.00	188.20	6.5
CFB 20 h	330.71	198.20	6.0
Control	250.00	180.00	5.5

* Total soluble sugars content (TSS) at harvest is 201.90 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0475	0.0491	0.0527
Duration (D)	0.0411	0.0425	0.0456
P x D	0.0822	0.0850	0.0913
CD at 5 %			
Packaging (P)	0.139	0.143	0.154
Duration (D)	0.120	0.124	0.133
P x D	0.240	0.248	0.266

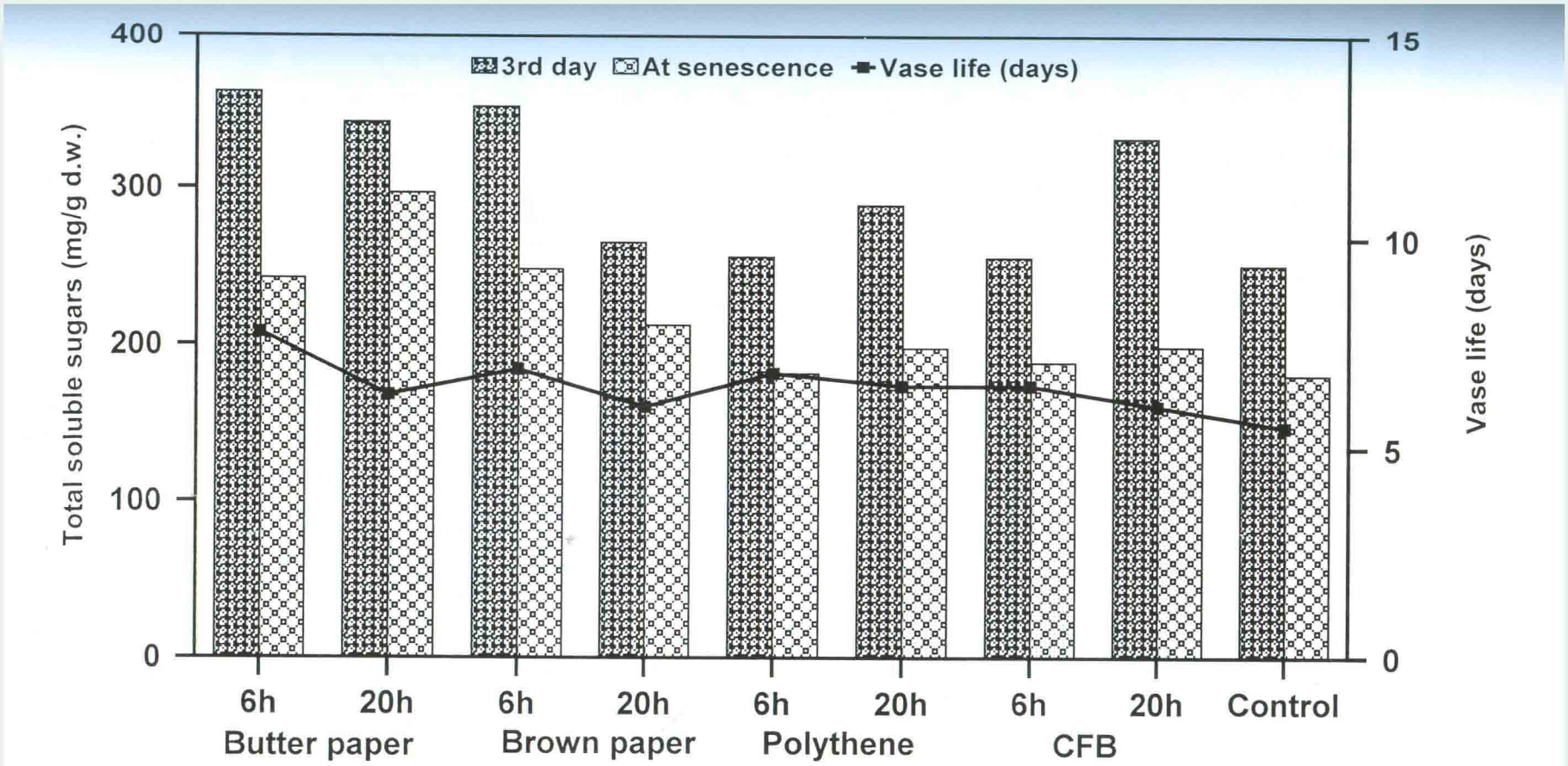


Fig. 6. Total soluble sugars content in petals of Golden gate' cut roses as affected by cool storage (4^{O}C) for 24h, pulsing (DMSO 2%) and different packaging materials

content of total soluble sugars in rose petals was recorded with the untreated control flowers during the flower development and senescence (Fig. 6). At senescence, the highest TSS content in rose petals was found with flowers precooled, pulsed and packed with butterpaper for 20 h followed by flowers precooled, pulsed and packed with brownpaper for 6 h. Maximum vase life was associated with high TSS content in rose petals during the development of the flower.

4.6.7 Total free amino acids content in petals of 'Golden Gate' Cut roses as affected by precooling and pulsing

It reveals from Table 39 that the total free amino acids content (TFAA) in petals of cut 'Golden Gate' roses showed an increase on the 3rd day in vase and also at senescence over that at harvest. In all the treatments employed the petal TFAA contents were significantly lower than those of untreated control. Among the different treatments, the lowest petal TFAA content on the third day was recorded with the precooling with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min. At senescence, similar trend was observed. The highest TFAA content during the flower development and senescence was observed with the treatment of ice-cold water spray for 45 min and not pulsed followed by untreated control on the 3rd day in vase as well as at senescence (Fig. 7). Lower TFAA content in the petal tissues was associated with longer vase life of cut roses.

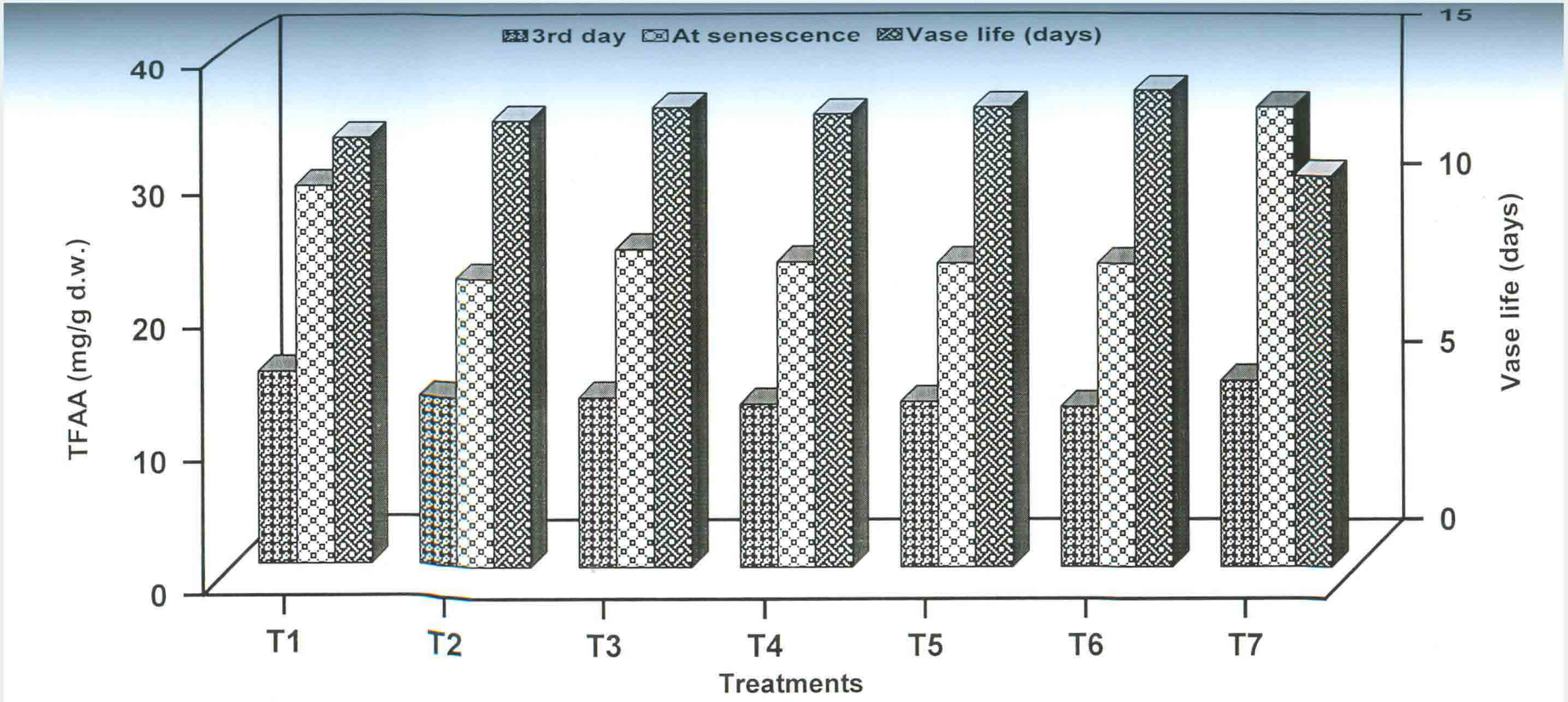
4.6.8 Total free amino acids content in petals of 'Golden Gate' cut roses as affected by precooling with ice cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials

Perusal of Table 40 clearly reveals that precooling, pulsing and different packaging materials significantly increased the TFAA content in

Table 39. **Total free amino acids content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing**

Treatments	TFAA (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Ice cold water spray for 45 min and not pulsed	14.43	28.35	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	12.64	21.65	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	12.76	23.90	13.0
Cool storage at 4^0C for 24 h and not pulsed	12.27	22.95	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	12.43	22.85	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	12.01	22.80	13.5
No precooling and no pulsing (Control)	14.00	34.60	11.0
'F' test	**	**	**
S.Em. ±	0.02	0.04	0.12
CD at 5 %	0.06	0.12	0.36

* Total free amino acids content (TFAA) at harvest is 11.82 mg/g d.w.



T1 = Ice cold water spray for 45 min and not pulsed
T2 = Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T3 = Ice cold water spray for 45 min and pulsed with DMSO(2%)
T4 = Cool storage at 4°C for 24 h and not pulsed
T5 = Cool storage at 4°C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T6 = Cool storage at 4°C for 24 h and pulsed with DMSO (2%)
T7 = No precooling and no pulsing (Control)

Fig. 7. Total free amino acids contents in petals of 'Golden gate' cut roses as affected by precooling and pulsing

Table 40. **Total free amino acids content in petals of 'Golden Gate' cut roses as affected by ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials**

Treatments	TFAA (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	22.75	33.0	7.3
Butter paper 20 h	23.49	37.75	7.0
Brown paper 6 h	25.79	43.25	6.5
Brown paper 20 h	25.39	39.25	6.0
Polythene 6 h	22.43	48.25	6.9
Polythene 20 h	31.57	42.25	5.3
CFB 6 h	23.50	35.00	7.0
CFB 20 h	34.03	38.75	6.8
Control	33.13	41.25	5.8

* Total free amino acids content (TFAA) at harvest is 11.82 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0037	0.0501	0.0471
Duration (D)	0.0032	0.0433	0.0408
P x D	0.0065	0.0867	0.0816
CD at 5 %			
Packaging (P)	0.011	0.146	0.137
Duration (D)	0.009	0.126	0.119
P x D	0.019	0.253	0.238

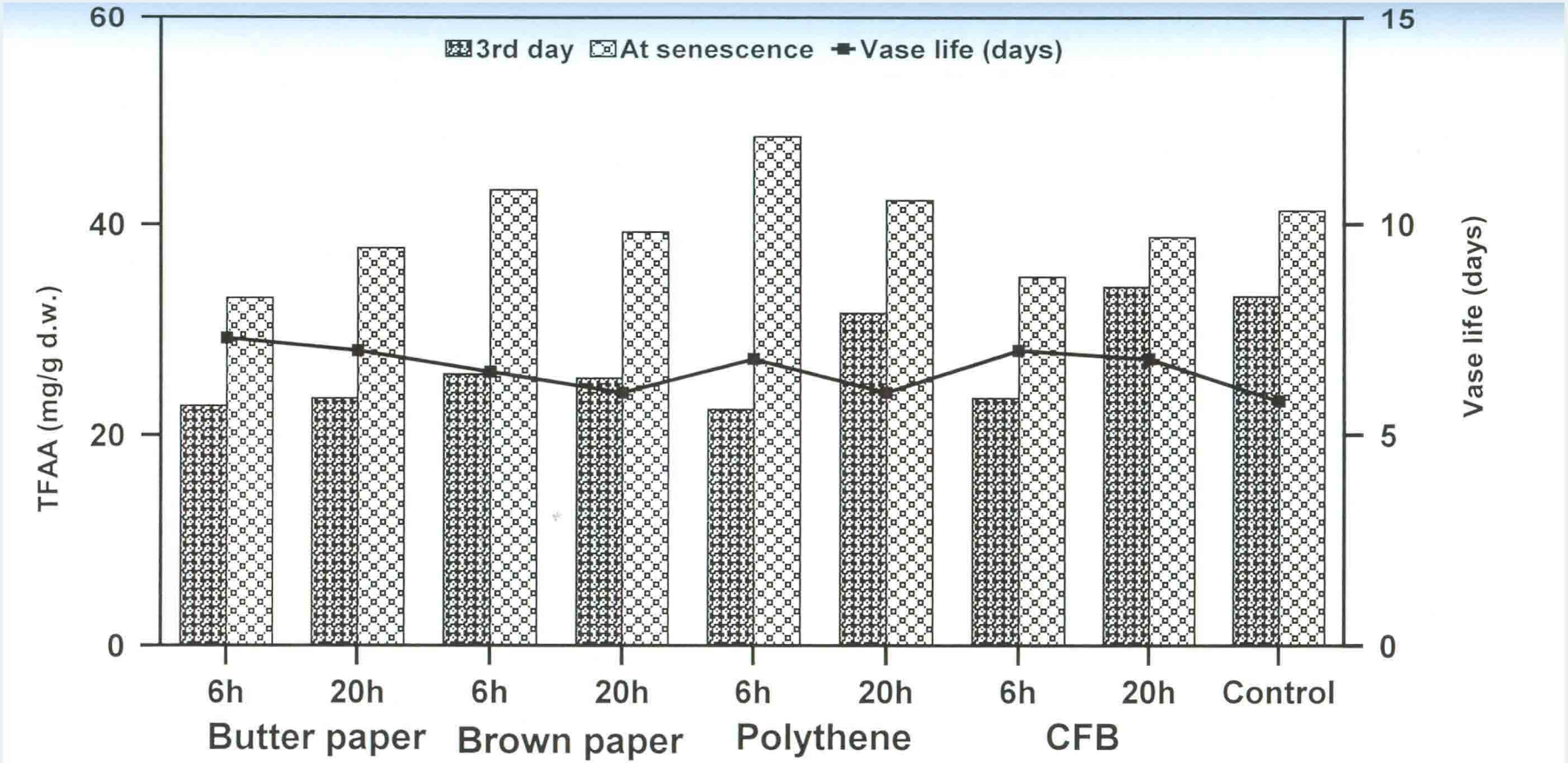


Fig. 8. Total free amino acids content in petals of Golden gate' cut roses as affected by ice-cold water spray for 45 min., pulsing (DMSO 2%) and different packaging materials

the petals of Golden Gate cut roses during different stages i.e. on the 3rd day in vase and at senescence over that at harvest. Precooled, pulsed and packed flowers showed significantly lesser content of TFAA of petals on third day over control. The lowest content of TFAA on the third day in vase was registered with flowers precooled, pulsed and packed with polythene bags (80 guage) for 6 h followed by butterpaper packed for 6 h (Fig. 8). At senescence there was rise in TFAA over the 3rd day and at harvest. It has been observed that at senescence, 6 h packging of precooled and pulsed flowers with butterpaper showed significantly lesser content of TFAA over other treatments and control. This treatment gave the maximum vase life of 'Golden Gate' cut roses.

