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New Jersey Agricultural Experiment Station

Frost Protection in the Orchard: Methods, Updates and Costs

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PEACH FARMING IN THE GARDEN STATE: NOT AS SWEET A DEAL AS IT USED TO BE

TARA NURIN | JULY 27, 2016

New Jersey's peach industry is going through some changes, some for the better, others — it remains to be seen

This spring, people worried about peaches. After an early April frost killed a quarter of New Jersey's crop, by one estimate, farmers, chefs, and consumers fretted that there wouldn't be enough of

l by the mid-

Passive Frost Protection Methods/decisions

1. Site selection, avoid poor air drainage
2. Variety selection – delayed and extended blooming varieties
3. Fall application of bloom delaying PGRs
4. Delayed pruning
5. Do not invite the frost! – use fall weed management, remove tall weeds and wind breaks along the edge of edges of orchards

Relative temperature differences as influenced by orchard floor conditions (Courtesy, Robert Crassweller, PSU).

Bare, firm, moist ground	**Warmest**
Shredded cover crop, moist ground	½°F colder
Low-growing cover crop	1°-3°F colder
Dry, firm ground.	2°F colder
Freshly disked, fluffy ground	2°F colder
High cover crop	2°-4°Fcolder
Where cover crop restricts air drainage	6°-8°F colder

Active Protection Methods

1. Heaters/smudge pots
2. Wind machines
3. Over head sprinklers
4. Under tree irrigation
5. Frost dragon
6. Helicopters
7. Chemicals (cellulose-based spray covers)

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First step: Estimate the risk of damage by monitoring the bud development and weather.

CRITICAL SPRING TEMPERATURES FOR TREE FRUIT BUD DEVELOPMENT STAGES

Pome Fruit (Apples and Pears)

Apples									
Apples	**Silver tip**	**Green Tip**	**Half inch green**	**Tight Cluster**	**First Pink**	**Full Pink**	**First Bloom**	**Full Bloom**	**Post Bloom**
Old temp	16	16	22	27	27	28	28	29	29
10% kill	15	18	23	27	28	28	28	28	28
90% kill	2	10	15	21	24	25	25	25	25

Peaches									
Peaches	**Swollen Bud**	**Calyx Green**	**Calyx Red**	**First Pink**	**First Bloom**	**Full Bloom**	**Post Bloom**		
Old temp	23	--	--	25	--	27	30		
10% kill	18	21	23	25	26	27	28		
90% kill	1	5	9	15	21	24	25		

Michigan State Uni.

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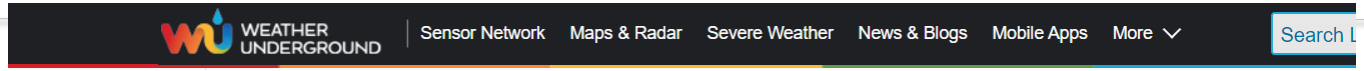


Grand Junction, CO Hourly Weather Forecast

28° **GRAND JUNCTION STATION** | CHANGE

TODAY | **HOURLY** | 10-DAY | CALENDAR | HISTORY | WUNDERMAP

Time	Conditions	Temp.	Feels Like	Precip	Amount	Cloud Cover	Dew Point	Humidity	Wind	Pressure
12:00 am	Partly Cloudy	30 °F	30 °F	4 %	0 in	43 %	24 °F	80 %	3 mph E	30.58 in
1:00 am	Partly Cloudy	29 °F	29 °F	3 %	0 in	50 %	24 °F	80 %	3 mph E	30.57 in
2:00 am	Partly Cloudy	28 °F	25 °F	3 %	0 in	49 %	23 °F	81 %	3 mph ESE	30.56 in
3:00 am	Partly Cloudy	28 °F	28 °F	3 %	0 in	55 %	23 °F	82 %	3 mph ESE	30.56 in
4:00 am	Mostly Cloudy	27 °F	24 °F	4 %	0 in	64 %	23 °F	82 %	3 mph ESE	30.56 in
5:00 am	Mostly Cloudy	27 °F	27 °F	3 %	0 in	64 %	22 °F	81 %	2 mph ESE	30.56 in
6:00 am	Mostly Cloudy	27 °F	23 °F	3 %	0 in	63 %	21 °F	79 %	4 mph ESE	30.56 in
7:00 am	Mostly Cloudy	27 °F	23 °F	3 %	0 in	62 %	21 °F	78 %	3 mph SE	30.56 in
8:00 am	Partly Cloudy	27 °F	23 °F	3 %	0 in	55 %	21 °F	76 %	4 mph SE	30.55 in
9:00 am	Partly Cloudy	30 °F	27 °F	2 %	0 in	53 %	22 °F	70 %	3 mph SE	30.53 in
10:00 am	Partly Cloudy	33 °F	30 °F	1 %	0 in	51 %	23 °F	65 %	4 mph ESE	30.49 in
11:00 am	Partly Cloudy	37 °F	33 °F	0 %	0 in	53 %	23 °F	57 %	4 mph ESE	30.44 in
12:00 pm	Partly Cloudy	39 °F	37 °F	0 %	0 in	57 %	24 °F	55 %	3 mph NE	30.39 in
1:00 pm	Mostly Cloudy	41 °F	41 °F	0 %	0 in	66 %	24 °F	51 %	3 mph NNE	30.33 in
2:00 pm	Mostly Cloudy	42 °F	42 °F	0 %	0 in	63 %	25 °F	50 %	3 mph N	30.29 in
3:00 pm	Mostly Cloudy	42 °F	41 °F	0 %	0 in	63 %	25 °F	50 %	3 mph NNW	30.26 in
4:00 pm	Partly Cloudy	42 °F	40 °F	1 %	0 in	58 %	25 °F	51 %	4 mph NW	30.26 in
5:00 pm	Mostly Cloudy	39 °F	39 °F	2 %	0 in	60 %	26 °F	60 %	3 mph NNW	30.26 in

