

Effect of Insulation on Temperature Inside Shipping Boxes

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Executive Summary

Four different trials were run to evaluate cooling and heating of cardboard shipping containers either without (“Uninsulated”) or with insulation (half-inch polystyrene [“Styrofoam”] or a double cardboard layer [“Double Box”]).

Because the box dimensions differed slightly, there were separate Uninsulated boxes as comparisons for each insulation type. All boxes contained cardboard inserts and moist growing media in 84-sized liner trays. External and internal air temperatures were measured every 10 mins.

1) **“Freezer trial”** Boxes were placed in a freezer with an average temperature of 4.6-7.1°F without plants to simulate below-freezing conditions.

- The Styrofoam boxes kept temperatures above freezing for 3.7 hours in both experimental runs, two hours more than the uninsulated boxes which froze after 1.7 hours.
- The Double Box provided either minimal freezing protection (run 1), or 0.6 h extra freezing protection (run 2) compared with no insulation.
- Overall, the Styrofoam appeared to provide better insulation than the Double Box.

2) **“Cooler trial”** Boxes were placed into a cooler room at 35.4°F without plants to simulate near-freezing conditions.

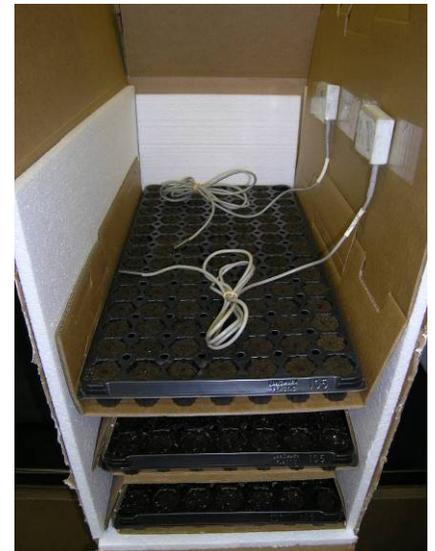
- The Uninsulated boxes reached 36°F faster (8.8 to 10 h) than the insulated boxes. The Double boxes remained above 36°F for 16h and the Styrofoam Boxes remained above 36°F for 15.2h.

3) **“Cooler trial with plants”** Boxes were placed in a cooler room at 34.3°F to simulate near-freezing conditions, and to measure the moderating effect of Bacopa rooted liners (through thermal mass and respiration) on cooling.

- The boxes without plants hit the 36°F point in 8.8h whereas the boxes with plants took 10.8 hours to drop to 36°F.

4) **“Heat trial”** Uninsulated and Styrofoam boxes with and without ice packs (no plants) were placed in a warm environment, to simulate summer heat extremes during shipping.

- The average temperature of the heat room ran at 90.7°F, with a peak temperature of 93°F.
- Box temperature was 78°F at the start of the experiment.
- The Uninsulated box rapidly warmed to over 90°F in 4.8h, and reached 85°F after 0.8h.
- Styrofoam and ice held the temperatures the lowest for the first 10 hours, dropping to 69.9°F and taking 10.5h to reach 85°F.



Introduction

Liners are normally shipped in cardboard boxes. Boxes are sometimes insulated with a 1/2 –inch thick polystyrene (Styrofoam) layer inside the box or double boxed (two layers of corrugated cardboard) to avoid temperature extremes.

Our grower research partners are interested in the external and internal temperatures that boxes experience during shipping, and whether it was worth the additional expense of adding polystyrene insulation or a double box to the shipping box.

Our objectives were to evaluate the following questions:

1. How do insulation materials protect inside box temperature from the cold at sub freezing and near freezing temperatures?
2. Do plants heat up the internal box temperature compared with media alone?
3. What are the effects of Styrofoam and Ice Packs at warm temperature?

Research Methods

We ran four temperature trials. In all trials, four 84-count trays filled with moist Greenway peat/perlite/vermiculite growing media per box were irrigated and let drain for one hour before placing into boxes. For the only trial that included plants (for objective 2), 84-count trays of rooted Bacopa cuttings were used with the same media and tray size. Unless stated otherwise, the beginning internal temperature was 68°F.

