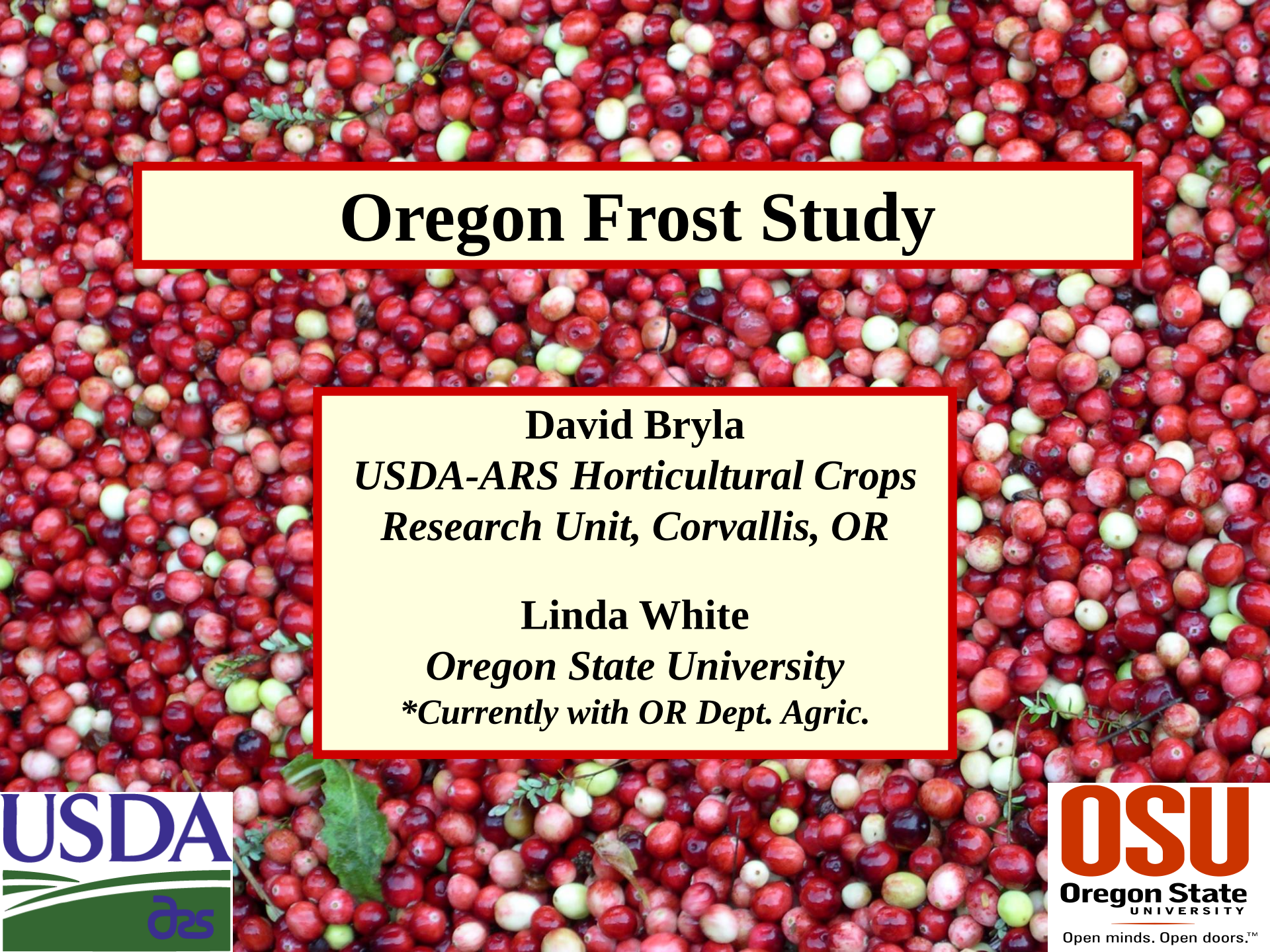




Oregon Frost Study

David Bryla
*USDA-ARS Horticultural Crops
Research Unit, Corvallis, OR*

Linda White
Oregon State University
**Currently with OR Dept. Agric.*



Open minds. Open doors.™

**Cold air
drainage**



“Frost pockets”

Insulation

**Low-lying
vegetation**

**Radiational
cooling**

**6-10 °F
colder than
berm**

Cloudy night

Absorbed radiation $\geq$ emitted radiation

**For example:
When air temperature is 34°F,
leaf temperature will be $\geq$ 34°F**

Clear night

Absorbed radiation < emitted radiation

For example:
When air temperature is 34°F,
leaf temperature will be < 30°F

Sprinklers!!!

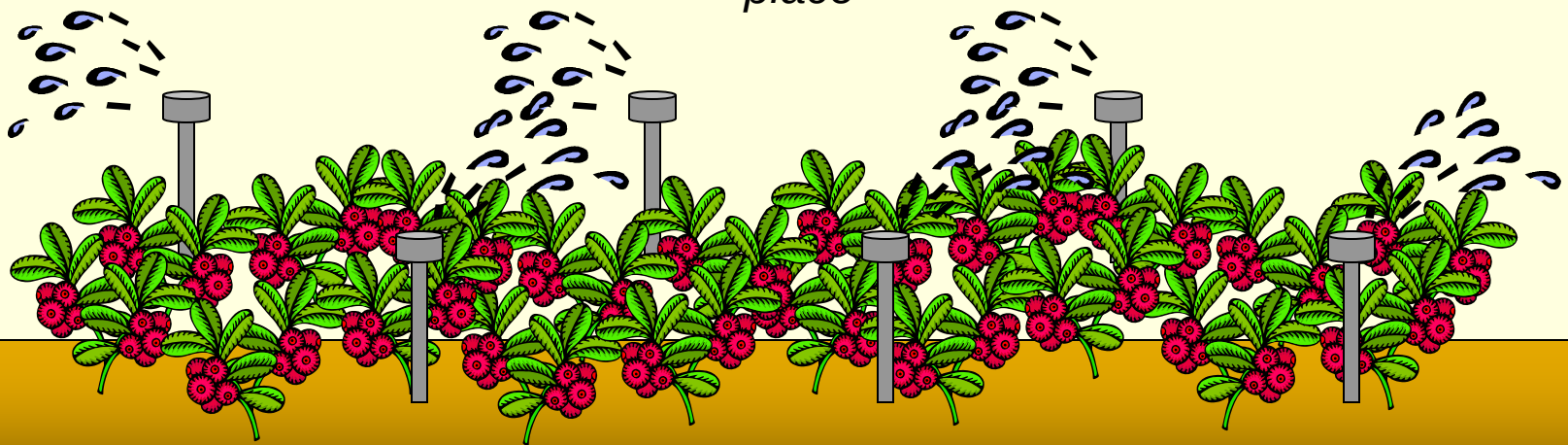
Goal

*Determine the critical temperatures for sprinkler frost protection
(i.e., when to start & stop)*

Turn system on
when wet-bulb
temperature is
2-3 °F above the
tolerance

*When the sprinklers
are turned on,
evaporation will take
place*

Don't turn it off
until at least
sunrise or
temperature is
above tolerance





Spring Frost Tolerance¹

Appearance of the bud	Ben Lear / Stevens ²	EB / Howes
Spring dormant (bud reddish)	20°F (<16°F)	18°F
White bud stage (loss of dormant color)	22°F	20°F
Slight loosening of bud scales (no bud swell)	25°F (<19°F)	22°F
Bud swell (cabbage head or popcorn stage)	27°F (21-25°F)	25°F
Bud elongation	29.5-30°F (27°F)	27°F
Roughneck – hook stage	29.5-30°F (27-30°F)	29.5-30°F

¹ DeMoranville (1998) *Frost Protection Guide for Massachusetts Cranberry Production*.

² Values in parentheses are for 'Stevens' in Wisconsin; Workmaster & Palta (2008) *Frost Hardiness of Cranberry Plant: A Guide to Manage the Crop During Critical Periods in Spring and Fall*.

