II

REVIEW OF LITERATURE
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The intimacy of flowers and floral designs are an integral part of the life of the people. Floriculture took birth as early as man's rendezvous with civilization. The postharvest handling of cut flowers and other ornamentals is as much as science, technology and art as is the care implemented to grow high quality produce during the postharvest period. Problems associated with the postharvest control of flowers have engaged the attention of horticulturalists for many years. Considerable progress has been made in recent years in the study of postharvest physiology and the development of postharvest technology for extending longevity and improving the quality of cut flowers. Concerning postharvest physiology of cut flowers, the greatest deal of attention is devoted to senescence process.

One of the most important abilities for a cut flower is a good keeping quality. The change in fresh weight pattern of different flowers reflects the difference in their vase life. Numerous preservatives including ions such as calcium, cobalt, silver and others have been found to be beneficial to cut flowers (Halevy and Mayak, 1981). Aluminium sulphate has been found in many preservative formulations for roses, gladiolus and other flowers. Weinstein and Laurencot (1963) attributed the effect of
Aluminium sulphate in lowering the rose petal pH and stabilizing the anthocyanins. Mayak and Bar-Yosef (1972) showed that roses exposed to aluminium sulphate for only 12 hours had reduced bent neck and wilting. De Stigter (1980) observed best results in terms of fresh weight and water balance in cut 'Sonia' roses when treated with a combination of aluminium sulphate and glucose. The effects of sugar added to the vase water along with an antimicrobial agent 8-HQS or aluminium sulphate are a quick stomatal closure which results in restricted transpiration and a reduction of diurnal weight fluctuation (De Stigter, 1981).

Beyer (1976) stated the silver ion to be a potent anti-ethylene agent in cut flower senescence. Halevy (1976) determined that pretreating carnations with a AgNO₃ dip and pulsing the flower with sucrose at 21°C for 24 h. provided support for the carnation during the entire postharvest period. The vase life of cut roses of 'Sonia' has been prolonged by keeping them in a preservative containing AgNO₃ + 8-hydroxy quinoline citrate + citric acid + sucrose (Ferreira and De Swardt, 1980). Awad et al. (1986) reported that placing flowers in sucrose solution after AgNO₃ dipping enhanced the longevity of Calendula and Zinnia. Cut Dahlias held in water lasted 5 days and placing them in the solution of glucose plus AgNO₃ resulted in an increase in their vase life (Lukaszewska, 1986 a). Holding solution containing combination of 8-HQS, AgNO₃ and sucrose increased the percentage of bud opening and vase life but decreased opening time in cut inflorescence of Dendrobium 'Pompadour' (Ketsa, 1989).
Murr et al. (1979) reported that the rate of water uptake in cut roses was maintained at a high level by cobalt nitrate treatment. Venkatarayappa et al. (1980) observed an increase in fresh weight percentage by cobalt treatment in cut rose flowers. Many workers recognized that cobalt promotes several growth processes in excised plant parts in presence (Miller, 1954) or absence (Loercher and Liverman, 1964) of IAA or cytokinin. Cobalt maintained high water potential and fresh weight of cut rose flowers, leading to increased vase life (Reddy, 1988). Murali (1990) observed higher fresh weight in cut gladioli placed in cobalt, nickel and sucrose than those of control. Data supporting the role of Ca$^{2+}$ as a regulator of plant growth, development and senescence are currently accumulating. Mayak et al. (1978) reported that calcium prevents stem softening and bending and increase the longevity of cut carnation flowers. Calcium is known as having various effects on plant life, such as decreasing membrane permeability, delaying senescence, modification of the action of plant hormones (Ferguson, 1984). Michalczuk et al. (1989) showed that calcium applied to cut rose flowers mainly as calcium nitrate extended longevity and promoted bud opening.

