Effects of EthylBloc Sachets on Post-Harvest Quality of Cuttings and Liners

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Executive Summary

- 1-MCP applied as EthylBloc™ sachets in simulated and actual shipping containers greatly improved the post-harvest quality of *Lantana* and *Euphorbia* unrooted cuttings and rooted liners exposed to ethylene gas or treated with Florel (ethephon).
- For ethylene-sensitive plants, this technology provides a good insurance against negative effects of ethylene (leaf and flower drop) during shipping. At 17.5 cents per sachet (35c per shipping box with two sachets), this is an affordable technology.
- 1-MCP was shown to diffuse through plastic bags and within cardboard boxes. Perforations in bags were not needed for 1-MCP to be effective with bagged cuttings. The EthylBloc sachets should be easier to incorporate into the supply process than applying EthylBloc as a gas treatment.
- Avoid applying Florel to stock plants or liners at least a week before shipping ethylene-sensitive plants, otherwise ethylene levels will be released in the shipping container which may affect not only the treated liners or cuttings, but also other plants in the same container.
- There are a small number of cultivars that are highly sensitive to ethylene as vegetative cuttings or liners, including lantana, Euphorbia, begonia, and portulaca (see other reports for details). Cuttings are more ethylene-sensitive than liners. However, there are many plants that are sensitive to ethylene once they have initiated flowering (think of greenhouse crop response to Florel) and will respond by dropping flowers and/or aborting flower buds. Therefore, when shipping pre-finished, flowering liners (for example, where flowering was initiated with long-day lighting), exposure to ethylene during shipping can negatively affect a wide number of crop species.

Introduction

Central and South America have become the primary providers of plant cuttings to the U.S. The time interval between when the plants are harvested and the time they arrive in the U.S. for rooting is approximately 2-3 days (Rapaka and Faust, 2006). The conditions under which the cuttings are exposed during storage and shipping are extremely important to ensure rooting success in propagation. During shipping, cuttings can be exposed to stresses including extreme temperatures and ethylene exposure (Rapaka and Faust, 2006). Ethylene is a naturally occurring hormones and is unique in that it is a gas (Wallace, 2006). It is responsible for plant ripening and leaf senescence

and abscission (leaf drop). Growers can use ethylene promote fruit or flower ripening, or enhanced branching using ethylene gas or Florel™ (ethephon) sprays. However, in cutting production ethylene exposure during shipping is generally a negative factor to be avoided.

1-MCP (1-methylcyclopropene) was first developed by North Carolina State University (Raleigh) and was later licensed to Floralife (Walterboro, SC) for use in the floral market (Wood, 2002) where it is sold as EthylBloc™ (http://www.floralife.com/industry_professionals/our_products/ethylbloc.asp). Rohm and Haas/AgroFresh received EPA certification in 2002 to market 1-MCP (Wood, 2002). 1-MCP works as a competitive inhibitor to the ethylene receptor binding sites on the plant. This prevents the plant from responding to endogenous and exogenous (internal and external) sources of ethylene (Wood, 2002). 1-MCP is considered biologically safe by the EPA and does not form residues on the plants or fruits (Wood, 2002). Use of 1-MCP was first tested on fruits such as tomatoes, papaya, mangoes, melons, and apricots; however, it is now being used on flowering plants that are sensitive to ethylene.

These commercial rooted liners of Euphorbia 'Diamond Frost' were shipped to the University of Florida in October 2007 without 1-MCP treatment, and show temporary epinasty (downward-bending leaves) in response to ethylene during shipping. Within two days on the greenhouse bench, plants appeared completely normal.

Lantana camara and *Euphorbia* 'Diamond Frost' are floricultural crops known to be ethylene sensitive as cuttings or liners. *Lantana camara* is indigenous to tropical American regions and is known for its vibrant colored flowers. It is an evergreen plant that thrives in sunlight and can reach up to six feet in height (Pherson, 2002). www.provenwinners.com reports that *Euphorbia* cultivar 'Diamond Frost' is a day-neutral plant with proliferous white flowers, and notes that liners of "Diamond Frost can have an adverse reaction to shipping in a box", although this reaction is normally temporary.

The objectives of this study were to determine

(1) The effects of 1-MCP and ethylene gas on leaf abscission in *Lantana camara* and *Euphorbia* cuttings and rooted liners. For this objective, we aimed to determine if 1-MCP was able to penetrate plastic bags, because cuttings are normally shipped in perforated bags, and to evaluate effects of 1-MCP on root number for cuttings or time to flower for rooted liners.
(2) The release rate of 1-MCP from Ethylbloc sachets.
(3) The effects of 1-MCP and Florel on cuttings and liners in *Lantana camara.* Florel is an ethylene-producing plant growth hormone (active ingredient ethephon) that is often applied as a spray in stock plant and liner production to enhance branching and remove flower buds. However, Florel applications applied before shipping can cause negative effects because of resulting production of ethylene in closed shipping containers.
(4) The effects of 1-MCP and Florel on *Lantana* liners during two FedEx overnight shipments using commercial corrugated boxes.

Materials and Methods

Experiment 1 (Effect of 1-MCP and ethylene gas on cuttings and liners)

Plant material

Unrooted cuttings of *Euphorbia sp* and *Lantana camara* cv. 'Samantha' were harvested from stock plants grown at the University of Florida greenhouses. Rooted liner trays of both species were also taken from the greenhouse, cut into 3 x 4 cell sections and moved into the postharvest evaluation room (Figure 1).