Weather conditions

Massachusetts vs. Oregon

Month	East Wareham, MA normal temperatures (°F)			Bandon, OR normal temperatures (°F)			Difference (OR - MA)		
	Mean daily avg.	Mean daily max.	Mean daily min.	Mean daily avg.	Mean daily max.	Mean daily min.	Mean daily avg.	Mean daily max.	Mean daily min.
January	29.0	37.7	20.3	47.5	55.2	40.9	18.5	17.5	20.6
February	30.9	39.5	22.3	47.6	55.1	40.7	16.7	15.6	18.4
March	37.0	45.7	28.4	48.4	55.5	41.6	11.4	9.8	13.2
April	45.8	54.9	36.8	49.6	56.6	42.4	3.8	1.7	5.6
May	55.8	64.9	47.0	53.2	59.8	46.6	-2.6	-5.1	-0.4
June	65.3	74.0	56.7	56.5	62.2	50.6	-8.8	-11.8	-6.1
July	71.4	80.0	62.9	58.8	64.4	53.3	-12.6	-15.6	-9.6
August	69.9	78.8	61.7	58.9	65.2	53.2	-11.0	-13.6	-8.5
September	62.9	72.0	53.8	57.4	65.1	50.3	-5.5	-6.9	-3.5
October	52.5	61.9	42.9	54.7	62.6	47.4	2.2	0.7	4.5
November	43.6	52.6	34.6	50.7	58.4	43.5	7.1	5.8	8.9
December	34.2	43.1	25.4	46.8	53.9	40.2	12.6	10.8	14.8
Average	49.9	58.8	41.1	52.5	59.5	45.9	2.7	0.7	4.8

Weather conditions

2014-2015

Month	East Warham, MA monthly extremes		Bandon, OR monthly extremes		Difference (OR-MA)	
	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
January	54.5	0.5	70.0	29.7	15.5	29.2
February	39.0	-13.0	71.6	32.2	32.6	45.2
March	59.9	-5.0	63.6	32.7	3.7	37.7
April	67.1	22.0	76.9	36.0	9.8	14.0
May	79.7	39.2	61.5	39.8	-18.2	0.6
June	90.5	41.0	65.8	44.6	-24.7	3.6
July	92.3	52.7	75.3	48.8	-17.0	-3.9
August	82.4	50.9	71.6	46.7	-10.8	-4.2
September	85.1	38.3	79.7	40.2	-5.4	1.9
October	77.9	35.0	81.4	42.6	3.5	7.6
November	63.0	19.0	70.3	34.0	7.3	15.0
December	67.0	15.0	68.6	27.2	1.6	12.2
Average	71.5	24.6	71.4	37.9	-0.2	13.2

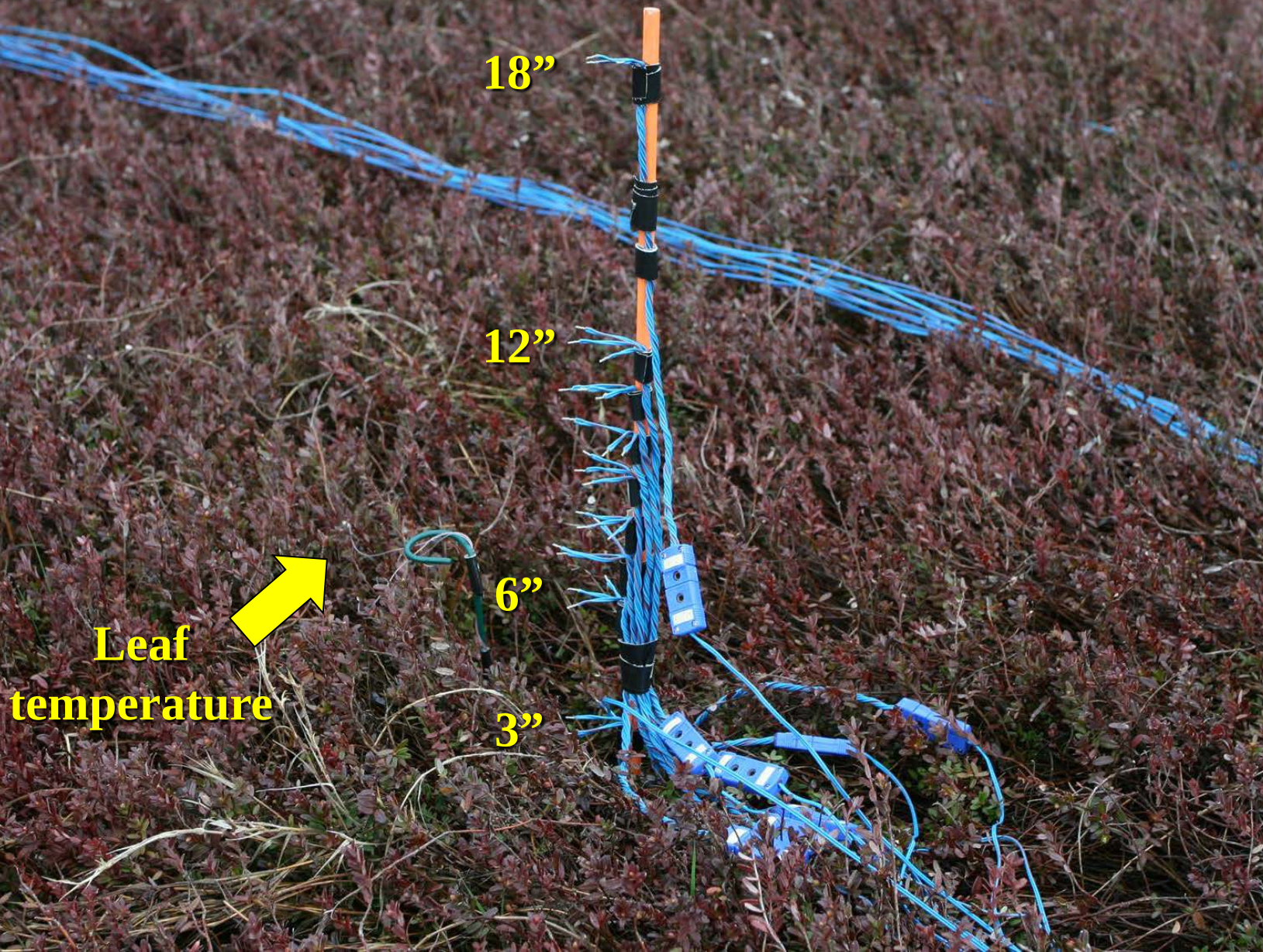
Field site (Sea Wind Farms)

‘Stevens’