4.6.9 Total free amino acids content in petals of 'Golden Gate' cut roses as affected by precooling with cool storage at 4^0C for 24 h, pulsing (DMSO 2%) and different packaging materials

With reference to Table 41 the total free amino acids content in petals of cut Golden Gate roses showed an increase on the third day in vase and also at senescence over that at harvest. Among the different treatments employed, the lowest petal TFAA content on the third day was recorded with the flowers precooled, pulsed and packed with polythene bags (80 guage) for 6 h followed by butterpaper packed for 6 h. Whereas at senescence there was rise in TFAA content from 3rd day and at harvest. The lowest petal TFAA content at senescence was recorded with butterpaper 6 h. The highest petal TFAA content was observed with the control on third day as well as at senescence. Maximum vase life was associated with low content of TFAA in the petals of 'Golden Gate' cut roses (Fig. 9).

Table 41. **Total free amino acids content in petals of 'Golden Gate' cut roses as affected by cool storage (4^0C) for 24 h, pulsing (DMSO 2%) and different packaging materials**

Treatments	TFAA (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	20.43	34.25	7.8
Butter paper 20 h	25.07	46.00	6.3
Brown paper 6 h	24.58	46.00	6.9
Brown paper 20 h	26.28	41.50	6.0
Polythene 6 h	20.15	47.25	6.8
Polythene 20 h	20.64	38.00	6.5
CFB 6 h	23.33	48.25	6.5
CFB 20 h	21.36	69.00	6.0
Control	27.51	71.25	5.5

* Total free amino acids content (TFAA) at harvest is 11.82 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0055	0.0697	0.0527
Duration (D)	0.0048	0.0604	0.0456
P x D	0.0096	0.1208	0.0913
CD at 5 %			
Packaging (P)	0.016	0.203	0.154
Duration (D)	0.014	0.176	0.133
P x D	0.028	0.353	0.266

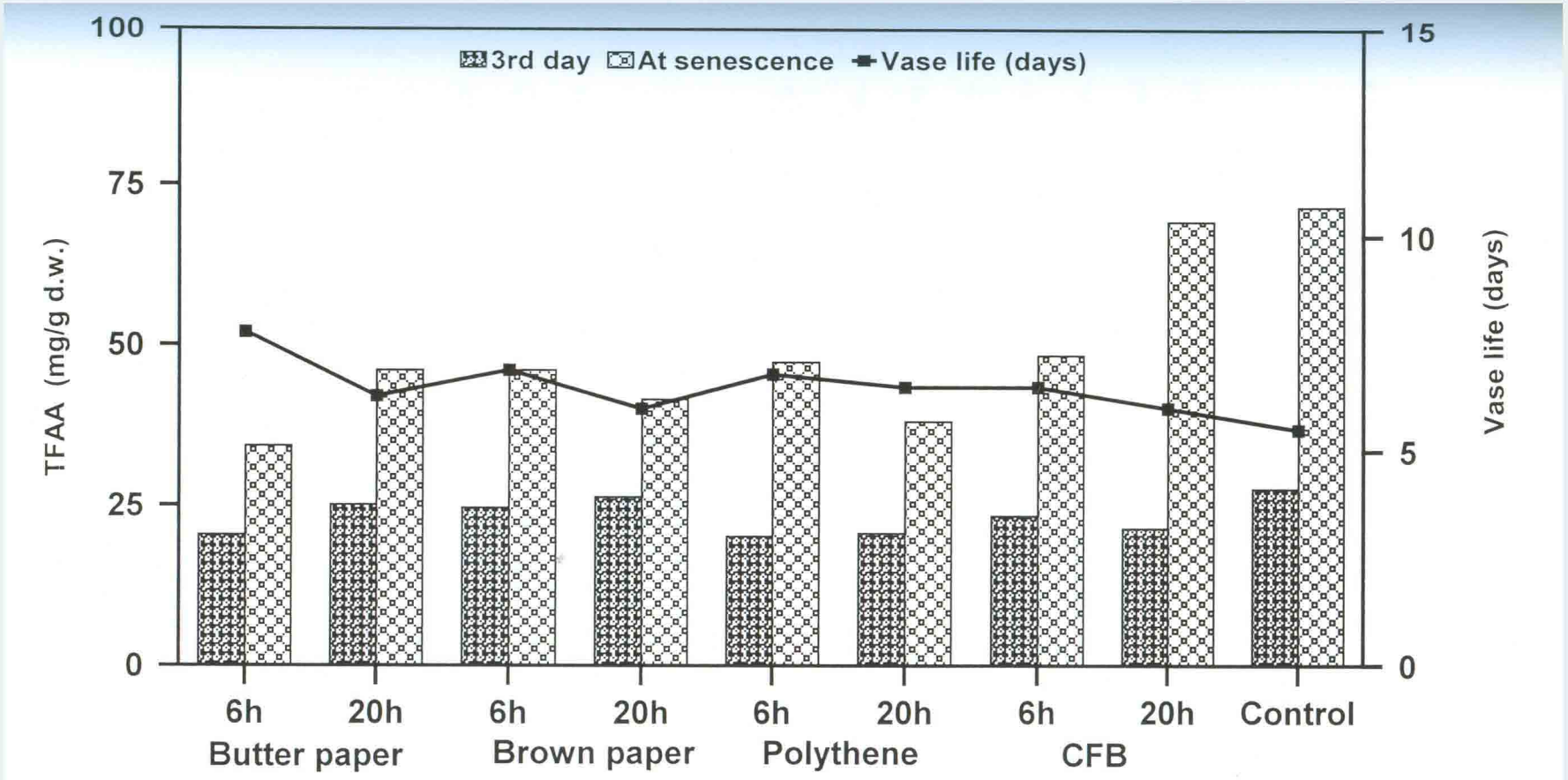


Fig. 9. Total free amino acids content in petals of Golden gate' cut roses as affected by cool storage (4^{O}C) for 24h, pulsing (DMSO 2%) and different packaging materials

4.6.10 Total phenol content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing

The total phenol content was significantly influenced by the precooling and pulsing treatments (Table 42). The phenol content in the petals of Golden Gate cut roses showed a decrease on third day at vase as well as at senescence over that at harvest except for treatments with ice cold water spray for 45 min and not pulsed and ice cold water spray for 45 min pulsed with D-fructose (3%) + 8-HQC (150 ppm) (Fig. 10). These two treatments also registered the highest phenol content on third day in vase and at senescence.

4.6.11 Total phenol content in petals of 'Golden Gate' cut roses as affected by precooling with ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials

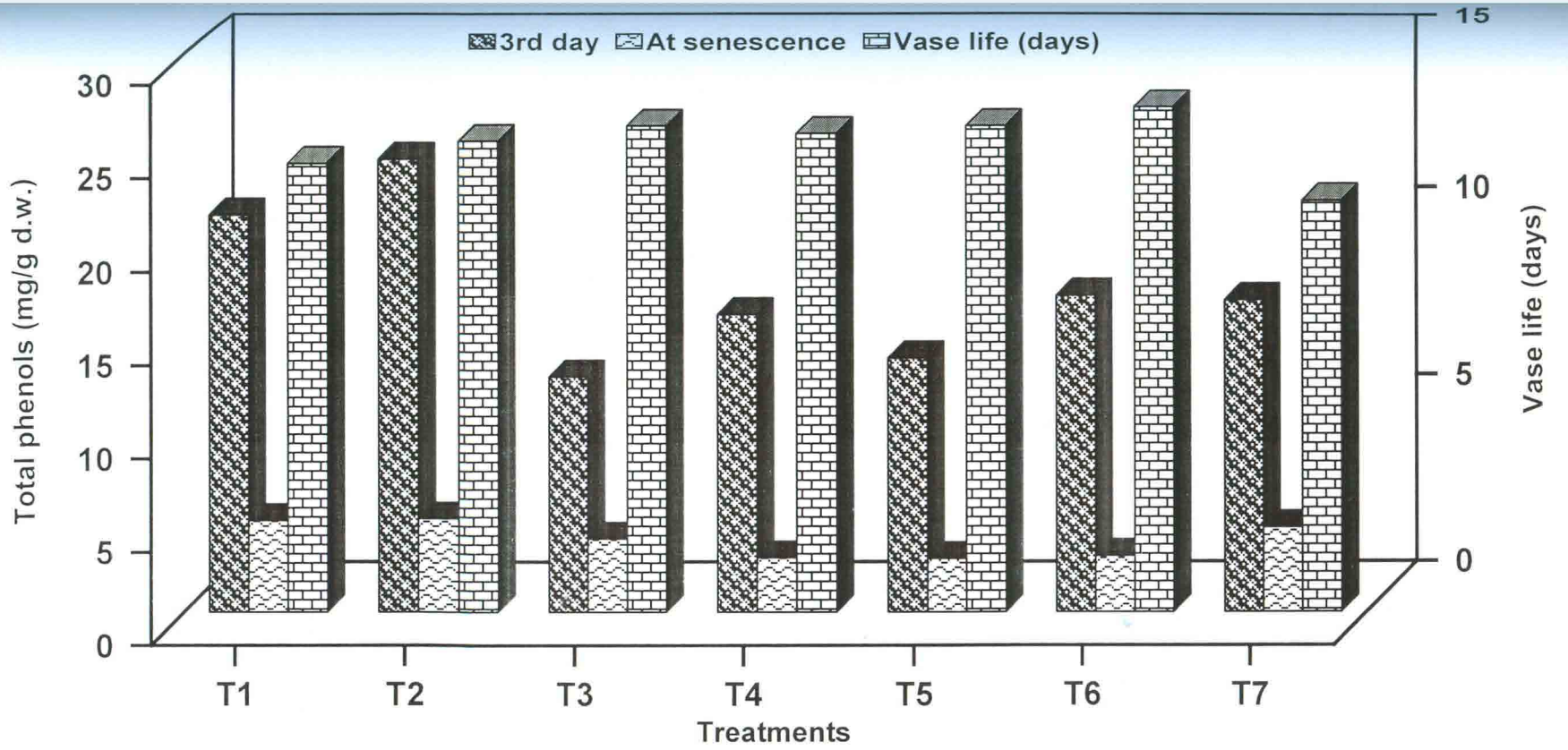
The total phenol content in petals of 'Golden Gate' cut roses was significantly influenced by precooling, pulsing and packaging materials (Table 43). Maximum content of phenols on 3rd day in vase was observed in the petals of flowers precooled, pulsed and packed with single layer corrugated fibre board sheet for 20 h followed by polythene packed for 20 h. Minimum phenol content on third day was observed with butterpaper packed for 6 h (Fig. 11). At senescence, the highest content of phenol was recorded with flower petals precooled, pulsed and packed with brown paper for 20 h followed by single layer corrugated fibre board sheet packed for 20 h. It was generally observed that as the packaging duration increased from 6 h to 20 h the phenol content in the petals also increased, except for butterpaper and polythene packaging material at senescence where 20 h recorded less phenol content than 6 hours.

Table 42. **Total phenol content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing**

Treatments	Total phenols (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Ice cold water spray for 45 min and not pulsed	24.26	4.90	12.0
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	24.22	5.00	12.6
Ice cold water spray for 45 min and pulsed with DMSO (2%)	12.62	3.92	13.0
Cool storage at 4^0C for 24 h and not pulsed	15.96	2.90	12.8
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	13.62	2.86	13.0
Cool storage at 4^0C for 24 h and pulsed with DMSO (2 %)	16.96	3.00	13.5
No precooling and no pulsing (Control)	16.70	4.52	11.0

* Total phenols at harvest 18.05 mg/g d.w.

'F' test	**	**	**
S.Em. ±	0.01	0.01	0.12
CD at 5 %	0.03	0.03	0.36



T1 = Ice cold water spray for 45 min and not pulsed
T2 = Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T3 = Ice cold water spray for 45 min and pulsed with DMSO(2%)
T4 = Cool storage at 4°C for 24 h and not pulsed
T5 = Cool storage at 4°C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)
T6 = Cool storage at 4°C for 24 h and pulsed with DMSO (2%)
T7 = No precooling and no pulsing (Control)

Fig. 10. Total phenol content in petals of 'Golden gate' cut roses as affected by precooling and pulsing

Table 43. **Total phenol content in petals of 'Golden Gate' cut roses as affected by ice-cold water spray for 45 min, pulsing (DMSO 2%) and different packaging materials**

Treatments	Total phenols (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	10.06	14.28	7.3
Butter paper 20 h	10.40	13.39	7.0
Brown paper 6 h	10.40	13.39	6.0
Brown paper 20 h	10.86	20.81	7.0
Polythene 6 h	29.44	14.68	6.8
Polythene 20 h	29.84	14.28	6.0
CFB 6 h	28.48	12.33	7.0
CFB 20 h	31.23	18.57	6.8
Control	28.37	16.70	5.8

* Total phenol content at harvest is 18.05 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0274	0.0041	0.0471
Duration (D)	0.0237	0.0035	0.0408
P x D	0.0474	0.0071	0.0816
CD at 5 %			
Packaging (P)	0.080	0.012	0.137
Duration (D)	0.069	0.010	0.119
P x D	0.138	0.021	0.238

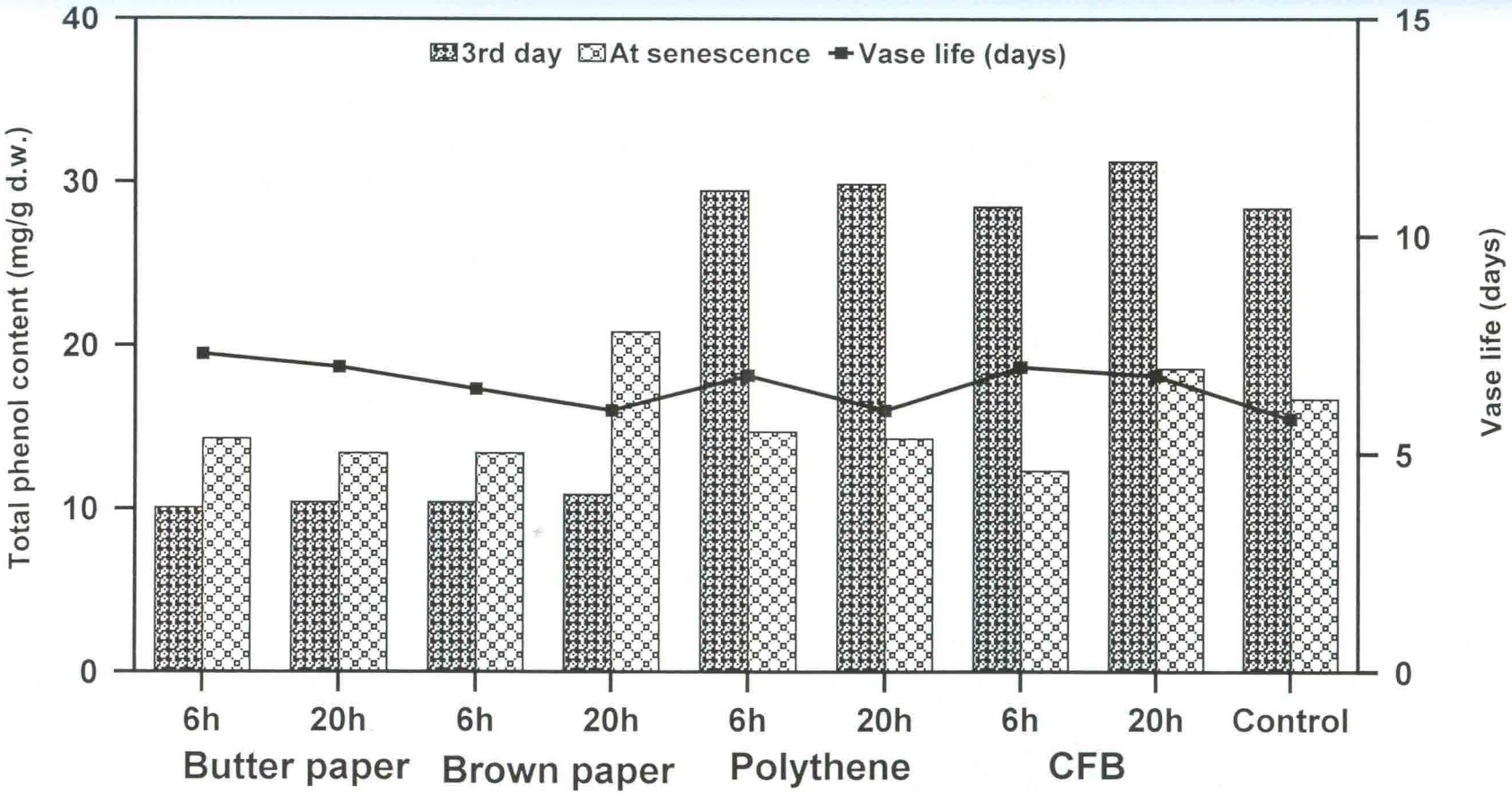


Fig. 11. Total phenol content in petals of Golden gate' cut roses as affected by ice-cold water spray for 45 min., pulsing (DMSO 2%) and different packaging materials

4.6.12 Total phenol content in petals of 'Golden Gate' cut roses as affected by precooling with cool storage at 4^0C for 24 h, pulsing (DMSO 2%) and different packaging materials

The total phenol content in petals of 'Golden Gate' cut roses was significantly influenced by precooling, pulsing and packaging materials (Table 44). The total phenol content in the petals of 'Golden Gate' cut roses increased at all stages of the flower development and senescence except in control on third day in vase. The highest phenol content on third day in vase was recorded with flower petals, precooled, pulsed and packed with butterpaper for 6 h followed by brownpaper packed for 6 h. At senescence, the highest phenol content was recorded with flower petals precooled, pulsed and packed with butterpaper for 6 h. Maximum vase life was associated with high phenol content on 3rd day and at senescence (Fig. 12).