Two HOBO data loggers with two external temperature sensors were placed into each box in the second tray from the top, taped to the cardboard insert. Air temperature was recorded inside and outside the box every 10 minutes.

“Double Box” boxes (22-in long by 13-in wide by 13-in high) were obtained from Lucas Greenhouses, N.J., and “Styrofoam” boxes (21.25-in long by 12.125-in wide by 17.25-in high) were obtained from Pleasant View Gardens, N.H. Corrugated cardboard was 7/16-in thick in all boxes. Because the box dimensions differed slightly between suppliers, we had separate “Uninsulated A and B” boxes to compare against each insulation type. “Uninsulated A” boxes were the same dimensions as the Styrofoam boxes, and “Uninsulated B” boxes were the same size as the Double Box.

Objective 1. How do insulation materials protect inside box temperature from the cold at sub freezing and near freezing temperatures?

- The “**Freezer Trial**” ran at an average temperature of 4.6-7.1°F for 24h, comparing temperatures inside Uninsulated A and B, Double Box, and Styrofoam boxes. Because of the limited freezer size, only two boxes were compared each time, one insulated and one uninsulated, and each type of insulated box was tested twice in each of two experimental runs. No plants were included.
- The “**Cooler Trial**” ran at an average of 35.4°F for 72 hours comparing Uninsulated A and B, Double Box, and Styrofoam boxes. Because we had more space than in the freezer trial, two boxes per treatment (8 boxes total) were run at the same time. No plants were included.

Objective 2. Do plants heat up the internal box temperature compared with media alone?

- The **“Cooler Trial with plants”** ran at an average 34.3°F, with three Uninsulated A boxes with media only and three Uninsulated A boxes with bacopa rooted liners in the same media and trays.

Objective 3. What are the effects of Styrofoam and Ice Packs at warm temperature?

- The **“Heat Trial”** included 2 Uninsulated A and 2 Styrofoam boxes, along with 4 Uninsulated A boxes and 4 Styrofoam boxes that also contained four 168 mL ice packs filled with saline solution. No plants were included.



Uninsulated Box with trays and temperature sensors.



HOBO Temperature sensor and external lead used in experiment.



Cross section of an insulated box with all four trays, temperature sensors and media.



Photo demonstrating how sensors were taped to the top of the third cardboard insert. Leads were fed out through the corner of the box.



Photo of closed box with external leads taped to outside.

Results

Objective 1. How do insulation materials protect inside box temperature from the cold at sub-freezing and near-freezing temperatures?

Figure 1. Average freezer temperatures outside the boxes (two experimental runs, with four 24-hour periods recorded in each experimental run).

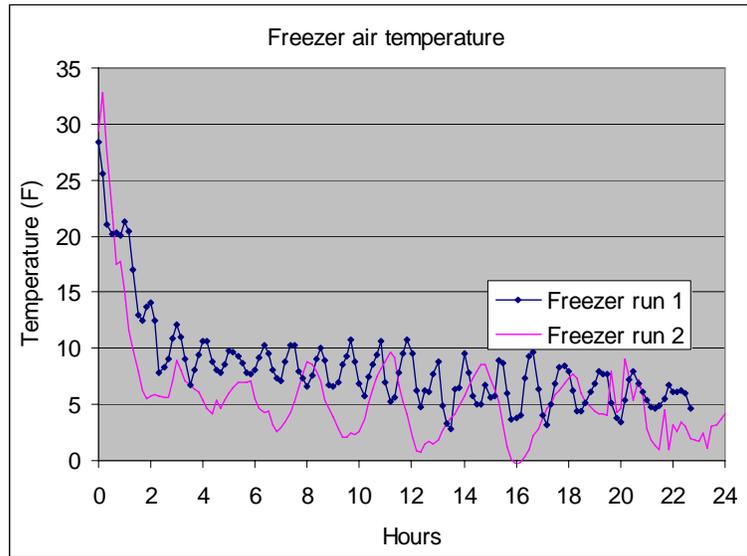


Figure 2. Temperature differences comparing Styrofoam and Uninsulated A boxes, or comparing Double Box and Uninsulated B boxes (two experimental runs, with each box type evaluated twice in each run).

