Proc. Fla. State Hort. Soc. 123:264–268. 2010.

Effect of Postharvest Application of 1-MCP on Basil Shoot Quality during Storage at Chilling Temperature

Adrian D. Berry, Steven A. Sargent*, and Donald J. Huber

University of Florida, IFAS, Horticultural Sciences Department, P.O. Box 110690, Gainesville, FL 32611-0690

Additional index words. *Ocimum basilicum*, postharvest technology, chilling injury

Basil (*Ocimum basilicum*) is one of the most temperature-sensitive of the fresh herbs, developing chilling injury symptoms within a few days of exposure to less than 12 °C, a common occurrence during commercial handling. The objective of this study was to evaluate the potential of increasing the tolerance of cut, basil shoots ('Nufar') to storage temperatures at 5 or 10 °C by postharvest immersion in an aqueous form of 1-methylcyclopropene (1-MCP), an ethylene-action inhibitor. Shoots were either left dry, dipped in deionized water or dipped in a 1-MCP solution of 500 µg·L^{-1} for 30 s. Dipped shoots were air-dried prior to packing in commercial, plastic clamshell containers and stored at 5 or 10 °C for 12 d. Shoots from all treatments retained good to excellent quality when stored up to 9 d at 5 or 10 °C. However, regardless of treatment, after 12 d at 5 °C basil shoots had significant necrosis due to chilling injury and were therefore unmarketable. Basil stored at 10 °C remained marketable during the 12-d storage period, but once transferred to 20 °C quality was significantly reduced. After 12 d at 5 or 10 °C there was no significant difference between treatments for the parameters tested. The following parameters were determined after 12 d at 5 and 10 °C, respectively: leaf hue angle was 121.7° and 119.8°; total chlorophyll content was 1.2 and 1.18 mg·g^{-1} fresh weight; moisture content was 89.32 and 89.58 %. These results showed that dipping basil shoots in a 1-MCP solution of 500 µg·L^{-1} did not reduce susceptibility to chilling injury during storage at 5 °C.

Basil (*Ocimum basilicum* L.) is a popular herb often marketed in bunches of shoots. As soon as the shoots are cut from the plant, senescence is induced, and commercial losses can be significant. Consequences of detachment include chlorophyll degradation and induction of stress-related hormones, especially ethylene (Ella et al., 2003). Basil is a tropical plant and is chilling sensitive when held below 12 °C during postharvest handling and shipping, and is expressed as darkened lesions on the leaves (Lang and Cameron, 1994). Ethylene plays an important role in senescence of detached leaves by promoting chlorophyll degradation (Able et al., 2003; Hassan and Mahfouz, 2010; Philosoph-Hadas et al., 1994). Ethylene, even at very low concentrations, exerts adverse effects on a number of non-climacteric fruits and vegetables (Wills et al., 1999).

1-Methylcyclopropene (1-MCP, SmartFresh Technology) has been shown to control ripening and senescence as well as other ethylene-dependent actions in various fruits and vegetables (Blankenship and Dole, 2003; Huber, 2008; Watkins, 2006). Mini cucumber (*Cucumis sativus* L.) treated with 1-MCP was protected against the effects of continuous ethylene exposure (10 µL·L^{-1}), maintaining firmness and epidermal color (Lima et al, 2005; Villalta et al., 2004).

1-MCP (gaseous formulation) has also been shown to extend the shelf-life of various detached leaves. Jiang et al. (2002) found that senescence of detached coriander (*Coriandrum sativum* L.) leaves was inhibited, and chlorophyll as well as protein degradation were significantly delayed by 1-MCP treatment. Application of 1-MCP delayed postharvest senescence of stored parsley (*Petroselium crispum* Mill.) leaves (Ella et al., 2003) and extended the postharvest shelf-life of mint (*Mentha longifolia* L.) (Kenigsbuch et al., 2007). 1-MCP had greater effect on floret tissue of broccoli (*Brassica oleracea* var. *italica* L.) than leafy tissue of pak choy (*Brassica rapa* var. *chinensis*). However, 1-MCP had minimal effect on either pak choy or broccoli shelf-life during tests that did not include applied ethylene treatments (Able et al., 2002). In general, the effects of 1-MCP on nonclimacteric commodities are more pronounced when they are also exposed to exogenous ethylene. During examination of six leafy, Asian vegetables, only mizuna (*Brassica rapa* var. *nipposinica*) and tatsoi (*Brassica rapa* var. *rosularis*) benefitted from 1-MCP treatment when stored in an environment free of exogenous ethylene (Able et al., 2003). Since ambient ethylene levels at retail are often sufficient to cause reductions in postharvest shelf life (Wills et al., 1999, 2000), 1-MCP may have potential for application to ethylene–sensitive, nonclimacteric commodities.