Temperature grid



Temperature profile



Temperature grid

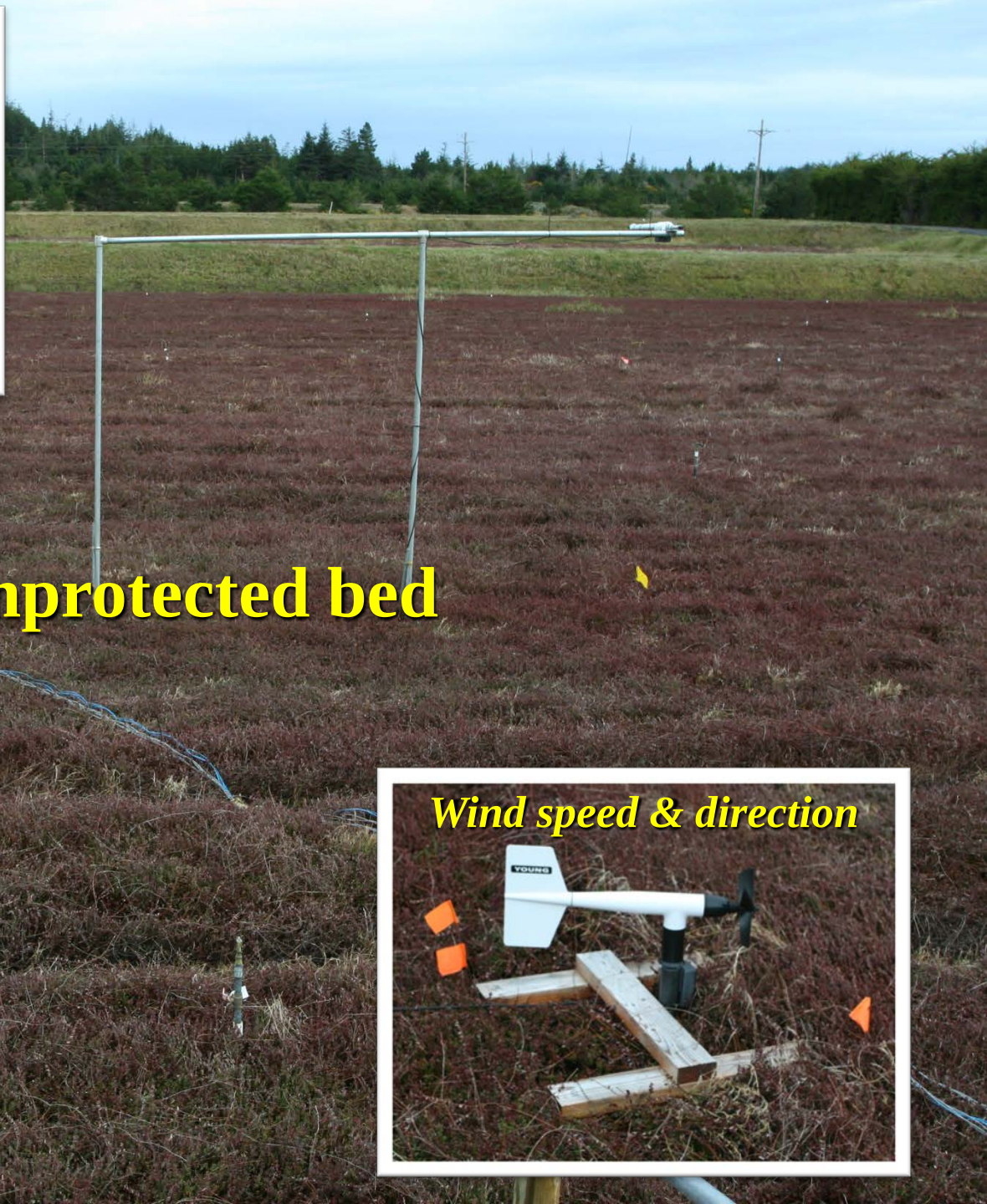


20 0 20
Scale in Meters
ELEVATIONS IN METERS

Net radiation



Unprotected bed



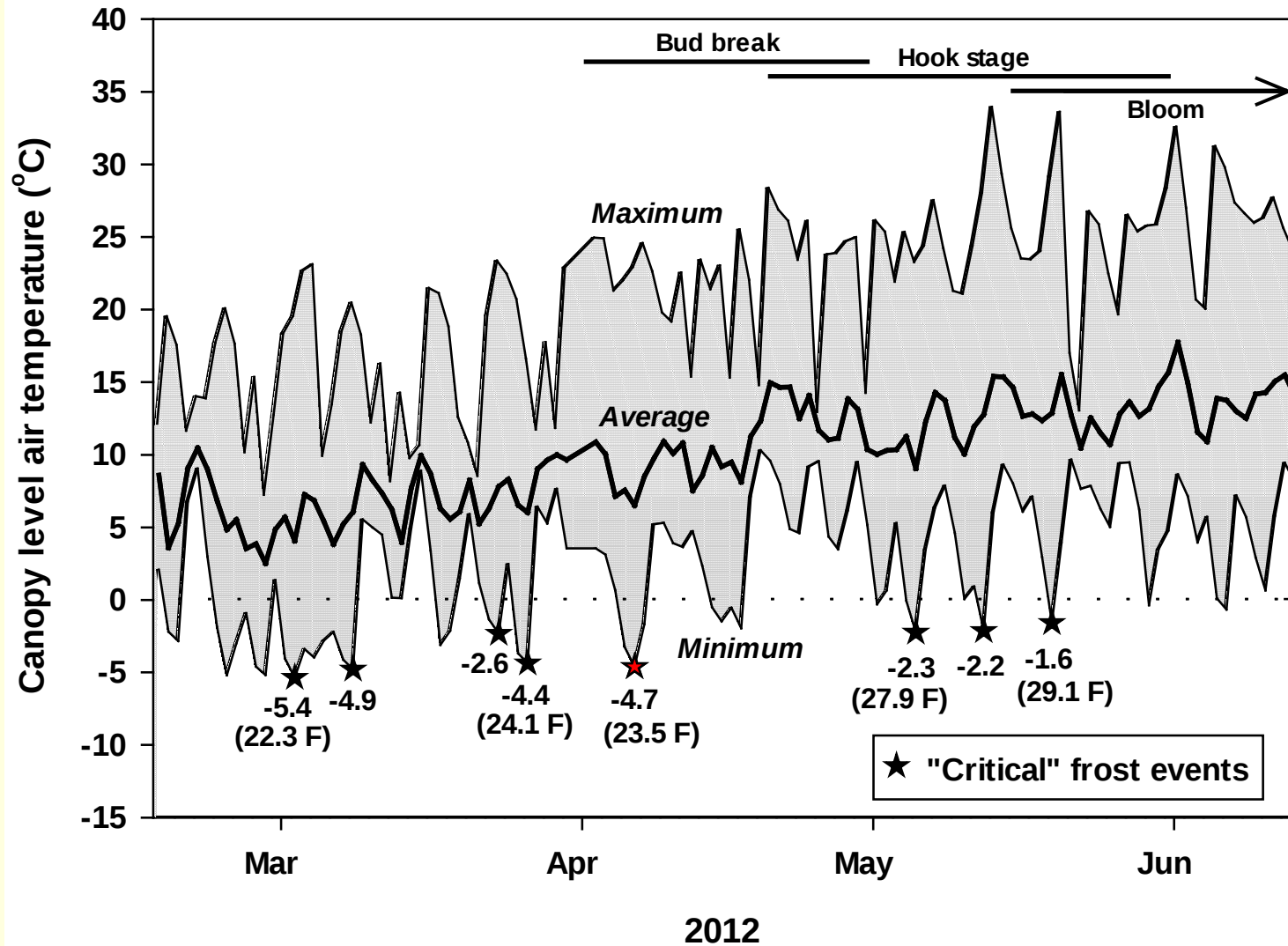
Temperature & relative humidity



Wind speed & direction



Unprotected bed

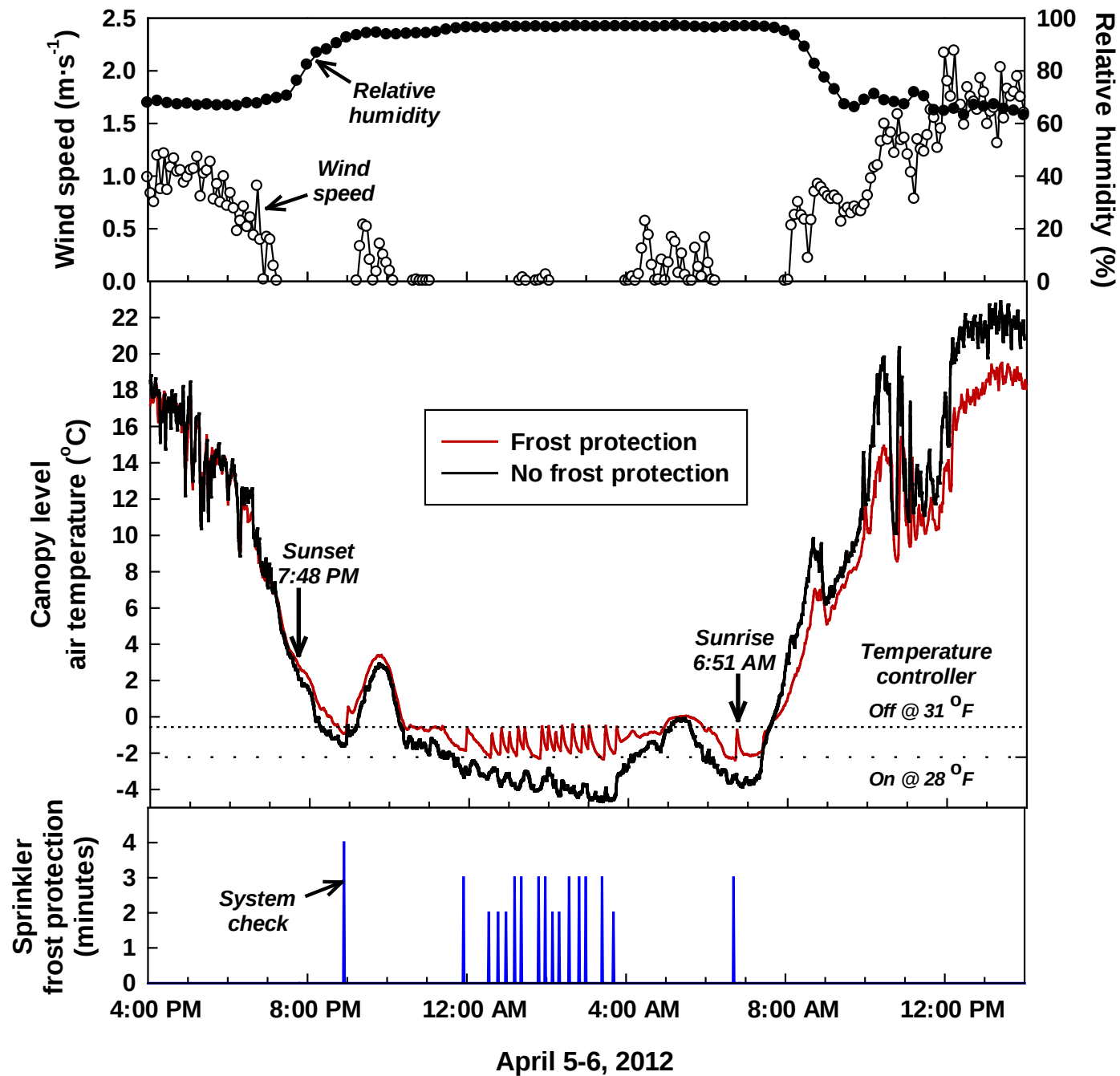


A close-up photograph of a plant, likely a type of heather or similar low-growing shrub. The plant features numerous small, elongated, reddish-pink buds or young leaves clustered along thin, dark brown stems. Interspersed among these are small, oval-shaped green leaves. The overall appearance is dense and textured, with some stems showing a slight curve. The lighting is soft, highlighting the varied colors and textures of the plant parts.

Early April

Tight bud – cabbage head

(20 – 27 °F)



