

A Tale of Two Boxes

Temperatures in Shipped Liner Boxes During Winter

Internal Report for UNH Young Plant Center Research Partners.

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Executive Summary

Two trials were run to evaluate cooling of cardboard shipping containers with and without half-inch polystyrene insulation. In a cool-down trial where boxes were placed at sub-freezing air temperature:

- Uninsulated boxes dropped more quickly in temperature, about twice the rate of insulated boxes.
- Within 3.5h, uninsulated boxes reached freezing point, compared with 7h for insulated boxes.
- Internal box temperatures remained near freezing for 10 hours, presumably from the heat released from freezing media.
- After media froze, uninsulated boxes dropped more quickly and finished colder than insulated boxes (final temperature was -12C (11F) compared with -4C (24F), respectively).

In a shipping trial where boxes were shipped six times between New Hampshire, New Jersey, and Colorado in January-February:

- Insulated boxes tended to be 2-3C (3-5F) warmer than uninsulated boxes in terms of average and minimum temperatures. The average temperature inside the boxes was 47.8F for the uninsulated boxes, and a warmer 50.8F for the insulated boxes. In comparison, the average temperature outside the box averaged 47.1F.
- The only case where temperature inside an insulated box fell below freezing was in the DHL shipment from Kube-Pak (NJ) to Welby Gardens (CO), where outside temperatures were below freezing for approx. 10 hours.
- Internal box temperature dropped below freezing in un-insulated boxes during 2 out of 9 shipments.
- In 81% (17 out of 21) of the shipments, external temperatures dropped below freezing.



This was a successful trial, and it would be worthwhile doing a “warm-up” trial with insulation and ice-packs in warm conditions, and repeating the box shipment during April and July.

Introduction

Liners are normally shipped in cardboard boxes. Boxes are sometimes insulated with a 1/2 –inch thick polystyrene (styrofoam) layer inside the box to avoid temperature extremes.

We are doing a series of trials related to post-harvest quality of rooted liners. We therefore wanted to know what temperatures were experienced by boxes being shipped between U.S. greenhouses by commercial couriers. Our grower research partners are also interested in the temperatures that boxes experience during shipping, and whether it was worth the additional expense of adding polystyrene insulation to the box.

Our objectives were to:

1. Quantify how quickly boxes with and without insulation cooled down in sub-freezing air temperature.
2. Quantify internal and external temperatures in boxes shipped between greenhouses during the winter, with and without insulation.

Evaluation Methods

We ran two trials for this experiment. In both trials, four trays filled with moist media were placed into the box, with internal cardboard spacers, at room temperature (68F) before initiating the treatments.

In the first “**Cool Down Trial**”, four boxes were insulated (with polystyrene inserts) and four boxes were not insulated. A HOBO data logger with two temperature sensors was placed into each box, and temperature was recorded inside and outside the box every 10 minutes. The boxes were placed into an unheated room at 1.30 p.m. on Jan. 17 in Durham, NH, and left for 24 hours. Outside temperatures averaged -9.2C (15.5F) during that 24h period and dropped for the first 20 h from -0.5C (31F) to -13C (8F). Temperatures were averaged between the two groups of four boxes, and compared with the external temperature.

In the second “**Shipping Trial**”, we used two boxes with polystyrene insulation and two without insulation. Each box contained two loggers that each measured both internal and external temperatures. The unopened boxes were shipped six times, from Loudon, NH to Allentown, NJ to Denver, CO to Loudon, NH to Monroeville, NJ to Denver, CO to Durham, NH over a 20-day period.

The date and time when boxes were received and shipped at each location were recorded (Table 1). When boxes arrived at the final location (Durham NH), data loggers were downloaded and temperature trends were analyzed. Boxes became separated from each other early in the shipping trial. Even where boxes were shipped on the same day and time, we had separate records of external temperatures for individual boxes. Boxes a and b mostly traveled together, and boxes c and d were also together throughout the trial. Data loggers in one box (Box a) became erratic after the first three shipments, so data were only analyzed for the first three shipments for that box.



Photo of closed box with external leads taped to outside.



HOBO Temperature sensor and external lead used in experiment.