Chilling injury (CI) has been associated with ethylene synthesis in climacteric (Ben-Amor et al., 1999) and non-climacteric fruit (McCollum and McDonald, 1991); however, the process of CI is not well understood. 1-MCP has been shown to dramatically reduce postharvest CI in climacteric fruits such as melons (Ben-Amor et al., 1999) and persimmon (Salvador et al., 2004) and in non-climacteric fruits such as pineapple (Selvarajah et al., 2001). However, 1-MCP increased CI symptoms in other fruits such as 'Shamouti' orange (Porat et al., 1999) and 'Fortune' mandarin (Lafuente et al., 2003).

Recently, an aqueous form of 1-MCP was very effective for treating tomato and avocado (Choi et al., 2008; Pereira et al., 2008). Aqueous treatment time is very short (1 min) compared to 12 to 24 h required for the gaseous form and, therefore, has potential for use during packing operations. The aim of the present study was to evaluate the effect of postharvest application of aqueous

Acknowledgment. The authors thank Chuck Obern of C&B Farms for providing the plant material.

*Corresponding author; phone: (352) 273-4802; email: sasa@ufl.edu

1-MCP on chilling injury development, ethylene production, and quality changes during cold storage of basil shoots.

Materials and Methods

'Nufar' basil shoots were harvested in Nov. 2009 from a commercial field (C&B Farms, Clewiston, FL), placed in a cooler with ice, held overnight at 24 °C (in the cooler), then delivered to the Postharvest Horticulture Laboratory at UF. The basil was divided into three lots (approximately 20 shoots, 18 cm in length) for the following treatments: shoots were left dry (no dip), immersed in deionized water or aqueous 1-MCP at 500 μg·L^{-1} [active ingredient (a.i.)] for 30 s at 20 °C, then air dried. The 1-MCP solution was prepared from the powder formulation AFxRD-300 (2% a.i., AgroFresh, Inc., Philadelphia, PA) dissolved in deionized water, which was gently swirled for 1 min and applied 10 to 45 min after preparation (Choi et al., 2008). After air drying, three basil shoots were placed in each of three commercial, unvented plastic clamshells (10.2 × 17.8 × 2.5 cm) from each treatment, and then stored at 5 and 10 °C for 12 d. After 12 d at 5 or 10 °C all basil clamshells were transferred to 20 °C for 24 h to elucidate chilling injury symptoms.

Quality evaluations. Evaluations of overall appearance, wilting, leaf color, necrosis (darkened areas), decay and condensation were conducted at 0, 4, 9, 12 d and 12 d at 5 or 10 °C plus 24 h at 20 °C. For each assessment, subjective ratings were assigned from 1 to 5 as follows: 1 = very poor; 2 = poor; 3 = fair (limit of marketability); 4 = good; 5 = excellent (Fig. 1).

Respiration and ethylene production. To determine ethylene and respiration rates, individual basil leaves (n=3) from the water and 1-MCP dip treatments were placed inside 130-mL glass containers and stored at 5 or 10 °C for 6 d. At 0, 4, and 6 d the glass containers were sealed for 2 to 3 h; then a 3-mL headspace sample was taken and analyzed by a Varian gas chromatograph (CP-3800, Middelburg, The Netherlands) equipped with Valco valves system (Houston, TX). The CO_2 was separated in a Hayesep Q column and detected by a thermal conductivity detector, while ethylene was separated in a Molsieve column and Pulse Discharge Helium Ionization Detector. The GC was calibrated daily with a gaseous standard mix composed of 1.1 ppm C_2H_4, 1.03% CO_2, 19.98% O_2 and N_2 balance.