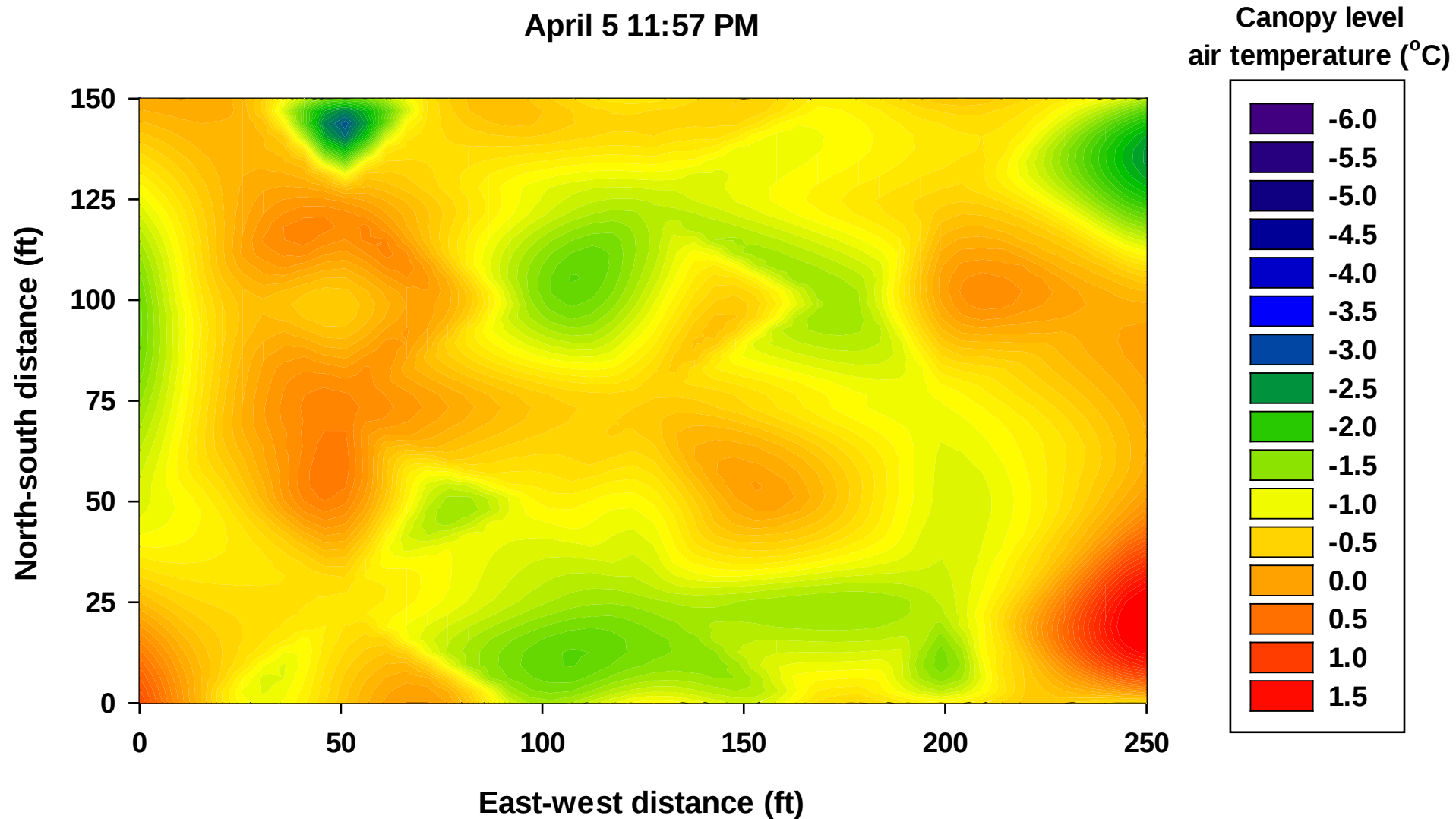
Temperature grid



20 0 20
Scale in Meters
ELEVATIONS IN METERS

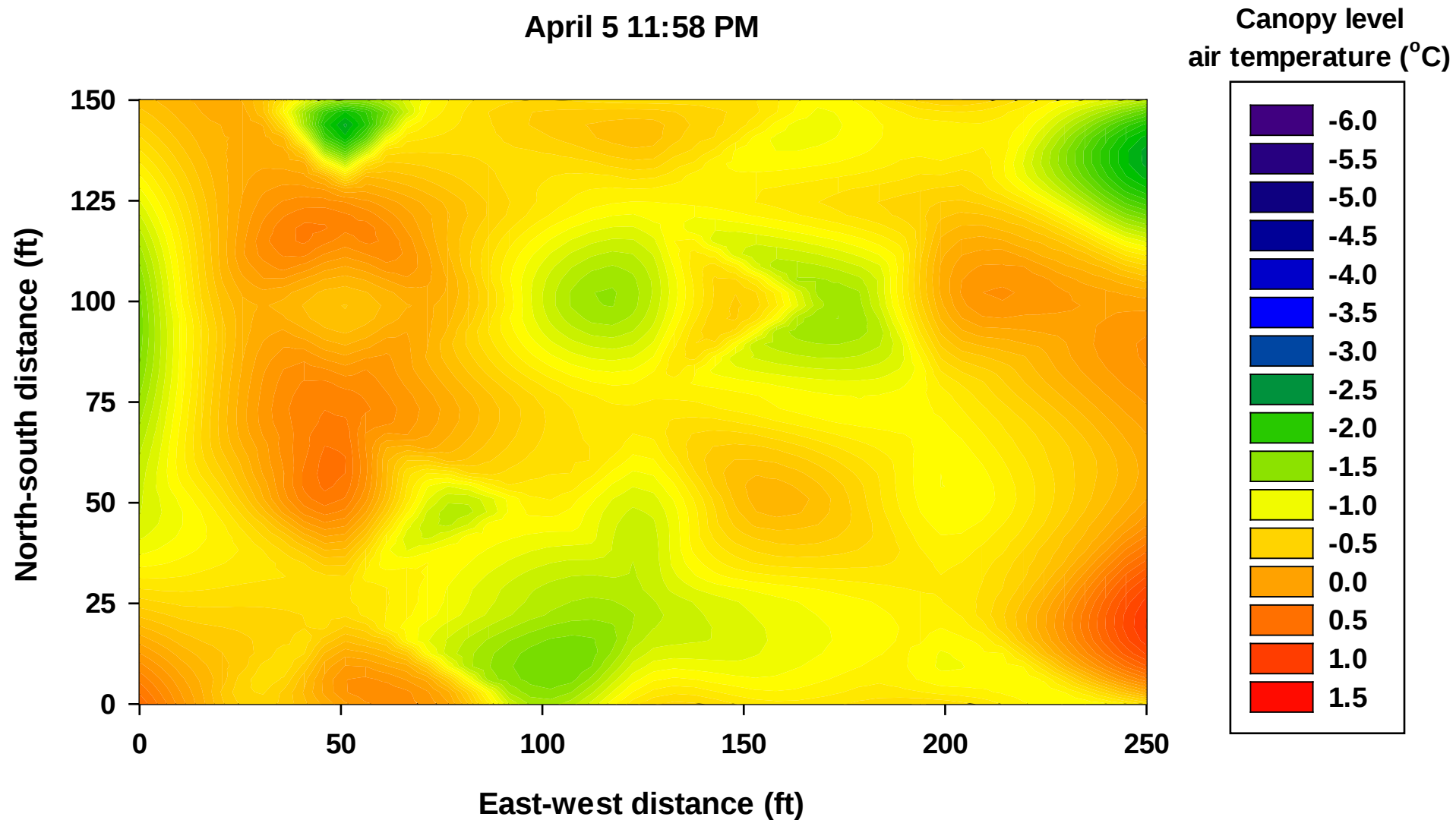
Sprinklers “On” (3 minutes)

April 5 11:57 PM