Data Collection Only: This is **NOT** a Shipping Label

Order	Address	Initiative Location	Initiative Manager
1	D.S. Cook Crown 4th, Chris Schlegel 311 North Village Road Windsor, NH 03097	Yes	Yes
2	Kube-Pak Corporation 4th, West Wharfedale 194 South St Aberdeen, ND 58501	Yes	Yes
3	Weldby Gardens 4th, 463 Fremont 2781 E. Park Street Denver, CO 80202	Yes	Yes
4	Pleasant View Gardens 4th, Mike Guyette 234 Pleasant Street Gardens, NH 03042, USA	Yes	Yes
5	Greenhouses 4th, Joe Adams 214 Whipple Road Middletown, NJ 08844 Center	Yes	Yes
6	Greenhouses 4th, Joe Adams 214 Whipple Road Middletown, NJ 08844 Center	Yes	Yes
7	Greenhouses 4th, Joe Adams 214 Whipple Road Middletown, NJ 08844 Center	Yes	Yes

Data sheet at the end of the Trial.



Box at the end of the trial.



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



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



Uninsulated Box with trays
And temperature sensors.



Another photo (uninsulated box
this time) illustrating how leads
were pulled out of box.

Table 1. Details of shipping locations and dates

			Uninsulated Box a				Insulated Box b					Uninsulated Box c				Insulated Box d				
Shipped from	Shipped to	Courier	Date Ship	Time Ship	Date Rec'd	Time Rec'd	Date Ship	Time Ship	Date Rec'd	Time Rec'd	Date Ship	Time Ship	Date Rec'd	Time Rec'd	Date Ship	Time Ship	Date Rec'd	Time Rec'd		
D.S. Cole Growers, NH	Kube Pak Corp., NJ	FedEx	20-Jan	14:30	21-Jan	9:30	20-Jan	14:30	21-Jan	9:30	20-Jan	15:05	21-Jan	9:30	20-Jan	15:05	21-Jan	9:30		
Kube Pak Corp., NJ	Welby Gardens, CO	UPS (a, b) or DHL (c, d)	24-Jan	14:45	25-Jan	11:30	24-Jan	14:45	25-Jan	11:30	24-Jan	16:00	25-Jan	11:30	24-Jan	16:00	25-Jan	11:30		
Welby Gardens, CO	Pleasant View Gardens, NH	FedEx	25-Jan	15:30	26-Jan	11:00	25-Jan	15:30	26-Jan	11:00	1-Feb	16:00	3-Feb	10:00	1-Feb	16:00	3-Feb	10:00		
Pleasant View Gardens, NH	Lucas Greenhouses, NJ	FedEx	31-Jan	14:40	3-Feb	10:00	31-Jan	14:40	2-Feb	11:00	3-Feb	16:00	4-Feb	10:00	3-Feb	16:00	4-Feb	10:00		
Lucas Greenhouses, NJ	Center Greenhouses, CO	FedEx	3-Feb	15:00	4-Feb	10:00	2-Feb	15:00	3-Feb	10:00	4-Feb	16:00	5-Feb	10:00	4-Feb	16:00	5-Feb	10:00		
Center Greenhouses, CO	Univ. of New Hampshire, NH	FedEx	6-Feb	15:00	7-Feb	14:15	6-Feb	15:00	7-Feb	14:15	8-Feb	15:00	9-Feb	14:00	8-Feb	15:00	9-Feb	14:00		

Results

Cool Down Trial

Figure 1. 24-hour period showing cooling of insulated and uninsulated boxes. Each data point for internal temperatures of insulated and uninsulated boxes is the average of four sensors, and the external temperature is the average of 7 sensors.