4.7 Rate of respiration of cut rose during the course of senescence as affected by the chemical treatments and cool storage

4.7.1 Rate of respiration of cut rose cv. Golden Gate during the course of senescence as affected by the holding solutions and wet storage (4^0C) for 3 days

The rate of respiration of 'Golden Gate' cut roses was significantly affected by the different holding solutions in vase (Table 45). At harvest, the respiration rate of the cut rose ranged from 609-613 cc of CO_2/g d.w/ h, but there was no significant difference among the cut flowers. After wet storage at 4^0C for 3 days, there was a decrease in the respiration rate, though the decrease among the treatments was non significant. However, on 3rd day in vase in the holding solutions, there was significant increase in the respiration rate of the cut roses irrespective of the treatments.

Table 44. **Total phenol content in petals of 'Golden Gate' cut roses as affected by cool storage (4^0C) for 24 h, pulsing (DMSO 2%) and different packaging materials**

Treatments	Total phenols (mg/g d.w.)		Vase life (days)
	On 3rd day	At senescence	
Butter paper 6 h	28.96	24.15	7.8
Butter paper 20 h	26.79	20.00	6.3
Brown paper 6 h	27.31	21.28	6.9
Brown paper 20 h	26.79	22.94	6.0
Polythene 6 h	26.69	21.61	6.8
Polythene 20 h	23.56	21.79	6.5
CFB 6 h	22.79	21.61	6.5
CFB 20 h	21.17	18.64	6.0
Control	17.69	18.79	5.5

* Total phenol content at harvest is 18.05 mg/g d.w.

'F' test	**	**	**
S.Em. ±			
Packaging (P)	0.0041	0.0104	0.0527
Duration (D)	0.0035	0.0090	0.0456
P x D	0.0071	0.0180	0.0913
CD at 5 %			
Packaging (P)	0.120	0.030	0.154
Duration (D)	0.010	0.026	0.133
P x D	0.021	0.053	0.266

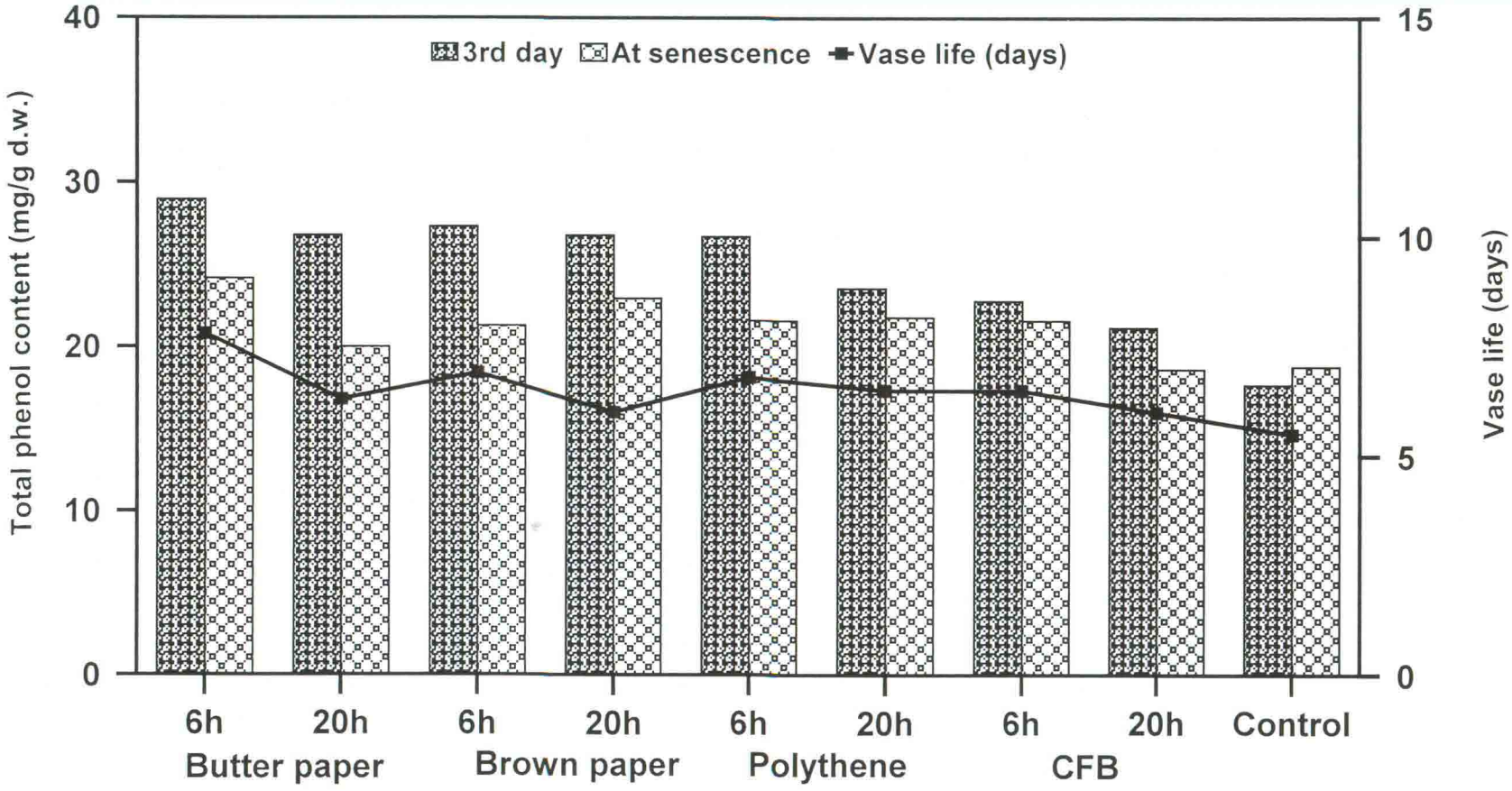


Fig. 12. Total phenol content in petals of 'Golden gate' cut roses as affected by cool storage (4^{O}C) for 24h, pulsing (DMSO 2%) and different packaging materials

Table 45. **Rate of respiration of cut rose cv. Golden Gate during the course of senescence as affected by the holding solutions and wet storage (4^0C) for 3 days**

Treatment (Holding solutions)	Rate of respiration in cc of CO_2/g d.w./hr				
	At harvest	After storage	3rd day in vase	Senes-cence	Vase life (days)
D-fructose 3% + Kinetin 2.5 ppm	613.19	580.24	650.00	515.09	15.8
D-fructose 3% + $AgNO_3$ 25 ppm	611.83	578.16	779.96	485.65	16.8
D-fructose 3% + Nickel chloride 300 ppm	610.37	567.30	815.80	375.44	18.5
Sucrose 3% + 8-HQC 200 ppm	613.00	570.25	810.78	320.40	20.5
Sucrose 2% + Captan 200 ppm	609.68	569.45	652.19	384.23	15.3
Sucrose 2% + Streptomycin sulphate 250 ppm	609.63	571.20	700.10	389.40	17.8
Control (Tap water)	611.45	575.42	979.56	656.24	13.3
'F' test	NS	NS	**	**	**
S.Em. ±	3.33	20.02	2.89	0.97	0.07
CD at 5%	-	-	8.77	2.94	0.20

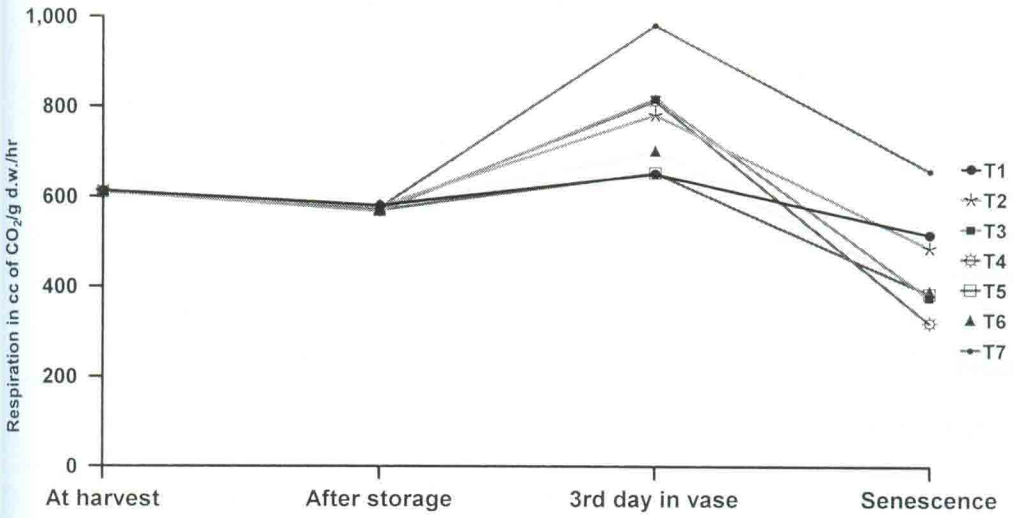
Maximum respiration rate was recorded with control (979.56 cc of CO_2/ g d.w/h) followed by D-fructose (3%) + nickel chloride (300 ppm) (815.80 cc of CO_2/g d.w/h). At senescence, the respiration rate declined from the third day in vase irrespective of the treatments (Fig. 13). The lowest respiration rate due to treatments was recorded with sucrose (3%) + 8-HQC (200 ppm) (320.40 cc of CO_2/g d.w/h) followed by D-fructose (3%) + nickel chloride (300 ppm) (375.44 cc of CO_2/g d.w/ h) which also gave maximum vase life.

4.7.2 Rate of respiration of cut rose cv. Noblesse during the course of senescence as affected by the holding solutions and dry storage (4^0C) for 6 days

The rate of respiration of cut rose cv. Noblesse was significantly affected by the different holding solutions in vase (Table 46). At harvest, the respiration rate of the cut roses ranged from 550-555 cc of CO_2/g d.w/ h, but there was no significant difference among the fresh cut flowers. After dry storage at 4^0C for 6 days, there was a decrease in the respiration rate irrespective of treatments from harvest. On 3rd day in vase in the holding solutions, the respiration rate increased with maximum recorded with control (915 cc of CO_2/g d.w./h); followed by D-fructose (3%) + nickel chloride (820.07 cc of CO_2/g d.w/h) (Fig. 14). At senescence, there was a decrease in the respiration rate from the third day in vase irrespective of treatments. The lowest respiration rate due to treatments was recorded with D-fructose (3%) + nickel chloride (300 ppm) (350.79 cc of CO_2/g d.w/ h). The maximum vase life was associated with low respiration rate at senescence.

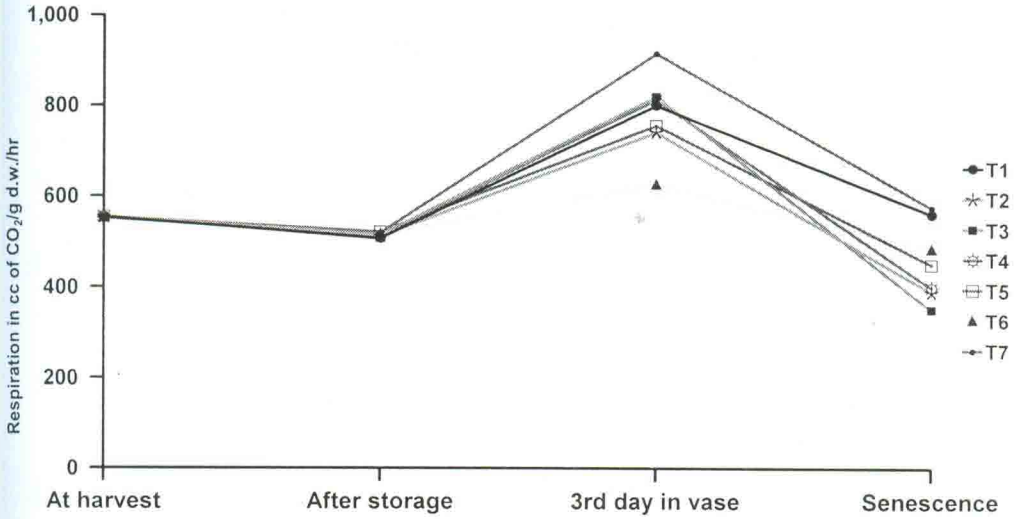
Table 46. Rate of respiration of cut rose cv. Noblesse during the course of senescence as affected by the holding solutions and dry storage (4^0C) for 6 days

Treatment (Holding solutions)	Rate of respiration in cc of CO_2/g d.w./hr				
	At harvest	After storage	3rd day in vase	Senes-cence	Vase life (days)
D-fructose 3% + Kinetin 2.5 ppm	553.85	506.69	800.03	560.35	13.0
D-fructose 3% + $AgNO_3$ 25 ppm	553.10	510.63	740.50	389.46	12.3
D-fructose 3% + Nickel chloride 300 ppm	555.64	514.25	820.07	350.79	13.5
Sucrose 3% + 8-HQC 200 ppm	552.20	512.42	812.77	399.10	12.8
Sucrose 2% + Captan 200 ppm	554.72	520.34	755.30	450.15	10.0
Sucrose 2% + Streptomycin sulphate 250 ppm	551.85	515.48	625.47	484.24	10.5
Control (Tap water)	550.35	518.90	915.00	575.27	10.5
'F' test	NS	NS	**	**	**
S.Em. ±	12.3	13.07	2.24	5.19	0.10
CD at 5%	-	-	6.79	15.74	0.29



T1 = D-fructose 3% + Kinetin 2.5 ppm
T2 = D-fructose 3% + $AgNO_3$ 25 ppm
T3 = D-fructose 3% + Nickel chloride 300 ppm
T4 = Sucrose 2% +8 HQC 200 ppm
T5 = Sucrose 2% + Captan 200 ppm
T6 = Sucrose 2% + Streptomycin sulphate 250 ppm
T7 = Control (Tap water)

Fig. 13. Rate of respiration of cut rose cv. 'Golden gate' during the course of senescence as affected by the holding solutions and wet storage (4^{O}C) for 6 days



T1 = D-fructose 3% + Kinetin 2.5 ppm
T2 = D-fructose 3% + $AgNO_3$ 25 ppm
T3 = D-fructose 3% + Nickel chloride 300 ppm
T4 = Sucrose 2% +8 HQC 200 ppm
T5 = Sucrose 2% + Captan 200 ppm
T6 = Sucrose 2% + Streptomycin sulphate 250 ppm
T7 = Control Tap water)

Fig. 14. Rate of respiration of cut rose cv. Noblesse during the course of senescence as affected by the holding solutions and dry storage (4^{O}C) for 6 days

4.8 Influence of precooling, pulsing and packaging duration on the growth of microorganism in the vase water of the cut roses

4.8.1 Influence of precooling and pulsing on the growth of microorganisms in the vase water of cut rose cv. Noblesse

It is evident from Table 47 that the cut rose cv. Noblesse was affected by a number of fungal genera in the vase water during different days in the vase. It can be observed that the maximum activity of the fungal and bacterial pathogens were on the 4th and 5th day of vase life of the cut rose. In the control treatment where no precooling and no pulsing was given, *Alternaria alternata* and *Dreschlera specifera* were identified in the vase water on 1st day. On 2nd day, *Cladosporium oxysporum* was added along with the microorganisms of 1st day. On 4th day, another new genera *Aspergillus flavus* was observed along with the other genera already present on 1st, 2nd and 3rd day. On 5th day, *Streptomyces albus* was added to all the above mentioned genera, and thus maximum number of fungal genera was found activated on 5th day resulting in the end of vase life of the cut rose on the same day.

