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Ethylene as a Postharvest “Evil” and its Remedies in some Horticultural Crops

By

Seid Hussen

Research Article

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Seid Hussen

Department of plant sciences, Wollo University.

Email: hamidashm@gmail.com

ABSTRACT

Postharvest is an agricultural operation starting from the time of harvesting till the commodity reaches to the ultimate user/consumer. The postharvest life of horticultural produces is different from other produces in having shortest shelf life. In some horticultural crops which we call climacteric, there is an increase rate of respiration mainly due to a very high synthesis of the ripening hormone (ethylene), which has both beneficial and detrimental (“evil”) effects depending on the type of commodity. The effect of ethylene is accumulative so continuous exposure to a low concentration of ethylene throughout marketing can cause significant harm. In climacteric fruits exogenous C₂H₄ caused the peel and flesh to ripen out of phase, with the flesh ripening faster than the peel. In a study of cut flowers, exposure to ethylene at 100 $\mu\text{l l}^{-1}$ reduced vase life by about 30%. In order to minimize this evil effect different vase solutions have been investigated. STS (silver thiosulfate) and 1-MCP (1-methylcyclopropene) can effectively protect flowers against exogenous ethylene. Pre-treatment of plants with 1 $\mu\text{l l}^{-1}$ 1- MCP for 2 h completely inhibited ethylene-induced petal abscission. Applications of Silver thiosulphate (STS) and 1-MCP have a great role to withstand the impact of ethylene. Thus they give relief for those concerned with horticultural crops which are sensitive to ethylene action. However more researches have to be done about the level and time of application of these chemicals and a new chemical against ethylene should be investigated.

Key words: climacteric, respiration, postharvest, STS, MCP.

1. INTRODUCTION

Postharvest is an agricultural operation starting from the time of harvesting till the commodity reaches to the ultimate user/consumer. It has passed the different pathways/channels from producer to final consumer. Different authors have defined it; “the post-harvest system should be thought of as encompassing the delivery of a crop from the time and place of harvest to the time and place of consumption, with minimum loss, maximum efficiency and maximum return for all involved”. The postharvest life of horticultural produces is different from other produces in having shortest shelf life. The main reason for that is they are in a living state for a certain period after harvesting, thus continue their metabolic process including respiration (Seid *et al.*, 2013). In some horticultural crops which we call climacteric, there is an increase rate of respiration mainly due to a very high synthesis of the ripening hormone (ethylene), which has both beneficial and detrimental (“evil”) effects depending on the type of commodity.

Ethylene is a colourless gas with a faint sweetish smell that is the naturally produced ripening hormone of some fruit. It is also produced as an exhaust gas from petrol combustion engines. The important role of ethylene as a plant growth regulator has only been established over the last 50 years but its effects have been known for centuries. Reid (1992) gives the example of how the flammable gas used for lighting street lamps in Europe contained added ethylene so the lamps burnt with a yellow flame. It was observed that plants growing near any leaky pipes showed some strange growth patterns such as premature leaf fall and death of their flowers.

Ethylene can be found either in its naturally occurring form or in synthetic form. Its form, structure and site of production are presented in the following table.

Naturally occurring	Synthetic	Structure	Stage of the plant for production
Ethylene	ethephon or ethrel (release ethylene inside plant)	$\text{HC}=\text{CH}_2$	ripening fruits, aging flowers, germinating seeds, wounded tissue

Ethylene is produced in the following sequence of steps in plants.

Methionine $\rightarrow$ S-Adenosylmethionine (SAM) $\rightarrow$ 1-AminoCyclopropane-1-Carboxylic acid (ACC) $\rightarrow$ ethylene

The presence of ethylene is not always beneficial, especially in terms of postharvest shelf life (Optimal Fresh, 2001). It seems that because it is a colourless gas that is not often measured in commercial situations its presence is overlooked. Loss of quality and quantity occurs along the postharvest chain of horticultural crops. However, the loss of shelf life will be most frustrating for the final consumer as the loss of quality will not be obvious during marketing and retail sale. The major reason for the loss of shelf life is that ethylene exposure increases the rate of the product ages.