Stock Plants- *Lantana*

Liner Tray- *Euphorbia*

Figure 1 Plant material before treatment

Experiment Design

In the postharvest evaluation room, unrooted cuttings from each one of the species were randomly placed into resealable plastic Zip-Lock^{TM} type bags (16.8 x 14.9 cm) that were complete closed, complete open or close but perforated with 30 holes on each side of the bag. 216 unrooted cuttings from both *Euphorbia* and *Lantana camara* 'Samantha' were used, randomly divided into eighteen groups of 12 cuttings per bag.

Two bags from each type and one liner from each species were placed into six 10-gallon (0.0379 m^3) clean glass aquarium tanks. The tank was closed with a clean glass lead and completely sealed using 6 metal clamps. A rubber stopper was firmly secured to the lid with 100 % Silicone Aquarium Sealant (Figure 2). A total of six tanks were evaluated, with three tanks containing 1-MCP sachets and three tanks without 1-MCP.

Figure 2 Glass tanks sealed with metal clamps with unrooted cuttings (bags) and liners.

1-MCP treatment

Two EthylBloc sachets (Rohm and Haas Company, Philadelphia, PA, Concentration (0.013-0.015% 1-Methylcyclopropene, 99.6-99.8% Dextrose) were dipped in deionized water (according to label instructions) and immediately placed into the tanks before closing. Tanks were closed for 48 hours and all tanks were closed at the same time. Tanks were maintained at 21^{o}C in the dark.

Ethylene measurements

One hour after tanks were sealed, ethylene gas was injected at a consistent concentration to every tank. 9 ml of ethylene were taken from a compressed ethylene tank (99.5% purity) using a 10 ml syringe. The gas was then injected into a tightly sealed 0.48 l mason jar through a rubber septum. Two ml of the air-ethylene mixture were drawn from the jar and immediately injected into a tank through the septum. The jar was opened, aerated and resealed. This procedure was repeated for each one of the tanks. Ethylene concentration in the tank was monitored at regular intervals through the 48 hour period by taking 1 ml of air sample from the tank using a 1 ml a syringe. Samples were analyzed with gas chromatograph (Hewlett-Packard 5890 Series II). Ethylene level averaged 0.9 ppm, decreasing from 1.25 ppm at 1 h to 0.8 ppm at 48 h, with no difference in ethylene levels between the tanks with and without 1-MCP.

Plant assessments

After 2 days, tanks were opened outdoors and the number of dropped leaves from each tray of liners and each bag of cuttings was counted and recorded.

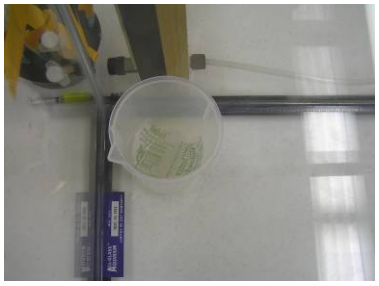
The cuttings were immediately stuck into 102-count liner trays filled with Pindstrup propagation media and placed under mist in the greenhouse. All 12 cuttings from each bag were randomly stuck into 3 x 4 cell sections of the trays. Control cuttings taken from stock plants in the greenhouse and not stored were also transplanted into trays (three replicates of 12 cuttings). The cuttings were evaluated for root development twelve days after they were planted.

To evaluate performance of stored rooted liners, 4.5-in (11.5 cm) diameter azalea pots were filled with Pindstrup peat medium and watered thoroughly. Six rooted liners from each twelve-liner tray were randomly selected and planted. Liners from the greenhouse that had not been used in the experiment were also used as a control. The control consisted of three groups of six liners for each species for a total of thirty six control plants. A total of 108 pots, thirty-six for the experimental group and thirty-six for the control group, were used for planting the liners. Eight days after being planted, the *Euphorbia* were evaluated for flower development. The number of cyathea was counted. The *Lantana* were evaluated fifteen days after being planted for the number of flower buds formed. The date of the first open flower was recorded for every plant.

Experiment 2 (Release rate of 1-MCP from Ethylbloc^{TM} sachets)

This experiment was conducted to determine the rate of 1-MCP released inside the tanks on experiment one. 1-MCP concentration was monitored in a 48 hour period from clean glass sealed tanks containing EthylBloc sachets with no plant material inside. The EthylBloc sachets were placed into a 250 mL plastic beaker inside each tank (Figure 3). Once the tank was sealed with the clamps, a 10 mL syringe was placed through the rubber septum and 10 mL of warm distilled water were slowly released onto the sachets,

covering all of its surface area. 1 ml air samples were taken with a 1 ml syringe from the tanks and analyzed with a gas chromatograph Hewelett Packard 5890 series II. The tanks were closed for 48 hours and the 1-MCP levels were measured after 2 minutes, 20 minutes, 1 hour, 24 hours, and 48 hours. Two samples were taken from each tank at each sampling time.