In case of precooling with ice cold water spray for 45 min and no pulsing, one number of fungal genera *Acremonium* sp. along with bacteria was present in the vase water upto the 3rd day. On 4th day, *Alternaria alternata* was added and on 5th day, *Cladosporium cladosporoides* was added along with all the other genera present from 1st day.

Maximum activity of fungal genera was observed on the 5th day of vase life. Precooling with ice-cold water spray for 45 min + D-fructose (3%) + 8-HQC (150 ppm) for 24 h pulsing resulted in bacteria and *Cladosporium cladosporoides* presence on 1st and 2nd day. On 3rd day of vase life, two fungal genera i.e. *Alternaria alternata* and *Streptomyces griseus*

Table 47. Influence of precooling and pulsing on the growth of microorganisms in the vase water of cut rose cv. 'Noblesse'

Treatments	1st day	2nd day	3rd day	4th day	5th day
No precooling + No pulsing	*Alternaria alternata* *Dreschlera specifera*	*Cladosporium oxysporum* *Alternaria alternata* *Dreschlera specifera*	*Cladosporium oxysporum* *Alternaria alternata* *Drechslera specifera*	*Aspergillus flavus* *Alternaria alternata* *Cladosporium oxysporum* *Dreschlera specifera*	*Streptopmyces albus* *Cladosporium oxysporum* *Dreschlera specifera* *Alternaria alternata* *Aspergillus flavus*
Precooling - Ice cold water spray for 45 min + No pulsing	*Acremonium* sp. Bacteria	Bacteria *Acremonium* sp.	Bacteria *Acremonium* sp.	*Alternaria alternata* Bacteria *Acremonium* sp.	*Cladosporium cladosporoides* *Alternaria alternata* *Acremonium* sp., Bacteria
Ice cold water spray for 45 min + 8-HQC + D-fructose (3 %) (150 ppm)	*Cladosporium cladospoiroides* Bacteria	*Cladosporium cladospoiroides* Bacteria	*Alternaria alternata* *Streptomyces griseus* *Cladosporium cladosporoides* Bacteria	*Aspergillus flavus* *Alternaria alternata* *Cladosporium cladosporoides* Bacteria *Streptomyces griseus*	-
Ice cold water spray for 45 min + DMSO (2%)	Bacteria *Aureobasidium pullulescens*	*Alternaria alternata* *Aureobasidium pullulescens* Bacteria	*Alternaria alternata* Bacteria *Aureobasidium pullulescens*	*Alternaria alternata* Bacteria *Aureobasidium pullulescens*	*Alternaria alternata* Bacteria *Aureobasidium pullulescens*

Contd...

Table 47 contd.

Treatments	1st day	2nd day	3rd day	4th day	5th day
Cool storage at 4^0C + No pulsing	–	–	*Acremonium strictum* Bacteria	*Cladosporium oxysporum* *Alternaria alternata* *Acremonium strictum* Bacteria	
Cool storage at 4^0C + D-fructose (3%) + 8-HQC (150 ppm)	*Alternaria alternata* *Alternaria brassicicola* Bacteria	*Alternaria alternata* *Alternaria brassicicola* Bacteria	*Alternaria alternata* *Alternaria brassicicola* Bacteria	*Alternia brassicicola* Bacteria *Alternaria alternata*	
Cool storage at 4^0C + DMSO (2%)	–	–	*Alternaria alternata*	*Alternaria alternata* *Cladosporium oxysporum*	*Alternaria alternata* *Fusarium pallidoroseum* *Cladosporium oxysporum*

was identified in the vase water. On 4th day, *Aspergilus flavus* was identified along with the other fungal genera, thus resulting in the end of vase life on 4th day itself.

Ice cold water spray for 45 min and DMSO (2%) pulsing for 15 min. had bacteria and *Aureobasidium pullulescens* on the 1st day. From 2nd day to 5th day of vase life, two fungal genera were only present in the vase water i.e. *Alternaria alternata* and *Aureobasidium pullulescens.*

Precooling with cool storage at 4^0C and no pulsing as well as pulsing with DMSO (2%) for 15 min had no activity of microorganisms upto the 2nd day of vase life inferring that precooling with cool storage at 4^0C for 24 h and pulsing with DMSO (2%) for 15 min was beneficial in controlling the growth of microorganisms for 2 days and resulted in a vase life of 5 days.

4.8.2 Influence of precooling, pulsing and packaging material (butterpaper) for different duration on the growth of microorganisms in the vase water of cut rose cv. Noblesse

It reveals from the Table 48 that the precooled, pulsed and packed with butterpaper packaging material was affected by a number of microorganism growth in the vase water of cut rose cv. Noblesse. In case of precooled and packed cut roses, the number of different fungal genera were more than the precooling treatment alone. The precooled and packed in butterpaper packaging mateiral was effective in extending the vase life of cut rose upto the 7th day, but created a microclimate congenial for the microorganism growth at room temperature. In control, five different fungal genera i.e. *Cladosporium oxysporum, Aspergillus flavus, Alternaria alternata, Aspergillus niger, Dreschlera sp.* were present which

Table 48. Influence of precooling, pulsing and packaging material (Butter paper) for different duration on the growth of microorganisms in the vase water of cut rose cv. Noblesse

Treatments	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
Precooling with ice cold water spray for 45 min and no packaging	-	1, 2	1, 2, 3, 4	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5	1, 2, 3, 4, 5, 6
Precooling with ice cold water spray for 45 min and packaging for 6 h	1, 7	1, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 7, 8, 9	1, 2, 3, 4, 7, 8, 9	1, 2, 3, 4, 7, 8, 9	1, 2, 3, 4, 7, 8, 9
Precooling with ice cold water spray for 45 min and packaging for 20 h	1	1, 10	1, 2, 10, 11, 12	1, 2, 3, 10, 11, 12, 13	1, 2, 3, 10, 11, 12, 13	1, 2, 3, 9, 10, 11, 12, 13, 14	-
Precooling with cool storage (4^0C) for 24 h and no packaging	9	1, 9	1, 9, 15	1, 9, 15	1, 9, 6, 15	1, 2, 9, 6, 15	1, 2, 9, 6, 15, 20
Precooling with cool storage (4^0C) for 24 h and packaging for 6 h	1	1, 3	1, 2, 3, 9, 10	1, 2, 3, 9, 10, 4, 16	1, 2, 3, 4, 9, 10, 16	1, 2, 3, 4, 9, 10, 16	1, 2, 3, 4, 9, 10, 16, 17

Contd...

Table 48 contd...

Treatments	1st day	2nd day	3rd day	4th day	5th day	6th day	7th day
Precooling with cool storage (4^0C) for 24 h and packaging for 20 h	1	1, 2, 3, 8	1, 2, 3, 5, 8	1, 2, 3, 5, 8	1, 2, 3, 5, 8, 6	1, 2, 3, 5, 6, 8, 19	-
No precooling and no packaging	1, 10	1, 9, 10	1, 2, 9, 10	1, 2, 8, 9, 10, 18	1, 2, 8, 9, 10, 18	-	-

1 : Bacteria; 2 : *Alternaria alternata;* 3 : *Penicillium* sp.; 4 : *Taloromyces flavus;* 5. *Sartoria* sp.; 6 : *Cephalosporium restrictum;* 7 : *Torula* sp.; 8 : *Aspergillus niger;* 9 : *Aspergillus flavus;* 10 : *Cladosporium oxysporum;* 11 : *Fusarium pallidoroseum;* 12 : *Acremonium persicicum;* 13 : *Penicillium chrysogenum;* 14 : *Curvularia lunata;* 15 : *12; 16 : Fusarium oxysporum;* 17 : *Acremonium restrictum;* 18 : *Dreschlera* sp.; 19 : Yeast; and 20 : *Cladosporium cladosporoides.*

resulted in the end of vase life on 5th day. In case of precooled and packed flowers, maximum activity of microorganisms was observed from the 2nd and 3rd day itself. Precooling with ice cold water spray for 45 min and no packaging had no growth of microorganisms on 1st day, but on 2nd day, *Alternaria alternata* and bacteria were present in the vase water. Later at senescence on 7th day, *Alternaria alternata, Penicillium* sp. *Taloromyces flavus, Sartoria* sp. *Cephalosporium restrictum* were identified in the vase water.

Ice cold water spray for 45 min and packaging for 20 h had more number of microorganisms attacking at senescence which resulted in the end of vase life on 6th day itself. The fungal genera identified were *Cladosporium oxysporum, Altenaria alternata,* bacteria, *Fusarium pallidoroseum, Acremonium persicicum Penicillium* sp., *Penicillium chrysogenum, Aspergillus flavus* and *Curvularia lunata.*

Cool storage at 4^0C for 24 h and no packaging had upto the 4th day three fungal genera but towards senescence on 7th day, bacteria, *Alternaria alternata, Cephalosporium restrictum, Aspergillus flavus, Paecilomyces varcitii* and *Cladosporium cladosporoides* were identified in the vase water. Precooling with cool storage at 4^0C and packaging for 6 h gave a vase life of 7 days and maximum number of fungal genera were identified on that day resulting in the end of vase life. Precooling with cool storage at 4^0C and packing for 20 h had maximum microorganism activity on 5th and 6th day and the fungal genera responsible for early senescence were *Alternaria alternata, Penicillium* sp., *Sartoria* sp. *Cephalosporium restrictum, Aspergillus niger* and yeast.

4.8.3 Influence of precooling and pulsing on the growth of microorganisms at the basal stem portion of cv. Noblesse at senescence

It is evident from Table 49, that some fungal genera were present at the basal stem portion of cv. Noblesse at senescence. The control treatment had the maximum number of fungal genera such as *Penicillium* sp., *Alternaria alternata, Taloromyces flavus* and bacteria on the basal stem portion at senescence. Ice-cold water spray for 45 min and not pulsed had *Aspergillus flavus,* while ice cold water spray for 45 min and pulsing with DMSO (2%) for 15 min. had no growth of microorganisms on the basal stem portion at senescence. Cool storage at 4^0C for 24 h and not pulsed as well as pulsed with DMSO (2%) for 15 min. had *Alternaria alternata.* Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (250 ppm) had *Atlernaria brassicicola* and bacteria at the basal stem portion at senescence.

4.8.4 Influence of preccoling, pulsing and packaging material (butterpaper) on the growth of microorganisms at the basal stem portion of cv. Noblesse at senescence

The precooled cut flowers pulsed with DMSO (2%) for 15 min. and packed with butterpaper packaging material showed an increase in the number of fungal genera identified at the basal stem portion at senescence (Table 50). Treatment of precooling with ice-cold water spray for 45 min and packaging for 20 h had only *Penicillium* sp. while that packed for 6 h had *Penicillium* sp., *Penicillium crysogenum* and *Dreschlera tetramera* identified at the basal stem portion of the cut rose cv. Noblesse. Treatment of precooling with cool storage at 4^0C for 24 h and packaging for 20 h showed fungal genera such as *Atlernaria alternata, Acremonium* sp., bacteria

Table 49. Influence of precooling and pulsing on the growth of microorganisms at the basal stem portion of cv. 'Noblesse' at senescence

Treatments	Microorganisms identified at senescence
Ice cold water spray for 45 min and not pulsed	*Aspergillus flavus*
Ice cold water spray for 45 min and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	Bacteria
Ice cold water spray for 45 min and pulsed with DMSO (2%)	–
Cool storage at 4^0C for 24 h and not pulsed	*Alternaria alternata*
Cool storage at 4^0C for 24 h and pulsed with D-fructose (3%) + 8-HQC (150 ppm)	*Alternaria brassicicola,* Bacteria
Cool storage at 4^0C for 24 h and pulsed with DMSO (2%)	*Alternaria alternata*
No precooling and no pulsing (Control)	*Penicillium* sp., *Alternaria alternata, Taloromyces flavus,* Bacteria

Table 50. **Influence of precooling, pulsing and packaging material (Butter paper) for different duration on the growth of microorganisms at the basal stem portion of cv. Noblesse at senescence**

Treatments	Microorganisms identified at senescence
Precooling with ice-cold water spray for 45 min and no packaging	*Paecilomyces lilacinus, Penicillium* sp.
Precooling with ice-cold water for 45 min and packaging for 6 h	*Penicillium crysogenum, Drechslera tetramera, Penicillium* sp.
Precooling with ice-cold water spray for 45 min and packaging for 20 h	*Penicillium* sp.
Precooling with cool storage (4^0C) for 24 h and no packaging	*Aspergillus flavus, Penicillium* sp.
Precooling with cool storage (4^0C) for 24 h and packaging for 6 h	*Fusarium monoliforme, Penicillium* sp., Bacteria
Precooling with cool storage (4^0C) for 24 h and packaging for 20 h	*Alternaria alternata, Acremonium* sp., Bacteria, Yeast
No precooling and no packaging	*Aspergillus flavus*

and yeast populations. While flowers precooled with cool storage at 4^0C and packed for 6 h had *Fusarium monoliforme, Penicillium* sp. and bacteria. Control treament, which was neither precooled nor packed, showed the growth of *Aspergillus flavus* only.

4.9 Isolation and identification of fungal colonies from vase water of cut roses

The individual fungal colonies were isolated from petriplates containing PDA using sterilized inoculation needle and then grown in test tube for establishing pure culture. Then pure culture of all fungal colonies were subjected to identification.

The following fungal genera were identified in Indian type culture laboratory

1. *Alternaria alternata* (Fr) Keissler, Beth. Bot. Zhl. 29 : 434 (1912)

Condidiophores are found in single or small group, straight or flexuous geniculate, sometime, pale to mild olivaceous. Conidia are in long often branched chain, obclavate, obpyriform, often short conical or cylindrical beak, pale to mid golden brown, smooth or verruculose.

2. *Alternaria brassicicola* (Schw) Wiltshire, 1947, Mycol. pap., 20 : 8

Conidiophores are arising single or in group, occasionally geniculate, slightly swollen base. Conidia are mostly in chain upto 20 or more, branched, arising through small pore of conidiophores wall straight, nearly cylindrical. Beak usually almost non existant. The apical cell being more or less rectangular or resembling truncate cone.

3. *Aspergillus flavus* **(Aspergillus Link (1809) (Dictionary of Fungi, 1995)**

Soil borne. Colonies fast growing, mycelium mostly submerged, heavily sporulating, conidial heads yellow to green becoming brownish in age, radiate, splitting into several loose columns, reverse uncoloured to pink. Sclerotia white at first becoming red brown or black.

4. *Aspergillus niger*

Mycelium white to yellow heavily sporulating in black or deep brownish black, reverse colourless or yellow, conidial heads large, globose to radiate in well defined columns, atypical heads also develop, peripheral conidia may not be fully pigmented. Conidiophores wall is smooth, thick, colourless to brownish.

5. *Acremonium restrictum*

Mycelium are prostrated, slendered, producing simple upright conidiophores, conidia are hyaline, 1-celled, borne singly, apically and saprophytic.

6. *Aureobasidium pullulescens* **Viala and Boyer**

Hyphae thin walled when young, older hyphae thick walled with thick septa, conidia hyaline, ovate, capable of giving rise to secondary conidia by budding in yeast like manner. All hyphae at first hyaline, gradually and finally becoming very dark coloured.

7. *Cephalosporium restrictum* **Corda**

Vegetative hyphae creeping, septate, branched, hyaline. Conidiophores simple, arising laterally on creeping hyphae, erect, non-septate, hyaline. Conidia produced singly and successively at the tips of

the phialides (conidiophores) usually aggregated in false heads, 1-celled, usually ovate, hyaline often bright in mass.

8. ***Curvularia lunata*** **(Wakker) Boedijn Bull. Fard. bot. Buitenz 1933**

Mycelium septate, profusely branched, in the substratum subhyaline to light brown, at the surface brown. Conidiophores dark brown, unbranched septate toward the tip, sometimes twisted. Conidia boat shaped brown, 3-septate, third cell from the base conspicuously larger, broader and darker than the others, curved or sometimes straight, each with a subhyaline, rounded apical cell and a subhyaline obconical basal cell which bears a scar indicating point of attachment to the conidiophore.