The responses of harvested fruits, vegetables, and ornamental crops to endogenously produced and exogenously applied ethylene are numerous and varied, and they can be beneficial or detrimental depending on each case (Saltveit, 1999). In general, ethylene can influence the postharvest life of both climacteric and non climacteric fruit by affecting their quality attributes and the development of physiological disorders and postharvest diseases (Kader, 1985). Effects of ethylene on fruit external appearance, texture, flavor, and nutritive value have been extensively reviewed by different authors. Frequently, the action of ethylene results in promotion of fruit softening, acceleration of deterioration, and consequent abbreviation of postharvest life. Thus it is clear that in some commercial horticultural crops, ethylene has detrimental effects; it accelerates senescence and ultimate death of the plant/plant part. As an evil leads/guides human being in the wrong direction and facilitates weakness and loss of strength, so does ethylene in some horticultural crops. Thus this paper is initiated to review the effects of ethylene, especially in climacteric fruits and cut flowers.

2. THE ROLE OF ETHYLENE ON FRUITS AND CUT FLOWERS

2.1 Effect of ethylene on climacteric fruits

The marked rise in oxygen uptake and carbondioxide output, known to fruit physiologists as the "climacteric" rise, is a characteristic phenomenon of the ripening process. It marks a transition phase between development and the onset of functional breakdown, between ontogeny and senescence. In the course of fruit ripening, starch decreases from about 20 to 1 % and sugars increase from about 1 to 18 %. The nitrogen content in the edible portion of the ripe banana amounts to about 0.2 % of the fresh weight. Applied ethylene accelerates the chemical changes associated with ripening and causes a shift in the time axis of the onset of the climacteric rise.

Fruit softening is not taking place while the fruit is attached to the tree and while the stem is healthy. However, immediately after harvesting the processes leading to senescence are set into action and the typical climacteric course of respiration ensues, as shown in figure 1 for fruit placed at 20°C, and in figure 2 for fruit at 15°C. The effect of ethylene is accumulative so continuous exposure to a low concentration of ethylene throughout marketing can cause significant harm (Wills *et al.*, 2000).

Ethylene biosynthesis rises prodigiously in ripening climacteric fruit and is thought to coordinate many ripening phenomena (Abeles *et al.*, 1992). In general, C₂H₄ enhances taste and flavor by stimulating fruit ripening. Ethylene-treated carambola fruits had lower total soluble solids concentration, higher titratable acidity and pH, and a less preferred flavor and texture than control fruits (Miller and McDonald, 1997). The sensory qualities of fruitiness, greenness and softness of banana were evaluated by a trained analytical sensory panel (Scriven *et al.*, 1989). Banana fruit that were harvested mature green and naturally ripened were considered more fruity, less green and softer than fruit ripened with the aid of C₂H₄ (Fig. 1). They concluded, as have other authors, that exogenous C₂H₄ caused the peel and flesh to ripen out of phase, with the flesh ripening faster than the peel.

Figure 1: Effect of ethylene treatment on the subjective quality of banana fruit harvested mature-green and left untreated or exposed to ethylene to promote ripening (redrawn from Scriven *et al.*, 1989).

2.2 Effect of ethylene in cut flowers

Ethylene is an important factor in the postharvest life of cut flowers (Han and Miller, 2003), as it accelerates flower abscission and leaf yellowing (Joyce and Poole, 1993; Cameron and Reid, 2001; Celikel *et al.*, 2002). Reid *et al.* (1989) found that various cut rose cultivars show a range of responses to ethylene treatment, such as inhibition of opening, acceleration of opening, abnormal opening, petal and leaf abscission, and loss of petal gloss.