Example EthylBloc sachets inside Glass Tank

Syringes used to measure ethylene levels

Measuring 1-MCP levels inside tanks

Figure 3 EthylBloc sachets and glass tanks for 1-MCP determination

Experiment 3 (Effect of 1-MCP and Florel (ethephon) on cuttings and liners of *Lantana*)

Plant material

Stock plants of *Lantana camara* 'Samantha' were sprayed to run off with 500 ppm of Florel, and 62.5 mL of solution per 25-cm-diameter pot. Cuttings were harvested 24 hours after the Florel application. A total of 356 cuttings were taken from the stock plants that were sprayed with Florel and 356 cuttings were taken from 32 stock plants that had no Florel application. All stock plants were the same age.

Experiment design

Sprayed and unsprayed cuttings were taken to the postharvest room and randomly placed into open plastic Zip-Lock bags and then into clean glass tanks. The bags were left open and were laid on their side in the bottom of the tank (Figure 4). The tanks were sealed as in experiment 1 and allowed to sit for forty-eight hours.

Four tanks contained Florel-sprayed liners and cuttings from Florel-sprayed stock plants, and four tanks contained non-sprayed cuttings and liners. In a factorial design with Florel sprays, two replicate tanks per Florel treatment contained either two EthylBloc sachets or no EthylBloc sachets. Eighty-nine cuttings were placed into each tank. Two plastic bags were used to hold the cuttings in each tank (for a total of 16 bags) and approximately half (44 or 45) of the cuttings were placed into each bag.

Ethylene measurements

Ethylene concentration in the tanks was monitored through the 48 hour period by taking 1 ml of air sample from the tank using a 1ml a syringe. Samples were analyzed with gas chromatograph (Hewlett-Packard 5890 Series II (c. 1987). Ethylene levels were measured after three, twenty-one, twenty-seven, forty-five, and forty-eight hours of closure.

Plant assessments

After 48 h in the tanks, the cuttings were stuck into liner trays using Pindstrup peat growing medium. On Day 13 of the experiment, the cuttings were evaluated for rooting and the number of primary roots was determined.

Figure 4 Tank with two bags of cuttings and two EthylBloc sachets

Experiment 4 (Effect of 1-MCP and Florel (ethephon) on liners of *Lantana* in commercial corrugated shipping boxes)

Six 102-count *Lantana* liner trays were sprayed with Flore one day prior to the experiment. Line trays were placed in 0.073m^3 Proven Winners™ cardboard boxes. Cardboard inserts were made from corrugated sheets taped to the inside of the box walls to separate four compartments. The liner trays were cut in half and one half was placed in both the second and fourth compartments. Empty trays of soil the same size as the plant trays were secured inside paper bags and placed in the first and third compartments. One HOBBO data logger (Onset Computer Corporation) was taped to the inside top wall of each box to record temperature changes during shipping. Two EthylBloc sachets were dipped in distilled water and then placed into the top (first) compartment of three of the six boxes.

The boxes were sealed and shipped within on hour via Fedex to Knox Nursery in Winter Garden, FL (approximately 100 miles from Gainesville, FL). The boxes were received at Knox Nursery approximately 16 hours after being ship from the University. Boxes were shipped back via FedEx to the University the next day.

The boxes were received at the University of Florida approximately fifty hours after the initial packaging of the boxes. Two gas samples were drawn from each tank with a 1ml syringe. One sample was analyzed for 1-MCP and the other for ethylene using gas chromatography. The boxes were then opened and 17 plants from each box were randomly selected and planted into 4.5-in (11.5-cm) diameter pots. The number of intact leaves was determined for each potted plant and flower development was evaluated after two weeks.

Results

Experiment 1. Effect of 1-MCP and ethylene on leaf abscission of cuttings and liners

1-MCP greatly reduced leaf abscission in *Lantana* and *Euphorbia* unrooted cuttings and liners when they were exposed to an average 0.9 ppm ethylene for 48 hours. Cuttings in sealed glass tanks with EthylBloc sachets retained almost 100% of their leaves. Cuttings stored in sealed glass tanks for the same amount of time without EthylBloc sachets had drastic leaf abscission. There were no abscised leaves from the *Lantana* cuttings when 1-MCP was used (with an average 5.27 intact leaves remaining on cuttings). In contrast, an average of 3.27 leaves abscised per cutting when no 1-MCP was used (over 62% leaf drop). An average of 1.77 leaves (43%) fell from *Euphorbia* cuttings in the bags when no 1-MCP was used and an average of 0.08 leaves per cutting fell from cuttings in bags when 1-MCP was used, out of a total 4.08 intact leaves on 1-MCP cuttings.

Lantana cuttings treated with 1-MCP on left; no 1-MCP on right

Euphorbia cuttings treated with 1-MCP on right; no 1-MCP on left

Figure 5. Effect of EthylBloc sachets on *Lantana* (left) and *Euphorbia* (right) cuttings stored for 48 hours with an average 0.9 ppm ethylene.

Potted *Lantana* liners
Control (not stored, left);
With 1-MCP (center)
No 1-MCP (right)

Potted *Euphorbia* liners
Control (not stored, left);
With 1-MCP (center)
No 1-MCP (right)

Figure 5. Effect of EthylBloc sachets on *Lantana* (left) and *Euphorbia* (right) rooted liners (bottom) stored for 48 hours with an average 0.9 ppm ethylene.

Effect of plastic bags on 1-MCP penetration.