Second step:

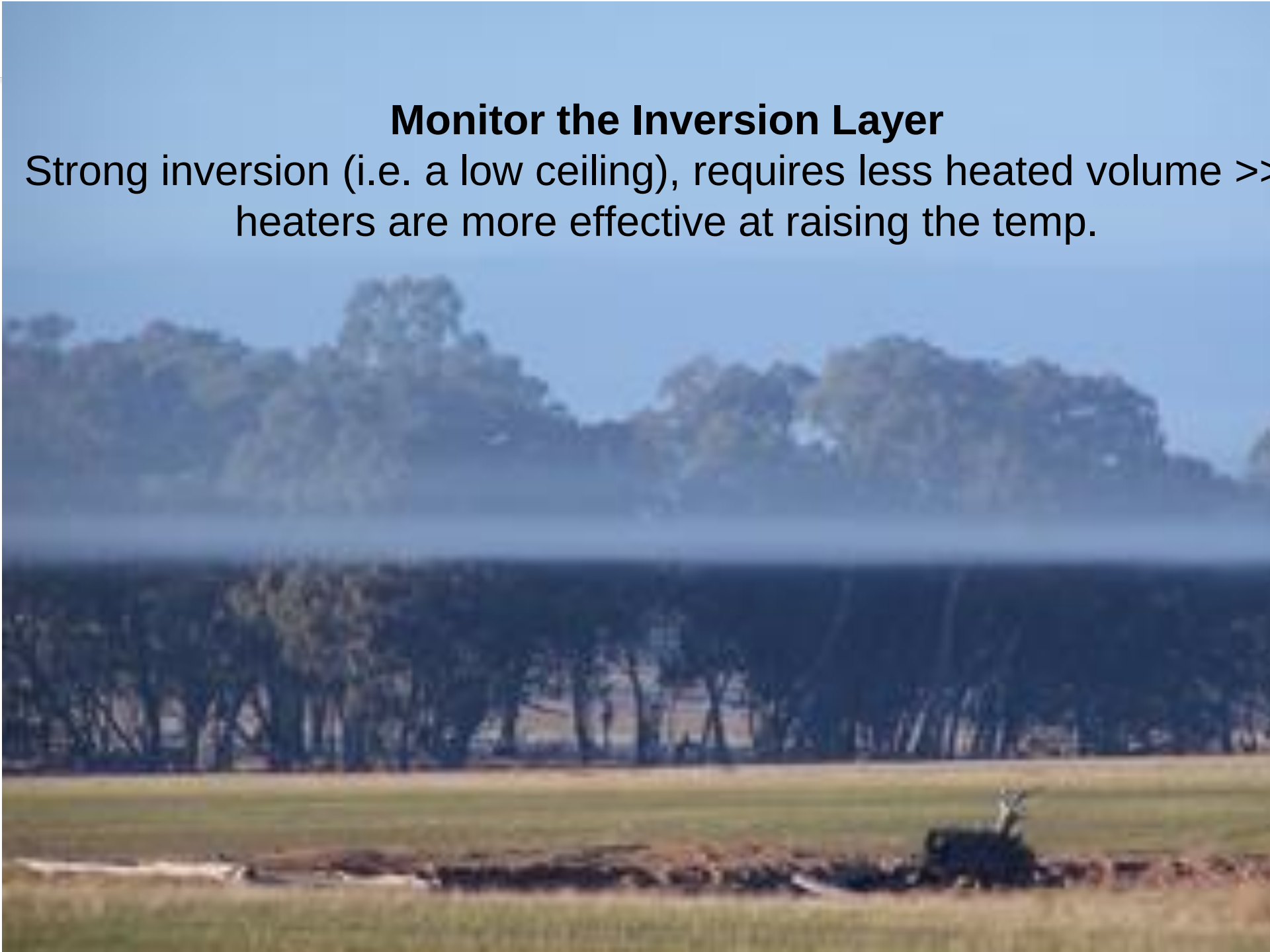
Estimate risk of damage Vs. cost-benefits of frost protection

Heaters or Smudge Pots

- Heaters provide supplemental heat to help replace energy losses.
- Raises temp. by few degrees and <5mph is necessary
- Generally inefficient so proper design and management is necessary.
-

Monitor the Inversion Layer

Strong inversion (i.e. a low ceiling), requires less heated volume >> heaters are more effective at raising the temp.



Matt Davenport's comments on in-ground propane Heaters

- 3°F temp increase
- Fuel lines must handle 300 psi by code
- Minimum of 4-1000 gal tanks to feed system so it doesn't freeze up.