Leaf color. At 0, 9, 12, and 12 d at 5 or 10 °C plus 24 h at 20 °C external color was measured on the upper epidermis using a chromameter (CR 400 series, Minolta Co., Japan) operating with a *C* illuminant and 11-mm-diameter light projection tube aperture. The chroma meter was calibrated with a white standard tile. The CIELAB values L* (lightness), a* and b* were measured. The results are presented as hue angle (90° hue angle = yellow; 180° = green), which was calculated from the measured a* and b* values using the formula h=arc tangent (b*/a*)

Chlorophyll. Individual leaf samples were taken for chlorophyll determination at 0, 9, 12, and 12 d at 5 or 10 °C plus 24 h at 20 °C and frozen (–30 °C) for future analysis. Basil leaf tissue (0.2 g) was placed inside vials filled with 10 mL of *N,N*-dimethylformamide, stored at 5 °C for 36 h, and then measured at 625, 647, and 664 nm with a spectrophotometer (PowerWave XS2, Biotek Instruments, Winooski, VT).

Moisture content. Basil leaf moisture content was measured at 0, 12, and 12 d plus 24 h at 20 °C. Three replications for each treatment and temperature were measured. Approximately 8 g of basil leaf tissue was weighed, air-dried at 60 °C for 24 h, then weighed again to calculate moisture content on a fresh weight basis.

Results and Discussion

Quality evaluations. Basil from all postharvest treatments maintained excellent (rating = 5) overall quality during 4 d at 5 or 10 °C. Overall quality decreased (3.5 to 4.3) for basil stored for 9 d at 5 °C mainly due to necrosis (Fig. 2). After 12 d, basil from all postharvest treatments stored at 10 °C and the 1-MCP-treated basil stored at 5 °C retained acceptable overall quality. However, after transfer to 20 °C for 24 h all basil was rated unmarketable. Throughout storage there were minimal differences between postharvest treatments. Chilling injury symptoms (necrosis) developed sooner and were more evident on basil stored at 5 °C.

Respiration and ethylene production. Respiration rates were similar between water and 1-MCP treated basil stored at either 5 or 10 °C. Basil leaves exhibited lower respiration when stored at 5 °C. During the 6-d evaluation at 5 °C, respiration increased from 68 to 110 for basil dipped in 1-MCP and 54 to 113 mg·kg^{-1} per hour for basil dipped in water. At 10 °C respiration increased from 154 to 303 for basil dipped in 1-MCP and from 178 to 332 mg·kg^{-1} per hour for basil dipped in water at day 1 and 6, respectively (Fig. 3a). The increase in respiration after 6 d was most

Fig. 1. Quality rating scale: 1= very poor; 2 = poor; 3 = fair; 4 = good; 5 = excellent.

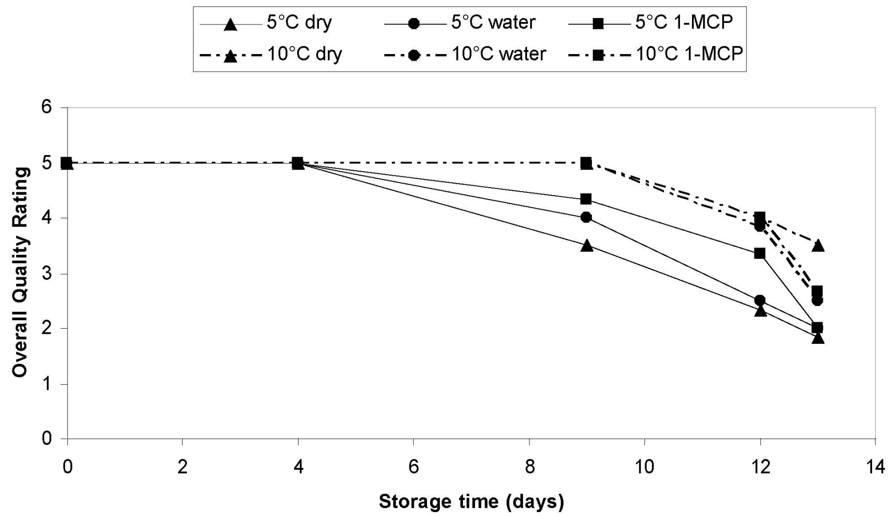

Fig. 2. Quality ratings of basil stored for 12 d at 5 or 10 °C plus 24 h at 20 °C.