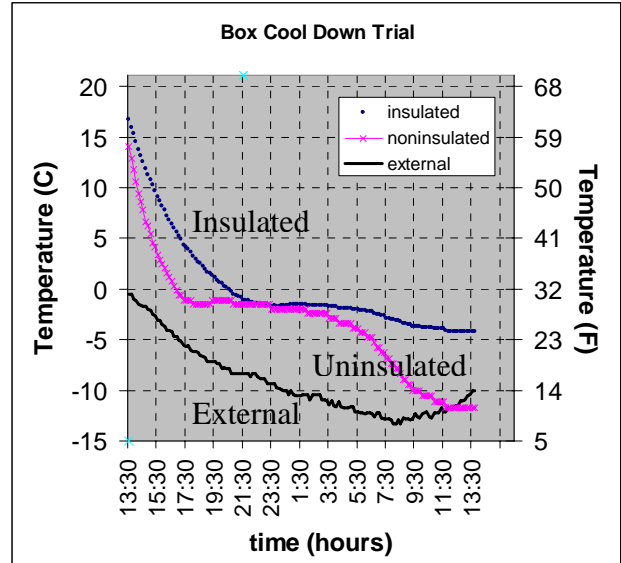
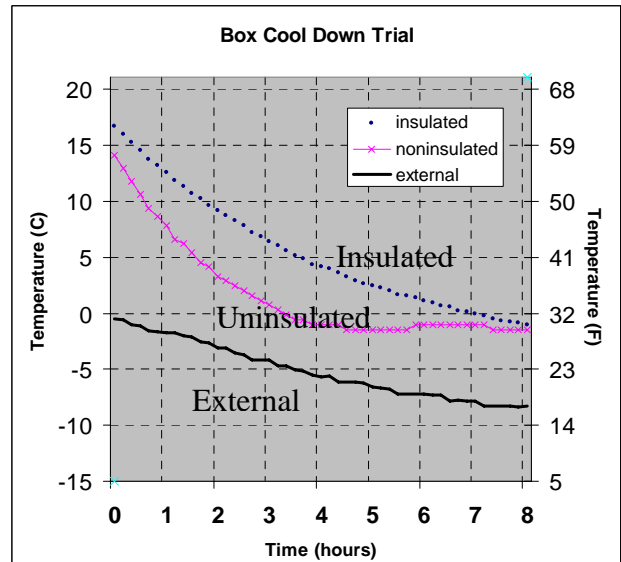


Figure 2. Close-up of the first 8 hours in the Cool Down Trial.



- Uninsulated boxes dropped more quickly in temperature, about twice the rate of insulated boxes.
- Within 3.5h, uninsulated boxes reached freezing point, compared with 7h for insulated boxes.
- Internal box temperatures remained near freezing for 10 hours, presumably from the heat released from freezing media.
- After media froze, uninsulated boxes dropped more quickly and finished colder than insulated boxes (final temperature was -12C (11F) compared with -4C (24F), respectively).

Shipping trial

Figure 3. Temperature log over time (Boxes a and b). The black bars shows the shipping periods. The difference line shows the inside box temperature minus the external temperature. The loggers failed in Box a during the fourth shipment, so the data from the last three shipments are not presented for Box a. Between the shipping periods, boxes were stored at the greenhouses. Boxes a and b traveled together during the first three shipments.

