

Winter Lettuce Variety Trial

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Introduction

Mild winter temperatures in western Washington combined with the use of season extension can make growing lettuce for winter harvest a potential market niche for farmers who are looking for additional crops during the off-season. Local produce buyers have indicated a strong interest in Washington-grown lettuce during the winter months. In 2004 and 2005, we screened lettuce varieties for suitability for winter production in western Washington. Varieties were grown in a field hoophouse and in a field cloche, and we: 1) evaluated the effect of month of planting on variety performance; and 2) compared variety performance between the field hoophouse and field cloche. Varieties included in both studies represented a range of Crisphead, Looseleaf, Butterhead, Romaine and Oakleaf lettuce types, and also included early, middle, and late maturing varieties. After harvest, lettuce was evaluated for yield, flavor and number of days to maturity.

Materials and Methods

We evaluated 26 varieties in 2004 and 34 varieties in 2005. Only 9 varieties were evaluated both years, therefore, results are presented separately for each year. In 2004 hoophouse lettuce plantings were all conducted in one structure (HH1), which measured 12 ft x 60 ft. In 2005 we added a second hoophouse structure (HH2), which measured 24 ft by 60 ft, and the plantings were conducted in both HH1 and HH2. As an addendum to this variety trial, HH2 is a new structural design that we have developed and are testing. Both HH1 and HH2 were unheated and unlit, and consisted of single-layer 4-mil greenhouse plastic over aluminum (HH1) or PVC (HH2) hoops. Ends and sides were closed for the duration of the study. Hoophouses were located in the field and adjacent to the outdoor cloche planting. Cloches were made by placing 8-gauge wire hoops over the beds in the field and covering them with Agribon AG-19, a thin spun-bonded polypropylene fabric that lets in light (85% transmission) and water, and provides up to 4⁰ F of frost protection. This product has a weight of 0.55 oz/sq yd. Temperatures in the hoophouses and cloche were measured throughout the studies using HOBO soil temperature probes. In 2004, temperatures were measured at the soil level in the hoophouse. In the cloche, temperature was measured at the soil level below the paper mulch and on the surface of the mulch. In 2005, temperatures were measured at the soil level and at a 2-inch depth in both the hoophouse and the cloche.

Table 1 is a summary of planting dates and numbers of varieties included each year. These studies were managed organically, and all seed was untreated. The research design was a randomized complete block with 3 replications. Both years, 3-inches of compost was applied to beds before the first planting and was tilled into the soil. Beds were 4 ft wide by 54 ft long. Lettuce was seeded into 72-cell seedling trays in the greenhouse, and transplanted into the hoophouses and field cloche. Varieties were planted in single row

plots, 6 plants per plot in 2004 and 5 plants per plot in 2005. Spacing in the row was 8 inches in 2004 and 9 inches in 2005, and spacing between rows was 12 inches both years.

Table 1. Number of varieties, planting, transplanting and harvest dates, and days to maturity for winter lettuce studies in 2004 and 2005.

Year	No.	Varieties Structure	Date				Days to Hrv
			Planting	Transpl.	Harvest		
2004							
Planting 1	23	HH1	13-Aug	15-Oct	Nov18-Dec 16	34-62	
		Cloche	13-Aug	15-Oct	Nov18-Dec 16	34-62	
Planting 2	26	HH1	Jan 20 ^z	16-Mar	6-May	50	
		Cloche	20-Jan	16-Mar	7-Jun	82	
Planting 3	26	HH1	27-Feb	12-Apr	27-May	45	
		Cloche	27-Feb	12-Apr	7-Jun	56	
2005							
Planting 1	34	HH1	30-Sep	30-Nov	Mar 8-Apr 8	98-129	
Planting 2	34	HH2	21-Oct	21-Dec	Mar 17-Apr 11	86-110	
		Cloche	21-Oct	30-Dec	Apr 28-May 18	119-139	
Planting 3	34	HH1	3-Mar	18-Apr	May 23- June 20	35-63	

^z Planting 2 in 2004 was first seeded on December 22, but was lost when our greenhouse collapsed in an ice storm.

For each planting, liquid fertilizer was applied to lettuce immediately after transplanting and again 2 weeks later. Fertilizer used in these studies was soluble fish powder (Mermaid 12-0.25-1) and soluble seaweed extract powder (Acadian 1-0-4 w/ trace minerals), and was applied at a rate of 5 lb/A and 3 lb/A respectively. In the cloche in 2004, paper mulch was applied for weed control, and was effective throughout the study. In the hoopouses both years and in the cloche in 2005, plots were hand weeded as needed throughout the course of the studies. Both years, trickle tape was installed in the hoopouses for irrigation, while field cloches received natural precipitation.

In Planting 1 in 2004, all varieties were harvested once a week from the hoopouse and cloche for 4 weeks. Harvest began when the first varieties reached maturity in the hoopouse and ended when the last variety was mature in the hoopouse. Because growth rate in the cloche was slower than in the hoopouse, this resulted in significantly lower yields in the cloche than in the hoopouse. In all subsequent plantings in 2004, the hoopouse and cloche were harvested separately on one date, when the majority of varieties were mature and none had become over mature. In 2005, the hoopouse and cloche were again harvested separately, varieties were harvested as they reached maturity, and harvest extended over a period of 1 month. Total head weight (kg), trimmed (marketable) head weight (kg), bunched circumference (cm), and bunched length (cm) were measured for each plant. After harvest, each variety was evaluated for

flavor on a scale of 1 to 5, where 1 indicated very poor, 2 was poor, 3 was fair, 4 was good, and 5 was excellent.

Results and Discussion

Of the 26 varieties evaluated in 2004 and 34 in 2005, only 9 varieties were evaluated both years. Therefore, results are presented separately for each year. In 2004, Planting 1 was harvested over a period of 1 month, and the cloche was harvested at the same time as the hoop house. However, varieties were not fully mature in the cloche at harvest and this led to an under representation of yield potential in the cloche. In Plantings 2 and 3 in 2004, varieties were harvested on one day, when the majority reached maturity but none were overmature. In 2005, varieties were harvested as they reached maturity, and harvest extended over a period of 1 month.

Yield. In both 2004 and 2005, varieties differed in general in their performance in the hoop house as compared to the cloche. But in both the hoop house and the cloche, varieties with the greatest and lowest total head weight also tended to have the greatest and lowest marketable head weight. There were no significant differences in total head weight and marketable (trimmed) head weight in the hoop house based on planting date in 2004 but there were significant differences in 2005 (Tables 2 & 3). Total and marketable yields were greatest for Planting 1, followed by Planting 2 and Planting 3; yet head circumference and head length did not differ based on Planting date. In the cloche in 2004, total head weight and marketable head weight of Planting 1 were significantly lower for all varieties as compared to Plantings 2 and 3 (Table 2). This was because Planting 1 in the cloche was harvested at the same time as the hoop house rather than when varieties in the cloche had reached maturity. Due to the slower growth rate in the cloche, this resulted in very low yields in the cloche planting. Because cloche Planting 1 yields were not representative of actual yield potential, they were not used to calculate average yields across plantings.