9. ***Cladosporium cladospoiroides*** **(Fres) de Vries 1952**

Aerial mycelium absent on more or less profuse, sterile or covered by conidial structures. Colony powdery and woolly. Mycelium composed of narrow, hyaline hyphae. Conidiophores arising lateraly or less often terminally from the hyphae, growing in every direction, usually unbranched, irregularly septate, often with one or two short, lateral, outgrowths just beneath a septum, bearing chains of conidia.

10. ***Dreschelra spicifer*** **Nelson-Mycologia 56 : 198 (1964)**

Drechslera have hyphal conidiomata having 2 to many celled multiseptae, pigmented or dark conidia. Conidiophores are solitary or in small group, straight or flexuous, repeatedly geniculate with scars, mid to dark brown upto 250 μm long. Conidia is straight, oblong or cylindrical, rounded at the ends, golden, brown, except for small area just above the small scar, which remains hyaline or very pale, smooth.

11. *Fusarium oxysporum* Schlect-Flora berol. 2 : 139, 184 emend. Synder and Hansen-Am. J. Bot 27 : 64-67, 1940.

Growth rate is fast. Conidiophores consist of simple phialides, arising laterally on the hyphae or short branched conidiophores, often grouped forming tubercularia like sporodochia.

12. *Fusarium pallidoroseum* (Cke) Sacc.-Syll. Fung. 4 : 720, 1886.

Conidiophores arising single from aerial mycelium, later loosely irregular, rarely verticillately branched. Colony colour is floccose, white changing to peach, avellaneous to buff brown. Two types of conidia, primary and other secondary are found.

13. *Fusarium monoliforme* Shelden, Rep. Neb. Agric. Exp. Stn. 17 : 23-32, 1904

Colony fast growing, colour of colony is pale, lilac, vinaceous (blueish tinge), cream or violet. Conidiophores are bearing microconidia consisting of simple with a single opening phialides whereas macroconidia form lateral branches, consisting and bearing conidiophores, a basal cell bearing 2-3 phialides or metulae which later forms doliiform to obclavate simple phialides, but always have single opening (not proliferating).

14. *Penicillium* sp. Link (1809)

These had uncoloured seperate branched mycelium, septate, aerial conidiophore perpendicular to and walled off from the submerged hyphae from which they arise, brush like spore bearing heads, with sterigmata borne in clusters and essentially in one plane, a chain of conidia arising from each sterigma, colour of conidia are green.

15. ***Paecilomyces lilacinus*** **(Thom) Samson studies in Mycol. 6 : 59-62**

Colonies at first white changes to vinaceous, reverse uncoloured, usually vinaceous shades. Conidiophores are arising from lateral hyphae occasionally forming loose synnemata upto 2 mm high, stalk rather thick walled, pigmented in yellow or purple shades, consisting of verticillate branches in whorls of 2-4. Conidia are in divergent chains which sometimes become tangled, ellipsoidal to fusiform, smooth wall or rough, hyaline, purple swollen basal part tapering into a thin distinct neck of 1 μm wide.

16. ***Paecilomyces varcitti*** **Bainier (1907)**

This genus is closely related to *Penicillium* but differing in the absence of green coloured colonies and by short cylindrical phialides which taper into long necks.

17. ***Torula*** **sp. (Pers.) Link ex Fries**

Hyphae subhyaline to pale brown, septate, branched. Conidiophores short, mostly 1 celled and swollen, terminal or lateral on hyphae. Conidia phaeophragmospores formed in a simple or branched acropetal chains on the swollen tip of the conidiphore, the apical cell of each conidium usually characteristically darkened and thickened like the terminal cell of the conidiophore from which the conidial chains arise. Conidia sometimes fragmented into 1 celled units.

18. ***Taloromyces flavus*** **Stolk and Samson, stud. Mycol. Baarn 2 : 10, 1972**

Conidiophores borne from aerial hyphae, smooth walled, bearing delicate terminal penicilli, predominantly biverticillate but also monoverticillate; phialides 4-6 per metula, acerose, commonly with long

gradually tapering collula, conidia ellipsoidal to fusiform, less commonly broadly ellipsoidal, with walls smooth to spinulose, borne in short disordered chains.

4.10 Isolation and counting, gram reaction and shape observations of bacteria from vase water of cut roses

Isolation

Subculturing was done to transfer the inoculum from the colony under aseptic conditions in Laminar flow chambers to fresh medium to get a pure culture. The single colonies were touched with an inoculating needle and transferred to nutrient agar slants in a tube. These individual colonies were then subjected to gram reaction for observing response of bacteria to gram reaction i.e. (+ or -) and shape of bacteria.

Counting

The counting of bacterial colonies was done by using serial dilution techniques taking samples from the vase water of cut rose cv. Noblesse which was precooled with ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min and another treament precooled with ice cold water spray for 45 min without pulsing during different days in vase.

The changes in microbial growth during vase life period of cut rose cv. Noblesse after the precooling and pulsing treatment is presented in Table 51. The longevity of cut rose cv. Noblesse was significantly affected by the number of bacteria present in the vase water. On day 0, the precooled and not pulsed flower vase solutions differed significantly with a maximum microbial growth observed (3×10^2) whereas precooled and pulsed flower vase solutions were having minimum number of bacterial

Table 51. Bacterial counts in the vase water of cut rose cv. 'Noblesse' on different days in vase

Days	No. of bacterial colonies per ml of water	
	Ice cold water spray for 45 min and no pulsing	Ice cold water spray for 45 min + 2% DMSO for 15 min
0	3×10^2	1×10^1
1	10×10^3	4×10^3
2	10×10^4	6×10^4
3	4×10^4	15×10^3
4	45×10^3	5×10^3
5	16×10^3	4×10^3
6	11×10^4	5×10^4
7	16×10^4	11×10^3
'F' test	* *	* *
S.Em. ±	3824.55	2332.21
CD at 5 %	11464.78	6991.22

colonies per ml of vase water (1×10^1). Number of bacterial colonies per ml of vase water significantly varied from first day to senescence day of the total vase life of cut flowers (Plate 21 and 22). However, there was no significant difference on the number of bacterial colonies in the vase water of 3rd and 4th day of precooled and not pulsed treatment, and between 4th day and 5th day of the ice cold water spray for 45 min and pulsed with DMSO (2%) for 15 min. There was a significant increase of bacterial colonies in ice cold water spray for 45 min without pulsing towards the senescence i.e. 7th day. Maximum number of colonies per ml of vase water was recorded on the 7th day i.e on senescence day (16×10^4) with ice-cold water spray for 45 min and no pulsing whereas minimum (11×10^3) was recorded with ice cold water spray for 45 min with DMSO (2%) pulsing for 15 minutes.

Gram staining

The smear of individual bacterial colonies was prepared on slides and gram staining was followed. The bacterial colonies took both primary stain (crystal violet) and safranin (red) colour. So it can be concluded that the bacteria colonies cultured from vase water of cut roses cv. Noblesse were both gram positive and gram negative.

Observation of shape of bacterial colonies

The smear of individual bacteiral colonies was prepared on glass slides and observed under microscope. The Table 52 reveals that different shapes and structure of bacteria ranging from small rod shaped, cocci, spherical, thick curved like a comma were present in the vase water of cut rose cv. Noblesse during different days of vase life. There was increase in various shapes and number of bacteria from 4th day upto senescence i.e. 7th day.

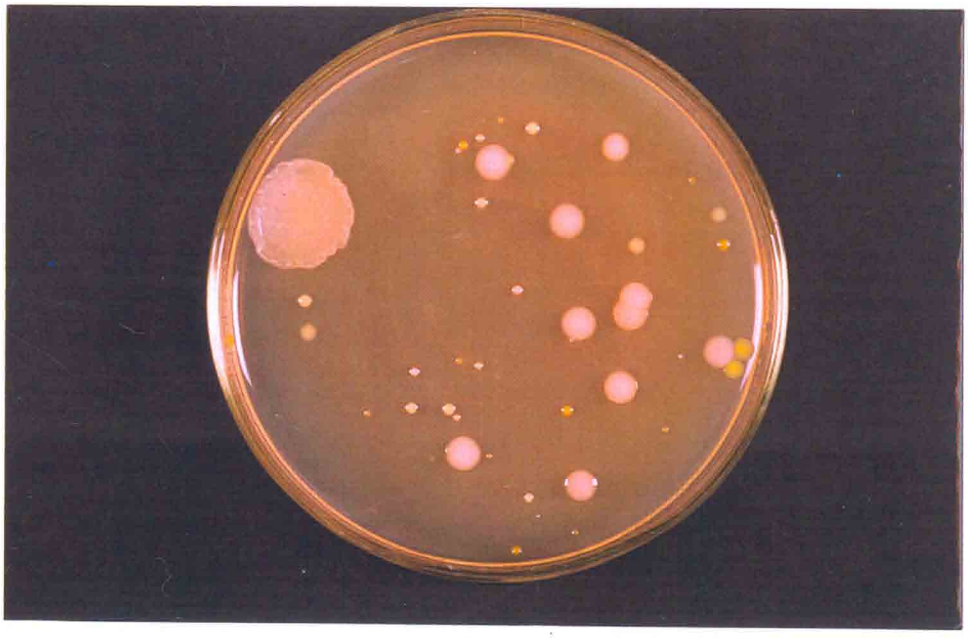


Plate 21. Bacterial colonies (cfu/ml) in the vase water of precooled and pulsed cut roses of cv. 'Noblesse' on the 2nd day of vase life

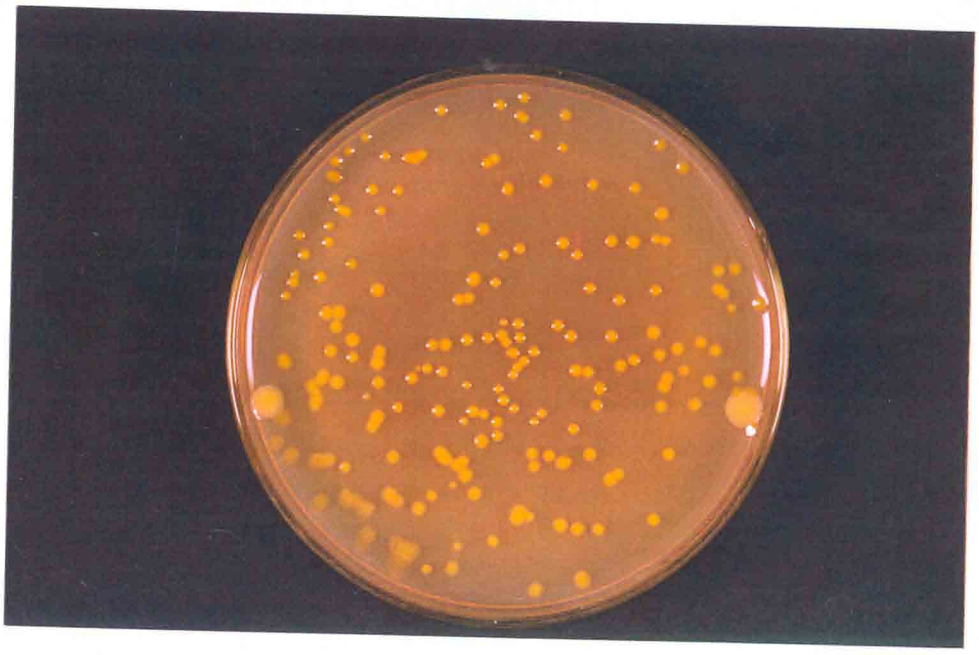


Plate 22. Bacterial colonies (cfu/ml) in the vase water of precooled and pulsed cut roses of cv. 'Noblesse' on 4th day of vase life

Table 52. **Bacterial isolates (Gram positive or negative) isolated from vase water on different days in vase**

Days	Structure	Gram reaction
0	(i) Small, rod shaped	-
1	(i) Small, rod shaped	-
	(ii) Small, thick, curved like comma	+
	(iii) Small, round cocci/spherical	+
2	(i) Small, thick, curved like comma	+
	(ii) Rod shaped in a chain	-
	(iii) Small, round cocci/spherical	+
3	(i) Small rod shaped	-
	(ii) Small thick, curved like comma	+
	(iii) Small, round cocci/spherical	+
4	(i) Small rod shaped	-
	(ii) Small, thick, curved like comma	-
	(iii) Small, round cocci/spherical	+
5	(i) Small, rod shaped	-
	(ii) Small, round cocci/spherical	+
	(iii) Small, thick curved like comma	+
6	(i) Small, rod shaped	-
	(ii) Small, round cocci/spherical	+
	(iii) Small, thick curved like comma	+
	(iv) Rod shaped in a chain	-
7	(i) Small, rod shaped	-
	(ii) Small, round cocci/spherical	+
	(iii) Small, thick curved like comma	+
	(iv) Rod shaped in a chain	-

5. DISCUSSION

In the present investigations, an attempt was made to find out the effects of precooling treatment and pulsing chemicals on the post harvest life and quality of different cultivars of cut roses. Efficiency of the precooling treatments and pulsing chemicals on different packaging materials (half covered and full covered) and storage for different duration under packing in relation to, ultimately, keeping quality of cut flowers in vase was also investigated. Biochemical changes in the content of total starch, total soluble sugars, total free amino acids and total phenols occurring in the cut rose flowers during flower development and senescence as affected by the above treatments were also studied. Experiments were also carried out to find out the influence of pulsing chemicals and holding solution on post harvest life and quality of both wet stored and dry stored cut roses. Rate of respiration during the course of flower development and senescence as affected by chemical treatments and cool storage was also studied. Finally, the influence of precooling, pulsing and packaging duration on the growth of microorganisms in the vase water of cut roses were also investigated. The results of the different experiments carried out in the present investigations are discussed in this chapter.

5.1 Studies on the effect of precooling and pulsing on the postharvest life and quality of cut rose flowers

Four cultivars of freshly harvested cut roses viz. "Golden Gate", "Noblesse", "First Red" and "Mercedes" were precooled with ice-cold water-spray for 45 min, cool storage at 4^{0}C for 24 h and pulsed with

D-fructose (3%) + 8-HQC (150 ppm) for 24 h and DMSO (2%) for 15 min. There was significant increase in the changes in fresh and dry weight on 3rd day in vase, flower diameter, water uptake and vase life of precooled and pulsed cut roses over the non precooled and non pulsed cut roses. The best precooling and pulsing chemical was ice-cold water spray for 45 min, pulsed with DMSO (2%) for 15 min for three rose cultivars viz. 'First Red', 'Noblesse' and 'Mercedes', while for 'Golden Gate' variety, cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min gave best results. Similar findings were reported with these precooling methods in 'Raktagandha' cut roses by Palanikumar *et al.* (2000a). Increase in fresh and dry weight was maximum on third day over the harvest weight irrespective of the treatments; the fresh and dry weights, however, reduced on the senescence day. The increase in fresh and dry weights is due to maintenance of high water potential because of the precooling and pulsing treatments, uninterrupted water uptake, increased turgidity, and continuous development of the cut flowers. Similar results were obtained by Coorts (1973) in roses. Decline in fresh weight at the end of vase life and water loss due to transpiration mostly through stomata was also observed by Mayak *et al.* (1974).

Pulsing with the chemical DMSO (2%) for 15 min gave best results on all the four cultivars and resulted in longest vase life, maximum water uptake, maximum gain in fresh and dry weight on 3rd day in vase and largest flower diameter in the present investigation. This result is similar to the findings of Sankar Vidhya (2001). Beneficial effects of DMSO as a pulsing chemical was also reported by Wilkins (1983). He found that open carnation (*Dianthus caryophyllus*) flowers survived storage at -3^0C

for 15 days, after pulsing with DMSO (6%) and still showed a vase life of 7.5 days. He attributed this to the cryoprotectant nature of DMSO. Plant cells contain considerable amounts of non-protein thiols which are involved in many molecular, metabolic and physiological functions via thiol/disulphide exchange reactions (Kunert and Foyer, 1993). Thiols are important antioxidants involved in DNA and protein synthesis as well as the activation and inactivation of enzymes. In the present investigation D-fructose (3%) + 8-HQC (150 ppm) also gave beneficial effects with regard to flower diameter, vase life and quality in all the four cultivars of cut roses. Fructose is a metabolizable sugar which can improve the vase life (Halevy and Mayak, 1981). D-fructose is one of the monosaccharide units which along with D-glucose combine together to form a sucrose molecule. Beneficial effects were observed with D-fructose (3%) as pulsing treatment on cut roses cv. 'Happiness' (Bhattacharjee, 1999b). Ichimura *et al.* (1999) also reported that treatment combination with sucrose and 8-HQS significantly improved the vase life of cut 'Sonia' roses. Sugars provided the respirable substrate whereas 8-HQS worked as an antibacterial component. HQC or HQS may affect flower longevity by reducing solution pH and thereby inhibiting stem plugging.