Cost of 36 heaters/acre = $2,700

Cost of in-ground lines = $4,500

Total set up cost = $7,200

Fuel cost per acre = $82

Over-head Irrigation for icing

- Very effective (down to 23°F)
- Target only the canopy
- Uses much less energy, labor
- Needs strong scaffold branches

A mixture of ice and water exposed to below freezing point remains at 32ºF until all the water is frozen

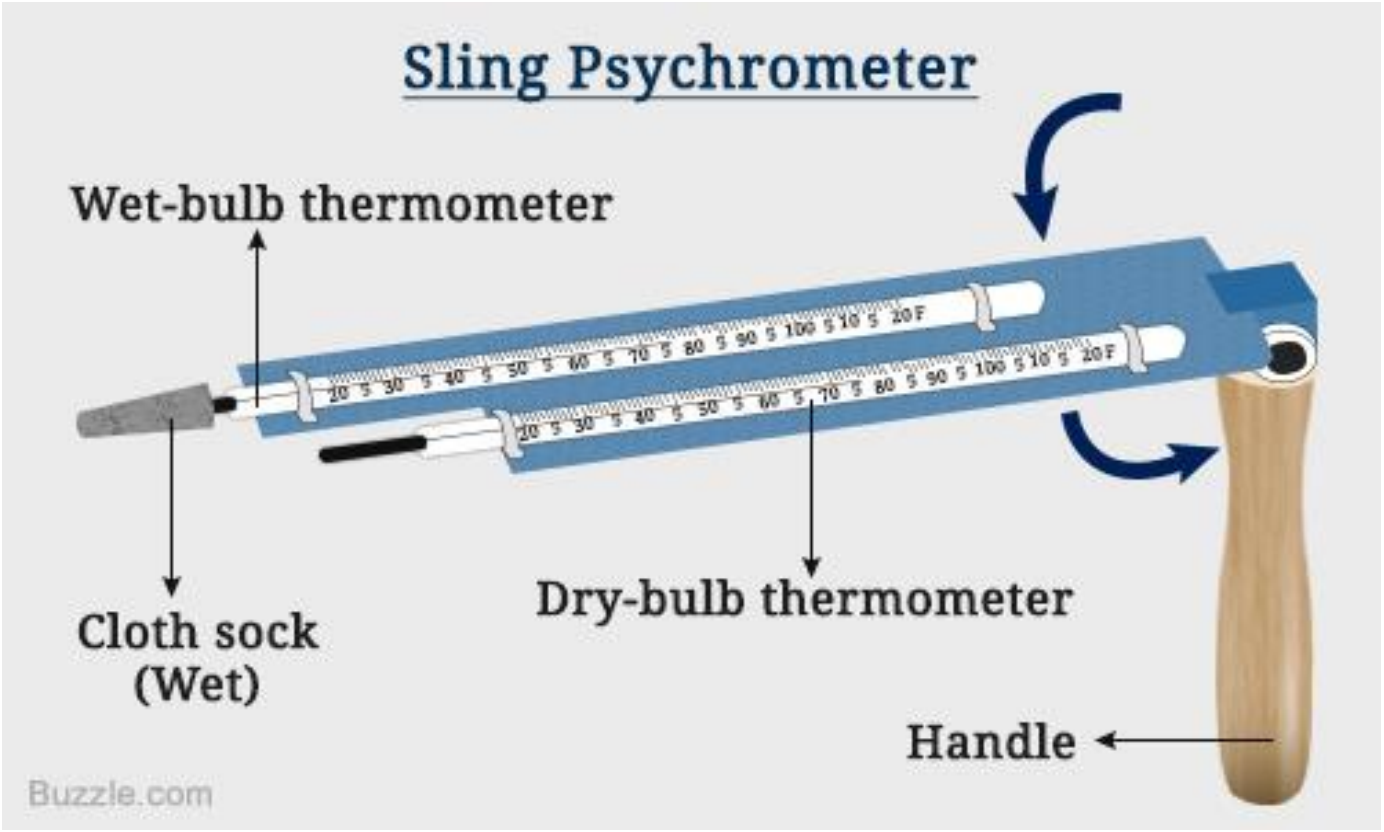
Specifications for over-head

- Solid set system, pond fed
- Standard impact sprinklers 27/ac.
- 0.2”/hr application rate at 35 psi
- 5430 gal/acre per hour
- Effective down to 23 degrees

RH will determine the feel-like temperature

- At low temp. moisture in the air condenses from a vapor to a liquid. It reaches “dew point.”
- The wet-bulb temp. is the lowest temp. that can be reached by the evaporation of moisture.
- Trees will be dealing with this ‘cooled temp.’, not the ambient temp.

Sling Psychrometers costs ~ $100 or less



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Avoid too early or too late irrigation to form icing

Calculated Wet-Bulb Temperatures based on Ta-[(Ta-DP) x 0.3333], (Knox et al, 2017).