In 2004 in the hoop house, average total head weight ranged from 0.08 to 0.27 kg, with a mean of 0.18 kg, and in 2005 ranged from 0.17 to 0.37 kg, with a mean of 0.27 kg (Tables 2 & 3). Average total head weight in 2004 was greatest for Trout's Back, Victoria, Romaine Dark Green, and New Fire Red, and lowest for Bijou, Yugoslavian Red, and Little Leprechaun. Average total head weight in 2005 was greatest for Redneck F2 black, Chaos Mix II black, and Cardinale, and lowest for Merlot, Phat Merlot white and Oscarde. In 2004, average marketable head weight ranged from 0.07 to 0.24 kg, with a mean of 0.16 kg, and in 2005 ranged from 0.14 to 0.29 kg, with a mean of 0.21 kg (Tables 3 & 4). Average marketable head weight in 2004 was greatest for Trout's Back, Romaine Dark Green, Victoria, and Austrian Greenleaf, and lowest for Bijou, Little Leprechaun, and Roger. Average marketable head weight in 2005 was greatest for Chaos Mix II black, Redneck F2 black, Cardinale and Nova F4 black, and was lowest for Merlot, Divina, and Sucrine.

In 2004 in the cloche, average (Plantings 2 and 3 only) total head weight ranged from 0.09 to 0.42 kg, with a mean of 0.26 kg, and in 2005 ranged from 0.22 to 0.41 kg, with a mean of 0.30 kg (Table 2 & 3). Average total head weight in 2004 was greatest for

Bronze Arrowhead, Blushed Butter Oak and Cardinale, and lowest for Victoria, Oakleaf Redder Ruffled and Roger. In 2005, average total head weight was greatest for Chaos Mix II black, Nova F4 white and Forencellus, and lowest for Sucrine and Optima. Average marketable head weight in 2004 ranged from 0.08 to 0.35 kg, with a mean of 0.21 kg, and in 2005 the range was 0.14 to 0.32 kg with a mean of 0.22 kg (Tables 2 and 3). Average marketable head weight in 2004 was greatest for Simpson Elite, Bronze Arrowhead and Blushed Butter, and lowest for Victoria, Oakleaf Redder Ruffled and Roger. In 2005, average marketable head weight in 2004 was greatest for Chaos Mix II black and Nova F4, and lowest for Optima, Sucrine and Divina.

In 2004 and 2005, there were no significant differences in head circumference and bunched length of marketable heads in the hoop house based on planting date, except for in 2004 where cloche Planting 1 was significantly smaller than Plantings 2 and 3 (Tables 5, 6 & 7). In each planting, there were significant differences among varieties in both in the hoop house and the cloche. Only New Red Fire (2004), Pirat (2005), Cardinale (2005) and Jack Ice (2005) had a large head circumference in both the hoop house and cloche, while Outredgeous (2004) had a small head circumference in both. Bronze Arrowhead (2004), Oaky Red Splash (2004, 2005), Craciovensis (2005), Outredgeous (2005) and Hyper Red Rumble (2005) had the greatest head length in both the hoop house and cloche, while Roger (2004), Winter Density (2004), and Pirat (2005) had the smallest.

Comparison of Lettuce Types

In 2004, 4 lettuce types were included in this study and in 2005, 5 types were included: Butterhead, Crisphead, Looseleaf, Romaine, and Oakleaf (not included in 2004). Both years, there were no significant differences in total and marketable head weight due to lettuce type (Tables 2, 3 & 4). In 2004, lettuce types differed significantly in head length for some plantings, while there was a significant difference in head circumference only in hoop house Planting 3. In 2005, there were significant differences in head length and circumference for all plantings both in the hoop house and the cloche. In 2004, Romaine and Looseleaf types produced the longest heads while Butterhead and Crisphead produced the shortest. Butterhead had the greatest head circumference while Romaine had the smallest. In 2005, Looseleaf and Oakleaf types produced the longest heads while Butterhead produced the shortest. Crisphead produced heads with the largest circumference while Looseleaf had the smallest.

Days to Maturity

In both 2004 and 2005, planting date and environment (hoop house and cloche) significantly affected days to maturity, but this difference was not as great for later plantings (Tables 1 and 8). In both 2004 and 2005, Planting 2 in the cloche was harvested approximately 30 days after the hoop house. Planting 1 in the cloche in 2004 was harvested at the same time as the hoop house, and this led to an under representation of days to maturity for that planting in the cloche.

Flavor Evaluation

In 2004, lettuce from Planting 1 was rated for flavor, and all varieties in the cloche and most varieties in the hoop house had good to very good flavor rating, with an overall

average rating of 3.4 (Table 9). Only two varieties were rated 'poor' in flavor in the hoop house (Outredgeous and New Red Fire) and in the cloche (Brunia and Bijou). In addition to these ratings, lettuce was also evaluated for taste by Kath Sherman, Washington State University Vancouver Food Service Director. She found all of the varieties acceptable and served them all in her salad bar. In 2005, Planting 3 was rated for flavor, and varieties were found to have very good flavor overall, with an average rating of 3.67 (Table 10). Nine varieties had excellent flavor, while 2 varieties were very poor (Craciovensis) or poor (Phat Merlot).

Temperature

Over the course of this study in 2004, day temperatures in the hoop house tended to be greater than in the cloche (Figures 1 & 2). Night temperatures in the hoop house tended to be similar to temperatures below the paper mulch in the cloche. In the cloche, day temperatures on top of the paper mulch were greater than temperatures below the mulch, and night temperatures on top of the paper mulch were lower than below the mulch. In 2005, day temperatures at the soil surface in the hoop houses tended to be higher than in the cloche, while night temperatures at the soil surface in the hoop houses and the cloche tended to be similar throughout the study (Figure 3). Temperatures below the soil surface were higher in the hoop houses than in the cloche in January and February but were similar in March (Figure 4). Night temperatures in HH 1 (a standard, commercially available hoop house design) were approximately 2-5° C lower than in HH 2 (our new, developmental design), and HH 1 day temperatures were 5-12° C lower than HH 2. This suggests that HH 2 provides greater heating during the day and greater heat retention at night as compared to HH 1, likely due to the greater width of HH 2 (24 feet) as compared to HH 1 (12 feet).

Pest Damage

In 2005, we observed pest damage throughout the study, primarily due to slugs, white flies, and aphids, and this damage was the main cause for leaf trimming at harvest. We rated each variety in Planting 3 for pest damage on a scale of 0 to 5, where 0 indicated no damage, and 5 indicated extreme damage (unmarketable). Mean pest damage ranged from 0.44 to 2.25, with an average rating of 1.23, and in no case did pest cause a head to be unmarketable (data not shown). Slugs tended to be more common in the outdoor planting, and white flies and aphids were more common in the hoop house. In addition to these pests, powdery mildew and leaf necrosis were also observed in the hoop house but were less prevalent in the outdoor planting.