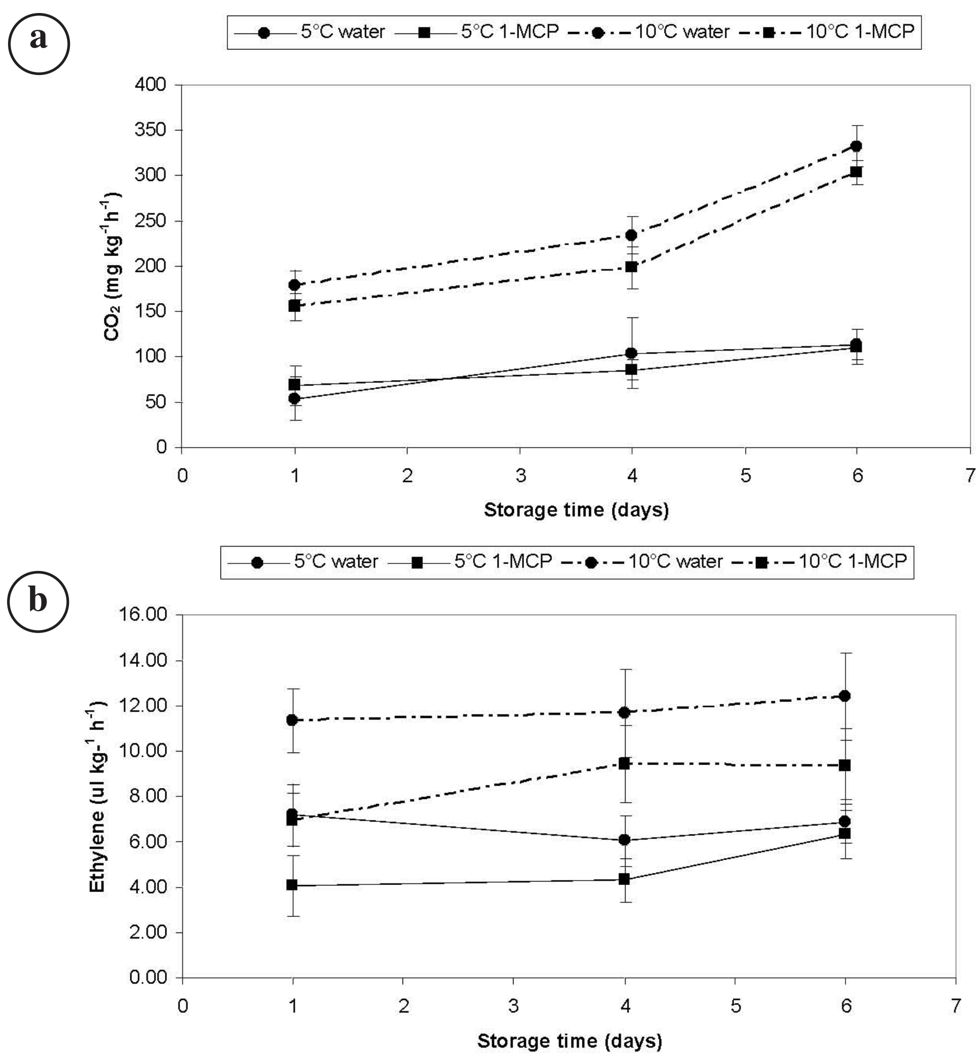

Fig. 3. Respiration rate (a) and ethylene production (b) of basil during 6 d at 5 or 10 °C.

likely due to basil leaf senescence and possible decay organisms.

After 1 d storage, 1-MCP treated basil produced slightly less ethylene than basil dipped in water at either 5 or 10 °C. However, during subsequent storage ethylene rates were only related to temperature, being lower at 5 °C.

Leaf color. Basil leaf hue angle was similar between postharvest treatments throughout the storage period. Basil stored at 10 °C had lower hue values after 12 d, indicating leaf yellowing. Hue angles ranged from 123.72 to 121.60 on day 0 to 120.76 and 113.59° on day 12 plus 24 h at 20 °C, depending on treatment and temperature (Table 1).

Chlorophyll content. 1-MCP treated basil maintained higher chlorophyll content throughout the storage period. Chlorophyll values were similar for basil stored at either temperature and decreased during storage (Table 1).