In the literature of cut flower physiology much attention has been given to the effects and roles of exogenously supplied sugar in improving duration and quality of vase life. Sucrose treatments improved bud development and increase the vase life of cut gladiolus spikes (Bravdo et al. 1974). Borochov et al. (1976b) reported that the water balance and the fresh weight of cut rose flowers were improved by treatment with
sucrose solutions. Markable senescence inhibition was obtained by Halevy and Mayak (1981), when sugar was combined with other chemical constituents of preserved solutions, especially with hydroxyquinoline and citric acid. Paulin (1986) observed that flowers supplied with sucrose solution have a longer vase life, associated with a constant fresh weight and a regular increase in dry matter.

The role of growth regulators in flower senescence is well documented; ethylene accelerates while cytokinins delay senescence processes (Halevy and Mayak, 1979). In roses, Halevy et al. (1978) observed the inhibition of petal senescence and increase in vase life by adding cytokinins to water or to preservative solutions. Holding cut leafless flowers continuously in kinetin solution delayed fading (Mayak and Halevy, 1974). Halevy and Mayak (1981) reported that cytokinin application resulted in the longevity extension of isolated carnation petals as well as attached flowers. Mor et al. (1983) delayed the petal senescence by cytokinin application. Cook et al. (1985) opines that cytokinins and cytokinin like compounds delay the ethylene climacteric and also decreases the sensitivity of petals to ethylene. Gibberellins are very important in the regulation of flower growth and development. Harris et al. (1969) observed an increase in growth, flower dry weight and petal size in carnation through GAs treatment. In cut Lilium 'Prima' inflorescences, Nowak and Mynett (1985) observed increasing longevity and floret size, and retardation of foliage discolouration by gibberellic acid treatment. The addition of gibberellic acid to HQC and sucrose solution significantly prolonged the vase life of cut
tulips. The effect of gibberellic acid on carnation flower senescence well reflects an involvement in maintaining the pre-senescent stage of flower development (Saks and Van Staden, 1992).

Water balance is a major factor in determining the quality and longevity of cut flowers (Rogers, 1973). Marousky (1969) found that roses held in sucrose containing solutions absorbed less water than roses held in water alone, but sustained their fresh weight increase longer due to partial stomatal closure and reduced transpirational water loss. In cut Gerbera flowers, Meeteren (1978) observed that for the flowers placed in silver nitrate solution, during the first 3 days after cutting absorption was higher than transpiration, resulting in an increase in fresh weight. Although loss of water was higher in Co treatments in cut roses, Reddy (1988) noticed that the water loss/water uptake ratio was significantly lowered by all concentrations of Co when compared to controls. Murali (1990) reported that the gladioli flowers treated with metallic salts and sucrose show significantly higher water uptake and water loss over control flowers. It was demonstrated that plant hormones influence water balance during senescence. According to Mayak and Halevy (1974) in cut roses the main initial effect which kinetin had on water balance was the enhancement of water uptake. Zieslin et al. (1974) reported the association of GA3 with an increase of water uptake through petal tissue. In the later stages of carnation senescence, the petals lose increasing amounts of water, leading to a dry matter content of about 20% at the wilted stage (Nichols and Ho, 1975).
Properties of cell sap like conductivity and pH of cell sap can be used as objective indicators of senescence. The cell sap pH increased regularly with ageing cut rose petals (Barthe et al., 1991). The frequently observed colour change in senescing rose petals is generally associated with a steady increase in pH of cell sap (Borochov et al. 1976a) which was attributed to proteolysis followed by accumulation of free ammonia (Weinstein, 1957). Halevy and Mayak (1979) observed that treatment of harvested roses with sugar solutions decreases bluing as a result of inhibition of proteolysis and stabilization of the pH. Ageing of cut flowers in a vase is accompanied by an increasing leakage of ions from petal tissue. Meeteren (1979a) showed that the pretreatment of the Gerbera flower heads with the cytokinin 6-benzyl-adenine (BA) retarded the increase in ion leakage. Increase in membrane permeability was demonstrated during the senescence of morning glory corolla by Hanson and Kende (1975).