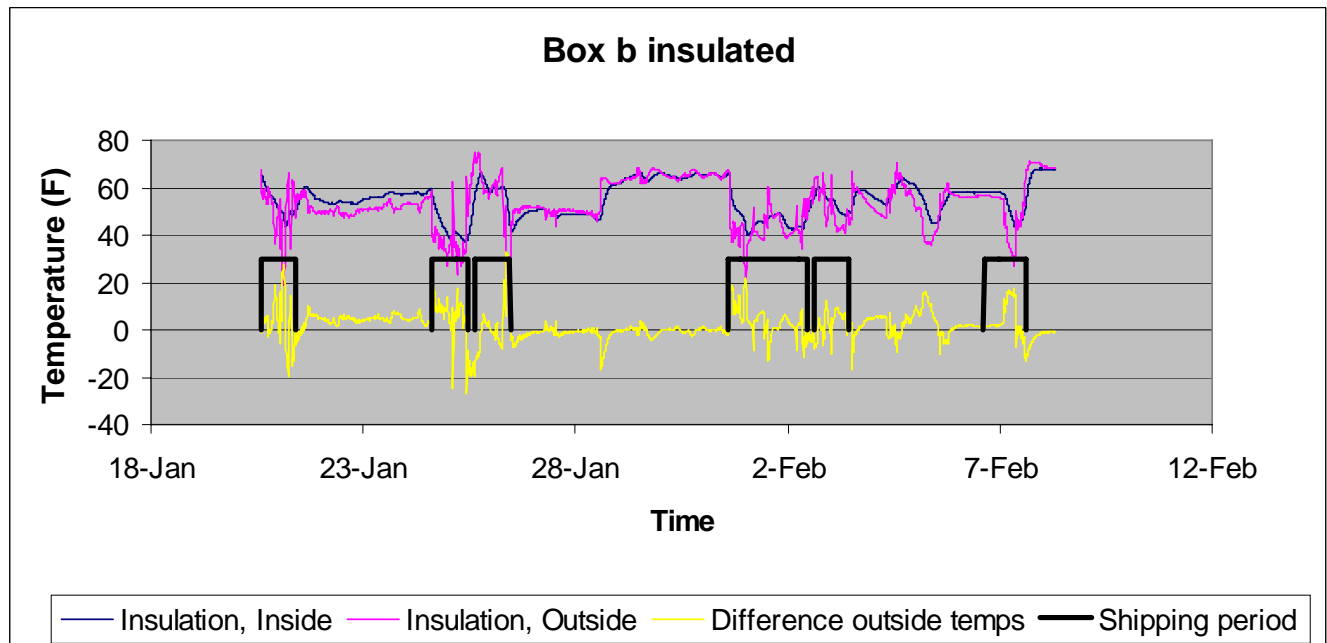
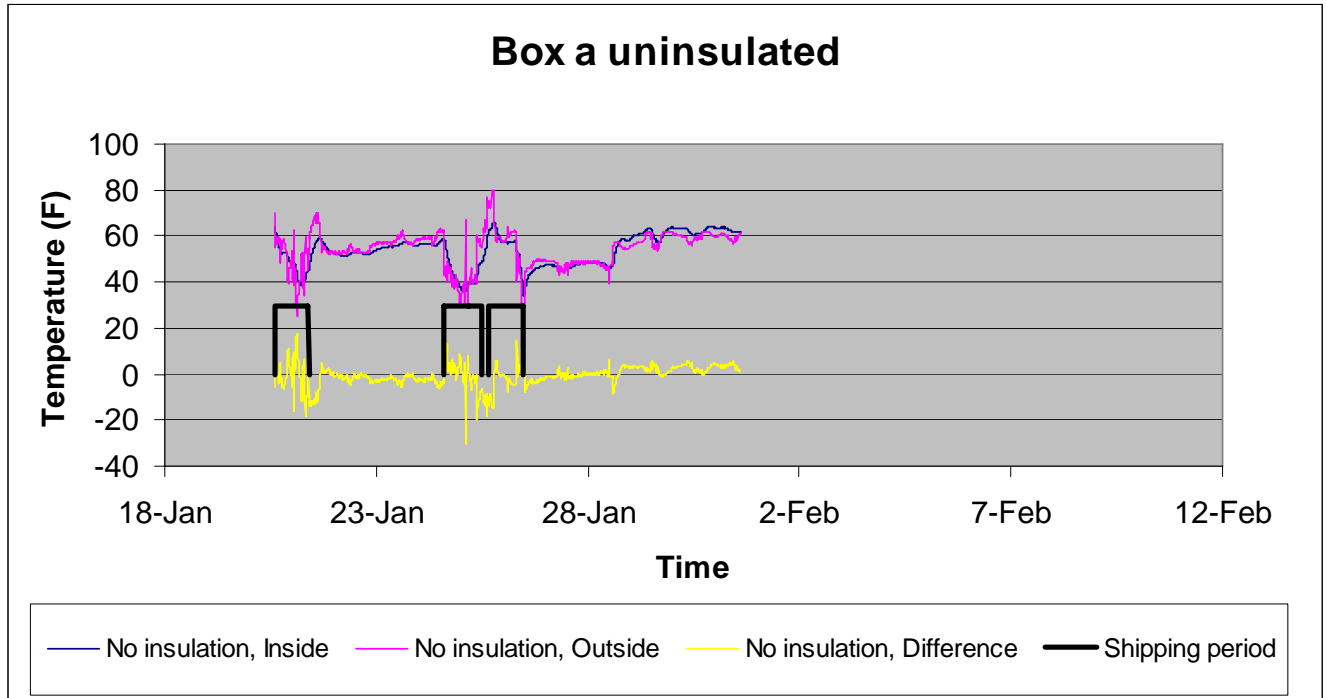


Figure 4. Temperature log over time (Boxes c and d). The black bars shows the shipping periods. The difference line shows the inside box temperature minus the external temperature. Between the shipping periods, boxes were stored at the greenhouses. Boxes c and d traveled together during all shipments.