Dew Point (°F)	Air (Dry-Bulb) Temperature (°F)								
	32[z]	33	34	35	36	37	38	39	40
34			34.0	34.7	35.3	36.0	36.7	37.3	38.0
33		33.0	33.7	34.3	35.0	35.7	36.3	37.0	37.7
32	32.0[y]	32.7	33.3	34.0	34.7	35.3	36.0	36.7	37.3
31	31.7	32.3	33.0	33.7	34.3	35.0	35.7	36.3	37.0
30	31.3	32.0	32.7	33.3	34.0	34.7	35.3	36.0	36.7
29	31.0	31.7	32.3	33.0	33.7	34.3	35.0	35.7	36.3
28	30.7	31.3	32.0	32.7	33.3	34.0	34.7	35.3	36.0
27	30.3	31.0	31.7	32.3	33.0	33.7	34.3	35.0	35.7
26	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.7	35.3
25	29.7	30.3	31.0	31.7	32.3	33.0	33.7	34.3	35.0
24	29.3	30.0	30.7	31.3	32.0	32.7	33.3	34.0	34.7
23	29.0	29.7	30.3	31.0	31.7	32.3	33.0	33.7	34.3
20	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.7	33.3
19	27.7	28.3	29.0	29.7	30.3	31.0	31.7	32.3	33.0
18	27.3	28.0	28.7	29.3	30.0	30.7	31.3	32.0	32.7

[z] Row is dry-bulb temperatures in °F
[y] Wet-bulb calculated temperatures

Start sprinklers when the wet-bulb temperature is above 32 °F (Between blue and gray boxes)

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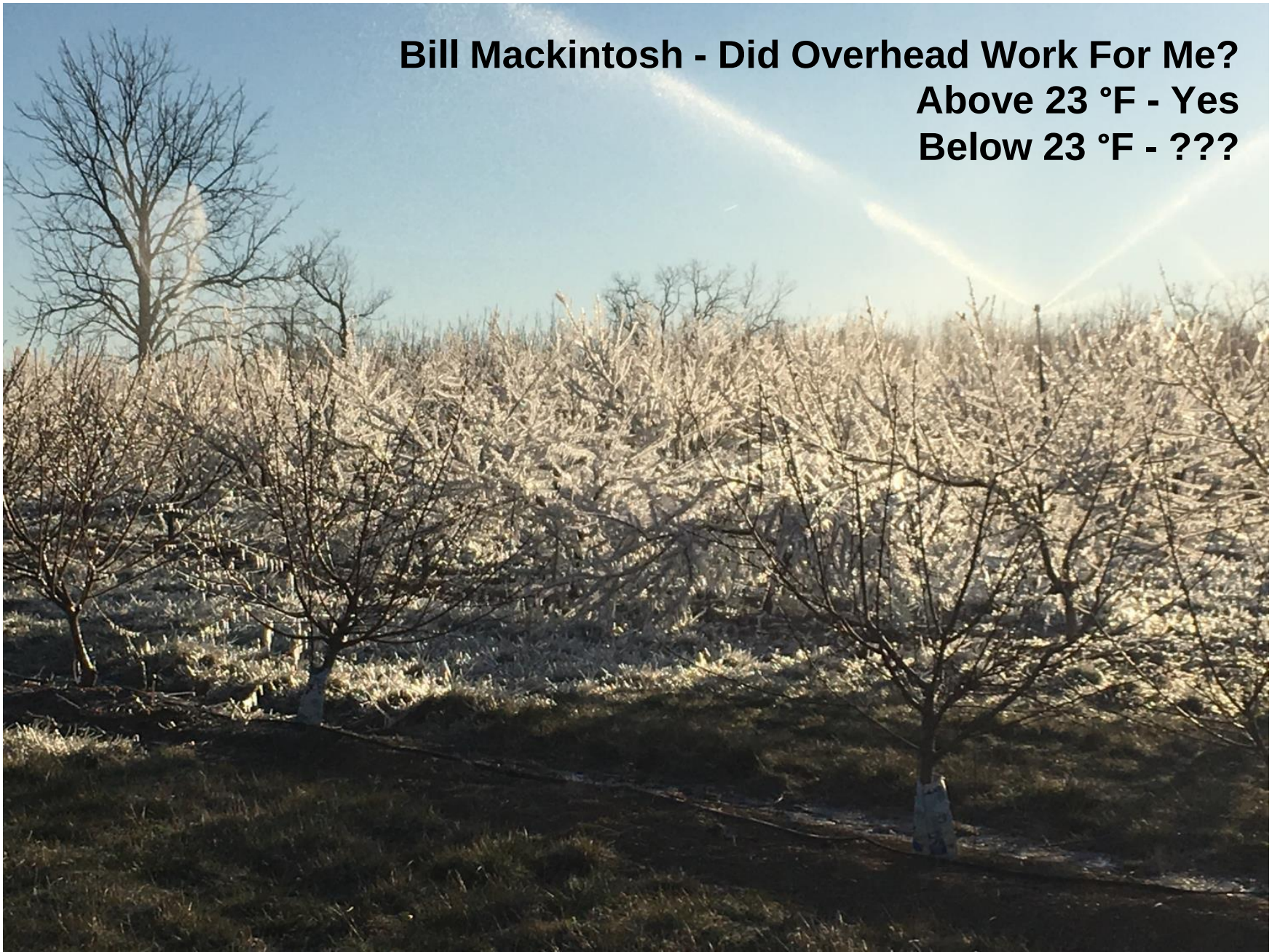

Bill Mackintosh - Did Overhead Work For Me?
Above 23 °F - Yes
Below 23 °F - ???