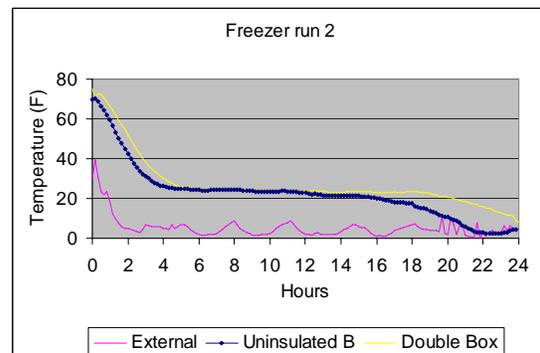
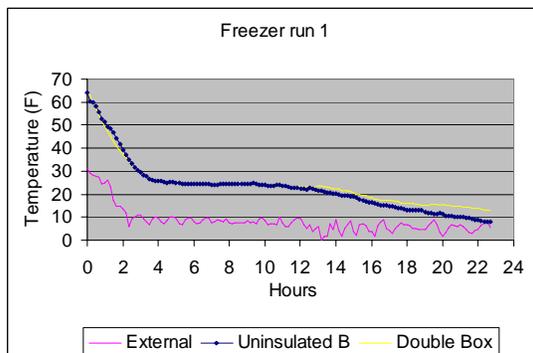
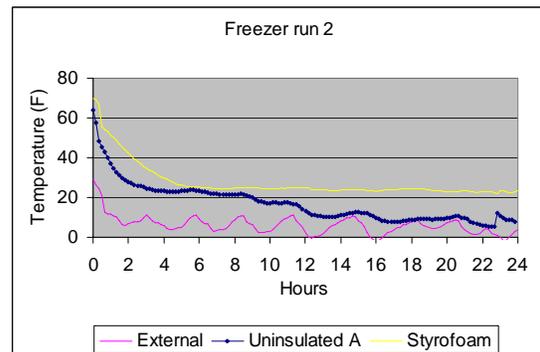
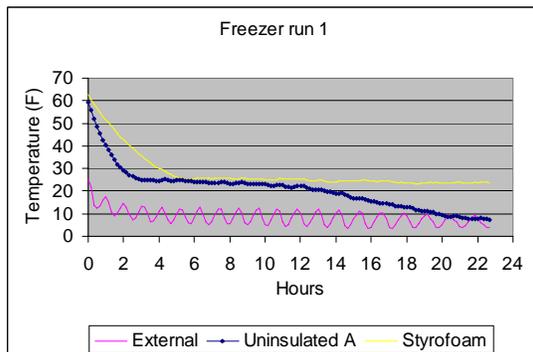


Figure 3. How much warmer was the internal temperature inside Styrofoam or Double boxes compared with uninsulated boxes in the same experimental runs?