Senescence of cut flowers is closely related to depletion of energy required for synthetic reactions. Carbohydrate status of a flower is an important factor which affect the postharvest life of cut flowers (Halevy and Mayak, 1979). Nichols and Ho (1975) observed that the final stage of flower development is characterized by decline in the content of carbohydrates and dry weight of petals. Lukaszewska (1980a) found an increase in soluble sugars in the ray florets in sugar fed Dahlias and decrease in soluble sugar in control flowers. Amariutei et al. (1986) worked on gerbera flowers and recorded diminishing soluble sugar content and
reducing sugar content during vase-life, but this decrease was greater in nonpulsed than pulsed inflorescence. The chrysanthemum flowers treated with silver thiosulphate showed an increase in soluble sugar content upto two weeks after which decrease was noticed, while the control flowers showed decreasing level throughout the period (Su et al., 1991).

In petals of cut rose flowers, Borochov et al. (1976a) observed a higher reducing sugars content at later advanced stages of senescence. Ferreira and De Swardt (1980) reported an increase in total free reducing sugar content throughout the period of senescence except for a short duration prior to climacteric minimum as well as climacteric maximum where it decreased. The flower development in cut carnations seemed to depend on the exogenous sugar supply and on the concomitant accumulation of soluble reducing sugars (Paulin and Jamain, 1982). In contrast to the continuous accumulation of starch found in the intact corolla, Ho and Nichols (1977) reported that the reducing sugar pool of the cut rose corolla maintained at the expense of starch which depleted fairly quickly. During the developmental period of cut rose cv. 'Sonia', progressive decrease in starch content was recorded by Buxton and Stoltz (1977). Ramanuja Rao and Mohanram (1979) reported that the exogenous application of GAs on gladioli spike results in prolonged flowering by increasing supply of soluble sugars through stimulation of starch break down. Ferreira et al. (1986) observed a rapid decrease in starch concentration, in gladioli inflorescences, during the postharvest period. During the developmental stages in attached flowers of rose, Sharma (1981) observed first a decline in non-reducing and
reducing sugars, which showed a sharp rise in the second phase followed by a decline in the last phase.

Senescence of flower petals is often associated with a decline in protein content (Matile and Winkenbach, 1971). Stickland (1972) has been found a decline in the amount of protein during growth in chrysanthemum; and in rose flowers by Paulin (1979). Sucrose in the preservative solution is known to exert a sparing action on the breakdown of proteinaceous substances in carnations (Bruszewski, 1968). Carfantan (1970) observed that the initially rapid accumulation of protein in the petals of tulip ceases and proteolysis becomes dominant even before the opening of the flower. Increased protein synthesis with the onset of senescence in *Hibiscus rosasinensis* petals has been shown by Woodson and Handa (1987). In an analysis of carnation petals, Woodson (1987) found an increase in several proteins an mRNAs during senescence but a decrease in others and opines that both synthesis and degradation of protein are important during senescence process. Kinetin application delayed petal senescence in detached flowers by retarding the reduction in total protein. In Sandersonia flower the soluble protein content of the attached tepals started to decline from fully mature flower stage onwards (Eason and Webster, 1995).

Sopanen and Carfantan (1976) observed about 3 fold increase in free amino acids content during senescence in tulip petals. Paull et al. (1985) studied the effect of silver pulsing on aminoacid content in cut
anthurium flowers. They found that amino acid content increased in the spathe tissue of both treated and control flowers, but the increase was larger for the control flowers. Lukaszewska et al. (1989) could not find a direct relation between ageing of flowers and accumulation of total amino acids in corollas from 'Sonia' roses. They found the presence of individual free amino acids—glycine, leucine, valine, isoleucine, histidine, serine, lysine, alanine, aspartic acid and proline during various stages of studies. Proline plays an important role in senescence as a stabilizer of membrane phospholipids (Rudolph et al., 1986).