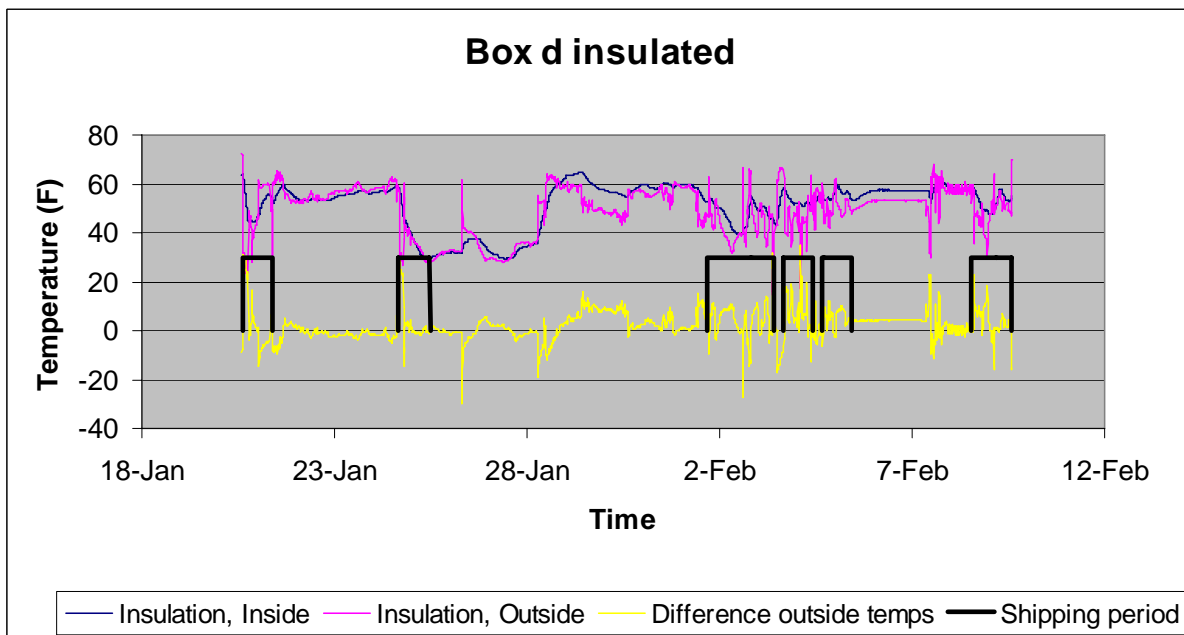
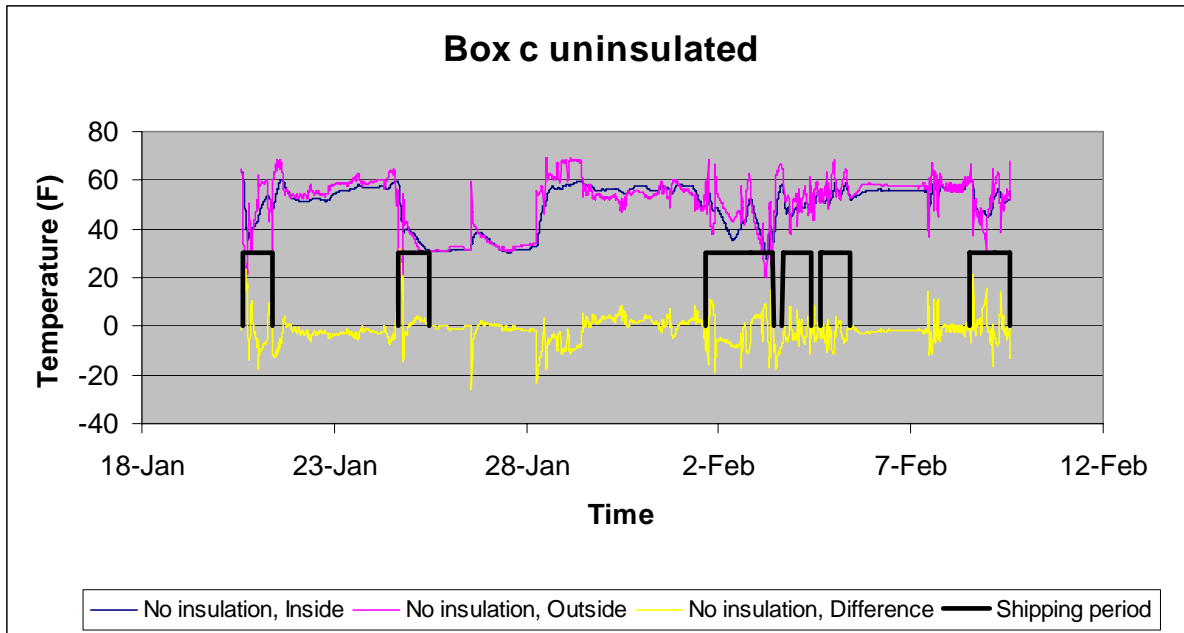