Sprinklers “Off”

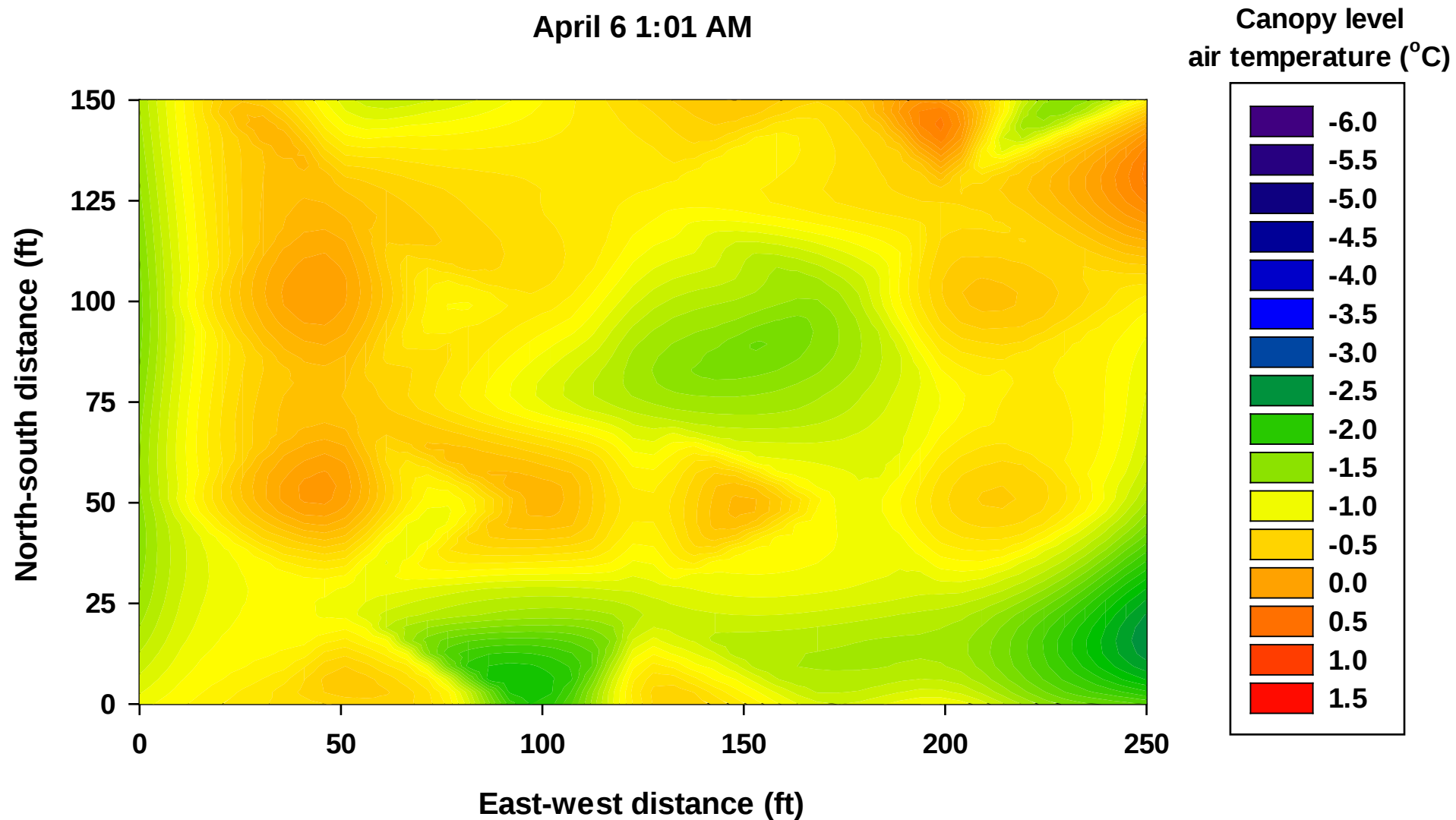
April 5 11:58 PM



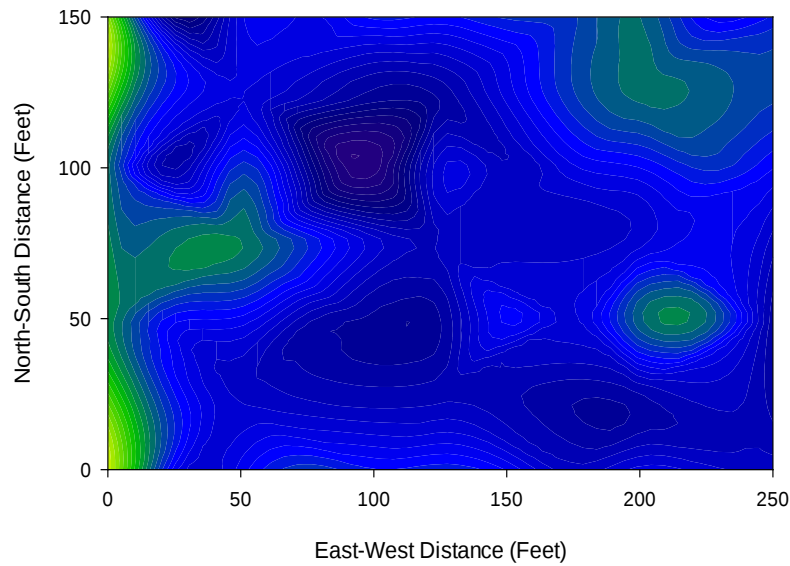
Temperature varied from -1.6 to 0.3 °C (29.1–32.5 °F)

Sprinklers “Off”