Conclusions

Results of this study show that many lettuce varieties can be grown successfully in western Washington during the winter season. All varieties in this study produced marketable, good quality heads throughout the winter. Some varieties such as Tom Thumb and Kweik were low yielding, but this is to be expected as they are small-headed lettuce varieties. Variety selection can depend on numerous factors such as head type, leaf color, days to maturity, temperature suitability, and flavor. Growers must decide which factors are most important when selecting a variety. New growers are

recommended to plant 3 or 4 varieties or types to determine which are most marketable in their area.

Growing lettuce within an unheated, unlit hoophouse can reduce time to harvest, resulting in more plantings over time, which can result in increased yield. In addition, a hoophouse is a very good working environment during the winter months, and is preferred in general by field workers over a cloche. Yet high quality lettuce can be produced in a field cloche, and by staggering several plantings throughout the winter season, total yields can be increased. Growth in a field cloche is significantly slower (30 days) than in a hoophouse during the coldest months.

Hoophouses result in higher day temperatures than a cloche, but night temperatures are similar between the two environments. Thus it is important to protect crops in the hoophouse if night temperatures are below freezing for several weeks at a time. A cloche within the hoophouse can provide the extra protection that is needed for long periods of cold night temperatures. In the field, the paper mulch exhibited an insulating effect, causing less temperature fluctuation below the mulch than above. Mulch in the cloche or in the hoophouse may provide extra protection that is needed for long periods of cold night temperatures.

A 50-ft long by 4-ft wide bed can produce 250 heads of lettuce per planting and a planting can be harvested in 1 ½ - 4 months. At a retail value of \$1-2 per head during the winter, farmers who sell direct can earn \$250-500 per bed per planting. A typical hoophouse contains at least 2 beds, thus, the potential return from 1 hoophouse of winter-grown lettuce is \$1500-3000 assuming at least 3 plantings from October through May. Local produce buyers have indicated a strong interest in Washington-grown lettuce during the winter months. Currently, most lettuce during the winter months is from California (even in food co-ops and small health food stores), and there are very few local winter lettuce growers.

Table 2. Total head weight (kg) of lettuce growing in a hoophouse and cloche during the winter of 2003-04 at WSU Vancouver REU.

Variety	Hoophouse				Cloche			
	P1	P2	P3	Avg	P1	P2	P3	Avg ^y
Butterhead^z	0.16	0.20	0.19	0.17	0.06	0.25	0.30	0.28
Blushed Butter Oak	0.19	0.13	0.25	0.19	0.06		0.38	0.38
Brune d'Hiver						0.41	0.22	0.32
Kweik	0.21	0.19	0.12	0.18	0.06			
Sanquine Ameliore	0.09	0.22	0.25	0.19	0.03			
Tom Thumb	0.12	0.20	0.13	0.15	0.06			
Victoria	0.24	0.24	0.24	0.24	0.09	0.09		0.09
Yugoslavian Red	0.13		0.15	0.14	0.04			
Looseleaf	0.18	0.20	0.16	0.18	0.08	0.32	0.23	0.28
Austrian Greenleaf	0.20	0.24	0.18	0.21	0.08	0.39	0.17	0.28
Bijou	0.06	0.13	0.05	0.08	0.06	0.26	0.20	0.23
Bronze Arrowhead	0.18	0.20	0.19	0.19	0.10	0.45	0.39	0.42
Brunia	0.18	0.28	0.12	0.19	0.12	0.33	0.07	0.20
Cracoviensis	0.23	0.26	0.12	0.20	0.11			
New Red Fire	0.16	0.27	0.25	0.23	0.10	0.32	0.21	0.27
Oakleaf Redder Ruffled	0.20	0.17	0.18	0.18	0.08	0.12	0.14	0.13
Oaky Red Splash	0.24	0.16	0.22	0.21	0.05	0.32	0.30	0.31
Simpson Elite	0.18	0.14	0.12	0.15	0.05	0.37	0.40	0.38
Romaine	0.20	0.19	0.17	0.18	0.05	0.28	0.24	0.26
Brown Golding	0.12	0.21	0.22	0.18	0.05	0.26	0.28	0.27
De Morges Braun	0.19	0.25	0.12	0.18	0.04	0.39	0.22	0.31
Forellenschluss		0.18	0.13	0.15		0.36	0.25	0.30
Little Leprechaun		0.09	0.10	0.10		0.22	0.16	0.19
Outredgeous	0.12	0.13	0.16	0.13	0.04	0.19	0.15	0.17
Romaine Dark Green	0.25	0.16	0.28	0.23	0.06	0.21	0.32	0.26
Trout's Back	0.28	0.27	0.25	0.27	0.06	0.26	0.28	0.27
Winter Density	0.22	0.22	0.10	0.18	0.07	0.32	0.28	0.30
Crisphead	0.24	0.20	0.11	0.17	0.07	0.28	0.16	0.22
Cardinale	0.21	0.27	0.13	0.20	0.08	0.53	0.17	0.35
Reine Des' Glaces	0.27	0.16	0.13	0.19	0.06	0.14	0.20	0.17
Roger		0.17	0.07	0.12		0.16	0.10	0.13
Mean	0.19	0.19	0.16	0.18	0.07	0.29	0.23	0.26
P Value - Varieties	0.0000	0.0000	0.0000		0.0000	0.0017	0.0671	
P Value - Types	0.4186	0.9429	0.3636	0.9773	0.0501	0.8401	0.3818	0.1541

^y Average for cloche is calculated for Planting 2 and Planting 3 only.

^z Means are given for each lettuce type.

Table 3. Total and marketable head weight (kg) of lettuce growing in a hoophouse and cloche during the winter of 2004-05 at WSU Vancouver REU.