1-MCP greatly reduced the number of abscised leaves in cuttings, regardless of whether cuttings were in open, closed, or perforated bags with both speces (Figure 7). The 1-MCP and ethylene gases were therefore able to penetrate the closed bags.

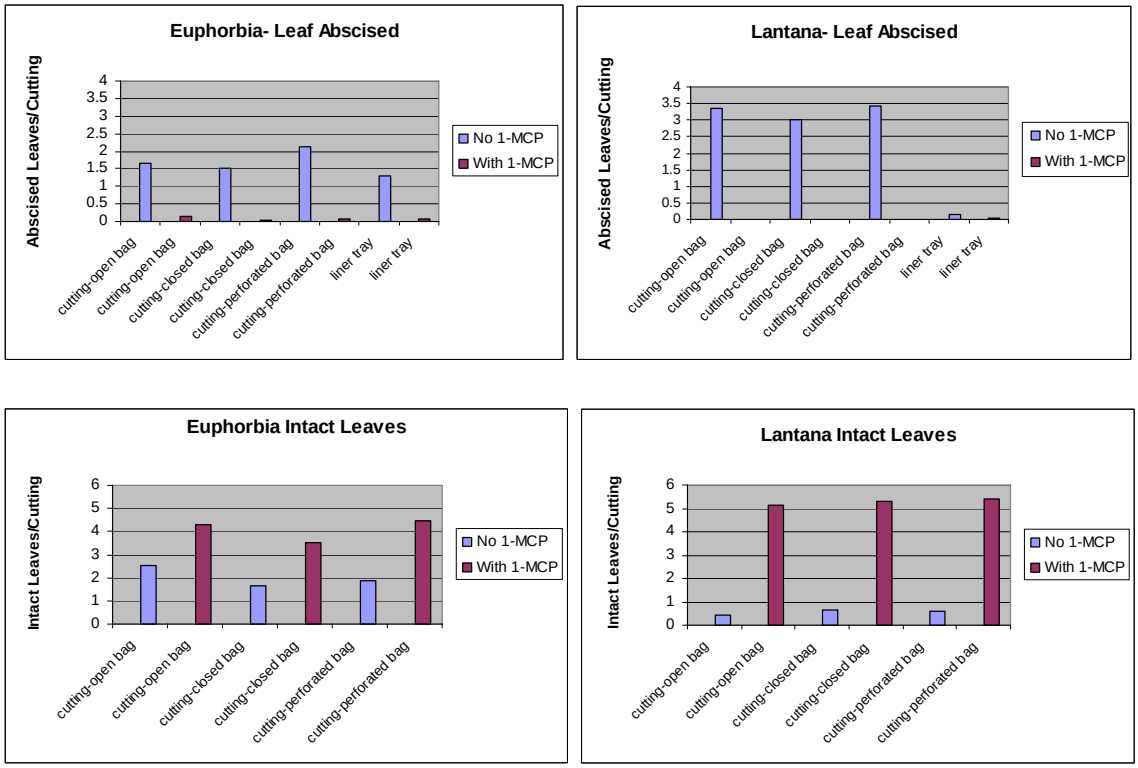


Figure 6 Number of abscised and intact leaves of *Euphorbia* and *Lantana* cuttings and liners with and without 1-MCP sachets, exposed to an average 0.9 ppm ethylene for 48 hours. Cuttings were in bags that were open ("cutting-open bag"), closed ("cutting-closed bag"), or perforated("cutting-perforated bag"). Rooted liners ("liner tray" in top two figures) were not placed in bags.

Effect of 1-MCP on Rooting

Rooting was evaluated on Day 14 of the experiment. Storage plus ethylene and 1-MCP decreased the number of primary roots in *Euphorbia* cuttings by 45% compared with unstored cuttings (taken directly in the greenhouse and immediately stuck), with only an average of 12 roots/cutting compared with 24 roots/cutting for the control groups. The plants stored with ethylene and 1-MCP had over twice the number of primary roots (12.0) compared with plants exposed to the ethylene and no 1-MCP treatment (5.8).

Lantana cuttings stored with ethylene and 1-MCP had the same number of roots per cutting (5.4) as unstored control cuttings. Most *Lantana* cuttings stored with ethylene and no 1-MCP died.

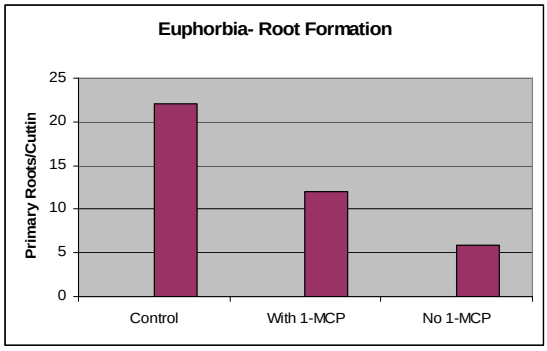
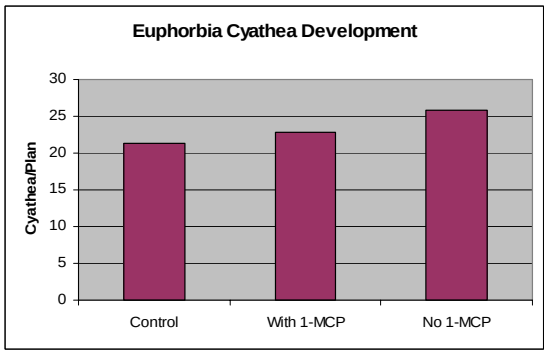


Figure 7 Effect of 1-MCP on *Euphorbia* root development

Effect of 1-MCP on Flower Development in Stored Rooted Liners

The number of flowers (cyathea) on *Euphorbia* potted plants was counted on Day 8 of the experiment. Storage treatments did not affect number of cyathea (Figure 9), and there was considerable variability between plants (ranging from 7 to 49 flowers/plant within a single treatment).