April 6 1:01 AM

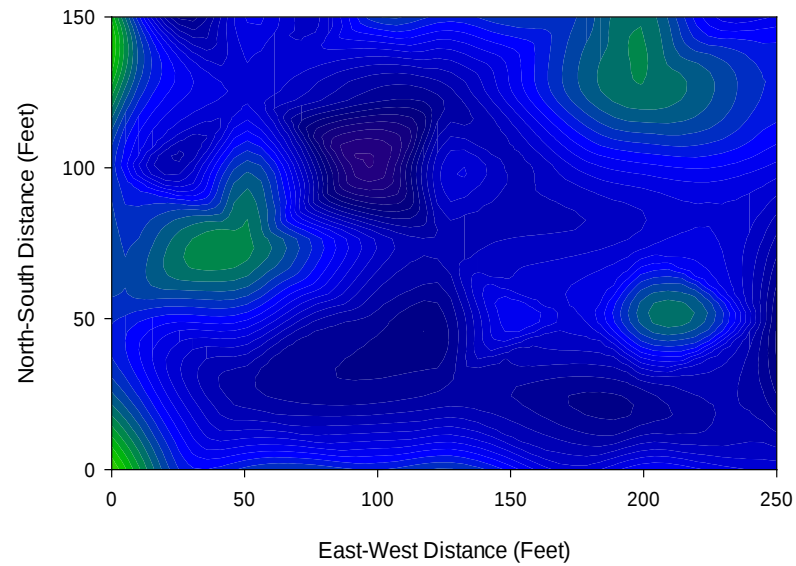


5-18-11 0:06 am



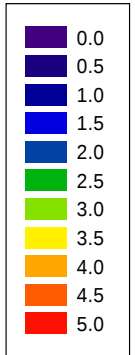
Ambient outside of bed: 4.3 °C

5-18-11 0:18 am

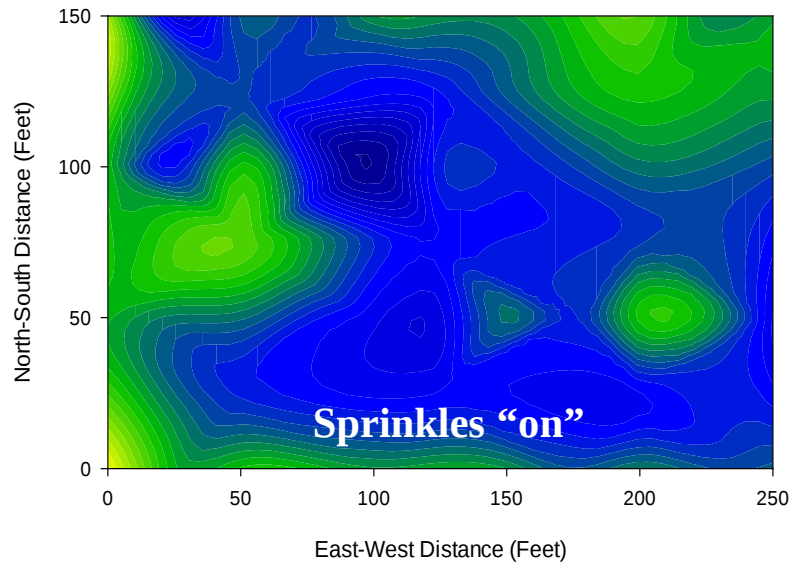


Ambient outside of bed: 4.1 °C

Temperature (°C)

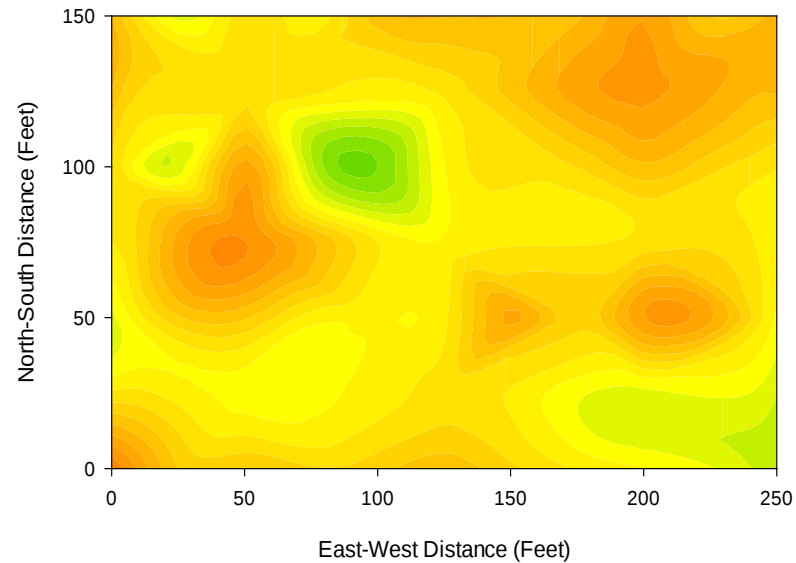


5-18-11 0:30 am



Ambient outside of bed: 4.0 °C

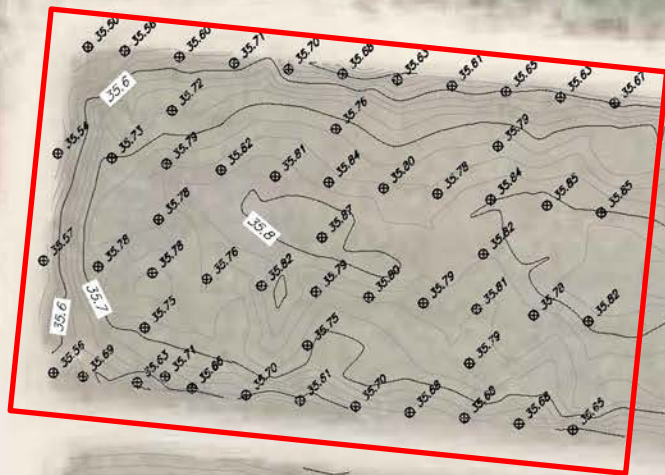
5-18-11 0:42 am



Ambient outside of bed: 4.0 °C

Temperature varied 3.5-4.0 °F before & after sprinkler frost protection was initiated