Table 2. Summary table of the Shipping Trial

Overall averages	Uninsulated inside	Uninsulated outside	Insulated inside	Insulated outside	All boxes, inside	All boxes, outside
Minimum temperature (median)	36.8	25.9	43.6	23.6	42.8	25.1
Maximum temperature (median)	59.1	67.0	60.0	66.5	59.8	67.0
Mean temperature (mean)	47.8	48.4	50.8	46.2	49.5	47.1
Minutes at or below 32F (median)	0.0	30.0	0.0	105.0	0.0	60.0
Proportion of shipments that froze	22% (2 of 9)	78% (7 of 9)	8% (1 of 12)	83% (10 of 12)	14% (3 of 21)	81% (17 of 21)

Table 2 summarizes all of the shipments, which are shown in more detail in Figures 3 and 4, and Table 3. The “take home” messages from the Shipping Trial are:

- Insulated boxes tended to be 3-5F warmer than uninsulated boxes. The average temperature inside the boxes was 47.8F for the uninsulated boxes, and a warmer 50.8F for the insulated boxes. In comparison, the average temperature outside the box averaged 47.1F.
- The only case where temperature inside an insulated box fell below freezing was in the DHL shipment from Kube-Pak NJ to Welby Gardens CO, where outside temperatures were below freezing for approx. 10 hours.
- In contrast, internal box temperature dropped below freezing in uninsulated boxes with 22 % (2 out of 9) of shipments.
- In 81% (17 out of 21) of the shipments, external temperatures dropped below freezing.