Esmail *et al.* (2005) on his research in Ethylene and anti-ethylene treatment effects on cut 'First Red' rose reported that treatment of cut 'First Red' rose with increasing concentrations of ethylene (1, 10, and 100 $\mu\text{l l}^{-1}$) progressively reduced postharvest life. Exposure to ethylene at 100 $\mu\text{l l}^{-1}$ reduced vase life by about 30%. Relative fresh weight of 'First Red' rose declined in a linear manner for the controls and the treated flowers. They further revealed that actual relative fresh weight loss was increased by the ethylene treatments and the differences became apparent on the first day of measurement after the ethylene treatment period. Flowers continued to absorb vase solution faster than it was lost until day three.

3. ANTI-ETHYLENE TREATMENTS

3.1 STS and its role on ethylene

The discovery that the action of ethylene could be inhibited by Ag^+ and the subsequent development of the stable, nontoxic, yet effective silver thiosulfate complex (Veen and Geijn, 1978) has provided an important commercial tool, still in widespread use, for preventing ethylene-mediated senescence and abscission in cut flowers.

Treatments with anti-ethylene compounds, such as STS (silver thiosulfate) and 1-MCP (1-methylcyclopropene), can effectively protect flowers against exogenous ethylene (Redman *et al.*, 2002; Hunter *et al.*, 2004). Pre-treatment of *Pelargonium peltatum* plants with 1 $\mu\text{l l}^{-1}$ 1-MCP for 2 h completely inhibited ethylene-induced petal abscission (Cameron and Reid, 2001). Celikel *et al.* (2002) reported that pre-treatment of oriental lilies (*Lilium* cvs 'Monalisa' and 'Stargazer') with 500 $\mu\text{l l}^{-1}$ 1-MCP for 18 h at 25 °C completely inhibited the ethylene response, but did not prevent normal senescence, wilting and abscission of open flowers. Application of 1-MCP at 25 nl l⁻¹ for 6 h to cut phlox flowers reduced flower abscission from 100% to 22% (Porat *et al.*, 1995). Similarly, flower abscission was reduced to 24% in flowers pre-treated with 1 mM STS for 2 h. Using the more mobile silver thiosulphate (STS) complex, Veen and Geijn (1978) demonstrated that inhibition of ethylene action greatly extends the life of cut carnations. This material has become an important commercial treatment for flowers sensitive to ethylene (Fig 2).

Figure 2: Effect of STS treatment (1 pmol/stem) on the life of “White Sim” carnations.

3.2 MCP and its role on ethylene

A new ethylene inhibitor was discovered by researchers at North Carolina State University. The compound, 1-methylcyclopropene (MCP), acts as a binding site competitor and is very promising as a postharvest treatment for both potted plants and fresh cut flowers. MCP is a gas, like ethylene. When plants are pre-treated with MCP and then exposed to ethylene-polluted environments, MCP appears to give ethylene protection equal to that obtained from STS, but without silver. 1-Methylcyclopropene (1-MCP) is an inhibitor of ethylene action that has been widely used to improve shelf life and quality of agricultural products. Also, this inhibitor has been used by scientists to make advances in understanding the role of ethylene in plants. At room temperature and pressure, the 1-MCP molecule is a gas with a weight of 54 g and a formula of C_4H_6 . 1-Methylcyclopropene has been known to occupy ethylene receptors such that ethylene cannot bind and initiate action (Sisler et al., 1999).

The response of ethylene-sensitive ornamentals to treatment with 1-MCP varies widely—in many cases, the inhibitory effects are quickly lost at room temperature and wears off quite quickly. In a study of ethylene-induced petal abscission in *Pelargonium*, for example, Cameron and Reid (2001) measured the response to ethylene by determining percentage petal abscission from detached flowers after a 2-h ethylene exposure. The half-life of 1-MCP activity was determined to be 2, 3, and 6 days after 1-MCP treatment at 25, 20, and 12°C, respectively, and there was no evidence for a residual effect. In another study by Mahnaz et al. (2012) on cut carnation, results showed that 1-MCP (at all concentrations), AOA (100 or 150 mg l⁻¹) and BA (30 mg l⁻¹) decreased ethylene production in the flowers of cut spray carnation ‘Optima’. They delayed the onset of wilting in the flowers.