Moisture content. Moisture content was similar between treatments at 5 or 10 °C. Basil stored at 10 °C maintained slightly higher moisture content as compared to basil stored at 5 °C. Moisture content of basil decreased during storage, from 94% to 87% and 94% to 91% at 5 and 10 °C, respectively (Table 2).

The results of this research indicate that postharvest immersion of basil shoots in 1-MCP at 500 μg·L^{-1} had no significant effect on alleviation of chilling injury symptoms. Basil stored at 5 °C developed darkened lesions by 6 d, thereafter increasing in severity and becoming unmarketable by 9 d, irrespective of 1-MCP treatment. These findings were similar to reports for mint (Kenigsbuch et al., 2007), watercress (Bron et al., 2005), and pak choy (Able et al., 2002) leaves, which showed that, in an ethylene-free environment, 1-MCP had little or no effect on increasing postharvest life. By packaging basil in unvented, clamshell containers, shippers can expect some protection against chilling injury up to 9 d at 5 °C and 12 d at 10 °C. There is minimal research reported that investigates the effects of 1-MCP application on quality and shelf life of fresh, detached leafy vegetables and herbs. Future studies should evaluate the application of different 1-MCP concentrations and immersion times for pre- or postharvest application to basil on subsequent quality.

Table 1. Leaf color (hue angle) of basil stored for 12 d at 5 or 10 °C plus 24 h at 20 °C.

Storage time (days)	Treatment	Hue angle (h*) Storage temp 5	10	Chlorophyll content (mg/g) Storage temp 5	10
0	Dry	121.60	121.60	1.41	1.32
	Water	123.72	123.72	1.26	1.17
	1-MCP	122.93	122.93	1.37	1.30
9	Dry	121.05	121.81	1.26	1.26
	Water	121.57	122.06	1.14	1.14
	1-MCP	121.47	122.72	1.32	1.29
12	Dry	122.33	119.64	1.21	1.16
	Water	121.70	120.48	1.12	1.10
	1-MCP	121.08	119.28	1.27	1.27
12+24 h at 20 °C	Dry	121.12	113.59	1.16	1.15
	Water	120.76	118.40	1.02	1.11
	1-MCP	121.38	116.86	1.27	1.26

Table 2. Moisture content of basil stored for 12 d at 5 or 10 °C plus 24 h at 20 °C.

Storage time (days)	Treatment	Moisture content (%) 5 (°C)	10 (°C)
0	Dry	94.24	94.24
	Water	94.58	94.58
	1-MCP	94.22	94.22
12	Dry	87.39	93.07
	Water	87.88	93.40
	1-MCP	86.24	89.12
12+24h at 20 °C	Dry	87.54	93.48
	Water	87.84	93.34
	1-MCP	86.15	88.93

Literature Cited

Able, A.J., L.S. Wong, A. Prasad, and T.J. O'Hare. 2002. 1-MCP is more effective on a floral brassica (*Brassica oleracea* var. *italica* L.) than a leafy brassica (*Brassica rapa* var. *chinensis*). Postharvest Biol. Technol. 26:147–155.

Able, A.J., L.S. Wong, A. Prasad, and T.J. O'Hare. 2003. The effects of 1-methylcyclopropene on the shelf-life of minimally processed leafy Asian vegetables. Postharvest Biol. Technol. 27:157–161.

Ben-Amor, M., B. Flores, A. Latché, M. Bouzayen, J.C. Pech, and F. Romojaro. 1999. Inhibition of ethylene biosynthesis by antisense ACC oxidase RNA prevents chilling injury in Charentais cantaloupe melons. Plant Cell Environment 22:1579–1586.

Blankenship, S.M. and J.M. Dole. 2003. 1-Methylcyclopropene: a review. Postharvest Biol. Technol. 28:1–5.

Bron, I., D. Vitti, R. Kluge, M. Arruda, A. Jakomino, and G. Lima. 2005. Influence of low temperature storage and 1-methylcyclopropene on the conservation of fresh-cut watercress. Braz. J. Food Tech. 8:121–126.

Choi, S.T., P. Tsouvaltzis, C.I. Lim, and D.J. Huber. 2008. Suppression of ripening and induction of asynchronous ripening in tomato and avocado fruits subjected to complete or partial exposure to aqueous solutions of 1-methylcyclopropene. Postharvest Biol. Technol. 48:206–214.