Lantana potted plants were evaluated for both flower bud formation and time to open flower. The number of flower buds was determined for each plant on Day 17 of the experiment. All plants had similar numbers of open flowers (Figure 9), and days to first open flower (Figure 10).



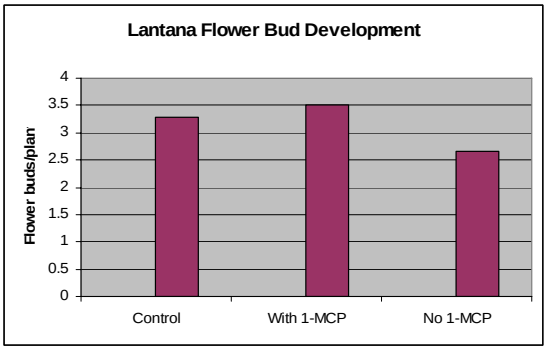


Figure 8 Storage of liners did not affect flower number. This chart shows the effect of no storage ("Control"), 48h storage with 0.9 ppm ethylene and 1-MCP ("With 1-MCP") or 48h storage with 0.9 ppm with ethylene only ("No 1-MCP") on *Euphorbia* and *Lantana* flower development

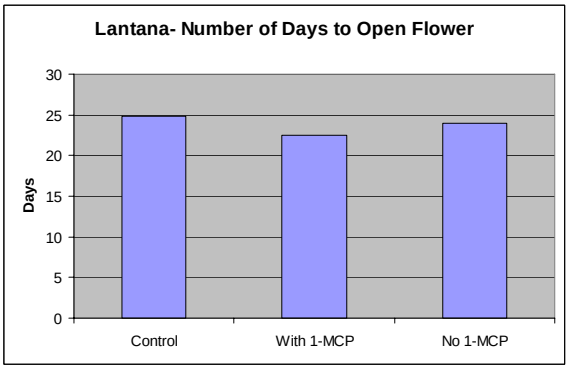


Figure 9 Storage of lantana liners did not affect flower time. Effect of no storage ("Control"), 48h storage with 0.9 ppm ethylene and 1-MCP ("With 1-MCP") or 48h storage with 0.9 ppm with ethylene only ("No 1-MCP") on number of days to first open flower for *Lantana*

Experiment 2. Rate of 1-MCP release from Ethylbloc sachets

The release of 1-MCP from the EthylBloc sachets began at the moment they were hydrated with distilled water. During the first hour, the concentration of 1-MCP climbed to 1.4 parts per million. The rate was faster initially and then became more constant by the end of the first hour. The concentration reached its maximum (approximately 2.5 parts per million) between 24 and 30 hours. 1-MCP concentration declined slightly to 1.9 parts per million by 48 hours (Figure 11).

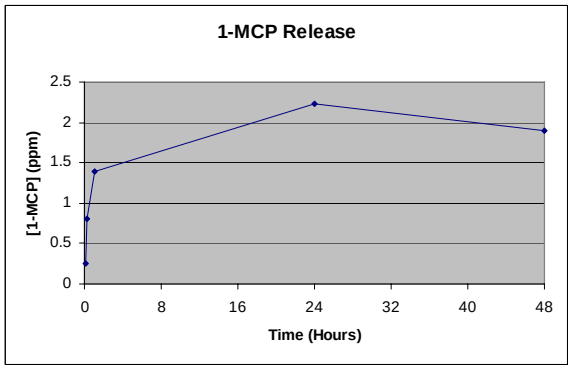
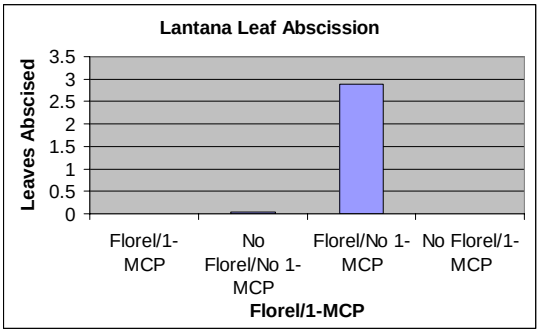


Figure 10 1-MCP concentration inside glass tanks over a 48 hr period.

3. Effect of 1-MCP on cuttings and liners treated with Florel

Cuttings

The effects of 1-MCP on leaf abscission were once again dramatic. Nearly all leaves remained intact on the cuttings exposed to 1-MCP, regardless of whether or not stock plants had been treated with Florel at 500 ppm one day before storage. Cuttings treated with Florel and no 1-MCP all died during propagation. Cuttings treated with Florel and 1-MCP did not root as well as cuttings not treated with Florel, but did form roots (Figure 12 and 13). 1-MCP applied to cuttings that did not receive Florel did not have a detrimental effect on rooting compared with control (no Florel/no 1-MCP) cuttings.