All the precooling and pulsing treatments resulted in an increased water uptake, flower diameter and vase life over the control flowers. Continuous water supply to the xylem vessels in ambient temperature contributed by precooling treatment and pulsing chemical resulted in an increased water uptake and turgidity of the petals. Increased vase life in chrysanthemum cut flowers by precooling and shipping at low temperature was also reported by Cheon (1995). Gao *et al.* (1994) found

that the vase life of precooled flowers was greatly improved from 4 to 9 days. Varietal differences could be a reason for the differences in vase life of the four cultivars of cut roses due to precooling and pulsing treatments. Different cultivars vary in their stem diameter and rigidity which ultimately affect the post harvest life (Nowak and Rudnicki, 1990). Variation in vase life among the different cultivars has also been attributed to differences in number of thick walled supporting cells in the xylem element and phloem fibres and presence or absence of a complete ring of secondary thickening in the flower peduncles (Zamski, 1991).

5.2 Studies on the effect of precooling and pulsing on packaging material (half covered and full covered) and storage for different durations

The best precooling treatments and pulsing chemical, one through ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min, and another through cool storage at 4^0C for 24 h and pulsing with DMSO (2%) for 15 min, were chosen from experiment 5.1. The main aim of these studies was to find out, the lasting effects of precooling and pulsing treatment on the flowers when packed with different packaging material (half covered and full covered) for 6 h, 20 h and 24 h duration. Precooling with ice-cold water spray for 45 min, pulsed with DMSO (2%) for 15 min and packed (half covered) with single layer of corrugated fibre board sheet for 6 h was found to be most suitable with regard to maximum vase life and improving the post harvest quality of 'Golden Gate' cut roses. Precooling with cool storage at 4^0C for 24 h, pulsed with DMSO (2%) for 15 min and packed (full covered) with butter paper for 6 h gave maximum vase life and quality of cut roses. Similar results were reported by Krahn (1978), where precooling before packing was beneficial in

extending the acceptability of the chrysanthemum flowers by 2-6 days. All the cut flowers after the packaging and storage duration exhibited increased fresh and dry weights on the 3rd day, irrespective of the treatments.

Wrapping with butter paper for 6 h, polythene bags (80 guage) for 6 h or brownpaper for 6 h were also found to be beneficial in significantly extending the vase life and quality of precooled, pulsed and packed cut flowers. In tuberose cv. 'Single', packaging in 300 guage with no ventilation was found to be the best leading to reduced physiological loss of weight (PLW) and a vase life of 4.6 days compared to with 1.3 days in control (Madaiah and Reddy, 1994). Packaging of pulsed and precooled gladiolus spikes in polyethylene liners resulted subsequently in good vase life and quality (Meir *et al.*, 1995). Half covered (i.e. covering only the floral portion of the cut flower) roses performed better than full covered (i.e. covering the entire cut stem with packaging material). Due to high humidity and high ambient temperature, the full covered packaging material could have resulted in the attack of *Botrytis* infection or other pathogens, which resulted in less vase life than half covered. A significant increase in *Botrytis cinerea* spotting was observed on packed rose flowers cv. 'Sonia' which experienced both cooling and slow rewarming in the box (Swam *et al.*, 1996).

The precooled, pulsed and packed flowers for 6 hours duration resulted in maximum vase life, increased water uptake, flower diameter and increase in fresh weight on 3rd day in vase in ambient temperature. The different packaging material provided a modified atmosphere by increasing CO_2 and decreasing O_2 through the normal respiration process

carried out by the flowers in the package. However, the beneficial effects of precooling and pulsing and modified atmosphere condition remains only upto a specific period of time. Flowers packed for 24 h duration showed water stress symptoms and resulted in bent neck in a few cases in the vase, resulting in a short vase life. This may have been caused due to vascular blockage or entry of air bubble in the water conducting tissues. Apart from this since, the flowers were held dry inside the package for a long duration i.e. 24 hours. The continuous transpiration of the flower might have led to water deficit and reduced turgidity of the cut flower. It was also reported by Zieslin (1978), that the water deficit in the neck region of cut roses is the reason for the bent neck and was due to continuous transpiration by the leaves which were present on the shoots. The effect of precooling either by cool storage at 4^{0}C for 24 h or ice-cold water spray for 45 min was maintained only for 8 h under polyethylene packaging (Palanikumar *et al.*, 2000c). Corrugated fibre board sheet and polyethylene bags (150 guage) were found to be beneficial as wrapping material for packing pulsed and precooled flowers in telescopic type corrugated fibre board (CFB) boxes, the packaging duration being 20 and 22 h respectively, resulting in enhanced longevity and flower quality as compared to the fresh cut flowers (Sankar Vidhya, 2001).

5.3 Influence of pulsing and holding solution on postharvest life and quality of wet stored cut roses

The cut rose cv. Golden Gate after pulsing with STS 0.5 mM and BA (25 ppm) for 45 min could be wet stored for 3 days at 4^{0}C without affecting its subsequent vase life and quality. However, by pulsing with

$CaCl_2$ (1%) for 20 h, the flowers survived wet storage upto 4 days at 4^0C without affecting the vase life and quality. Similar results were obtained by Rajan (1993) in 'Super Star' roses which could be wet stored for 4 days at 4^0C without having any adverse effect on vase life and quality at ambient temperature. Flowers stored for 3 days at 4^0C gave maximum vase life compared with other treatments and freshly cut unstored flowers (Palanikumar and Bhattacharjee, 2001). The wet stored cut roses of 'Golden Gate' resulted in gain in fresh and dry weights over control after storage and on the 3rd day in vase in all the treatments. Since the flowers were handled in water (wet storage), there was continuous water uptake by the cut rose stem which ultimately increased the turgidity of the flowers so that they were in continuous developmental stage. Increase in fresh weight of cut flowers following wet storage was also observed by several researchers (De Boer and Witmondt, 1975; Rajan, 1993). Increased water potential and higher water content in the petals of wet stored roses was reported by Faragher *et al.* (1984) and Palanikumar *et al.* (1999). Maximum vase life, maximum water uptake and flower diameter were obtained by pulsing chemical with STS 0.5 mM for 45 min. Pulsing prior to storage has been useful in extending the vase life. Pulsing with STS 0.5 mM for 45 min and not stored gave a vase life of 2 days more than the control treatment. Mor *et al.* (1989b) reported that silver thiosulphate as a 0.5 h pulse at 0.5 mM extended the life of fresh and cold stored roses by 2 and 3 days, respectively. The anionic STS complex is mobile in the rose stem and its action is supposed to prevent the ill effects of exogenous ethylene (Reid *et al.* 1989). Beneficial effects of STS as a pulsing chemical was also reported by several other workers (Goszcynska and Reid, 1985; Ketsa *et al.*, 1993; Seddiqi *et al.*, 1995;

Bhattacharjee and De, 1998). The next best pulsing treatment in the present study was BA (Benzyladenine) 25 ppm for 45 min. Pulsing with BA (25 ppm) for 45 min before wet storage and wet storing for 3 days gave a maximum vase life of 12.4 days as against 10.0 days for the non pulsed and non stored cut flowers. Heide and Oydwin (1969) also reported that immersions of carnations in a BA solution was especially effective on stored flowers. The effect of BA on stored flowers could be due to increasing their resistance to water stress damage as shown in rose (Mayak and Halevy, 1974). BA at 5 ppm showed beneficial effects on vase life, flower diameter, water uptake and fresh weight of cv. 'Eiffel Tower' cut roses (Bhattacharjee, 2000).

In these investigations, calcium chloride $CaCl_2$ (1%) for 20 h pulsing before wet storage was also found to be beneficial with regard to post harvest life and quality of cut rose cv. 'Golden Gate'. Significant improvement in the vase life of cut roses with calcium chloride was also reported by several workers (Hong and Zhao, 1998; Torre *et al.*, 1999; Bhattacharjee *et al.*, 2001). Use of calcium increased the flower fresh weight and water uptake (Nagarajaiah and Reddy, 1991). Calcium chloride helped in maintaining the membrane stability in petals during the vase life period (Hong and Zhao, 1998).

In the present investigation, among the different holding solutions used, sucrose (3%) + 8-HQC (200 ppm) enhanced the vase life (20.5 days) and flower quality of pulsed and wet stored (3 days) cut roses. Use of sucrose (1-6%) in combination with other ingredients like germicide, salts and growth regulators had been reported by Venkatarayappa *et al.* (1981); Nagarajaiah and Reddy (1991); Ahn and Um (1991); Bhattacharjee

(1993). Lengthening the vase life of cut rose by the use of sucrose is because of probable role of sucrose as an energy source (Ferreira and Swardt, 1980b). When the natural carbohydrates are depleted, sucrose is used as a substrate for respiration (Paulin, 1977). Sugar gets accumulated in the flower tissues, increases their osmotic concentration and improves their ability to absorb water and maintain turgidity (Acock and Nichols, 1979). Beneficial effects of sucrose (3%) + 8-HQC (200 ppm) in holding solution was also reported by Bhat *et al.* (1999b). The highest flower diameter displayed at cessation, greatest percentage of bud opening and exemplary display of vase life in *Dendrobium* orchid was recorded by 8-HQS (100 ppm) + sucrose (2%) (Jawaharlal *et al.*, 2002).

The next best holding solution which gave maximum vase life, and enhanced the holding solution uptake and flower diameter of 'Golden Gate' variety were D-fructose (3%) + nickel chloride (300 ppm), sucrose (2%) + streptomycin sulphate (250 ppm) and D-fructose (3%) + silver nitrate (25 ppm). D-fructose is one of the monosaccharide units which along with D-glucose combines to form a sucrose molecule. Since D-fructose is also a part of sucrose, all the characters of sucrose in lengthening the vase life of cut roses must hold true. Nickel chloride may act as a germicide and as an ethylene inhibitor (Lau and Yang, 1976; Rogers, 1973; Nowak and Rudnicki, 1990).

Nickel promotes stem water conductance (Aharoni and Mayak, 1977) as observed in *Phalaenopsis*, orchids resulting in greater solution uptake and thereby maintaining freshness of cut flowers for a longer period. It is also known to reduce the stem or vascular blockage, allowing higher water uptake by cut flowers and preventing water stress as

reported in tuberose (Reddy *et al.* 1994), thereby extending the vase life in cut roses. Lengthening the vase life in other cut flowers like chrysanthemum and gladiolus by the use of $NiCl_2$ in combination with sucrose in the holding solution was reported by Pardha Saradhi (1985) and Murali and Reddy (1993). Benefits of streptomycin sulphate in lengthening the vase life of cut flower was reported by Zagory and Reid (1986a). Extending vase life of cut 'Golden Gate' roses by the use of streptomycin sulphate was related to gain in fresh and dry weight on 3rd day in vase and at senescence and maximum holding solution uptake. Prolonging the vase life of rose flowers by the use of bactericides was related to their resulting in a reduction of microbial population, improving of water balance (Burdett, 1970; Van Doorn and Perik, 1990). Increasing the vase life of rose, chrysanthemum, gladiolus, carnation, snapdragon, lupin and narcissus by the combination of 8-HQC + streptomycin + sucrose have been reported by Mohan Ram and Ramanuja Rao (1977) and Rao and Mohan Ram (1982).

The role of silver nitrate ($AgNO_3$) in holding solution may act as an antimicrobial agent and not as an inhibitor of ethylene synthesis (Ketsa *et al.*, 1995). $AgNO_3$ in the holding solution could improve the vase life of cut 'Priyadarshini' rose (Bhattacharjee, 1993) and in combination with sucrose improved the vase life of rose cultivars "Eiffel Tower", "Swartmore" and "Yankee" but not "King's Ramsom" and "Confidence" (Ketsa *et al.*, 1993). Significant increase in vase life and post harvest quality was also obtained by D-fructose (3%) + kinetin (2.5 ppm) and sucrose (2%) + captan (200 ppm) in this investigation. Beneficial effects of kinetin at 2.5 ppm on vase life of cut rose cv. "Eiffel Tower", flower diameter, water uptake and fresh weight was reported by Bhattacharjee

(2000). The best combination of chemicals for prolonging post harvest life and quality of Raktagandha roses was D-fructose (3%), L-ascorbic acid (500 ppm) and kinetin (2.5 ppm) (Bhattacharjee, 1999d). Delaying petal senescence was also observed by the use of kinetin and GA_3 each at 10 mg/l in *Rosa damascena* (Rao, 1982). Captan may act as a fungicide in the holding solution and reduce the plugging of xylem vessels due to fungi as reported by De stigter and Broekhuysen, 1986; Van Doorn *et al.*, 1991).

5.4 Influence of pulsing and holding solution on the postharvest life and quality of dry stored cut roses

In the present study, cut rose cv. 'Noblesse' after pulsing with BA (25 ppm) for 45 min and STS (0.5 mM) for 45 min could be dry stored for 6 days at 4°C without affecting the ultimate vase life and quality at ambient temperature. Van Beek (1984) also reported that dry storage at 4°C in closed refrigerated containers was beneficial for cut roses cv. 'Sonia' in terms of subsequent vase life. The pulsed cut roses were packed in polyethylene bags (80 guage) and kept in the cool storage at 4°C. After storage period the fresh and dry weight decreased from the initial weight at harvest in all the treatments except for 6 days dry stored and pulsed with STS 0.5 mM for 45 min showed slight gain in weight after storage. Similar results were also obtained in gerbera where the water absorption increased and fresh weight decreased with increasing period of dry storage (Sang *et al.*, 1998) and in carnation, the stems also showed continuous decrease in per cent fresh weight in dry storage which was apparently due to loss of water from the cut flower as manifested by the deposition of water droplets on the inner surface of the

polyethylene sleeves (Singh *et al.,* 2002). Increase in vase life, water uptake and flower diameter of pulsed and dry stored 'Noblesse' cut roses with BA (25 ppm) for 45 min could be associated with improved water uptake and increase in fresh and dry weight on 3rd day. Mayak and Halevy (1974) also found the beneficial effect of BA on stored flowers and attributed it to the increase in their resistance to water stress damage as shown in rose. Quality of potted rose cv. 'MeijiKatar' 5 days after removal from storage was better with BA treatment at 50 or 100 mg/ l than 0 mg/l (Clark *et al.,* 1991). Silver thiosulphate (STS) 0.5 mM pulsing for 45 min before dry storage also enhanced the vase life and quality of 'Noblesse' cut roses. The beneficial effects of pulsing with BA (25 ppm) for 45 min and STS (0.5 mM) for 45 min has been already described in experiment 5.3. Similar results were obtained by Mor *et al.* (1989b) where STS as a 0.5 h pulse at 0.5 mM extended the life of fresh and cold stored roses by 2 and 3 days respectively. Pulsing the mini-gladiolus spikes cv. Adi with sucrose (10%) and silver thiosulphate (STS 0.4 mM) before dry storage at 2^0C for 14 days and prior to modified atmosphere packaging improved flower quality and opening (Meir *et al.,* 1995).

In the present investigation, among the different holding solutions used, D-fructose (3%) + nickel chloride (300 ppm) increased the vase life (13.5 days) and flower quality (water uptake and flower diameter) of pulsed and dry stored cut 'Noblesse' roses over the control flowers. The next best holding solution found to have pronounced beneficial effect in improving vase life of pulsed and dry stored 'Noblesse' roses were D-fructose (3%) + kinetin (2.5 ppm), sucrose (3%) + 8-HQC (200 ppm), D-fructose (3%) + $AgNO_3$ (25 ppm) and sucrose (2%) + streptomycin

sulphate (250 ppm). Improving the vase life of cut 'Noblesse' roses by the use of D-fructose (3%) + $NiCl_2$ (300 ppm) could be attributed to more uptake of water by the cut roses, increased flower diameter and sustained fresh and dry weight on the 3rd day in vase. The beneficial effects of all the holding solutions is explained in experiment 5.3. The 'Noblesse' cut roses held in Sucrose (2%) + captan (200 ppm) gave less vase life than the flowers held in tap water (control). Mor *et al.* (1989a) also observed that vase life of roses cv. 'Gabriella' stored dry at 1^0C for 3 weeks was 4 days shorter as compared to fresh roses.