During flower development in *Digitalis purpurea*, Stead and Moore (1977) found maximum RNA content soon after flower opening and the level decreased in ageing petals. Robert and Khan (1969) reported an increase in RNA content during leaf senescence. In carnation petals total cellular RNA remained unchanged initially, after which a loss of RNA was associated with the final stages of senescence (Woodson, 1987). Kenis et al. (1985) observed that during growth of carnation flowers, at the initial stages of flower opening (0-3rd stage) there was a steady increase in organic N and DNA per petal, while DNA content seemed to stabilize as from stage 3 onwards. RNA content starts to decrease in morning glory even before anthesis while degradation of DNA starts only after the onset of wilting (Matile and Winkenbach, 1971). Studies of Sharma (1981) on *Rosa damascena* revealed an increasing and decreasing pattern in RNA content and a gradual decrease in DNA content during development and senescence.
Senescing corolla of four-o-clock flower was accompanied by a decline in the content of RNA and increase in free nucleotides with no change in DNA content (Li et al., 1994).

Petals from various flowers contain a variety of phenolic compounds and in varying amounts (Weinstein, 1957). Twigg (1952) reported that the concentration of tannins and other phenolics was greater in blue petals of rose than non-blue petals. Paull et al. (1985) observed a 50% increase in total phenols in the spadix and spathe tissue in control flowers of anthurium between 10 and 18 days from harvest, while in silver pulsed flower total phenols decreased slightly, then increased between days 20 and 25 and thereafter remained constant.

Two major events occur in senescing petals are increase in respiration and hydrolysis of cell components. The enzymatic changes found during senescence are associated with these two processes. During rose bud opening, Hammond (1982) observed an increase in amylase activity in the crude starch fraction after harvest. GA$_3$ induced alpha amylase has been reported in leaves of *Digitaria decumbens* (Carter et al., 1973) and leaves of *Cicer arietinum* (Mehta et al., 1975). Vimala (1991) showed a decrease in amylase activity in *Hibiscus mutabilis* and increase in activity in *Vinca rosea* during development and senescence. Enzyme invertase plays a key role in carbohydrate metabolism and its activity increase during flower development and then decreases in wilting flowers (Halaba and Rudnicki,
BA in 10 ppm concentration enhanced invertase activity was nearly double than that of control flowers (Lukaszewaka, 1986). Halaba and Rudnicki (1986) showed that invertase activity in carnation petals began to decrease starting two days prior to the wilting of the petals.

Catalase, peroxidase, and polyphenol oxidase are important oxidising enzymes which play significant role during senescence process. In cut Gerbera, immediately after treatment with combination of sucrose, HQS and silver nitrate, activities of catalase, peroxidase and polyphenol oxidase decreased in the pulsed inflorescences (Amariutei et al., 1986). They studied that after a period of 6-7 days, the activities of these enzymes showed distinct increases, both in the pulsed and non-pulsed inflorescences. Increase in peroxidase was found in petals of tulip (Carfantan and Daussant, 1975). Increased activity of peroxidase is apparently involved in senescence promotion (Baker et al., 1977). In chrysanthemum flowers treated with STS or silver nitrate, Su et al. (1991) observed an increase in peroxidase activity at the beginning of storage, decrease for two weeks and then again an increase, while in control flowers peroxidase activity increased throughout the storage period. Droillard et al. (1987) reported a progressive increase in catalase activity upto the withering stage in petals of cut carnations. In Arachnis orchids a decrease in polyphenol oxidase activity was recorded in ageing corolla (Tan and Hew, 1973).

Kar and Mishra (1976) found a decrease in catalase activity while there was an increase in peroxidase and polyphenol oxidase activities
during senescence of both attached and detached rice leaves. Peroxidase and IAA oxidase exist in isoenzymatic forms (Shannon, 1968). Sirjun and Wilson (1974) observed that ageing of sweet potato tuber discs resulted in increased peroxidase activity as well as the development of IAA-oxidase.

The major types of pigments contributing to the colour of the flowers are carotenoids and anthocyanins. Most red roses show an undesirable bluing as they senesce. Co-pigmentation, the bluing of anthocyanins by flavonoids and related substances was suggested by Robinson and Robinson (1931). In the 'Masquerade' rose, more than a ten fold increase in anthocyanin level was measured during senescence where freshly opened orange-yellow flower turn deep red (Shisa and Takano, 1964). Arditti and Flick (1976) reported that the increase in anthocyanin formation with wilting is one of the typical post-pollination phenomena in Cymbidium orchids. Lukaszewska (1980a) recorded higher anthocyanin content in carnations placed in preservatives than the control flowers. A decrease in total carotenoid content was observed in senescing chrysanthemum flowers (Stickland, 1972). Zeislin et al. (1974) reported that GA treatments enhanced flower pigmentation in Bacara roses whereas Sang et al. (1992) recorded a decrease in anthocyanin content by GA in cut snapdragon flowers.