On a work by Reid (unpublished), the role of 1-MCP on flowers of snapdragons were presented on figure 3 in which ethylene induced shattering was inhibited by pretreatment of the snapdragons with 600 ppb 1-MCP for 2 h. Muller et al. (2001) also showed that treatment with 1-MCP resulted in increased accumulation of ACC and reduced ethylene production during senescence in miniature rose flowers. They reported that no accumulation of ACC was observed after the treatment with 1-MCP and subsequent exposure to ethylene, suggesting that not only ACC oxidase but also ACC synthase was inhibited by 1-MCP.

Figure 3: Inhibition of ethylene-induced shattering by 1-MCP. Snapdragon flowers on right were pretreated with 600 ppb 1-MCP for 2 h and then both vases were exposed to 1ppm ethylene for 2 days (M. Reid, unpublished).

Recent data from experiments at the University of California, Davis, and at California packing houses and supermarkets have shown a dramatic increase in display life for MCP treated plants and flowers that are exposed to ethylene-contaminated environments (Anna *et al.*, 1997).

The role of MCP is not only limited to cut flowers but also works for fruits and vegetables. Researches are being conducted on fruits. Effects on ripe versus pre-ripe fruits (most previous studies have focused on the latter). Ripe fruit must remain responsive in order for benefits to be applicable with fresh-cut tissue. It also permits true 'on-vine' ripening (Figure 4).

Figure 4: Firmness of whole 'Sunrise Solo' papaya treated with 9 µl/l 1-MCP and stored at 20 °C. Shaded areas represent the period during which the fruit were acceptable for consumption (Ergun and Huber, 2004).

4. DISCUSSION AND CONCLUSION

The effects of ethylene in postharvest life of some horticultural crops were investigated by different researchers. The results all showed the evil effect of ethylene in such crops. It is one of the major constraints in the expansion of floriculture industry. The vase life of different cut flowers such as rose and carnations were highly affected by both endogenous and exogenous ethylene. The effects of ethylene are not limited to cut flowers but also extend to some fruits and vegetables. Its evil effect makes such fruits more perishable and shortens the shelf life of these crops. Moreover the impact of ethylene on these horticultural crops resulted in huge postharvest loss which can discourage all involved groups in the postharvest chain. Thus there should be an action to be taken in order to minimize this evil effect of ethylene.

Application of Silver thiosulphate (STS) and 1-MCP have a great role to withstand the impact of ethylene. Thus they give relief for those concerned with horticultural crops such as flowers, fruits and vegetables which are sensitive to ethylene action. However more researches have to be done about the level and time of application of these chemicals and a new chemical against ethylene should be investigated.