Type Variety	Total Head Weight (kg)					Marketable Head Weight (kg)				
	HH1 P1	HH2 P2	HH1 P3	Avg	Cloche ^y	HH1 P1	HH2 P2	HH1 P3	Avg	Cloche
Butterhead^z	0.31	0.28	0.20	0.26	0.28	0.23	0.18	0.17	0.19	0.19
Carmona	0.34	0.32	0.25	0.31	0.28	0.26	0.22	0.22	0.23	0.16
Divina	0.26	0.29	0.19	0.25	0.27	0.13	0.16	0.16	0.15	0.14
Emerald Oak	0.26	0.20	0.16	0.21	0.25	0.22	0.12	0.15	0.16	0.18
Flashy Butter Oak	0.33	0.27	0.21	0.27	0.33	0.24	0.17	0.19	0.20	0.24
Kweik	0.31	0.31	0.20	0.27	0.29	0.24	0.23	0.16	0.21	0.21
Optima	0.39	0.32	0.20	0.30	0.22	0.27	0.21	0.15	0.21	0.13
Pirat	0.32	0.32	0.20	0.28	0.34	0.25	0.21	0.18	0.21	0.24
Yugoslavian Red	0.31	0.22	0.17	0.23	0.25	0.24	0.15	0.14	0.18	0.22
Crisphead	0.33	0.25	0.22	0.26	0.32	0.27	0.17	0.19	0.21	0.23
Cardinale	0.41	0.34	0.28	0.34	0.33	0.34	0.22	0.26	0.27	0.23
Jack Ice	0.32	0.22	0.21	0.25	0.35	0.27	0.15	0.19	0.20	0.27
Oscarde	0.25	0.19	0.16	0.20	0.28	0.21	0.15	0.14	0.17	0.21
Looseleaf	0.32	0.28	0.16	0.26	0.29	0.24	0.19	0.13	0.20	0.21
Craciovensis	0.28	0.20	0.23	0.24	0.27	0.15	0.14	0.19	0.16	0.20
Fine Frilled	0.32	0.34	0.15	0.27	0.33	0.24	0.24	0.14	0.21	0.24
Gold Rush	0.34	0.20	0.13	0.22	0.28	0.24	0.12	0.13	0.16	0.23
Merlot	0.20	0.19	0.11	0.17	0.26	0.15	0.17	0.11	0.14	0.20
Oaky Red Splash	0.39	0.33	0.16	0.29	0.31	0.35	0.22	0.15	0.24	0.22
Phat Merlot, white	0.23	0.24	0.13	0.20	0.34	0.21	0.18	0.11	0.17	0.24
Redneck F2, black	0.44	0.30		0.37	0.25	0.33	0.21		0.27	0.17
Redneck F2, white	0.39	0.41	0.19	0.33	0.30	0.29	0.28	0.12	0.23	0.21
Oakleaf	0.38	0.33	0.21	0.31	0.35	0.31	0.24	0.19	0.25	0.26
Nova F3, black	0.35	0.28	0.19	0.27	0.33	0.30	0.20	0.18	0.23	0.24
Nova F4, black	0.41	0.35	0.20	0.32	0.35	0.34	0.26	0.17	0.26	0.25
Nova F4, white	0.37	0.38	0.23	0.33	0.38	0.30	0.26	0.21	0.25	0.29
Romaine	0.33	0.28	0.19	0.27	0.31	0.27	0.19	0.17	0.21	0.23
Brown Golding	0.30	0.23	0.29	0.27	0.25	0.25	0.16	0.24	0.21	0.16
Chaos Mix II, black	0.44	0.42	0.20	0.35	0.41	0.37	0.30	0.19	0.29	0.32
Chaos Mix II, white	0.37	0.20	0.20	0.26	0.25	0.28	0.14	0.17	0.20	0.20
Dark Green Romaine	0.31	0.26	0.16	0.24	0.30	0.25	0.17	0.14	0.19	0.23
Forencellus	0.38	0.30	0.20	0.30	0.38	0.30	0.21	0.18	0.23	0.27
Mixed Chaos, black	0.38	0.38	0.20	0.32	0.36	0.32	0.25	0.19	0.25	0.26
Mixed Chaos, white	0.31	0.24	0.17	0.24	0.37	0.26	0.17	0.15	0.19	0.27
Outredgeous	0.29	0.27	0.15	0.24	0.32	0.26	0.21	0.13	0.20	0.25
Sucrine	0.24	0.21	0.20	0.22	0.20	0.16	0.12	0.18	0.15	0.14
Winter Density	0.29	0.32	0.20	0.27	0.30	0.22	0.21	0.17	0.20	0.22
Hyper Red Rurple	0.33	0.26	0.17	0.25	0.29	0.29	0.19	0.12	0.20	0.23
Mean	0.33	0.28	0.19	0.27	0.30	0.26	0.19	0.16	0.21	0.22
P Value - Varieties	0.0001	0.0000	0.0014		0.3991	0.0000	0.0000	0.0012		0.0435
P Value - Types	0.6912	0.6138	0.1173		0.1951	0.2614	0.4454	0.0677		0.0976

^y Cloche was planted at the same time as hoophouse Planting 2

^z Means are given for each lettuce type.

Table 4. Marketable head weight (kg) of lettuce growing in a hoophouse and cloche during the winter of 2003-04 at WSU Vancouver REU.

Type Variety	Hoophouse				Cloche			
	P1	P2	P3	Avg	P1	P2	P3	Avg ^y
Butterhead^z	0.13	0.16	0.17	0.15	0.04	0.20	0.25	0.22
Blushed Butter Oak	0.16	0.12	0.23	0.17	0.05		0.34	0.34
Brune d'Hiver						0.33	0.16	0.25
Kweik	0.18	0.13	0.12	0.14	0.03			
Sanquine Ameliore	0.08	0.20	0.18	0.15	0.02			
Tom Thumb	0.08	0.15	0.12	0.12	0.03			
Victoria	0.18	0.19	0.22	0.20	0.07	0.08		0.08
Yugoslavian Red	0.10		0.13	0.12	0.03			
Looseleaf	0.16	0.18	0.14	0.16	0.06	0.27	0.20	0.23
Austrian Greenleaf	0.19	0.22	0.18	0.20	0.08	0.33	0.15	0.24
Bijou	0.06	0.10	0.04	0.07	0.05	0.21	0.18	0.20
Bronze Arrowhead	0.18	0.17	0.16	0.17	0.06	0.36	0.33	0.35
Brunia	0.16	0.22	0.10	0.16	0.08	0.24	0.06	0.15
Cracoviensis	0.20	0.25	0.10	0.18	0.07			
New Red Fire	0.14	0.22	0.21	0.19	0.08	0.36	0.18	0.27
Oakleaf Redder Ruffled	0.17	0.15	0.17	0.16	0.08	0.10	0.06	0.08
Oaky Red Splash	0.22	0.15	0.21	0.19	0.05	0.23	0.25	0.24
Simpson Elite	0.16	0.10	0.12	0.12	0.04	0.32	0.38	0.35
Romaine	0.18	0.17	0.15	0.16	0.04	0.20	0.20	0.20
Brown Golding	0.11	0.19	0.21	0.17	0.02	0.14	0.20	0.17
De Morges Braun	0.15	0.20	0.09	0.14	0.02	0.18	0.19	0.18
Forellenschluss		0.15	0.11	0.13		0.32	0.23	0.27
Little Leprechaun		0.08	0.10	0.09		0.16	0.14	0.15
Outredgeous	0.11	0.12	0.15	0.13	0.03	0.13	0.10	0.12
Romaine Dark Green	0.24	0.17	0.23	0.21	0.04	0.19	0.28	0.23
Trout's Back	0.25	0.25	0.22	0.24	0.06	0.23	0.25	0.24
Winter Density	0.20	0.20	0.10	0.17	0.05	0.26	0.25	0.25
Crisphead	0.21	0.19	0.10	0.16	0.06	0.19	0.13	0.16
Cardinale	0.19	0.26	0.12	0.19	0.07	0.33	0.13	0.23
Reine Des' Glaces	0.24	0.14	0.12	0.17	0.05	0.13	0.19	0.16
Roger		0.16	0.07	0.12		0.12	0.07	0.10
Mean	0.16	0.17	0.15	0.16	0.05	0.23	0.20	0.21
P Value - Varieties	0.0000	0.0000	0.0000		0.000	0.0226	0.0133	
P Value - Types	0.2103	0.8669	0.4678	0.9539	0.0076	0.4276	0.4924	0.6122

^y Average for cloche is calculated for Planting 2 and Planting 3 only.