5.5 Effect of pulsing, conditioning, and holding solution on the post harvest life and quality of dry stored cut roses

In this experiment, the best treatment combination with regard to vase life and quality was observed to be that of pulsing with STS (0.5 mM) for 45 min + optimum dry storage day (6 days) + holding solution [D-fructose (3%) + nickel chloride (300 ppm)]. This treatment recorded minimum loss in fresh and dry weights after storage, maximum gain in fresh weight on 3rd day in vase and minimum loss of these at senescence, maximum holding solution uptake and largest flower diameter. Beneficial effects of STS as a pulsing chemical has been reported by several investigators (Reid *et al.*, 1989; Ketsa *et al.*, 1993; Bhattacharjee and De, 1998; Bhatia *et al.*, 2002). The use of holding solution in the vase has added to the beneficial effect of pulsing with STS. Combining D-fructose (respirable substrate) with nickel chloride (act as a germicide and ethylene inhibitor) contributed in increasing the vase life of dry stored 'Noblesse' cut roses. The next best treatment combination with regard to vase life and quality were optimum dry storage day (6 days) + citric acid

conditioning for 1 h + vase water and dry storage (6 days) + conditioning in water for 1 h + vase water. Conditioning restores the turgidity of the cut flowers from water stress during storage. Citric acid acidfies the water by lowering the pH to 4.5 and 5.0, thus improving the water uptake by the cut stem. Durkin (1981) also reported that hydration was improved when water was deareated or acidified or when a wetting agent like Twin 20 @ 0.01-0.1 was added.

5.6 Changes in biochemical constituents in petals of 'Golden Gate' cut roses as affected by precooling pulsing, and packaging materials

5.6.1 Total starch content

Among the various precooling and pulsing treatments the maximum amount of total starch was estimated from petals precooled with cool storage at 4^{0}C for 24 h and pulsed with DMSO (2%) for 15 min both on the third day and senescence day. In general, the total starch content in petals of precooled and pulsed 'Golden Gate' cut roses showed a continuous decrease on the third day in vase and at senescence over that at harvest. Decrease in starch level during senescence was also observed by earlier workers too (Ferreira and Swardt, 1980a; Porgoralskaya, 1980; Evans and Reid, 1986; Sankar Vidhya, 2001). This decrease could be attributed due to the brekdown of starch to simple sugars during the respiration process of the cut flowers. Pulsing with DMSO (2%) for 15 min and D-fructose (3%) + 8-HQC (150 ppm) for 24 h increased the content of total starch in petals over untreated control both on third and senescence day. Similar results were also obtained by Sivasamy *et al.* 2000 and Vidhya Sankar, 2001. In cut 'Lady X' roses treatment with a combination of 2% sucrose, 250 ppm 8-HQ, 500 ppm citric acid and 25

ppm $AgNO_3$, slightly increased the starch content of petals was also reported by Gao and Yang (1992). The amount of total starch accumulated at senescence stage in the petals ultimately determined the longevity. In general, maximum starch content during different stages of flower development and senescence was associated with increased vase life. Sankar Vidhya (2001) and Sivasamy *et al.* (2002) also reported higher total starch content during different stages after harvest to be associated with longer vase life.

In another experiment, effect of precooling with ice-cold water spray for 45 min and cool storage at 4°C for 24 h, pulsing with DMSO (2%) and different packaging materials on the changes in total starch content was investigated. The total starch content of the precooled and packed flowers decreased while the packaging duration increased from 6 to 20 hours after completion of packaging hours on 3rd day in vase. However, at senescence, maximum amount of starch was observed in precooling with ice-cold water spray for 45 min, pulsed with DMSO (2%) and packed with butterpaper for 20 h, while in precooling with cool storage at 4°C for 24 h, pulsed with DMSO (2%), it was observed with flowers packed with butterpaper for 6 hours. Thus it can be inferred that precooling effects with ice cold water spray for 45 min and pulsing with DMSO (2%) was retained or maintained in the butterpaper packed flowers for 20 h, and hence respiration rate of the cut flowers inside the package was minimised due to which the hydrolysis of starch was retarded. Similar finding was reported by Ho and Nichols (1977). In precooling with cool storage at 4°C for 24 h, pulsed with DMSO (2%), maximum starch content was estimated with precooled flowers packed with

butterpaper for 6 h which also resulted in maximum vase life. In general, higher total starch content in petals was associated with longer vase life as also reported by Sankar Vidhya (2001).

5.6.2 Total soluble sugars

There was significant increase in the content of total soluble sugars in the petals of 'Golden Gate' cut roses as affected by the precooling and pulsing treatments both on the third day and senescence day. This increase in soluble sugar concentration in the petals, presumably from hydrolysis of starch, during rapid petal expansion was also reported by (Evans and Reid, 1988). Maximum content of TSS was estimated from petals precooled with cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min both on the third day and senescence day. This increase in the sugar content of petals is also an indication of good keeping quality in comparison to fresh flowers as suggested by Jiang *et al.* (1989). Higher TSS content in petals was observed to be associated with a longer vase life in the present study. Celikel and Karacali (1991) also reported that 'Salmon Sim' carnations with higher sugar contents in petals had a longer vase life as compared to 'Astor' cultivar. Significantly high levels of sugars in petals were obtained from the pulse treatments of DMSO (2%) for 15 min. and D-fructose (3%) + 8-HQC (150 ppm) for 24 h. The beneficial effect of DMSO as a pulsing chemical could be due to the role of sulphur in activation of free radical scavenging enzymes. The beneficial effects of adding sucrose resulting in increase in sugars has also been reported by other researches (De *et al.,* 1996; Eason *et al.,* 1997; Ichimura *et al.,* 1999).

In another experiment, effects of precooling with ice-cold water spray for 45 min and cool storage at 4°C for 24 h, pulsing with DMSO (2%) and different packaging materials on the changes in total soluble sugar content was investigated. The content of total soluble sugars increased in the precooled, pulsed and packed flowers on the third day from harvest and decreased at senescence. This may be due to continuous development and respiration of flower in vase and the hydrolysis of starch and depletion of carbohydrate status of the cut flower. Similar results were reported by Horie (1962) and Ho and Nichols (1977). They stated that during the course of petal aging there is a drop in the level of macromolecular components viz. sugars and cell wall polysaccharides. Rajan (1993) reported that the total soluble sugar content of leaves decreased towards senescence, while those of corolla increased. This may be due to the movement of dry matter from leaves to petals (Sacalis and Durkin, 1972; Ho and Nichols, 1977). In this experiment, precooling with ice-cold water spray for 45 min, pulsing with DMSO (2%) for 15 min and packed with corrugated fibre board sheet for 6 h recorded high amount of TSS on 3rd day and at senescence and resulted in longer vase life. While in precooling with cool storage at 4°C, pulsing with DMSO (2%) for 15 min and packed with butterpaper for 6 hours recorded high amount of TSS on 3rd day and at senescence and resulted in longer vase life.

5.6.3 Total free amino acids

There was significant increase in the total free amino acids content in the petals of 'Golden Gate' cut roses from harvest to senescence as affected by precooling and pulsing. This might be due to breakdown

of the protein and level of amino acid increased in the petals. In cut roses of cultivars 'Dame de Couer' and 'Lady X', the concentrations of total and basic free amino acids increased throughout vase life (Gao and Wu, 1990; Gao, 1991). All the pulsing treatments employed in the current investigation resulted in a significantly lower TFAA content in petals as compared to the untreated control. Low content of TFAA was estimated with the flowers precooled with cool storage at 4^0C for 24 h and pulsed with DMSO at 2%. This treatment also gave maximum vase life. Low content of TFAA in petals of roses was associated with longer vase life (Sivasamy, 1998; Sankar Vidhya, 2001).

In another experiment, precooling with ice-cold water spray for 45 min and cool storage at 4^0C for 24 h, pulsing with DMSO (2%) and different packaging materials on the changes in total free amino acid content in cut rose petals was investigated. The precooled flowers (viz. ice-cold water spray for 45 min and cool storage at 4^0C for 24 h) packed with butterpaper packaging material for 6 hours exhibited higher vase life over 20 hours precooled, pulsed and packed flowers. This may be due to the reason that the breakdown of protein in 6 hours packed flowers was less than that of 20 hours packed flowers. This might be the reason for the longer vase life of precooled, pulsed and 6 hours packed flowers over precooled, pulsed and 20 hours packed flowers. However, total free amino acids (TFAA) content in both the precooled, pulsed and packed and non-precooled, not pulsed and non packed flowers was increased at senescence stage. Sultan and Farooq (1996) also observed increase in the free amino acid during the course of senescence of day lily flowers. Longest vase life obtained was associated with low TFAA content in the

petals of precooled, pulsed and butterpaper packed flowers for 6 h. An increased vase life of cut roses was also observed to be associated with the lowest contents of TFAA in petal tissues throughout senescence process (Bhattacharjee and De, 1998).

5.6.4 Total Phenols

In this invesigation, the phenol content in the petals of 'Golden Gate' cut roses showed a continuous decrease from harvest to senescence stage. However, on 3rd day in vase and senescence precooling with ice-cold water spray for 45 min and not pulsed as well as pulsed with D-fructose (3%) + 8-HQC (150 ppm) for 24 h recorded a high amount of phenols in the petals which also resulted in increased vase life. However, little information is available on the role of phenolic compounds in senescence of cut roses. In general, the total phenol content in petals showed a decreasing trend from harvest to senescence. Similar results were also observed by Sultan and Farooq (1998) in *Iris kashmeriana* flowers when tissue phenolics followed a declining trend with development and senescence. Aswath *et al.,* (1998) reported that the presence of phenols differed among the cultivars in gerbera cut flowers.

In another experiment effects of precooling with ice cold water spray for 45 min and cool storage at 4^{0}C for 24 h, pulsed with DMSO (2%) and different packaging materials was investigated. In precooling with ice-cold water spray for 45 min, pulsing with DMSO (2%) for 15 min and packed with single layer corrugated fibre board sheet, higher phenol content was estimated on 3rd day in vase as well as at senescence stage, which correlated with more vase life than the control. While in

case of precooling with cool storage at 4°C pulsing with DMSO (2%) and packed with butterpaper for 6 hours recorded maximum content of total phenols was recorded both on 3rd day in vase as well as at senescence stage. In this experiment high content of total phenols during the flower-development and senescence was associated with longer vase life. Similar results were obtained by Sankar Vidhya (2001).

5.7 Rate of respiration of cut roses cv. Golden Gate and Noblesse as affected by the holding solution and cool storage (Wet and dry)

The wet and dry storage at 4°C for 3 days and 6 days respectively resulted in a decrease in the respiration rate in all the treatments over the high initial respiratory rate of freshly harvested cut flowers. This reduced rate of repsiration may be due to the low temperature (4°C) wherein most of the metabolic activities of the cut flowers were minimised. Serrano *et al.* (1992) also reported in rose cv. Visa that the cold stored cut flowers at 4°C exhibited a minimum rate of repsiration after the storage duration. Pritchard *et al.* (1991) also observed a slower rate of respiration after cool storage at 4°C in *Anthurium* flowers. However, on the third day in vase in the holding solution all the treatments gave a significant increase in the respiration rate, highest peak being in the control, followed by flowers held in D-fructose (3%) + nickel chloride (300 ppm) and sucrose (3%) + 8-HQC (200 ppm). This may be due to the continuous and uninterrupted development of the cut flower held in the preservative or holding solution due to the beneficial effects of nickel and 8-HQC as an ethylene inhibitor and antimicrobial nature resulting in increased holding solution uptake. During senescence, the respiration rate of the cut flowers in all the treatments reduced markedly

with the lowest respiration rate in the treatment associated with the longest vase life. Kaltaler and Steponkus (1976) reported that decline in respiration during senescence was not due to substrate limitations, but to the inability of the mitochondria to utilise the substrate. Lower respiration rate at different stages of flower development being associated with longer vase life of cut roses has been reported by several investigators too (Sivasamy, 1998; Bhattacharjee and Pal, 1999; Sankar Vidhya, 2001; Monteiro *et al.*, 2001). That respiration rate decreased during senescence of cut flowers and increased by keeping them in the preservative solution was also reported by de Pascale *et al.* (1998). The respiration rate of cut rose cv. Lady X and Dame de Coeur also increased in a preservative combination of 2% sucrose + 250 ppm 8-HQ + 500 ppm citric acid + 25 ppm silver nitrate (Gao and Yang, 1992).

Son Ki Cheol *et al.* (1997b) investigated the effects of preservative solutions on the senescence of cut rose cv. 'Red Sandra'. The preservative Son K1 (2% sucrose + 200 ppm 8-HQS + 0.1 mM ethionine) stimulated the respiration rate compared to the control.

5.8 Influence of precooling, pulsing and packaging duration on the growth of microorganisms in the vase water of the cut roses

The present study indicated that cut flowers of 'Noblesse' roses were affected by the increase in bacterial population and a number of fungal genera in the vase water. Maximum activity of micro-organisms in the precooled and pulsed cut roses were observed on the 4th day of vase life, thus resulting in the end of vase life on the 5th day. However, in treatments of precooling with cool storage at 4^{0}C and no pulsing and pulsing with DMSO (2%) for 15 min, no activity of microorganisms was

observed upto the 2nd day of vase life. This could be due to the low temperature of precooling method at which most of the microbial activity is retarded and also due to the antimicrobial nature of DMSO as reported by Sankar Vidhya (2001). High bacterial population at the end of vase life resulted in the early senescence of cut rose cv. Noblesse. High bacterial counts in the vase water can shorten flower longevity of cut carnation flowers cv. Scania and white Sim, which was related to inhibition of water uptake (Van-Doorn *et al.*, 1995). Van Doorn *et al.* (1989) also reported that whenever the number of bacteria exceeded 10^6 colony forming units (cfu) per gram fresh weight, the vascular blockage was found, be it after 3 days in pure water or after a long period in the presence of an antimicrobial compound. A number of fungal genera were also found in the vase water of precooled, pulsed and packed cut flowers. Identification of similar fungal genera and increased number of bacterial colonies of various shapes were reported by De and Bhattacharjee (2002) in the vase water of 'Queen Elizabeth' cut rose which was responsible for early senescence of cut flowers. Increased number of fungal genera were found in 20 h duration butterpaper packing than in 6 h duration. This may be due to the microclimate created inside the package material which was congenial for the microorganism growth at room temperature. Also bacterial infection increased the level of flower opening inhibition caused by dry storage (Van-Doorn and D'Hont, 1994). Moreover, the fungus identified in the vase water were mainly tissue or water borne and caused the wilting of the cut flower due to the accumulation of toxic compounds produced by these fungi. Similar toxic microbial compounds excreted into the vase water which accelerates senescence was reported by (Put and Klop, 1990).

Bacterial suspensions containing *Pseudomonas aeruginosa* isolated from *Rosa hybrida* cv. Sonia stems significantly reduced water uptake and hydrolytic conductance of the stems compared with control stems (De Witte and Van Doorn *et al.,* 1991). The basal stem portion at senescence showed the growth of some fungal genera and bacteria which was responsible for the early senescence of cut roses cv. 'Noblesse'. Van Doorn and Perik (1990) also reported that a considerable number of bacteria high enough to result in vascular occlusion were present in the stems. A population of bacteria is also present on the outside of the stems. These bacteria may rapidly multiply in the water, the freshly cut stem and the xylem vessels as reported by Van Doorn and Tijskens (1991). Van-Doorn and De Witte (1997) observed that tap water containing *Pseudomonads* and *Enterobacter* sp. rapidly developed on the cut surface and inside the water conducting elements when rose cv. Sonia stems were placed in tap water, even when the stems had been surface sterilized. When the pH of the water is low, bacterial growth is initially suppressed but a population of yeasts rapidly develops and many filamentous fungi were found (Van Doorn, 1997). In cut roses cv. 'Norena' bacteria which cause vascular blockage were observed in the xylem vessels of stem ends after 10 days in distilled water. These bacteria were identified as *Pseudomonas fluorescens, Klebseilla oxytoca* and *Aeromonas hydrophila* (Kim *et al.,* 1997).