Table 3. Summaries of individual boxes in each shipment

Shipping event		Box a		Box b		Box c		Box d	
		no insulation		insulation		no insulation		insulation	
		inside box	outside box	inside box	outside box	inside box	outside box	inside box	outside box
1									
start: NH (D.S. Cole Growers)	minimum	38.7	25.1	43.9	19.3	35.3	21.6	44.3	23.8
end: NJ (Kube-Pak)	maximum	63.9	69.7	65.6	67.3	63.2	63.2	64.2	69
Courier: FedEx	mean	48.6	49.1	53.4	50.2	47	46.8	50.8	47.9
Duration: 19h	minutes at or below 32F	0	80	0	0	80	0	0	210
2									
start: NJ (Kube-Pak)	minimum	35.3	29.3	37.2	23.3	31.3	20.6	29.3	26.8
end: CO (Welby Gardens)	maximum	39.1	67	59.8	62.9	59.1	55.3	58.7	60.1
Courier: UPS (a&b), DHL (c&d)	mean	42.2	41.6	43.4	36.3	38.6	34.6	38.7	35.2
Duration: 20 (a&b) to 18.5h (c&d)	minutes at or below 32F	0	60	0	200	250	620	430	550
3									
start: CO (Welby Gardens)	minimum	36.8	25.9	43.2	19.7	27.6	19.7	39.1	14.5
end: NH (Pleasant View Gardens)	maximum	66.3	80.1	65.9	74.9	55.3	68.3	54.9	67
Courier: FedEx	mean	57.3	58.8	59.4	56.5	42.4	45	47.4	42.8
Duration: 19.5 (a&b) to 42h (c&d)	minutes at or below 32F	0	30	0	140	150	280	0	120
4									
start: NH (Pleasant View Gardens)	minimum			40.2	21.1	45	38	50.7	16.9
end: NJ (Lucas Greenhouses)	maximum			65.9	67.6	58	64.9	58.7	65.3
Courier: FedEx	mean			47.9	40.2	49.5	51	52.9	46
Duration: 18 to 19.5h	minutes at or below 32F			0	100	0	0	0	30
5									
start: NJ (Lucas Greenhouses)	minimum			47.9	40.9	49.7	48.3	53.2	41.7
end: CO (Center Greenhouses)	maximum			60.1	65.9	58.7	68.3	60.5	62.2
Courier: FedEx	mean			54	51.1	54.2	57.5	55.8	50.4
Duration: 19 (a&b) to 18h (c&d)	minutes at or below 32F			0	0	0	0	0	0
6									
start: CO (Center Greenhouses)	minimum			42.8	27.1	43.9	30.1	47.5	30.1
end: NH (Univ. of New Hampshire)	maximum			58.4	63.9	60.8	66.3	59.1	70.1
Courier: FedEx	mean			53.2	48.7	50.8	51	52.8	49.2
Duration: 23h	minutes at or below 32F			0	110	0	10	0	10

A Tale of Two Boxes – SUPPLEMENT 1: SPRING April-May

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In mid-April to early May 2005, we repeated the shipments of liner boxes between our grower research partners:

Shipped from	Shipped to	Courier	Date Shipped	Time Shipped	Date Rec'd	Time Rec'd	Duration (hrs)
D.S.Cole Growers, NH	Kube Pak Corporation, NJ	FedEx	14-Apr	4:10 PM	15-Apr	11:45 AM	19.35
Kube Pak Corporation, NJ	Welby Gardens, CO	UPS	15-Apr	4:00 PM	21-Apr	9:30 AM	137.50
Welby Gardens, CO	Pleasant View Gardens, NH	FedEx	22-Apr	4:00 PM	26-Apr	11:00 AM	91.00
Pleasant View Gardens, NH	Lucas Greenhouses, NJ	FedEx	27-Apr	4:00 PM	28-Apr	12:00 PM	20.00
Lucas Greenhouses, NJ	Center Greenhouses, CO	FedEx	2-May	2:00 PM	3-May	9:45 AM	19.45
Center Greenhouses, CO	University of New Hampshire, NH	FedEx	4-May	3:00 PM	9-May	3:00 PM	120.00

The same methodology was followed as in the winter trial. In this trial, however, the two insulated and two uninsulated boxes traveled together for the entire period. Each box contained two internal and two external temperature sensors. Internal temperatures were averaged from the four sensors in each box type. External temperature reported represent the average of all eight external sensors.

Results are presented on the next page.

- Insulated boxes had less fluctuations than uninsulated boxes.
- No boxes experienced freezing external temperatures.
- Average temperature in uninsulated boxes was 57°F, compared with 59°F in insulated boxes.
- The coldest temperature experienced in uninsulated boxes was 40°F, compared with 45°F in insulated boxes.
- The warmest temperature experienced in uninsulated boxes was 79°F, compared with 73°F in insulated boxes.
- External temperatures ranged from 41°F to 79°F during the trial.

Results from the April-May liner box shipping trial. Temperatures are in degrees Fahrenheit.

Shipping event		Uninsulated internal	Insulated internal	External
1				
start: NH (D.S. Cole Growers)	minimum	54	58	53
end: NJ (Kube-Pak)	maximum	73	72	70
Courier: FedEx	mean	59	63	59
2				
start: NJ (Kube-Pak)	minimum	40	45	41
end: CO (Welby Gardens)	maximum	79	71	77
Courier: UPS	mean	59	60	59
3				
start: CO (Welby Gardens)	minimum	41	46	44
end: NH (Pleasant View Gardens)	maximum	75	72	83
Courier: FedEx	mean	52	56	53
4				
start: NH (Pleasant View Gardens)	minimum	56	59	55
end: NJ (Lucas Greenhouses)	maximum	63	69	67
Courier: FedEx	mean	58	62	58
5				
start: NJ (Lucas Greenhouses)	minimum	46	52	45
end: CO (Center Greenhouses)	maximum	62	63	62
Courier: FedEx	mean	54	58	54
6				
start: CO (Center Greenhouses)	minimum	51	54	48
end: NH (Univ. of New Hampshire)	maximum	79	73	79
Courier: FedEx	mean	57	57	55