^z Means are given for each lettuce type.

Table 5. Head circumference (cm) of lettuce growing in a hoophouse and cloche during the winter of 2003-04 at WSU Vancouver REU.

Type Variety	Hoophouse				Cloche			
	P1	P2	P3	Avg	P1	P2	P3	Avg ^y
Butterhead^z	35.7	34.8	40.0	37.0	18.2	26.6	35.8	31.7
Blushed Butter Oak	36.0	30.0	46.7	37.6	18.4		45.0	45.0
Brune d'Hiver						32.7	26.5	29.6
Kweik	42.0	35.0	39.8	38.9	11.9			
Sanquine Ameliore	24.2	35.5	32.2	30.6	13.9			
Tom Thumb	30.8	35.5	33.7	33.3	16.3			
Victoria	48.0	38.0	45.2	43.7	31.0	20.5		20.5
Yugoslavian Red	33.3		42.7	38.0	17.9			
Looseleaf	34.6	35.5	33.0	34.4	22.7	36.4	35.2	35.8
Austrian Greenleaf	37.9	41.2	35.5	38.2	30.4	44.3	29.7	37.0
Bijou	24.8	31.8	27.2	27.9	17.2	35.7	37.5	36.6
Bronze Arrowhead	34.8	32.2	34.8	33.9	22.6	38.2	39.0	38.6
Brunia	36.3	37.0	33.8	35.7	19.5	34.3	25.5	29.9
Cracoviensis	33.3	39.3	32.0	34.9	21.9			
New Red Fire	38.4	45.6	36.5	40.2	31.5	43.8	39.4	41.6
Oakleaf Redder Ruffled	35.6	30.8	35.3	33.9	18.1	24.5	20.0	22.3
Oaky Red Splash	34.1	30.8	36.4	33.8	20.7	32.5	32.0	32.3
Simpson Elite	36.0	31.0	25.6	30.9	22.4	38.0	58.8	48.4
Romaine	32.4	33.3	32.1	32.3	17.1	30.3	33.4	31.9
Brown Golding	26.2	33.3	37.0	32.2	11.8	21.6	27.4	24.5
De Morges Braun	33.1	41.2	28.7	34.3	8.8	30.3	36.6	33.5
Forellenschluss		29.7	27.8	28.7		34.3	33.2	33.7
Little Leprechaun		23.6	30.6	27.1		29.5	27.5	28.5
Outredgeous	27.8	29.2	30.8	29.3	15.8	20.0	28.0	24.0
Romaine Dark Green	36.4	34.5	37.0	36.0	23.3	34.0	41.8	37.9
Trout's Back	37.0	39.0	34.5	36.8	26.4	33.7	37.2	35.4
Winter Density	34.1	36.0	30.8	33.6	16.2	39.0	35.6	37.3
Crisphead	36.3	38.2	35.0	36.3	23.3	36.6	34.1	35.4
Cardinale	39.4	43.2	39.8	40.8	23.5	43.3	29.7	36.5
Reine Des' Glaces	33.1	33.5	33.3	33.3	23.1	34.5	47.8	41.1
Roger		37.8	32.0	34.9		32.0	25.0	28.5
Overall Mean	34.5	35.0	34.6	34.7	20.1	33.2	34.4	29.2
P Value - Varieties	0.0008	0.0002	0.0000		0.0111	0.0003	0.0000	
P Value - Types	0.7356	0.5582	0.0037	0.1477	0.2387	0.1366	0.9801	0.6938

^y Average for cloche is calculated for Planting 2 and Planting 3 only.

^z Means are given for each lettuce type.

Table 6. Head length (cm) of lettuce growing in a hoophouse and cloche during the winter of 2003-04 at WSU Vancouver REU.

Type Variety	Hoophouse				Cloche			
	P1	P2	P3	Avg	P1	P2	P3	Avg ^y
Butterhead^z	17.6	19.4	20.0	18.9	10.9	24.3	24.3	22.4
Blushed Butter Oak	23.8	18.2	20.8	20.9	15.7		23.0	23.0
Brune d'Hiver						34.7	25.5	30.1
Kweik	15.2	16.7	17.6	16.5	6.0			
Sanquine Ameliore	25.0	29.5	27.2	27.2	14.6			
Tom Thumb	11.1	12.8	14.8	12.9	4.7			
Victoria	16.0	20.0	19.7	18.6	14.8	14.0		14.0
Yugoslavian Red	14.5		19.8	17.2	9.4			
Looseleaf	28.2	25.6	26.3	26.7	17.2	29.7	24.9	27.3
Austrian Greenleaf	26.1	21.3	21.8	23.1	15.2	29.7	18.7	24.2
Bijou	20.2	20.3	15.6	18.7	14.2	29.3	26.2	27.8
Bronze Arrowhead	33.4	28.8	27.0	29.7	21.6	38.0	32.0	35.0
Brunia	27.6	31.3	24.7	27.8	16.9	30.3	20.0	25.2
Cracoviensis	37.3	33.7	31.0	34.0	17.4			
New Red Fire	21.4	23.0	29.5	24.6	16.2	28.5	22.6	25.6
Oakleaf Redder Ruffled	28.4	24.5	26.2	26.4	18.2	25.3	21.5	23.4
Oaky Red Splash	34.4	27.3	35.0	32.2	19.6	30.5	31.5	31.0
Simpson Elite	24.6	20.6	26.0	23.7	15.2	25.8	26.5	26.2
Romaine	25.8	23.6	25.0	24.7	13.3	27.5	25.6	26.5
Brown Golding	24.2	25.7	25.2	25.0	16.5	29.8	27.8	28.8
De Morges Braun	24.2	25.3	25.0	24.8	7.6	28.0	23.6	25.8
Forellenschluss		23.2	26.2	24.7		28.0	28.0	28.0
Little Leprechaun		22.0	25.6	23.8		31.8	25.8	28.8
Outredgeous	25.6	28.4	27.0	27.0	15.6	30.3	25.5	27.9
Romaine Dark Green	30.3	20.0	26.8	25.7	12.8	23.3	26.0	24.7
Trout's Back	28.2	24.5	28.3	27.0	14.0	26.0	23.8	24.9
Winter Density	22.3	19.5	15.8	19.2	13.0	23.0	24.0	23.5
Crisphead	21.8	21.9	18.3	20.1	19.3	21.2	19.2	20.2
Cardinale	23.6	26.2	20.6	23.5	18.2	23.7	20.3	22.0
Reine Des' Glaces	20.0	21.5	18.8	20.1	20.4	18.0	20.3	19.1
Roger		18.2	15.5	16.8		22.0	17.0	19.5
Overall Mean	24.2	23.3	23.5	23.5	14.7	27.1	24.3	20.5
P Value - Varieties	0.0000	0.0000	0.0000		0.0070	0.0000	0.0010	
P Value - Types	0.0060	0.1362	0.0208	0.0068	0.0050	0.1045	0.0909	0.0452

^y Average for cloche is calculated for Planting 2 and Planting 3 only.