Bill Mackintosh's observations on Over-head

- Place valves in ends of all water lines for flushing
- Place a valve just below each sprinkler head
- Metal impact heads are better then the plastic ones
- Have several spare sprinklers on hand
- Monitor closely for ice build up as temps dip below 25, set alarm
- Consider water run off areas- main roads, neighbors
- Consider dormant overhead for bloom delay

Cost of the set-up – Mackintosh Orchard, VA

		Cost of equipment per acre	Cost of operation per acre
Overhead			
	Cost from pond to orchard	**6184**	
	2" lay flat sprinkler line 1000' per acre	353	
	V-Rain brass sprinklers(5gpm@35psi)x20/A, spacing 44'x50',100gpa	338	
	1" x 8' PVC stem, 1" T, metal T support post (20/A)	300	
	Bushings, T's, clamps, valves, miscellaneous items	100	
	Total $/A for in orchard set up	**1091**	
	Total $/A for in orchard set up	***7275***	
	Cost of water per acre		**17**

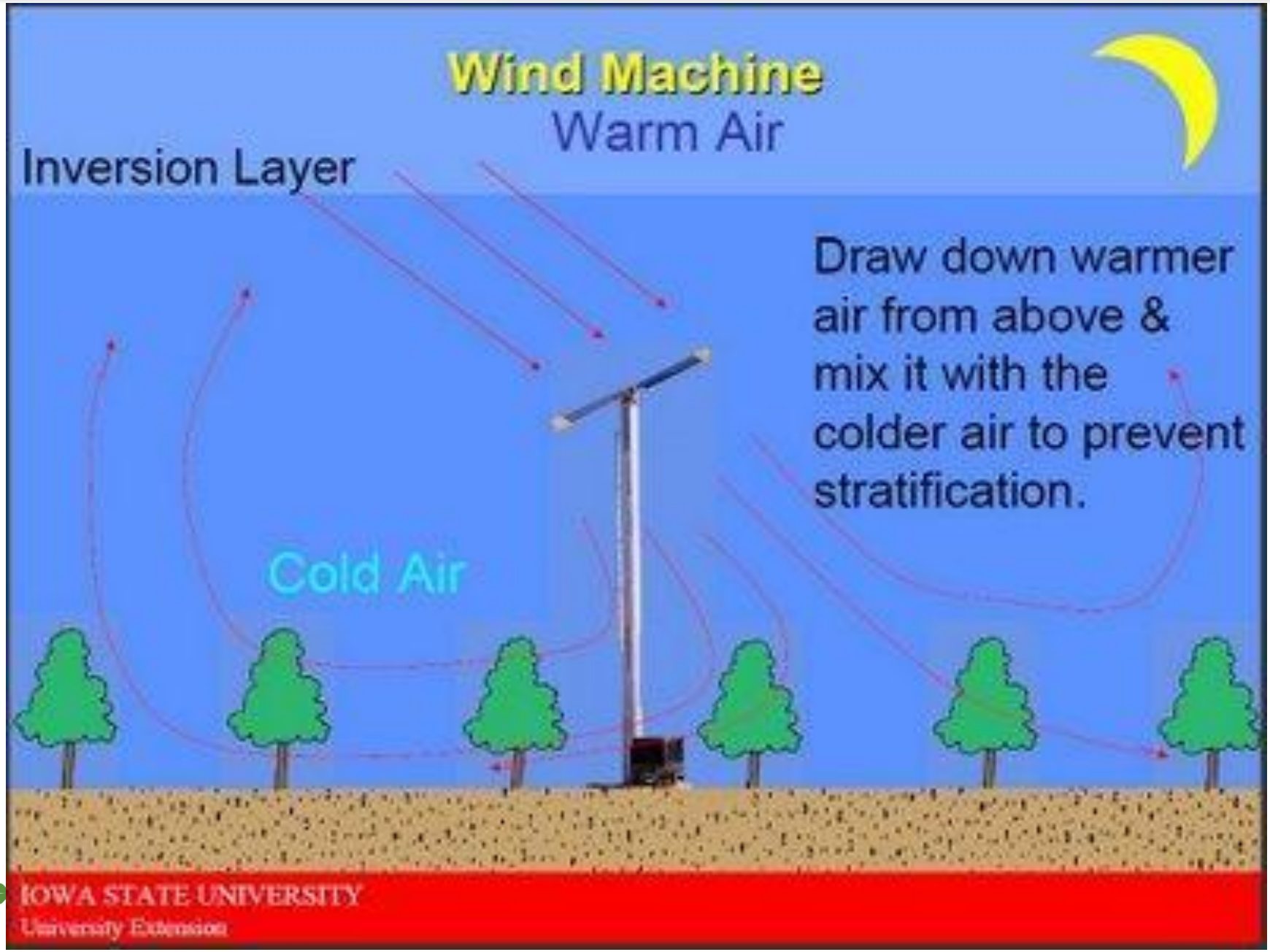
UNDER-TREE SPRINKLERS

Under tree micro-sprinklers

- Gaining popularity in drought and frost prone areas.
- Costly if only used for frost control.
- Uses half the water compared to over-head and lower pressure (20-25 psi).
- Requires lot more maintenance than drip or overhead.
- Don’t expect system to work perfectly a day before the frost! (Bobby Fifer, Fifer orchards) - Winter maintenance important.