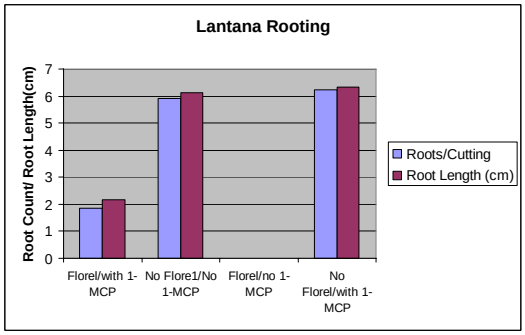


Figure 11 Effect of Florel applied to stock plants before storage, and 1-MCP sachets during 48h storage on initial leaf abscission and subsequent rooting of *Lantana* cuttings

Cuttings at 10 days- No Florel, No 1-MCP

Cuttings at 10 days- No Florel, With 1-MCP

Cuttings at 10 days- With Florel, No 1-MCP

Cuttings at 10 days- With Florel With 1-MCP

Figure 12 Effect of Florel and 1-MCP on *Lantana* cuttings

Rooted Liners

The effectiveness of 1-MCP on preventing leaf drop was once again demonstrated (Figure 14 and 15). An average of 5.5 leaves fell from each *Lantana* liner plant that received only Florel and no 1-MCP treatment and only 0.1 leaves fell from each *Lantana* plant treated with Florel and 1-MCP. *Euphorbia* liners were not as responsive to the 1-MCP treatment as the *Lantana*, but still showed 67% less leaf abscission when 1-MCP was used. An average of 25.1 leaves abscised from Florel-sprayed plants and only 8.3 were abscised when 1-MCP was used (Figure 14).

28 days after planting, there were no flowers on *Euphorbia* liners that had received Florel and no 1-MCP. *Euphorbia* plants from the other treatments (no Florel with and without 1-MCP, or Florel with 1-MCP) did have flowers on day 28, but flower number was highly variable (from 6 to 80 flowers/plant within the same treatment).

We did not have clear results on flowering in *Lantana* when plants were evaluated after 28 days. By that time, only seven of the *Lantana* had bloomed: two from the control group, three from the group with 1-MCP and no Florel, and two from the group with both 1-MCP and Florel.

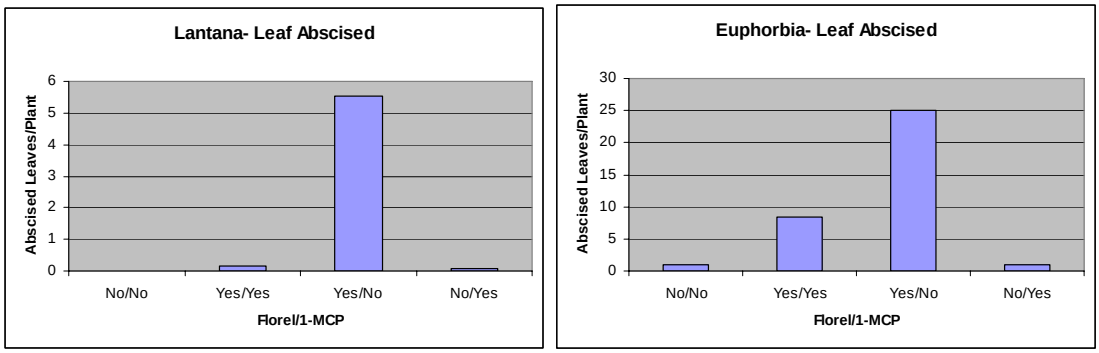
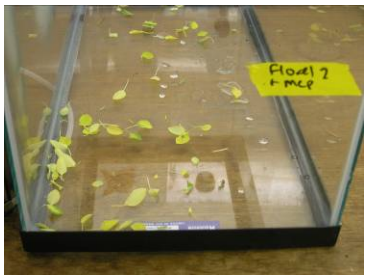


Figure 13 Effect of Florel and 1-MCP applied to rooted liners on leaf drop in *Lantana* and *Euphorbia*.

Fallen Leaves in Tank: Florel And No 1-MCP



Fallen Leaves in Tank: Florel And 1-MCP

Euphorbia No Florel and with 1-MCP

Euphorbia No Florel and No 1-MCP

Euphorbia Florel and with 1-MCP

Euphorbia Florel and No 1-MCP

Figure 14 Effect of Florel and 1-MCP on *Lantana* and *Euphorbia* liners

Ethylene production from cuttings and liners treated with Florel and 1-MCP

Ethylene level released by liners and cuttings treated with Florel increased steadily over 48h of storage, regardless of whether plants had been treated with 1-MCP (Figure 16). Ethylene production was low and undetectable on plants without Florel treatment with and without 1-MCP. The tanks with Florel and 1-MCP sachets appeared to have slightly higher ethylene levels over time than did those with Florel only, but this trial would need to be repeated to confirm that result (Figure 16).