REFERENCES

- Anna M, Julie N, Michael R and Linda D (1997). New Ethylene Inhibitor Could Extend Flower Life. Perishables Handling Quarterly Issue No. 92.
- Abeles, F.B., Morgan, P.W., Saltveit ME (1992). Ethylene in Plant Biology, vol. 15, 2nd ed. Academic Press, San Diego, California.
- Cameron, A.C. and M.S. Reid, 2001. 1-MCP blocks ethylene-induced petal abscission of *Pelargonium peltatum* but the effect is transient. *Postharvest Biology and Technology*, 22: 169-177.
- Çelikel, F. G. and L.L. Dodge, M.S. Reid, 2002. Efficacy of 1-MCP (1-methylcyclopropene) and Promalin for extending the post-harvest life of Oriental lilies (*Lilium* × 'Mona Lisa' and 'Stargazer'). *Scientia Horticulturae*, 93: 149-155.
- Ergun and Huber. 2004. Factors influencing sensitivity of climacteric fruits. *J. Hortic. Sci.*, 69:184-192.
- Esmail Chamani, Ahmad Khalighi, Daryl C. Joyce, Donald E. Irving, Zabih Allah Zamani, Younes Mostofi and Mohsen Kafi. 2005. Ethylene and anti-ethylene treatment effects on cut 'First Red' rose. *Journal of Applied Horticulture*, 7(1):3-7
- Han, S.S. and J.A. Miller, 2003. Role of ethylene in postharvest quality of cut oriental lily 'Stargazer'. *Plant Growth Regulation*, 40: 213-222.
- Hunter, D.A., M. Yi, X. Xu and M.S. Reid, 2004. Role of ethylene in perianth senescence of daffodil (*Narcissus pseudonarcissus* L. 'Dutch Master'). *Postharvest Biology and Technology*, 32: 269- 280.
- Joyce, D.C. and M.C. Poole, 1993. Effects of ethylene and dehydration on cut flowering stems of *Verticordia* spp. *Australian Journal of Experimental Agriculture*, 33: 489-493.
- Kader, A.A., 1985. Ethylene-induced senescence and physiological disorders in harvested horticultural crops. *HortScience* 20, 54_ 57.
- Mahnaz Karimi, Moazzam Hassanpour Asil, Ghorbanali Nematzadeh and Hedayat Zakizadeh. 2012. EFFECTS OF ANTI-ETHYLENE TREATMENTS ON ETHYLENE PRODUCTION AND ANTIOXIDANT ACTIVITIES IN CUT SPRAY CARNATION. *Journal of Fruit and Ornamental Plant Research* Vol. 20(2) 2012: 173-182
- Miller, W.R., McDonald, R.E., 1997. Carambola quality after ethylene and cold treatments and storage. *HortScience* 32,897-899.
- Muller R., Stummann B.M., Sisler E.C., Serek M. 2001 Cultivar differences in regulation of ethylene production in miniature Rose flowers (*Rosa hybrid* L.). *ARTENBAUWISSENSCHAFT* 66: 34-38.
- Optimal Fresh (2001). The Fruit, Vegetable & Fresh Produce Storage Expert System. CSIRO Publishing, Collingwood Vic. Australia.
- Porat, R., Weiss, B., Cohen, L., Daus, A., Goren, R., Droby, S., 1999. Effects of ethylene and 1-methylcyclopropene on the postharvest qualities of 'Shamouti' oranges. *Postharvest Biol. Technol.* 15, 155_ 163.
- Redman, P.B., J.M. Dole, N.O. Maness and J.A. Anderson, 2002. Postharvest handling of nine specialty cut flower species. *Scientia Horticulturae*, 92: 293-303.
- Reid, M. (1992). Ethylene in Postharvest Technology. In. *Postharvest Technology of Horticultural Crops*. Publication 3311. University of California p. 97 – 108.
- Reid, M.S., R.Y. Evans and L.L. Dodge, 1989. Ethylene and silver thiosulphate influence opening of cut rose flowers. *Journal of the American Society for Horticultural Science*, 114(3): 436-440.

- Saltveit, M.E., 1999. Effect of ethylene on quality of fresh fruits and vegetables. *Postharvest Biol. Technol.* 15, 279_292.
- Scriven, F.M., Gek, C.O., Wills, R.B.H., 1989. Sensory differences between bananas ripened without and with ethylene. *HortScience* 24, 983–984.
- Seid H, hassan Beshir and Yitbarek W/hawariyat. 2013. Postharvest Loss Assessment of Commercial Horticultural Crops in South Wollo, Ethiopia “Challenges and Opportunities”. *Food Science and Quality Management*. Vol.17, 2013, pp 34-39.
- Sisler, E.C., M. Serek, C. Dupille, and R. Goren. 1999. Inhibition of ethylene responses by 1- Methylcyclopropene and 3-Methylcyclopropene. *Plant Growth Regul.* 27:105-111.
- Veen, H. and S.C. van de Geijn. 1978. Mobility and ionic form of silver as related to longevity of cut carnations. *Planta* 140:93–96.
- Wills, R.B.H., Warton, M.A. and Ku, V.V.V. (2000). Ethylene levels associated with fruit and vegetables during marketing. *Australian Journal of Experimental Agriculture* 40(3): 357 –492.