Ella, L., A. Zion, A. Nehemia, and L. Ammon. 2003. Effect of the ethylene action inhibitor 1-methylcyclopropene on parsley leaf senescence and ethylene biosynthesis. Postharvest Biol. Technol. 30:67–74.

Hassan, F. and S. Mahfouz. 2010. Effect of 1-methylcyclopropene (1-MCP) treatment on sweet basil leaf senescence and ethylene production during shelf-life. Postharvest Biol. Technol. 55:61–65.

Huber, D.J. 2008. Suppression of ethylene responses through application of 1-methylcyclopropene: a powerful tool for elucidating ripening and senescence mechanisms in climacteric and nonclimacteric fruits and vegetables. HortScience 43:106–111.

Jiang, W., Q. Sheng, X. Zhou, M. Yhang, and X. Liu. 2002. Regulation of detached coriander leaf senescence by 1-methylcyclopropene and ethylene. Postharvest Biol. Technol. 26:339–345.

Kenigsbuch, D., D. Chalupowicz, Z. Aharon, D. Maurer, and N. Aharoni. 2007. The effect of CO_2 and 1-methylcyclopropene on the regulation of postharvest senescence of mint, *Mentha longifolia* L. Postharvest Biol. Technol. 43:165–173.

Lafuente, M.T., L. Zacarias, M.A. Martínez-Téllez, and A.G. Sanchez-Ballesta. 2003. Phenylalanine ammonia-lyase and ethylene in relation to chilling injury as affected by fruit age in citrus. Postharvest Biol. Technol 29:308–317.

Lang, D.D., A.C. Cameron. 1994. Postharvest shelf-life of sweet basil (*Ocimum basilicum*). HortScience 29:577–584.

Lima, L.C., B.M. Hurr, and D.J. Huber. 2005. Deterioration of beit alpha and slicing cucumbers (*Cucumis sativus* L.) during storage in ethylene or air: Responses to suppression of ethylene perception and parallels to natural senescence. Postharvest Biol. Technol 37:265–276.

McCollum, T.G. and E.E. McDonald. 1991. Electrolyte leakage, respiration, and ethylene production as indices of chilling injury in grapefruit. HortScience 26:1191–1192.

Pereira, M., S.A. Sargent, J. Crane, and D.J. Huber. 2008. Postharvest applications of aqueous and gaseous 1-methylcyclopropene delay ripening in 'Monroe' avocado. HortScience 43:1088 (Abstr.).

Porat, R., B. Weiss, L. Cohen, A. Daus, R. Goren, and S. Droby. 1999. Effects of ethylene and 1-methylcyclopropene on the postharvest qualities of 'Shamouti' oranges. Postharvest Biol. Technol 15:155–163.

Philosoph-Hadas, S., S. Meir, and N. Aharoni. 1994. Role of ethylene in senescence of watercress leaves. Physiol. Plant. 90:553–559.

Salvador, A., L. Arnal, A. Monterde, and J. Cuquerella. 2004. Reduction of chilling injury symptoms in Persimmon fruit cv. 'Rojo Brillante' by 1-MCP. Postharvest Biol. Technol 33:285–291.

Selvarajah, S., P. Bauchot and P. John 2001). Internal browning in cold-stored pineapples is suppressed by a postharvest application of 1-methylcyclopropene. Postharvest Biol. Technol 23:167–170.

Villalta, A.M. and S.A. Sargent. 2004. Response of beit alpha-type cucumbers (*Cucumis sativus* L. 'Manar') to continuous ethylene exposure. Proc. Fla State Hort. Soc. 117:368–372.

Watkins, C.B. 2006. The use of 1-methylcyclopropene (1-MCP) on fruits and vegetables. Biotechnol. Adv. 24:389–409.

Wills, R.B.H., V.V. Ku, D. Shohet, and G.H. Kim. 1999. Importance of low ethylene levels to delay senescence of non-climacteric fruit and vegetables. Aust. J. Exp. Agr. 39:221–224.

Wills, R.B.H., M.A. Warton, and V.V. Ku. 2000. Ethylene levels associated with fruit and vegetables during marketing. Aust. J. Exp. Agr. 40:465–470.