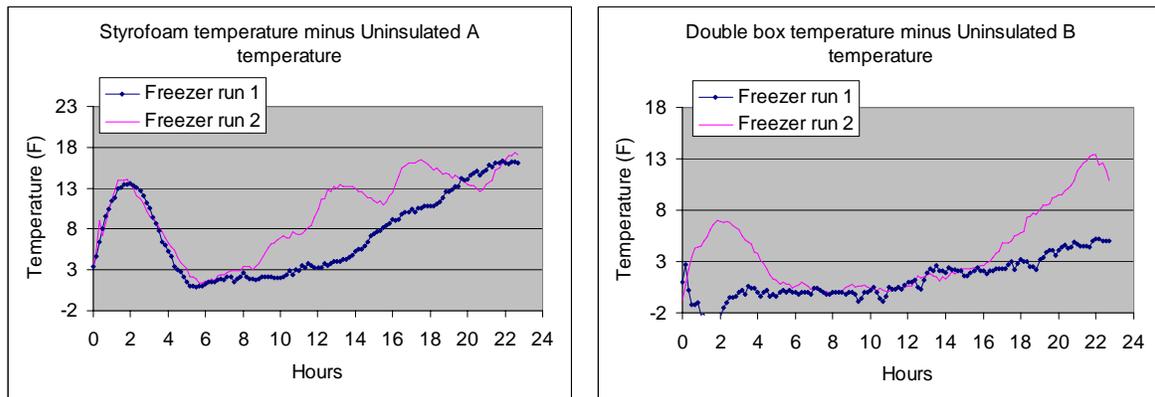


Table 1. Hours to reach an internal freezing temperature with different box types

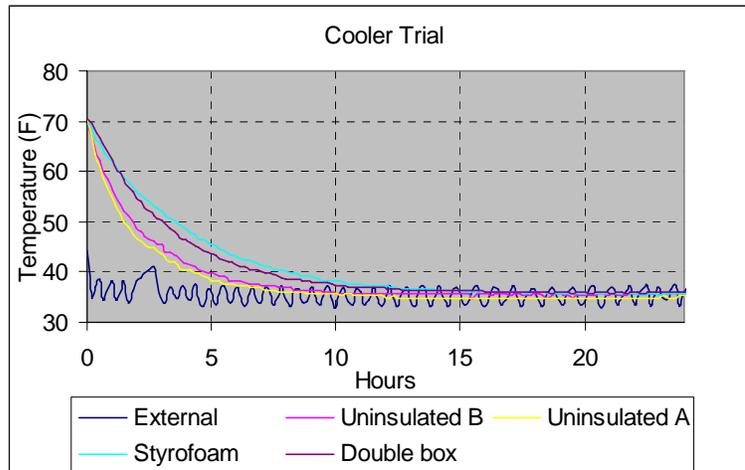
	Styrofoam	Uninsulated A	Double Box	Uninsulated B
Run 1	3.7	1.7	2.7	2.8
Run 2	3.7	1.7	3.8	3.2

Freezer Trial: cooling of insulated and uninsulated boxes over a 24h period.

- Because the freezer trial was run in a small area, with temperatures varying slightly between each run, the valid comparison is between paired Styrofoam and Uninsulated A boxes; or between paired Double Box and Uninsulated A boxes.
- “Time 0” when temperature recording began in Figure 2 and 3 occurred was the time when temperature dropped below 32°F (between 30-120 minutes after inserting boxes into the freezer).
- There were differences in freezer temperatures between the first and second experimental run. In run 1 (freezer located in a head house in Dec), the temperature dropped to an average 7.1°F after 4 hours compared with 4.6°F in run 2 (freezer located in an unheated barn in Feb-Mar).
- The Styrofoam boxes kept temperatures above freezing for 3.7 hours in both experimental runs, two hours more than the uninsulated boxes which froze after 1.7 hours.
- The Double Box reached 32°F after 2.7 (run 1) or 3.8 (run 2) hours. The Uninsulated B box (which had the same dimensions as the Double Box) reached 32°F after 2.8 hours (run 1) or 3.2 hours (run 2).
- The Double Box therefore provided either minimal freezing protection (run 1), or 0.6 h extra freezing protection (run 2) compared with no insulation.
- Overall, the Styrofoam appeared to provide better insulation than the Double Box.