Overall averages		Uninsulated internal	Insulated internal	External
Minimum temperature (median)	minimum	48	53	47
Maximum temperature (median)	maximum	74	72	74
Average temperature (mean)	mean	57	59	56

A Tale of Two Boxes – SUPPLEMENT 2: SUMMER August 2005

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From beginning to end of August, we repeated the shipments of liner boxes between our grower research partners:

Shipped from	Shipped to	Courier	Date Shipped	Time Shipped	Date Rec'd	Time Rec'd	Duration (hrs)
University of New Hampshire, NH	Kube Pak Corporation, NJ	FedEx	1-Aug	3:30 PM	2-Aug	9:45 AM	18.3
Kube Pak Corporation, NJ	Welby Gardens, CO	UPS	2-Aug	3:30 PM	8-Aug	9:30 AM	138.0
Welby Gardens, CO	Pleasant View Gardens, NH	FedEx	8-Aug	3:30 PM	12-Aug	10:30 AM	91.0
Pleasant View Gardens, NH	Lucas Greenhouses, NJ	FedEx	15-Aug	4:00 PM	16-Aug	10:30 AM	18.5
Lucas Greenhouses, NJ	Center Greenhouses, CO	FedEx	17-Aug	2:00 PM	18-Aug	8:30 AM	18.5
Center Greenhouses, CO	University of New Hampshire, NH	FedEx	18-Aug	2:00 PM	22-Aug	10:50 AM	92.8

The same methodology was followed as in the spring trial, with two insulated and two uninsulated boxes traveling together for the entire period. In the final shipment from Center to UNH, box 1 (uninsulated) arrived 2 days after the other 3 boxes, despite being shipped on the same day. Each box contained two internal and two external temperature sensors. Internal temperatures were averaged from the four sensors in each box type. External temperature reported represent the average of all eight external sensors.

Results are presented on the next page.

- Temperatures inside the boxes were similar to external temperatures, although the peak temperatures were higher outside the box.
- There was no benefit of insulation, and average temperature inside both types of boxes was 78°F.
- Because the media dried down over the duration of the trial, there was no benefit of evaporative cooling or buffering of temperature from moist media. Media also arrived to greenhouses warm and was shipped again in the same condition so never had a cooling down phase between shipments.

Results from the August liner box shipping trial. Temperatures are in degrees Fahrenheit.

Shipping event		Uninsulated internal	Insulated internal	External
1				
start: NH (UNH)	minimum	68	76	69
end: NJ (Kube-Pak)	maximum	79	83	89
Courier: FedEx	mean	75	80	77
2				
start: NJ (Kube-Pak)	minimum	68	70	69
end: CO (Welby Gardens)	maximum	84	91	93
Courier: UPS	mean	75	80	78
3				
start: CO (Welby Gardens)	minimum	67	69	68
end: NH (Pleasant View Gardens)	maximum	102	97	105
Courier: FedEx	mean	81	83	83
4				
start: NH (Pleasant View Gardens)	minimum	71	70	69
end: NJ (Lucas Greenhouses)	maximum	84	79	89
Courier: FedEx	mean	76	74	75
5				
start: NJ (Lucas Greenhouses)	minimum	67	66	62
end: CO (Center Greenhouses)	maximum	83	81	83
Courier: FedEx	mean	78	77	74
6				
start: CO (Center Greenhouses)	minimum	64	66	64
end: NH (Univ. of New Hampshire)	maximum	97	86	92
Courier: FedEx	mean	81	77	75

Overall averages		Uninsulated internal	Insulated internal	External
Minimum temperature (median)	minimum	67	70	68
Maximum temperature (median)	maximum	84	85	91
Average temperature (mean)	mean	78	78	77