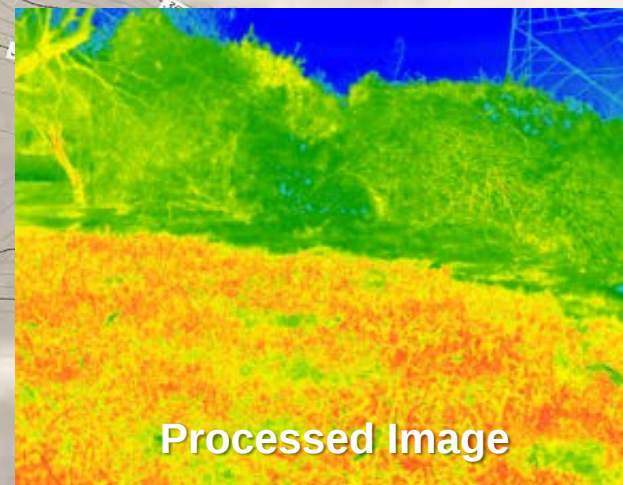
Temperature grid



Normal Lens

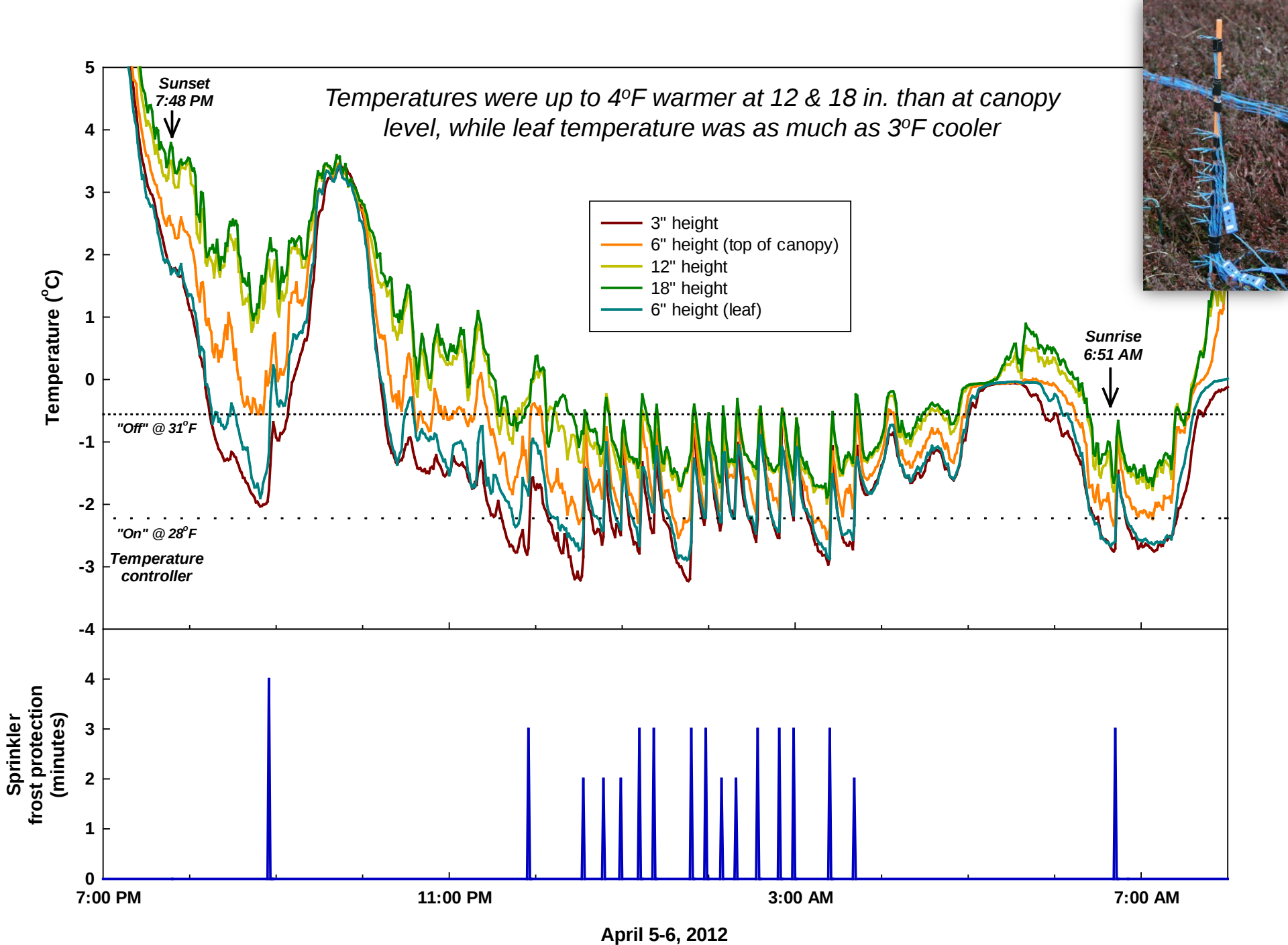


NDVI Lens



Processed Image

20 0 20
Scale in Meters
ELEVATIONS IN METERS



Total Water Use for Frost Protection (2012)

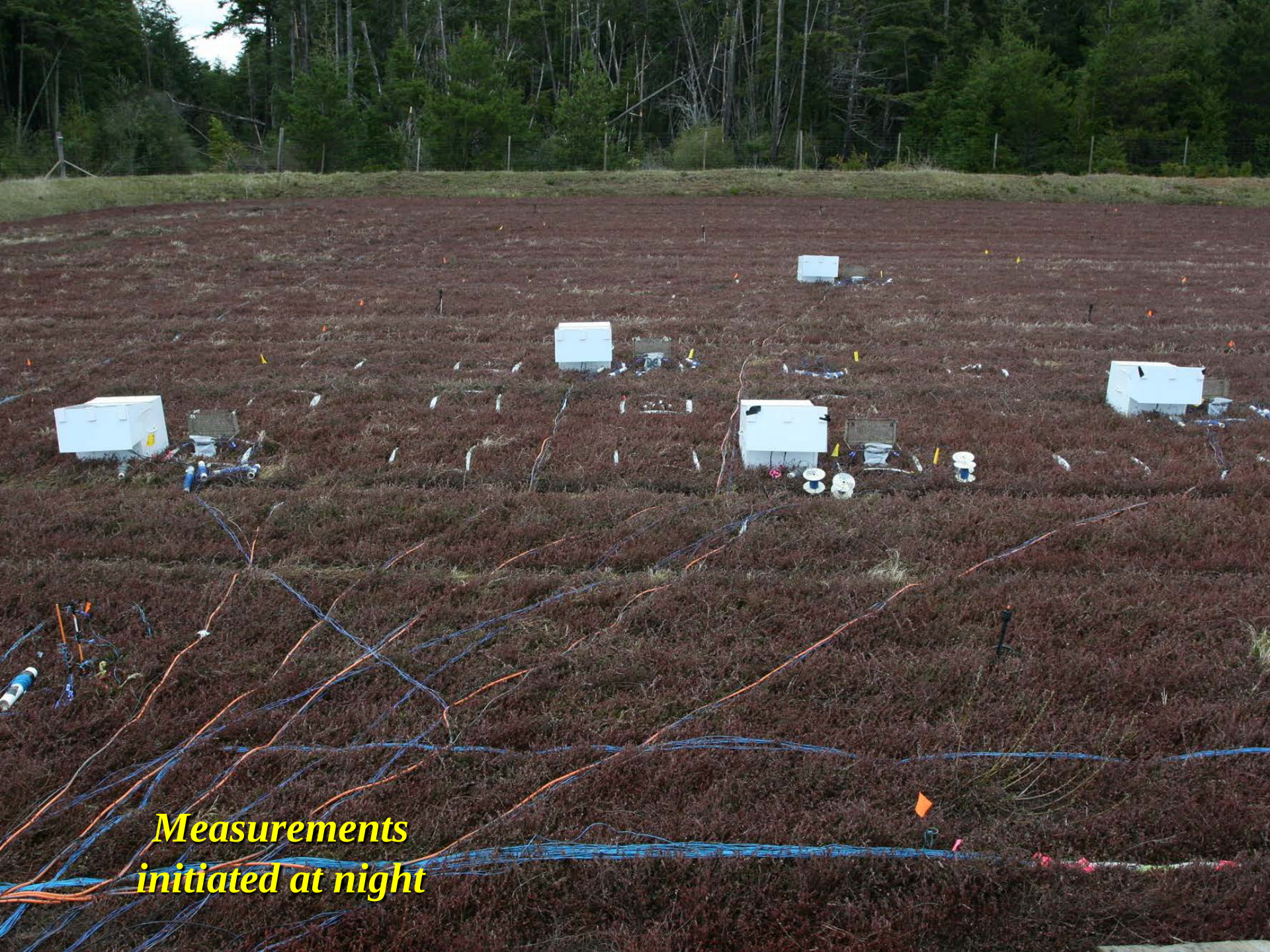
Frost event	Cycles	Irrigation		Water temperature (°F)
		Minutes per cycle	Total minutes	
March 1-2	18	1-4	43	55.2
March 7-8	12	1-4	29	--
March 23	1	2	2	--
March 25-26	23	2-3	55	--
April 5-6*	17	2-4	46	55.4
May 5	3	4-5	13	60.8
May 12	10	6-9	77	64.4
May 19	1	8	8	65.3
Total	85	--	273	--