Trickle-drip irrigation

- Less effective than over-head or under-tree. More effective in dry springs.
- Dry soils = open air spaces = rapid loss of radiative heat at night
  Wet soil = filled air-spaces = slow loss of radiative heat at night
- Wetting the soil will often make it darker and increases absorption of solar radiation during the day..
- The goal is to maintain the soil water content near field capacity.
- It is best to wet dry soils well in advance of the frost event, so that the sun can warm the soil.
- However, if evaporation rates are high, more energy can be lost to than gained by the freezing process.


Wind Machine
Warm Air
Inversion Layer
Draw down warmer air from above & mix it with the colder air to prevent stratification.
Cold Air
IOWA STATE UNIVERSITY
University Extension

Wind machines

- Uses only 5-10 % of the fuel consumed by a fuel-oil heater.
- Lower labor requirements and operational costs than other methods.
- Initial investment is high (~ $40K -50K per machine including equipment, automation and installation).
- However covers up to 10 acres and operating cost is under $20/acre.
- Higher frequency of frost events = investment is worth considering.

Eli cook's comments on Wind Machine

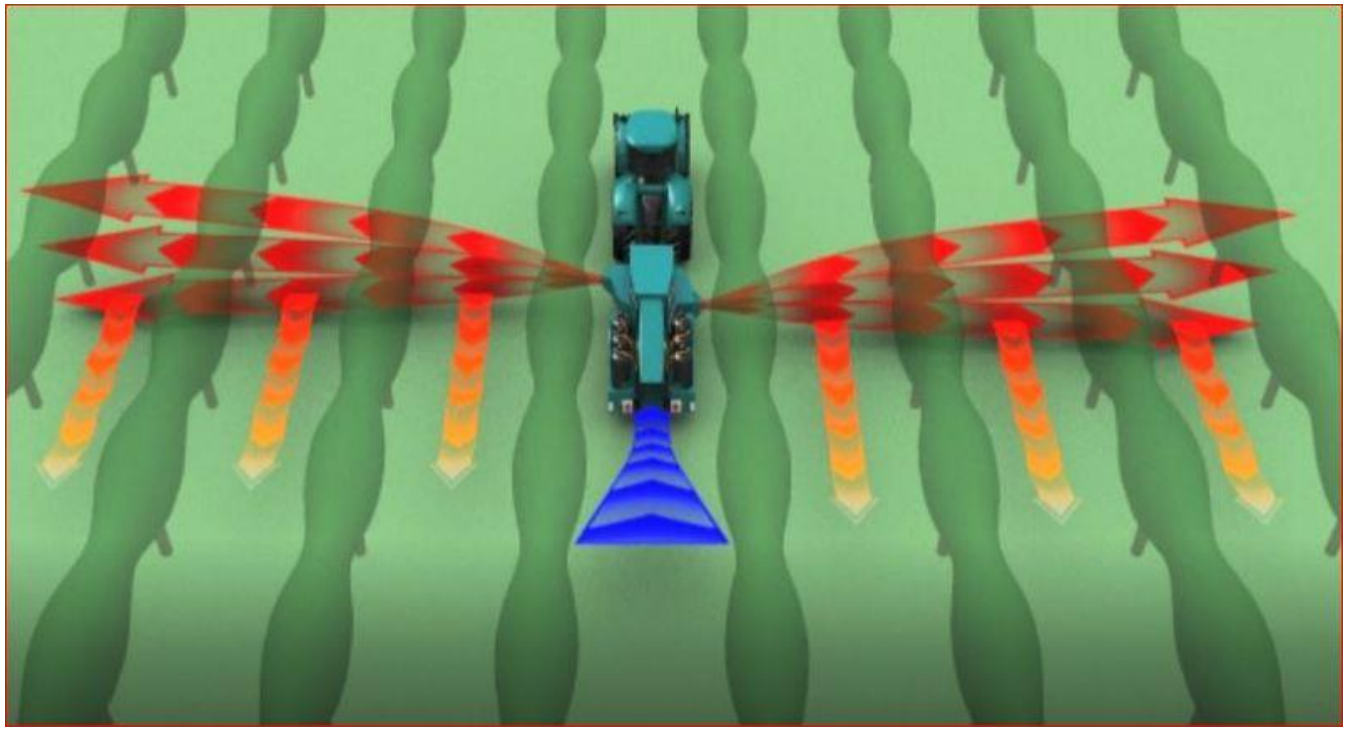
- Use natural air flow direction for WM placement

  If the machine covers 900' it would be placed 300' in from the upwind side and 600' up from the edge of the down wind side.
- Use smoke or helium balloons to find air flow direction.
- Use a contour head on hilly ground- critical to maximize efficiency.
- Improves flower survival even without an inversion by reducing frost.