Plant growth regulators play a very important role in flowering induction in many horticultural plants. Application with growth regulators like naphthalene acetic acid (NAA), indole acetic acid (IAA),
gibberellic acid (GA), tri-iodo benzoic acid (TIBA), kinetins, ethylene etc. proved effective in flower initiation and fruit set in vegetable crops.

Large number of flowers are born during the life span of chilli crop. Flower and fruit drop in chilli may range from 20-80 per cent of which a major portion occurs due to the physiological imbalance (Nagarathnum and Rajmani, 1963). Growth regulators in chilli crop are used for production of male sterile flowers, to induce early flowering, for preventing flower and fruit drop, for uniform ripening of fruits and to increase or decrease seed content in fruits (Hosmani, 1993).

Hitchcock and Zimmerman (1935) first showed that flowering of tobacco could be accelerated by the application of small amount of auxin. Practical importance in early flowering and maturity were noticed in pineapple by the application of small amounts of auxin (Clark and Kerns, 1942). Hormones particularly, gibberellins have also been reported to replace the temperature and day length requirements of some species. Asana et al. (1955) studied that the application of NAA through the cut leaf or as spray before the onset of the reproductive phase increased ear and grain numbers in wheat. Mathur (1959) reported that the treatment with NAA at 20 ppm developed more fertile branches and retained more bolls than the control in Gossipium arboreum. Mote et al. (1975) observed that the foliar application of NAA as pre-blossom sprays ranging from 10 to 20 ppm induces early flowering, prevents flower and fruit drop. It has been reported that 4-CPA, 2,4-D and NAA are the most effective in fruit set in
brinjal. Foliar application of NAA was found to be more effective than soil application. The earliest flowering was induced by higher doses of NAA in tomato (Singh and Upadyaya, 1967). Application of NAA induces early flowering and controls flower fall in chilli (Usha and Peter, 1995).

It has been reported that the primary effect of GA is on stem growth rather than on flowering which may be indirect. Krishnamurthi et al. (1959) reported the effect of GA on fruit set, size and quality of the 'Pusa seed less' variety of grapes. Ogawa (1961) studied a promotion of flowering in Pharbitis. Higher sugar content in tomato fruits was obtained from plants treated with 10 ppm GA3 though there was no increase in protein and ascorbic acid contents, and fruits of treated plants were lighter in colour. Increase in pod set with the use of gibberellin in French bean was reported by Rackham and Vaughn (1959). Opposite effect of GA also has been reported. La Red and Cucchi (1966) reported that spraying of gibberellin acid at 25 ppm 3 times during the vegetative growth caused flowering 18 days later than control in capsicum. GA promoted flowering ultimately led to an increased yield compared to control (Toledo, 1981). Singh (1995) reported the role of GA in flowering induction in tomato.

The effect of growth substances in increasing the fruit set is in link with the reduction in pre-mature flower drop and fruit drop which occur due to the increased level of abscisic acid. The abscisic acid (ABA) has been assigned a significant role in regulating the senescence in flowers. The hormonal control of abscission of different plant organs was originally
proposed by Laibach (1933a). Later La Rue (1936) reported the use of synthetic auxins for delaying leaf fall or prevention of pre-harvest fruit drop. As senescence is followed by abscission of organs many experiments have been performed to delay abscission through the delay of senescent phase. Gibberellic acid delays the abscission by delaying the onset of senescence (Brian et al., 1959). The treatment with NAA and IAA to prevent the onset of senescence and abscission has been reported by several workers. Various synthetic auxins have been tried to induce senescence followed by abscission. Jacobs (1962) reported that the senescence - abscission - inducing effects of these chemicals could be counteracted by concurrent addition of IAA, NAA and IBA.