>70% yield loss in unprotected bed

**Field
measurements**

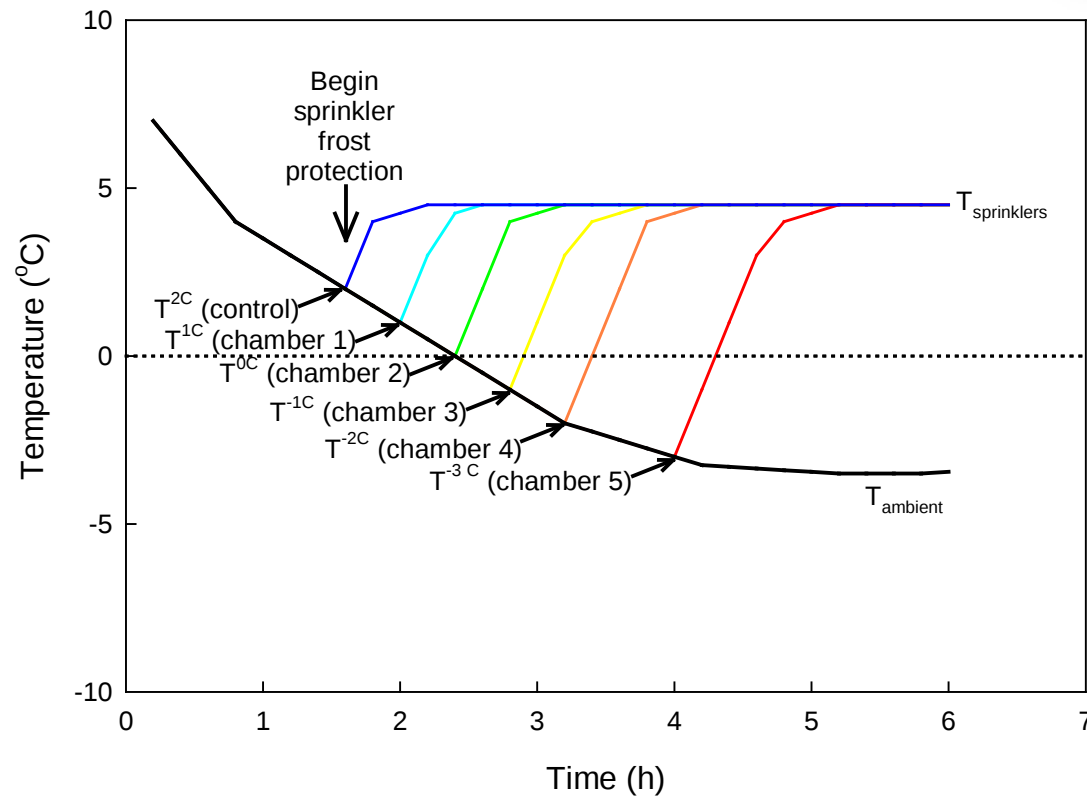


Temperature control unit



*Measurements
initiated at night*

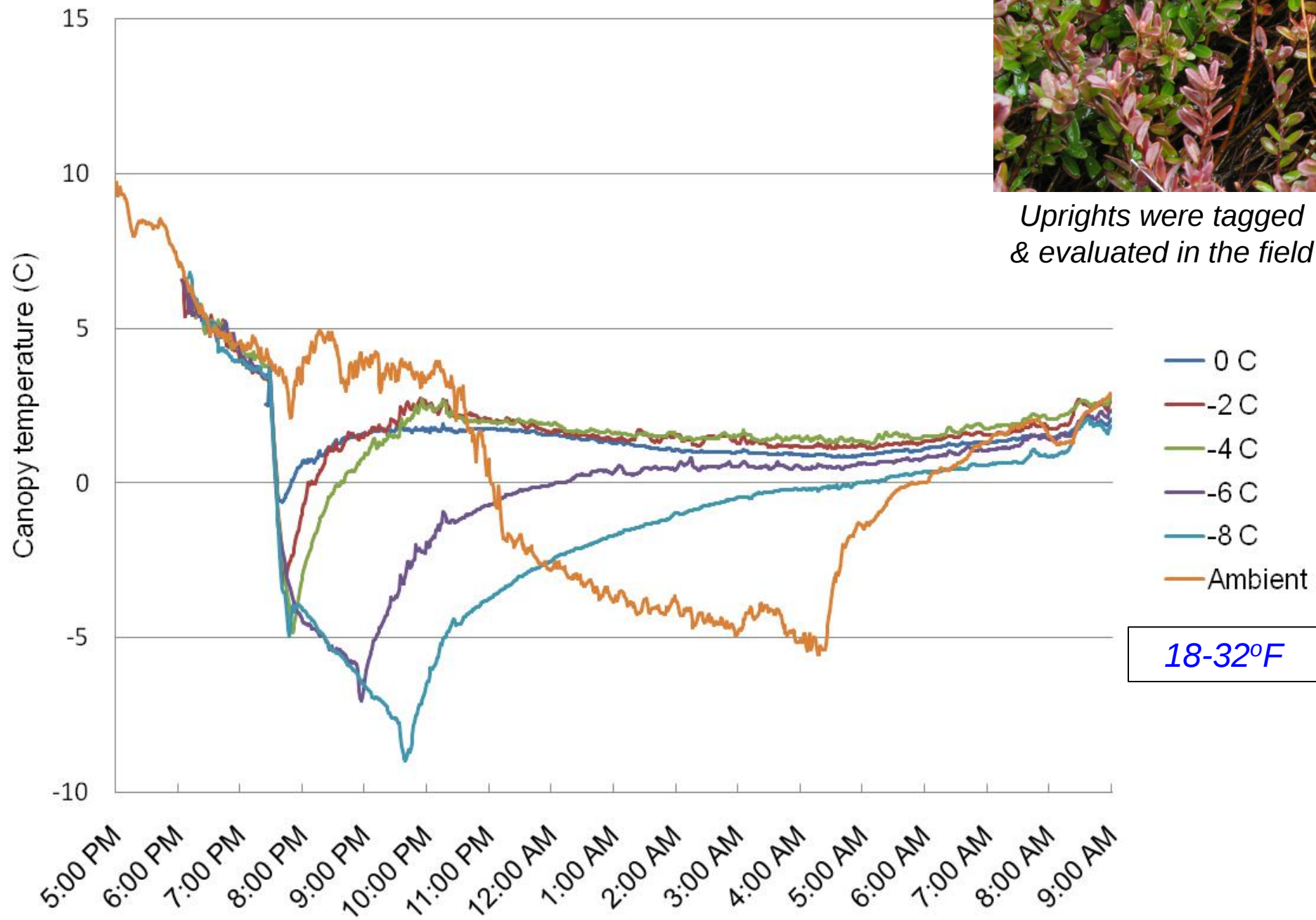
Critical temperatures for sprinkler frost protection



11-12 Feb. 2012



*Uprights were tagged
& evaluated in the field*



Frost Tolerance (Chamber Tests)

Minimum canopy level air temperature (°C)

Test date (stage)	0 (32°F)	-1 (30°F)	-2 (28.5°F)	-3 (26.5°F)	-4 (25°F)	-5 (23°F)	-6 (21°F)	-8 (18°F)
Feb. 11-12 (tight bud)	None	---	None	---	None	---	None	Light
April 12-13 (tight–cabbage)	None	---	None	---	V. light	---	---	---
April 26-27 (cabbage– roughneck)	None	---	V. light	---	Light	---	Mod.	<i>Toast</i>
May 16-17 (roughneck–hook)	None	Light	<i>Heavy</i>	---	---	---	---	---
May 30-31 (hook–bloom)	Light	Mod.	Mod.	Heavy	---	---	---	---

N.b., >70% yield loss in unprotected bed.



Spring Frost Tolerance (Stevens)

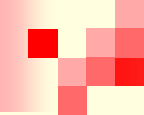
Appearance of the bud	Massachusetts ¹	Oregon
Spring dormant (bud reddish)	20°F	20°F
White bud stage (loss of dormant color)	22°F	--
Slight loosening of bud scales (no bud swell)	25°F	26°F
Bud swell (cabbage head or popcorn stage)	27°F	27°F
Bud elongation	29.5-30°F	30°F
Roughneck – hook stage	29.5-30°F	31°F
Bloom	--	32°F

¹ DeMoranville (1998) *Frost Protection Guide for Massachusetts Cranberry Production*.



SUMMARY

- Frost damage occurred in unprotected bed (>70% yield reduction)
 - Frost protection was critical
 - Cycled irrigation works
 - Irrigation requirements were minimal (4.5 h total)
- Leaf < canopy (air) temperature (2°F)
 - Leaf $\approx$ air temperature at 3" height
 - Increased rapidly with height (above canopy)
 - Varied 3.5–4°F within the bed
- Critical temperature for frost damage increased with bud development
 - Values were similar to Massachusetts
 - Time dependent?



Acknowledgements

- Amber Shireman, Kim Phillips (tech support)
- Sea Wind Farms (Knute Anderssen)
- USDA NRCS (Pat Jones, Tom Purvis & Ginny Cairo)
- OR Cranberry Growers' Association (Bob Donaldson)
- Northwest Center for Small Fruit Research
- Ocean Spray