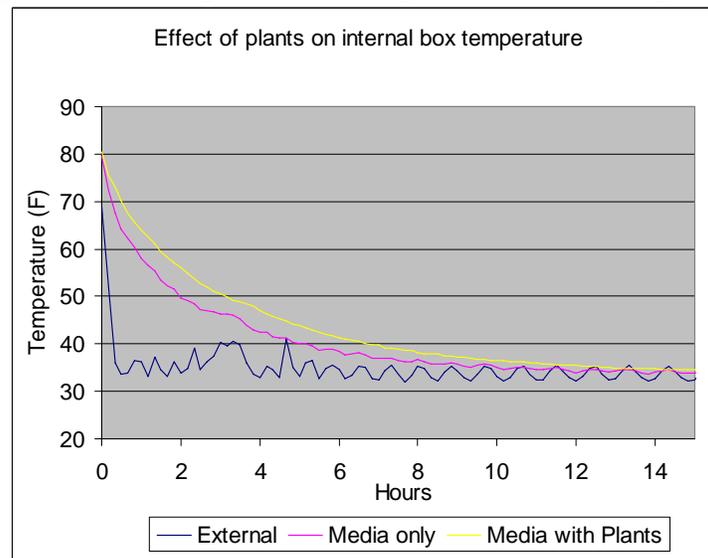
Figure 4. Cooler Trial: cooling of insulated and uninsulated boxes over a 24h period.

- In this trial, the Styrofoam and Double Box provided similar protection, remaining above 36°F for 15.2 h (Styrofoam) or 16.0 hours (Double Box).
- The Uninsulated B stayed above 36°F for 10 hours, and the Uninsulated A box stayed above 36°F for 8.7 hours.



Objective 2. Do plants heat up the internal box temperature compared with media alone?

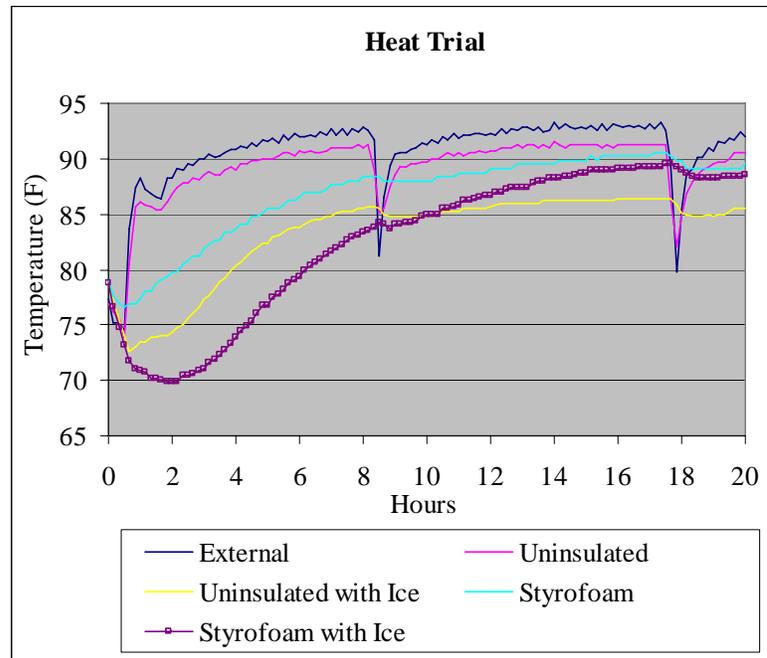
Figure 5. Effect of plants on cooling of internal box temperature



- The external temperature dropped to an average 34.3°F after 20 minutes.
- The plants kept the box warmer than the box with media alone, by up to 6°F for the first two hours.
- Boxes without plants dropped to 36°F in 8.8 h whereas the boxes containing plants took 10.8 hours to drop to 36°F.
- After 8 h the temperature difference with and without plants was less than 2°F.

Objective 3. What are the effects of Styrofoam and Ice Packs at warm temperature?

Figure 6. Heat Trial: Effect of Styrofoam and cold packs at a warm external temperature.



- The External temperature reached 93°F, but dropped twice when the door was opened to check other experimental material after 8 and 18h.
- The Uninsulated box rapidly warmed to over 90°F in 4.8h, and reached 85°F after 0.8h.
- Styrofoam and ice held the temperatures the lowest for the first 10 hours, dropping to 69.9°F and taking 10.5h to reach 85°F.
- Styrofoam alone slowed the warming of the box, which reached 85°F in 4.8h.
- The Uninsulated box with ice dropped temperature to 72.6°F, and reached 85°F in 7.2h.