A. Cuttings B. Liners

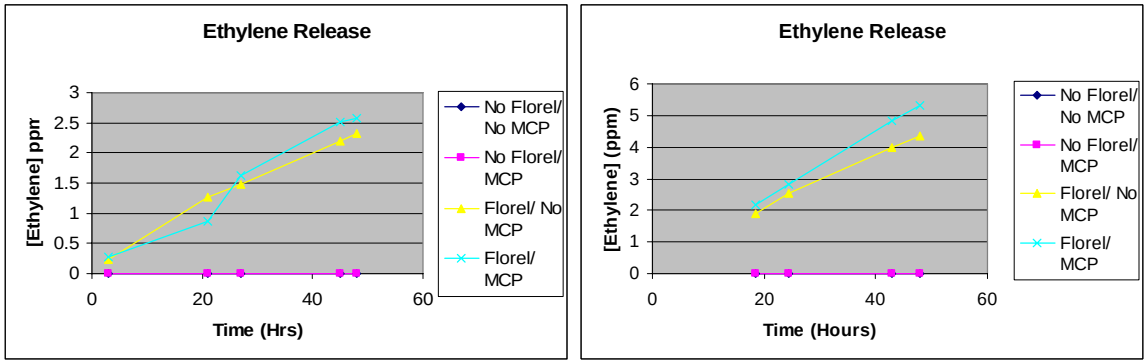


Figure 15 Ethylene concentrations inside tanks containing cuttings (left) and liners (right) treated with/without Florel and with/without 1-MCP.

4. Effect of 1-MCP on Florel treated liners in a commercial shipping boxes.

The purpose of this trial was to determine the effect of 1-MCP on Florel-treated liners during commercial shipping conditions between Gainesville Fl. (University of Florida) and Apopka Fl. (Knox Nursery) and back. Corrugated shipping boxes were used rather than sealed tanks. The results were similar to results from experiments (1-3). In general, 1-MCP significantly decreased leaf abscission and an average of 3.1 leaves remained intact per plant when 1-MCP was used. Plants only retained 0.2 leaves on average when no 1-MCP was used. However, 1-MCP effects were not as strong as the ones observed in experiment 1 (Figure 17).

Box inserts had to be made at the university for this experiment because of a lack of supply of commercial inserts. The plants were not well secured in the boxes and this increased damage of the plants during shipment. Overall, more than half of the plants from boxes with 1-MCP survived and only 12 percent of the plants from boxes without 1-MCP survived (Figure 18).

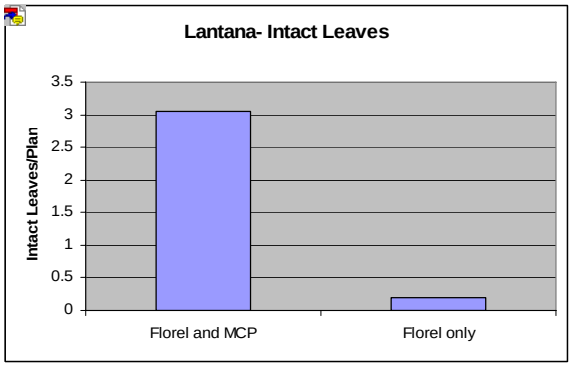


Figure 16 Number of intact leaves from Lantana treated with Florel with and without 1-MCP.

Figure 17 *Lantana* plants two weeks after potting: 1-MCP (right), No 1-MCP (left)

Ethylene levels were evaluated in boxes after the 2 days shipment (50 hours after packing). High levels were detected in one of the boxes (10.4 ppm in box (a)). Two boxes presented medium ethylene levels (2 ppm in box (c) and (d)). The other boxes showed very low ethylene levels (Figure 19). There was no obvious effect of 1-MCP on ethylene level

The average temperature inside the six boxes during shipping was 25°C, minimum temperature was 20°C and maximum 37°C. One box presented a maximum temperature of 40°C (104°F) and a minimum of 21°C (69°F) (Figure 19).

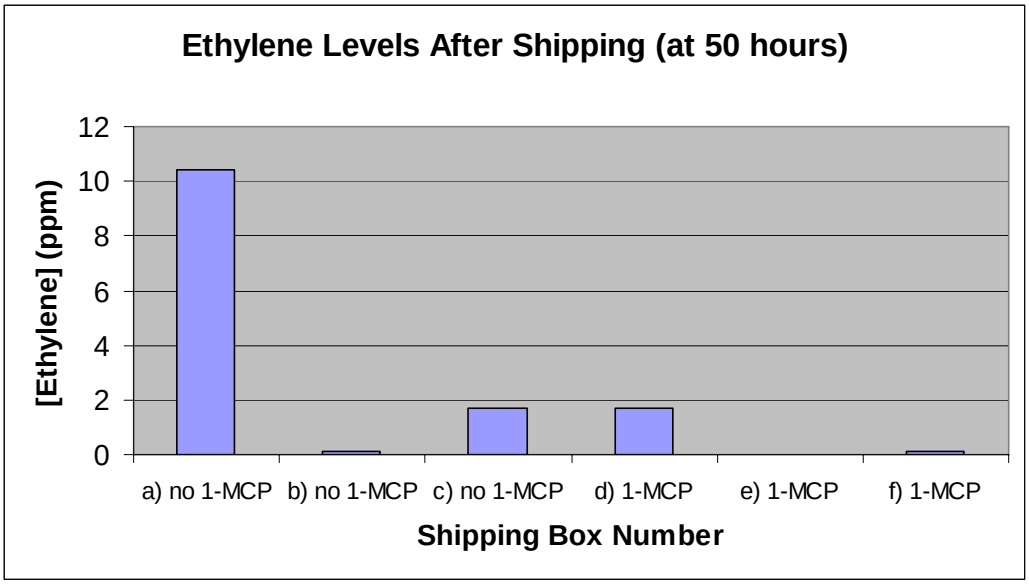


Figure 18. Ethylene levels inside corrugated boxes after 2 days shipment.