Portable wind machines (tow-and-blow)

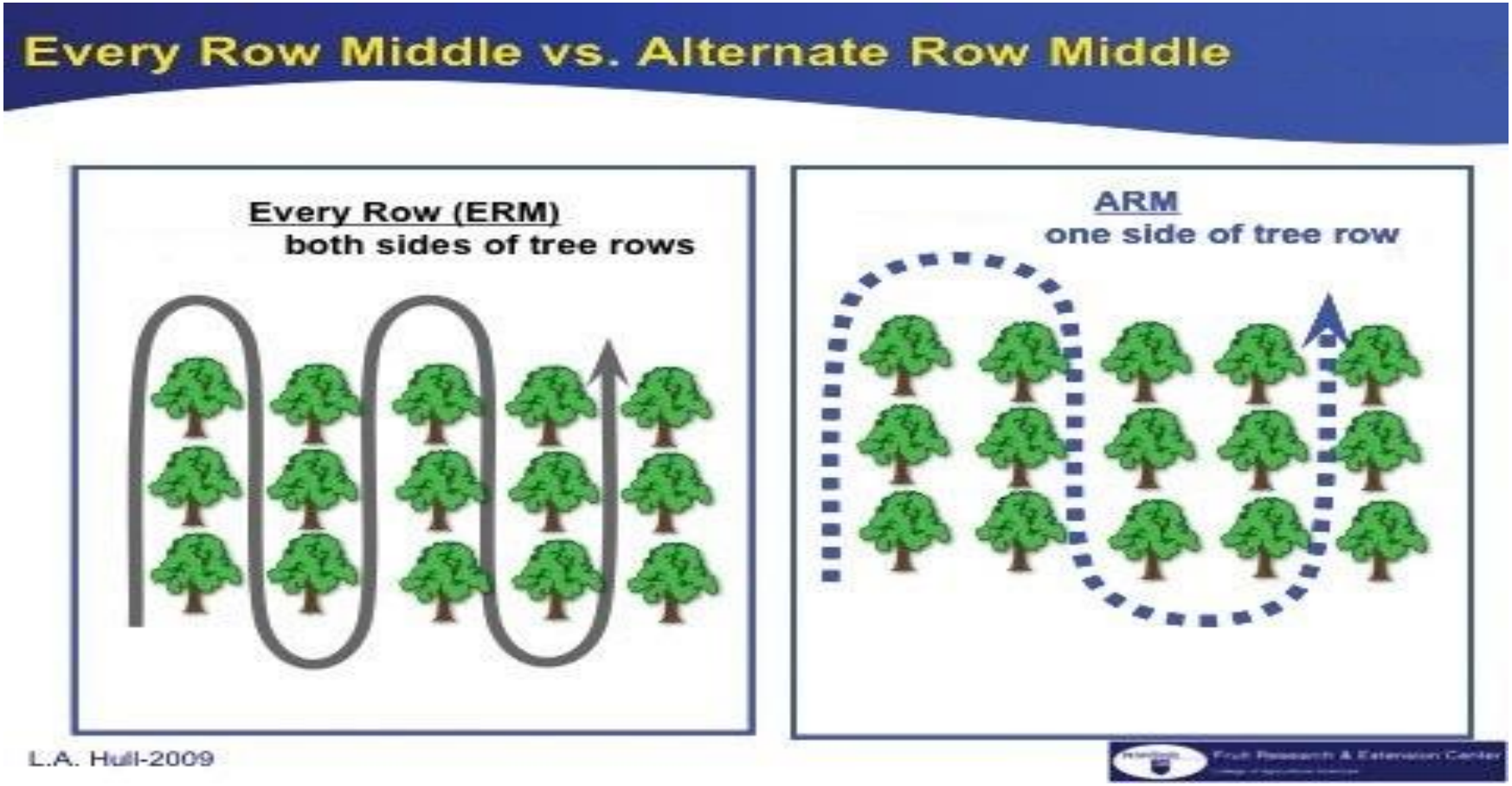
- https://www.chamberlinag.com/tow-and-blow-portable-wind-machines

FROST BUSTERS (Bill McKintosh)



- Covers multiple row, however slow wind, necessary
- 600 gallon tank, re-fill is not needed.
- ‘They’ say 10-12 acres but generally good for 5-6 acre
- Works on the principle of phase change and addition of heat