^z Means are given for each lettuce type.

Table 7. Head circumference (cm) and length (cm) of lettuce growing in a hoophouse and cloche during the winter of 2004-05 at WSU Vancouver REU.

Type Variety	Bunched Head Circumference (cm)					Bunched Head Length (cm)				
	HH P1	HH P2	HH P3	Avg	Cloche	HH P1	HH P2	HH P3	Avg	Cloche
Butterhead^z	36	34	38	36	36	19	21	17	19	17
Carmona	44	37	45	42	34	22	27	20	23	18
Divina	31	36	40	36	35	18	19	17	18	13
Emerald Oak	29	22	33	28	29	17	20	16	17	18
Flashy Butter Oak	34	27	37	32	31	29	29	21	26	28
Kweik	37	41	35	37	40	13	15	16	15	15
Optima	36	38	39	38	31	22	19	16	19	15
Pirat	40	40	42	41	45	16	17	16	16	14
Yugoslavian Red	38	34	35	36	40	17	20	17	18	16
Crisphead	41	35	41	39	40	21	22	19	21	17
Cardinale	43	38	46	42	38	24	24	22	23	15
Jack Ice	43	33	43	40	46	21	19	17	19	16
Oscarde	38	33	36	35	36	17	24	18	20	18
Looseleaf	32	27	30	30	28	28	32	23	28	29
Craciovensis	23	19	28	24	22	31	36	33	33	38
Fine Frilled	30	29	32	30	31	27	31	20	26	26
Gold Rush	34	24	33	30	37	22	23	19	21	22
Merlot	32	30	29	30	28	25	28	19	24	27
Oaky Red Splash	33	27	30	30	27	32	39	24	32	33
Phat Merlot, white	37	30	29	32	31	26	30	21	26	28
Redneck F2, black	33	25		29	23	32	35		34	29
Redneck F2, white	36	34	29	33	28	26	33	24	27	29
Oakleaf	36	30	36	34	30	29	31	23	28	28
Nova F3, black	36	29	38	34	29	28	31	23	27	28
Nova F4, black	35	30	33	33	30	30	30	22	27	28
Nova F4, white	35	30	38	35	32	30	31	24	28	27
Romaine	33	27	32	31	30	26	27	22	25	25
Brown Golding	31	26	33	30	22	26	23	25	25	24
Chaos Mix II, black	37	30	36	34	32	29	32	24	28	29
Chaos Mix II, white	35	25	38	33	30	31	25	22	26	23
Dark Green Romaine	28	24	28	27	29	21	24	19	21	20
Forencellus	33	27	30	30	32	25	27	25	26	25
Mixed Chaos, black	33	30	36	33	31	32	32	23	29	26
Mixed Chaos, white	33	26	32	30	32	24	28	21	25	25
Outredgeous	35	28	27	30	29	34	33	26	31	34
Sucrine	26	21	29	25	27	11	16	16	14	16
Winter Density	32	27	33	31	30	20	24	20	22	21
Hyper Red Rurple	40	29	28	32	33	34	33	24	30	31
Average	35	30	34	33	32	25	27	21	33	24
P Value - Varieties	0.0005	0.0000	0.0000		0.0000	0.0000	0.0000	0.0000		0.0000
P Value - Types	0.0206	0.0031	0.0000	0.0001	0.0011	0.0116	0.0007	0.0103	0.0017	0.0001

^y Cloche was planted at the same time as hoophouse Planting 2

^z Means are given for each lettuce type.

Table 8. Days after transplanting to maturity of lettuce growing in a hoophouse and cloche during the winter of 2004-05 at WSU Vancouver REU.

Type Variety	HH1 P1	HH2 P2	HH1 P3	Avg	Cloche ^y
Butterhead^z	110.78	95.29	41.95	82.67	131.01
Carmona	114	97	42	85	135
Divina	112	96	44	84	137
Emerald Oak	110	93	44	82	123
Flashy Butter Oak	113	97	43	84	134
Kweik	105	93	40	80	126
Optima	111	95	40	82	129
Pirat	110	93	38	80	129
Yugoslavian Red	110	98	45	85	134
Crisphead	112.08	100.55	45.29	85.98	131.62
Cardinale	121	103	48	90	138
Jack Ice	110	97	46	84	131
Oscarde	105	102	42	83	126
Looseleaf	111.94	97.11	39.67	85.56	127.61
Craciovensis	113	104	39	85	135
Fine Frilled	113	95	40	83	122
Gold Rush	112	95	39	82	128
Merlot	113	97	40	83	129
Oaky Red Splash	107	96	41	81	124
Phat Merlot, white	114	98	39	84	125
Redneck F2, black	110	97	n/a	103	132
Redneck F2, white	114	95	39	83	127
Oakleaf	111.92	95.08	41.06	82.69	131.99
Nova F3, black	113	96	42	84	133
Nova F4, black	112	95	39	82	131
Nova F4, white	111	94	41	82	132
Romaine	112.42	96.60	42.04	83.69	129.33
Brown Golding	117	105	46	89	142
Chaos Mix II, black	108	95	45	83	132
Chaos Mix II, white	113	97	42	84	131
Dark Green Romaine	113	97	42	84	123
Forencellus	112	95	40	82	131
Mixed Chaos, black	113	95	41	83	128
Mixed Chaos, white	115	98	43	86	129
Outredgeous	113	98	39	83	129
Sucrine	111	91	40	81	125
Winter Density	111	94	42	82	124
Hyper Red Rurple	112	98	43	84	128
Average	112	97	42	84	130
P Value - Varieties	0.0000	0.0000	0.0505		0.0005
P Value - Types	0.7786	0.0970	0.0061	0.6173	0.5458

^y Cloche was planted at the same time as hoophouse Planting 2

^z Means are given for each lettuce type.

Table 9. Rating of flavor, on a scale of 1 to 5, where 1 indicated very poor, 2 was poor, 3 was fair, 4 was good, and 5 was excellent, of lettuce Planting 1 grown in a hoophouse and cloche during the winter of 2003-04 at WSU Vancouver REU.

Type			
Variety	Hoophouse	Cloche	Average
Butterhead^z	3.57	3.78	3.68
Blushed Butter Oak	4	3.6	3.80
Kweik	3.4	3.8	3.60
Sanquine Ameliore	3.8	3.8	3.80
Tom Thumb	2.6	4.5	3.55
Victoria	3.8	3.2	3.50
Yugoslavian Red	3.8	3.8	3.80
Looseleaf	3.07	3.18	3.12
Austrian Greenleaf	2.4	2.8	2.60
Bijou	2.2	3.3	2.75
Bronze Arrowhead	2.6	3.4	3.00
Brunia	1.8	3.3	2.55
Cracoviensis	3.8	2.8	3.30
New Red Fire	3.6	2.4	3.00
Oakleaf Redder Ruffled	4.2	3.8	4.00
Oaky Red Splash	3.6	3.6	3.60
Simpson Elite	3.4	3.2	3.30
Romaine	3.73	3.45	3.59
Brown Golding	4	4	4.00
De Morges Braun	3.6	3	3.30
Outredgeous	3.2	2.3	2.75
Romaine Dark Green	3.6	3.8	3.70
Trout's Back	3.6	3.2	3.40
Winter Density	4.4	4.4	4.40
Summer Crisp	3.80	3.10	2.60
Cardinale	3.8	3	3.40
Reine Des' Glaces	3.8	3.2	3.50
Overall Mean	3.40	3.40	3.40
P Value - Varieties	0.0002	0.2671	
P Value - Types	0.1906	0.1818	0.0991

^z Means are given for each lettuce type.