Discussion

The use of 1-MCP applied as EthylBloc sachets in simulated and actual shipping containers greatly improved the post-harvest quality of *Lantana* and *Euphorbia* unrooted cuttings and rooted liners exposed to ethylene gas or treated with Florel (ethephon). For ethylene-sensitive plants, this technology provides a good insurance against negative effects of ethylene. At 17.5 cents per sachet (35c per shipping box with two sachets), this is an affordable technology. 1-MCP was shown to diffuse easily through plastic bags and within cardboard boxes. Perforations in bags were not needed for 1-MCP to be effective with bagged cuttings. The EthylBloc sachets should be easier to incorporate into the supply process than applying Ethylbloc as a gas treatment.

Avoid applying Florel to stock plants or liners at least a week before shipping ethylene-sensitive plants, otherwise ethylene levels will be released in the shipping container which may affect not only the treated liners or cuttings, but also other plants in the same container. There are a small number of cultivars that are highly sensitive to ethylene as vegetative cuttings or liners, including lantana, Euphorbia, begonia, and portulaca (see other reports for details). Cuttings are more ethylene-sensitive than liners. However, there are many plants that are sensitive to ethylene once they have initiated flowering (think of greenhouse crop response to Florel) and will respond by dropping flowers and/or aborting flower buds. Therefore, when shipping pre-finished, flowering

liners (for example, where flowering was initiated with long-day lighting), exposure to ethylene during shipping can negatively affect a wide number of crop species.

Cuttings and liners exposed to ethylene and 1-MCP are likely to have better quality than cuttings and liners exposed to ethylene only. However, the best quality plants will not be exposed to ethylene at all during shipping, and 1-MCP does not eliminate all negative ethylene effects. This was shown in experiment 3 (Figure 13) with lantana cuttings exposed to combinations of Florel and 1-MCP.

1-MCP serves as a biologically safe, effective replacement for silver thiosulfate as an irreversible inhibitor of ethylene binding sites (Reid, 2001). The binding affinity of 1-MCP to the ethylene receptor is nearly ten times greater than that of ethylene and therefore 1-MCP is effective at lower concentrations than ethylene (Blankenship, 2002). For ethylene to compete for the receptors, a concentration of 100 ppm is needed (Blankenship, 2002). 1-MCP action involves transcriptional regulation in the biosynthesis of ethylene. The mRNA is not made in cells and therefore the enzymes necessary for ethylene production, ACC oxidase and ACC synthase, are not formed (Blankenship, 2002).

In this study, the use of 1-MCP sachets almost completely prevented leaf abscission in both *Lantana camara* and *Euphorbia* cuttings and liners. *Lantana* cuttings demonstrated more ethylene sensitivity than did the *Euphorbia* cuttings. However, *Euphorbia* liners showed more abscission than did *Lantana*. Both species responded very well to 1-MCP treatments and reversed some of the ethylene effects.

Flowering in *Lantana* and Euphorbia was decreased by exposure to ethylene gas or Florel treatments, but the response was variable. A reduction in flower number from ethylene may have been largely a secondary symptom: ethylene-treated plants were highly stressed following the abscission of leaves and many died. 1-MCP kept plants alive, and plants subsequently flowered, but our trials were not conclusive on the direct effects of 1-MCP on flowering.

Previous research has shown that 1-MCP is completely released from the sachet between 20 and 30 minutes at room temperature (20-25° C) and one atmosphere. The effective concentration ranges from 2.5 parts per billion to one part per million and is dependent on the plant species being studied. Results from the current study were consistent with previous studies. 1-MCP concentration was within the effective range from two minutes to forty-eight hours. The concentration stayed at or above one part per million from approximately thirty minutes until the end of the forty-eight hour period.

1-MCP is more effective if applied to the plants prior to any ethylene exposure, but depending on the species, it can also be effective if applied at the same time as exposure (Blankenship, 2002). The current study showed that in *Lantana*,1-MCP was effective against ethylene regardless of whether it was applied before (in the case of the ethylene gas treatment) or after (in the case of the Florel treatment) ethylene exposure. *Euphorbia* demonstrated more viability and less leaf abscission when the 1-MCP was applied prior to the ethylene exposure, but also responded to 1-MCP applied after ethylene exposure.

The Florel treatments caused greater ethylene levels to accumulate in the tanks over time compared to the trials using one time ethylene gas injections. In experiment 1, ethylene gas was inserted into the tanks at the beginning of the experiment and the ethylene levels actually decreased over time. The excess ethylene from the Florel in the last three experiments is the most likely cause for the decreased health and quality of the plants in terms of flower delay and leaf abscission.

Despite the complications experienced in the last experiment because of plant physical damage, the use of 1-MCP proved effective for prevention of leaf loss in an actual shipping scenario.

Overall, this study clearly showed the effectiveness of 1-MCP sachets to minimize ethylene-related problems in *Lantana* and *Euphorbia* cuttings and liners during shipping.

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