6. SUMMARY

Experiments related to "Studies on the postharvest life, quality and biochemical constituents of cut roses as affected by precooling and storage" were carried out in the Division of Floriculture and Landscaping, biochemical studies were carried out at the Nuclear Research Laboratory and plant pathological studies were carried out at Indian Type Culture Laboratory, Division of Plant Pathology, IARI, New Delhi - 12 during 2000-2002. A series of experiments were conducted on greenhouse grown cut roses with the objective of studying the effect of precooling and pulsing on the postharvest life and quality of rose cut flowers; to investigate the effect of precooling and pusling on packaging materials and storage for different durations; to find out the influence of pulsing, conditioning and holding solution on post harvest life and quality of wet and dry stored cut flowers; to study the changes in biochemical constituents like total starch, total soluble sugars (TSS), total free amino acids (TFAA) and phenols as affected by pulsing, precooling and packaging materials; to study the rate of respiration of cut roses during the course of senescence as affected by holding solutions and wet and dry storage (cool storage), and to find out the influence of precooling, pulsing and packaging duration on the growth of microorganisms in the vase water of the cut roses. An attempt to summarize the salient results from these experiments has been made in this chapter.

6.1 Studies on the effect of precooling and pulsing on the postharvest life and quality of rose cut flowers

Four cultivars of rose were studied in this experiment. Precooled and pulsed cut roses irrespective of the cultivars and treatments significantly increased the fresh and dry weight of cut rose cultivars and improved the post harvest life and quality of the rose flowers. Precooling treatments either with ice-cold water spray (2 ± 1^{0}C) for 45 min or cool storage at 4^{0}C for 24 h and pulsed with DMSO at (2%) for 15 min gave maximum gain in fresh weight and dry weight over control and the rest of the treatments. These two treatments also resulted in maximum water uptake at senescence, largest flower diameter and maximum vase life.

6.2 Studies on the effect of precooling and pulsing on packaging (half covered and full covered) and storage for different durations

The cut flowers which were subjected to the precooling treatments with ice-cold water spray for 45 min and cool storage at 4^{0}C for 24 h, pulsed with DMSO at (2%) for 15 min were packed (half covered and full covered) with different packaging materials for 6 h, 20 h and 24 hours. All the precooled, pulsed and packed flowers showed an increase in the fresh and dry weight on 3rd day over the initial weight at harvest and control. However, increasing duration of packaging from 6 h - 24 h decreased the fresh weight of the cut roses on third day. Half covered cut stems with packaging material gave more vase life than full covered cut stems. Precooling with ice-cold water spray for 45 min, pulsed with DMSO (2%) for 15 min and packed (half covered) with single layer of corrugated fibre board sheet for 6 h gave maximum vase life (11.0 days) followed by butter paper for 6 h (10.5 days). The beneficial effects of

cool storage at 4°C for 24 h and pulsing with DMSO (2%) for 15 min was highly maintained upto 6 h in butter paper packed material (full covered) followed by brown paper and polythene (80 gauge) packaging material in the form of envelopes. Precooled, pulsed and packed with either butterpaper or brownpaper or single layer corrugated fibre board packaging material improved the water uptake, flower diameter and vase life of cut roses. The keeping quality of precooled and pulsed cut roses packed upto 20 h of duration gave more vase life and were as good as the untreated freshly harvested cut flowers.

6.3 Influence of pulsing and wet storage on the post harvest life and quality of cut rose cv. Golden Gate.

In the present investigations, all the pulsing treatments employed gave significant increase in the fresh and dry weight of wet stored cut rose cv. Golden Gate at 4°C after storage and on the third day in vase. The best pulsing treatment was found to be with silver thiosulphate STS (0.5 mM) for 45 minutes which resulted in a vase life of 13 days, maximum gain in fresh weight on the third day in vase (2.24 g), minimum loss in dry weight at senescence (0.01 g), maximum water uptake (30.1 ml) and second largest flower diameter of 7.5 cm.

The next best pulsing treatment was that of Benzyladenine BA (25 ppm) for 45 minutes which resulted in a vase life of 12.4 days with a wet storage duration of 3 days at 4°C. Pulsing with calcium chloride $CaCl_2$ (1%) for 20 hours also gave maximum gain in dry weight (0.90 g) on third day in vase, maximum gain in both fresh and dry weight after wet storage at 4°C, and maximum flower diameter (8.0 cm). Pulsing with STS (0.5 mM) for 45 minutes and calcium chloride (1%) for 20 hours,

the cut roses could be stored for 4 days under wet storage at 4°C, without any adverse effect on their subsequent vase life and quality.

6.3.1 Influence of holding solutions on wet stored and pulsed cut roses

Among the different holding solutions used, sucrose (3%) + 8 - HQC (200 ppm) was found best in extending the logevity of pulsed and wet stored cut roses cv. Golden Gate at 4°C. This treatment increased the fresh weight to the maximum after storage, on 3rd day in vase and at senescence, and gave maximum flower diameter, water uptake and vase life (20.5 days) from the other treatments. The next best holding solutions were D-fructose (3%) + nickel chloride (300 ppm) and Sucrose (2%) + Streptomycin sulphate (250 ppm) which gave a vase life of 18.5 days and 17.8 days respectively. In general, all the holding solutions employed in the experiment were effective in increasing the longevity and post harvest quality of pulsed (STS 0.5 mM, for 45 min) and wet stored (3 days, at 4°C) cut roses than the control treatment.

6.4 Influence of pulsing and dry storage on the Post harvest life and quality of cut rose cv. 'Noblesse'

In the present investigation, the best pulsing chemical in enhancing the longevity of dry stored cut rose cv Noblesse at 4°C was Benzyladenine BA (25 ppm) for 45 minutes. This treatment resulted in a maximum vase life of 13.0 days after 6 days of dry storage duration, minimum loss in fresh weight after storage (0.11 g), maximum gain in dry weight on 3rd day in vase (0.77 g), maximum water uptake (46.5 ml) and maximum flower diameter of (7.8 cm). Thus, the Noblesse cut roses can be stored dry at 4°C upto 6 days after pulsing with BA (25 ppm) for 45 minutes

without affecting the ultimate vase life and quality of the cut roses at ambient temperature.

6.4.1 Influence of holding solutions on dry stored and pulsed cut roses

Among the different holding solutions used, D-fructose (3%) + nickel chloride (300 ppm) was found best for prolonging the vase life of dry stored cut roses to the maximum. This treatment recorded maximum gain in fresh and dry weight after third day in vase, marked increase in total water uptake, largest flower diameter resulting in a maximum vase life of 13.5 days. The next best holding solution which enhanced the vase life and quality of pulsed & dry stored cut rose in 'Noblesse' were D-fructose (3%) + kinetin (2.5 ppm) followed by sucrose (3%) + 8-HQC (200 ppm).

6.5 Effect of pulsing, conditioning and holding solution on the post harvest life and quality of dry stored 'Noblesse' cut roses

The cut 'Noblesse' roses pulsed with STS (0.5 mM) for 45 minutes, dry stored for 6 days at 4^{0}C and held in a holding solution of D-fructose (3%) + nickel chloride (300 ppm) was most beneficial for improving the post harvest life and quality of cut rose cv. Noblesse. This treatment gave maximum gain in fresh weight on 3rd day in vase, minimum loss in fresh and dry weight at senescence, increased water uptake, largest flower diameter with a maximum vase life of 10.7 days. After dry storage of 6 days at 4^{0}C, conditioning with citric acid for 1 h and holding in tap water resulted in maximum gain in dry weight on 3rd day in vase and gave a vase life of 8.0 days. Dry storage for 6 days at 4^{0}C and conditioning in water for 1 h and holding in tap water also gave a vase life of 8.0 days which was comparable to that of control.

6.6 Changes in biochemical constituents in 'Golden Gate' cut roses as affected by pulsing, precooling and packaging materials

6.6.1 Changes in total starch content in petals of 'Goden Gate' cut roses as affected by precooling and pulsing

The total starch content in the petals of 'Golden Gate' cut roses showed a continous decrease on the third day in vase and at senescence over the harvest day. On the third day in vase, highest content of total starch was recorded with the precooling treatment of cool storage at 4°C for 24 h and pulsing with DMSO (2%) for 15 min. The treatment of ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min came next. The same trend could also be observed at senescence stage. In general, higher starch content in the petals at both the stages was associated with maximum vase life.

6.6.1.1 Changes in total starch content in petals of 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

The treatment combination of precooling with ice-cold water spray for 45 min, pulsing with DMSO (2%) for 15 min and packing with butter paper packaging material for 20 h followed by single layer of corrugated fibre board sheet for 20 h registered highest starch content at senescence and maximum vase life. While with treatment combination of precooling with cool storage at 4°C for 24 h, pulsing with DMSO (2%) for 15 min and packing with butter paper for 6 h followed by polythene bags (80 guage) for 20 h registered highest starch content at senescence. High level of starch on third day in vase as well as at senescence was associated with longer vase life.

6.6.2 Changes in total soluble sugars content in petals of 'Golden Gate' cut roses as affected by precooling and pulsing

The total soluble sugars content in the petals of 'Golden Gate' cut roses increased continously during the cut flower development and senescence. On the third day in vase, highest content of total soluble sugars was recorded with the precooling treatment of cool storage at 4°C for 24 h and pulsed with DMSO (2%) for 15 min. However, at senescence cool storage at 4°C for 24 h and no pulsing recorded maximum content of total soluble sugars followed by cool storage at 4°C for 24 h, pulsed with DMSO (2%) for 15 min. Higher TSS content in petals was associated with longer vase life.

6.6.2.1 Changes in total soluble sugars content in the petals of 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

The treatment combination of precooling with ice-cold water spray for 45 min pulsing with DMSO at (2%) for 15 min and packing with single layer of corrugated fibre board sheet for 6 h followed by packing with single layer of corrugated fibre board sheet for 20 h registered maximum content of total soluble sugars on third day in vase. At senescence precooled, pulsed and packed with polythene bags (80 guage) for 20 h registered maximum TSS content followed by brown paper packed for 20 h. The treatment combination of precooling with cool storage at 4°C for 24 h, pulsing with DMSO (2%) for 15 min and packing with butterpaper for 6 h followed by packing with brown paper for 6 h registered maximum TSS content on 3rd day in vase. However, at senescence, precooled, pulsed and packed with butter paper for 20 h gave highest content of total soluble sugars followed by brown paper packed

for 6 h. Higher TSS content in the petals of precooled, pulsed and packed flowers was associated with longer vase life.

6.6.3 Changes in total amino acids content in petals 'Golden Gate' cut roses as affected by precooling and pulsing

The total free amino acids content in the petals of 'Golden Gate' cut roses increased continuosly during flower development and senescence. All the precooling and pulsing treatments employed showed significantly lower content of TFAA in the petals as compared to the untreated control treatment. The least TFAA content on third day in vase was registered with the precooling treatment of cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min, while at senescence stage, least TFAA content was observed with ice-cold water spray for 45 min and pulsed with D - fructose (3%) + 8 - HQC (150 ppm) followed by cool storage at 4^0C for 24 h and pulsed with DMSO (2%) for 15 min. Lower content of total free amino acids in the petals was associated with maximum vase life.

6.6.3.1 Changes in total free amino acids content in petals of 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

The treatment combination of precooling with ice cold water spray for 45 min, pulsing with DMSO (2%) for 15 min and packing with polythene bags (80 guage) for 6 h followed by packing with butter paper for 6 h registered the lowest amount of TFAA content in the petals on 3rd day in vase. At senescence, precooled, pulsed and packed in single layer corrugated fibreboard sheet for 6 h followed by butterpaper packed for 6 h registered the least among of TFAA and gave maximum vase life.

In treatment combination of precooling with cool storage at 4°C for 24 h, pulsed with DMSO (2%) for 15 min and packed with polythene bags (80 guage) for 6 h followed by butter paper packed for 6 h registered the lowest contents of TFAA. At senescence, precooled, pulsed and packed with butter paper for 6 h recorded the lowest content of TFAA which gave maximum vase life. Thus, the lower content of TFAA in the petals during the development and senescence was associated with longer vase life.

6.6.4 Changes in total phenols content in the petals of 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

The total phenol content in the petals of 'Golden Gate' cut roses showed a decrease on 3rd day in vase except for two treatments where the content increased and then decreased markedly at senescence. The lowest content of phenol was observed with ice-cold water spray for 45 min and pulsed with DMSO (2%) for 15 min followed by precooling with cool storage at 4°C for 24 h and pulsing with D - fructose (3%) + 8 - HQC (150 ppm) for 24 h which gave a longer vase life. At senescence, lower content in phenols was observed with cool storage at 4°C for 24 h and pulsed with D - Fructose (3%) + 8 - HQC (150 ppm) followed by cool storage at 4°C for 24 h and not pulsed and cool storage at 4°C for 24 h and pulsed with DMSO (2%) for 15 min.

6.6.4.1 Changes in total phenols content in the petals of 'Golden Gate' cut roses as affected by precooling, pulsing and packaging materials

In treatment combination of precooling with ice-cold water spray for 45 min, pulsing with DMSO (2%) for 15 min and packed with single

layer corrugated fibre board sheet for 20 h registered highest content of phenols on 3rd day in vase. While at senescence, precooled, pulsed and packed with brown paper for 20 h recorded highest content of phenols. In treatment combination of precooling with cool storage at 4°C for 24 h, pulsed with DMSO (2%) for 15 min and packed with butterpaper for 6 h registered the highest content of phenols on the third day in vase. Same trend was observed at senescence stage. In general, high content of phenols was associated with longer vase life.

6.7 Rate of respiration of cut roses during the course of senescence as affected by the holding solutions and cool storage

The rate of respiration decreased after the wet and dry storage at 4°C, from the harvest but the decrease was non-significant. On the third day in vase, it showed a significant rise in the respiration rate when flowers were held in different holding solutions with a maximum recorded in untreated control, followed by D - fructose (3%) + nickel chloride (300 ppm) and sucrose (3%) + 8 - HQC (200 ppm). At senescence, there was a further decrease in respiration rate. Lower respiration rate at senescence was associated with longer vase life.

6.8 Influence of precooling and pulsing on the growth of microorganisms in vase water of cut rose cv. Noblesse

The beneficial effects of precooling with cool storage at 4°C for 24h and pulsing with DMSO (2%) resulted in no growth of microorganisms on 1st and 2nd day of the vase life of cut rose cv. Noblesse. However, maximum microorganism activity was observed on the 3rd and 4th day of vase life resulting in the end of vase life on 5th day. Increased number of bacterial colonies of various shapes both gram positive and negative and the fungal genera that were identified in the vase water of precooled

and pulsed cut roses such as *Alternaria alternata, Alternaria brassicicola, Aspergillus flavus, Streptomyces albus, Cladosporium cladospoiroides, Acremonium* sp., *Dreschlera specifera, Aureobasidium pullurlescens, Streptomyces albus, Cladosporium oxysporum* and *Fusarium pallidoroseum* were responsible for early senescence of cut rose cv 'Noblesse'.

6.8.1 Influence of precooled pulsed and packed cut roses cv. 'Noblesse' for different duration on the growth of microorganisms in the vase water

The precooled, pulsed and packed with butterpaper packaging material was affected by a number of microorganism growth in the vase water of cut rose cv. Noblesse. Precooled, pulsed and packed with butterpaper for 20 h resulted in more number of fungal genera from the 3rd day of the vase life. The fungal genera that were identified in the vase water were *Alternaria alternata, Aspergillus flavus, Aspergillus niger, Penicillium* sp. *Taloromyces flavus, Cephalosporium restrictum, Torula* sp. *Fusarium pallidoroseum, Acremonium persicicum, Penicillium chrysogenum, Curvularia lunata, Fusarium oxysporum, Dreschlera* sp., *Cladosporium oxysporum, Paecilomyces varcitti* and *Sartoria* sp.

6.8.2 Influence of precooling & pulsing and precooled, pulsed & packed cut roses on the growth of microorganisms at the basal stem portion of rose cv Noblesse at senescence

The fungal genera that were identified growing at the basal stem portion of cut rose cv. Noblesse at senescence were *Aspergillus flavus, Penicillium* sp, *Acremonium* sp, *Dreschlera tetramera, Paecilomyces lilacinus, Fusarium monoliforme,* yeast and bacteria. Precooling with ice-cold water spray for 45 min and pulsing with DMSO (2%) for 15 min showed no

growth of microorganisms at the basal stem portion thus extending the vase life to 5 days compared to 4 days with the control treatment.

Future line of work

* To study the properties and mechanism of action of DMSO in enhancing the vase life of cut roses.
* To explore the possibilities of various chemicals in delaying the enzyme activity responsible for early senescences of cut flowers.
* To find out the role and mechanisms of action of microorganisms responsible for vascular blockage in cut roses.
* To determine the chemicals which can intensify the pigments of the rose petals true to the type of the variety.

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