Table 10. Rating of flavor, on a scale of 1 to 5, where 1 indicated very poor, 2 was poor, 3 was fair, 4 was good, and 5 was excellent, of lettuce Planting 1 grown in a hoophouse and cloche during the winter of 2004-05 at WSU Vancouver REU.

Type	
Variety	Rating
Butterhead^z	4.0
Carmona	4
Divina	3
Emerald Oak	5
Flashy Butter Oak	5
Kweik	5
Optima	3
Pirat	3
Yugoslavian Red	
Looseleaf	3.0
Craciovensis	1
Fine Frilled	4
Gold Rush	4
Merlot	3
Oaky Red Splash	4
Phat Merlot, white	2
Redneck F2, black	
Redneck F2, white	3
Oakleaf	4.2
Nova F3, black	5
Nova F4, black	4
Nova F4, white	4

Type	
Variety	Rating
Romaine	4.4
Brown Golding	5
Chaos Mix II, black	4
Chaos Mix II, white	5
Dark Green Romaine	5
Forencellus	3
Mixed Chaos, black	5
Mixed Chaos, white	5
Outredgeous	3
Sucrine	5
Winter Density	5
Hyper Red Rurple	3
Crisphead	3.3
Cardinale	4
Jack Ice	3
Oscarde	3

Average	3.85
P Value - Types	0.0584

^z Means are given for each lettuce type.

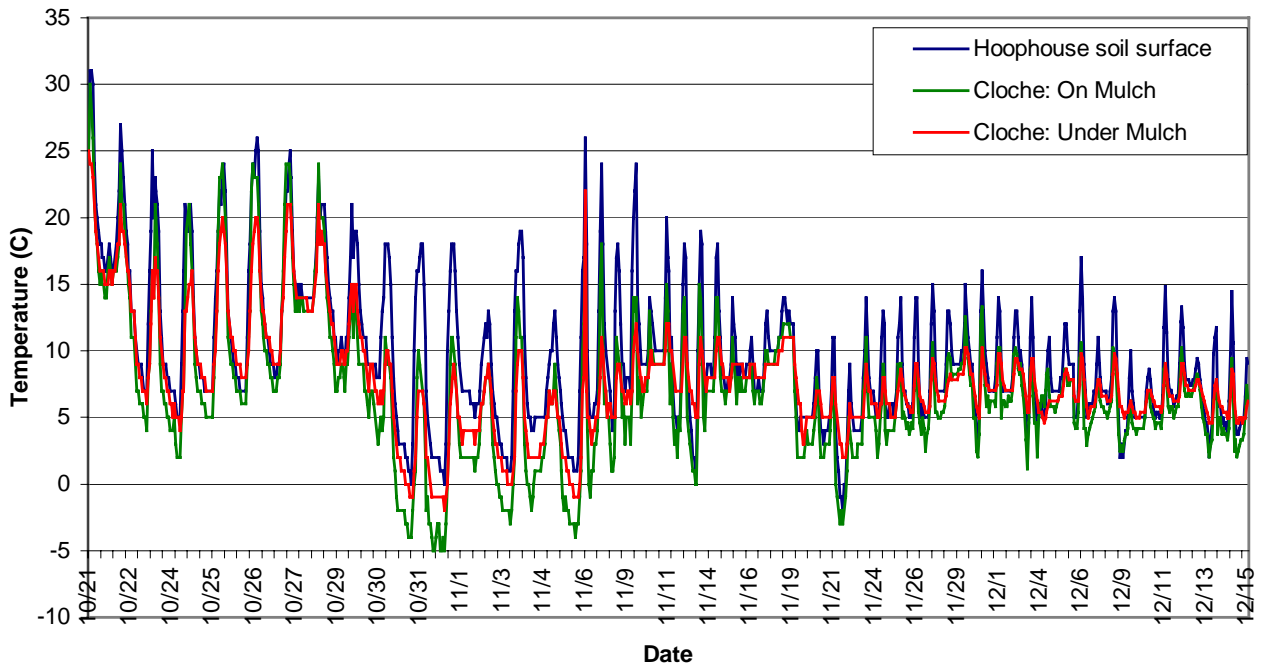


Figure 1. Temperatures during Planting 1 in the hoophouse (soil surface) and cloche (on top of paper mulch and under mulch) from October 21 to December 15, 2003.

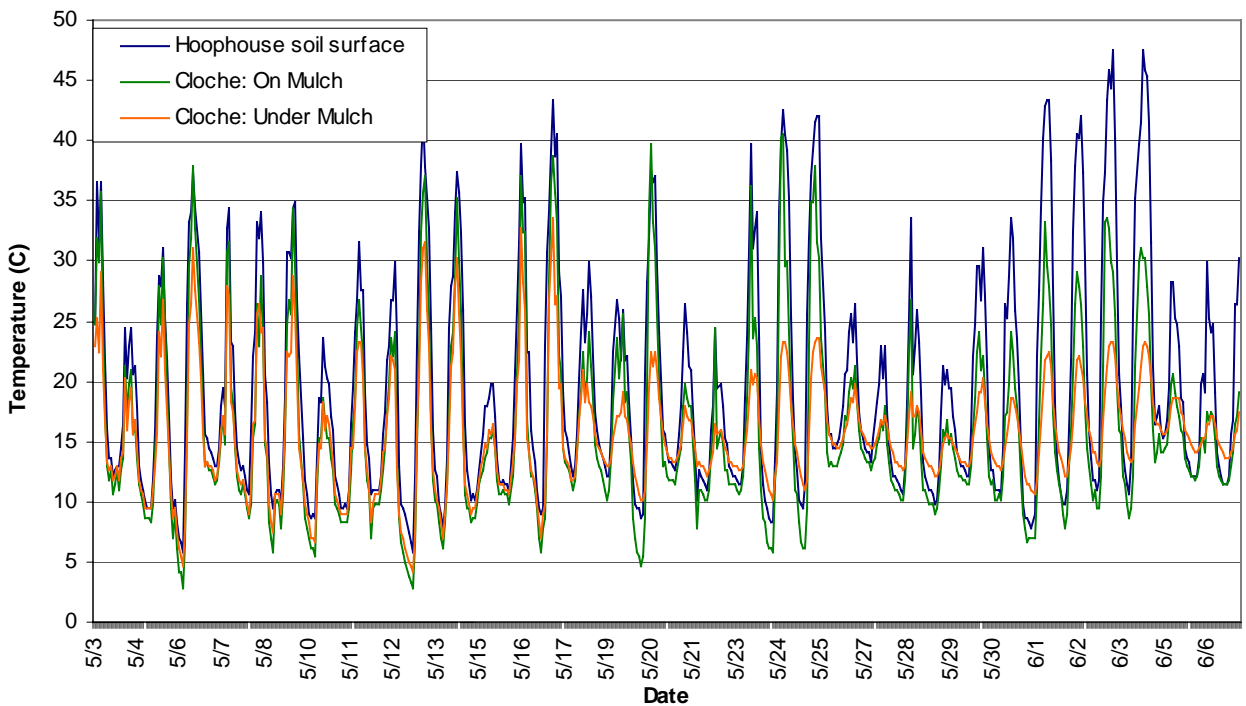


Figure 2. Temperatures during Plantings 2 and 3 in the hoophouse (soil surface) and cloche (on top of paper mulch and under mulch) from May 3 to June 7, 2004.

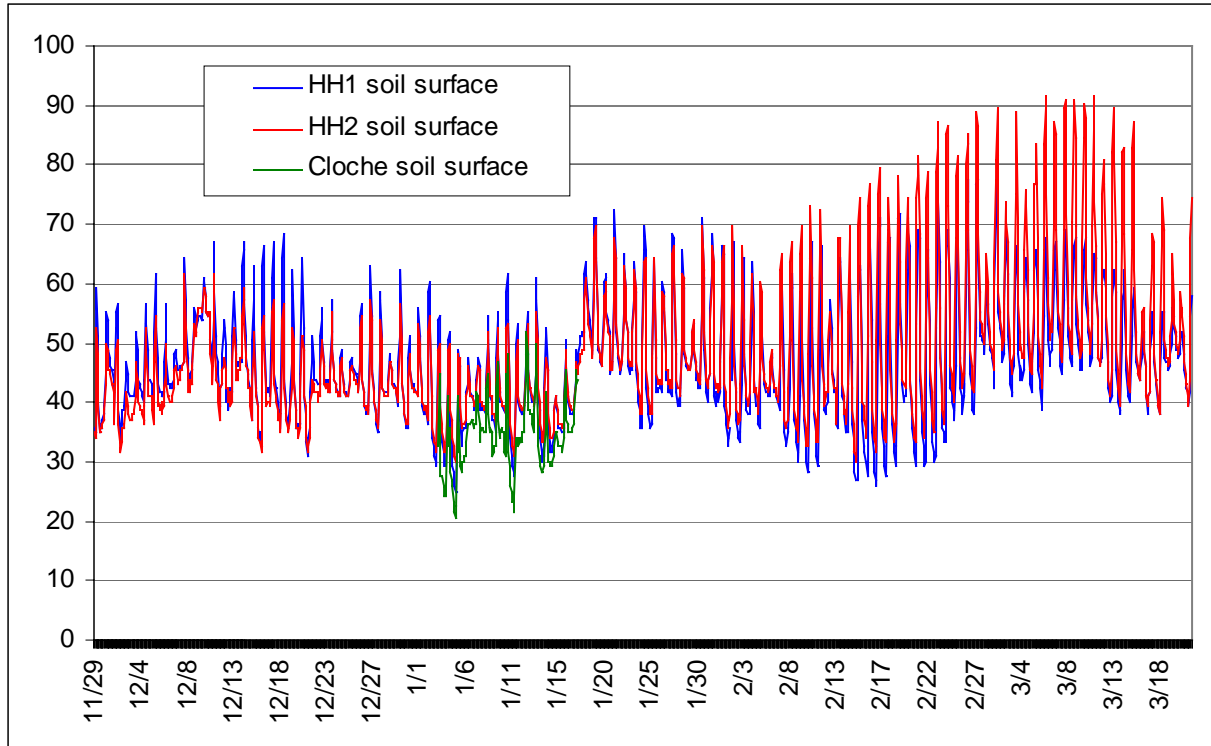


Figure 3. Temperatures at the soil surface in HH 1, HH2 and the cloche from December 2004 through March 2005.

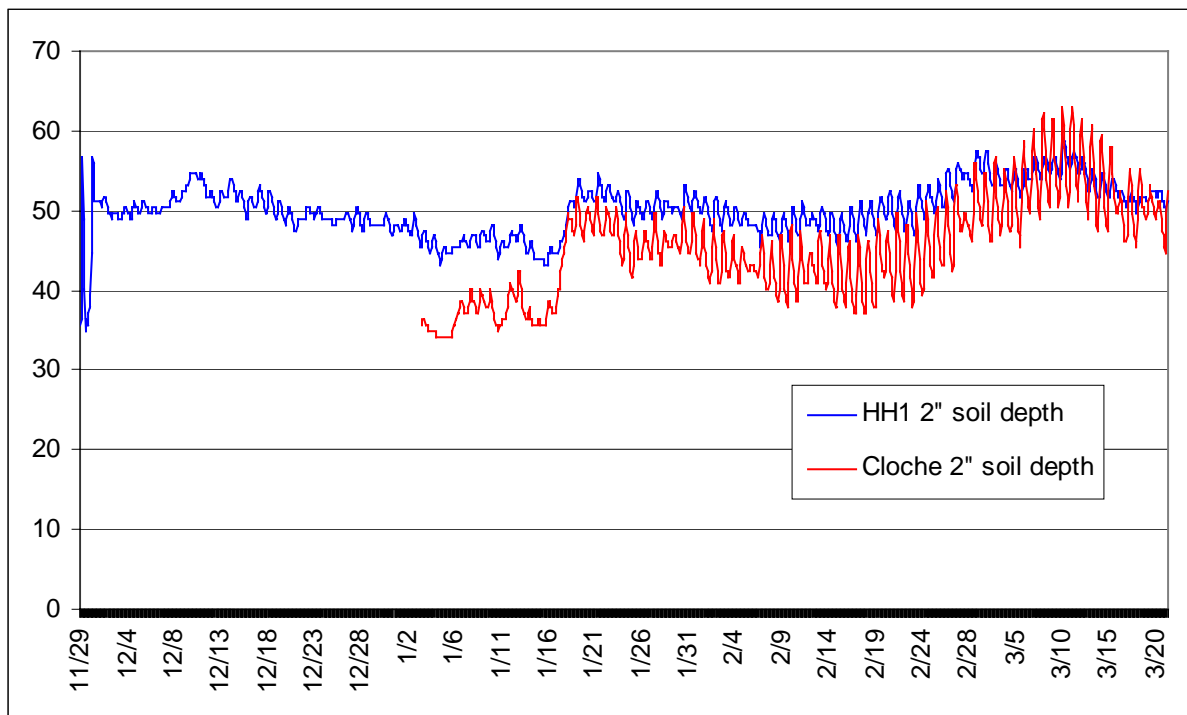


Figure 4. Temperatures at a 2-inch depth in HH 1 and the cloche from December 2004 through March 2005.