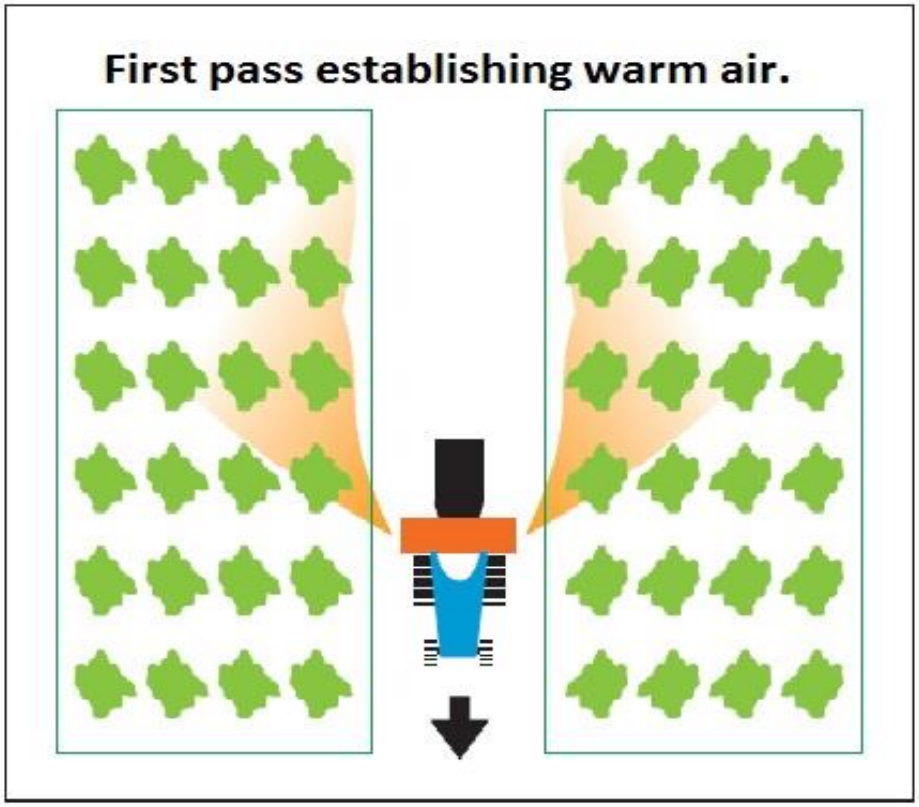
Create a timed loop and return in the same spot within 10 minutes…



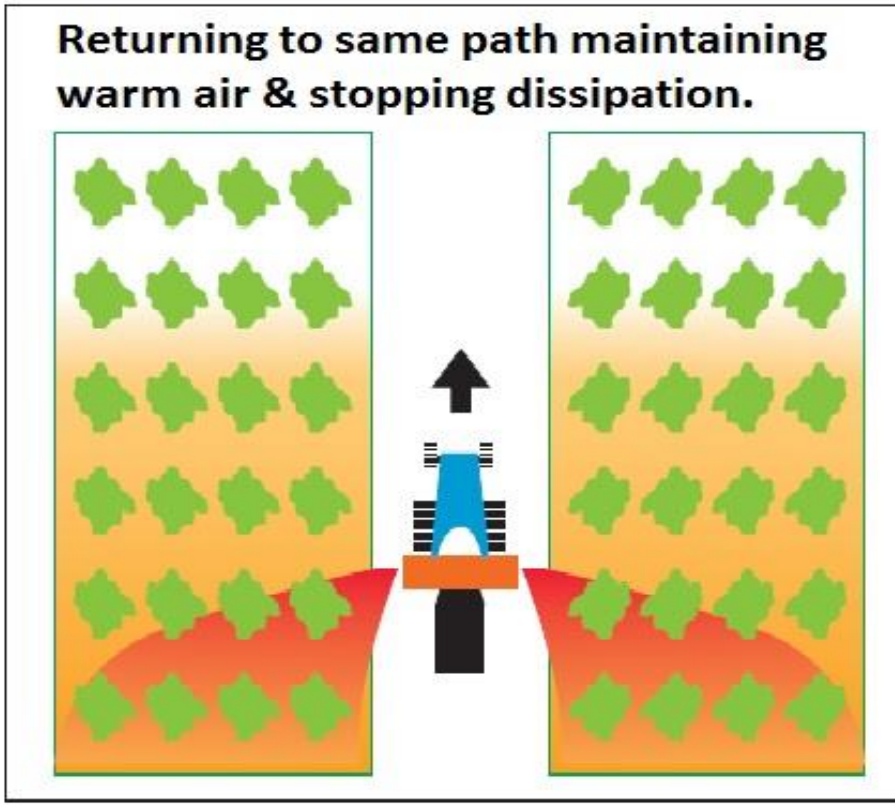
Disperses Hot Air 150 -200 feet in both Directions… Depends on landscape

Heat Retention…Creation of a micro-climate

First pass:



10 minutes later:



Eli Cook - How to get the most out of your Frost Dragon

- Max- 5 acres/machine,
  2 FDs on 11 Acres
  saved bloom @ 18.6 degrees
- Max speed 4 - 4.5mph, return to same spot every 6 mins
- Tree spacing 12’x22’, 160 trees/A, rows are 600’ long
- Alternate between the 3 rows with each pass
- Main points for efficiency: 5 acres, 4mph, 6 min return

Mark Boyer's observations

- Place thermometers throughout your orchard.
- Don't believe it can cover 20 Acres in the Appalachian region.
- Need at least 65hp Tractor with front end weights.
- No success with changing tanks. NASCAR PIT CREW.
- Lack of success because starting too soon.

  Our starting time was 3:30 am with 4 hrs. of running time, run until after sunrise. Used 400 lbs. of propane.

- Costs $26,000. Can last over 20 years.

		Cost of equipment per acre	Cost of operation per acre
Frost dragon			
	Machine 25,000, covers 5 acres	**2,400**	
	Fuel- 400 lbs.(94.40 gal)/night @ .91/gal= $86.00 for 5 acre Fuel cost/acre /night		17
	Labor for 7 hours = $100, labor cost/acre/night		20
	Tractor fuel tractor fuel/a/night		17
	Total cost/a/night after initial investment		**54**

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Bobby Fifer's observations

- 1 Helicopter for 30 acres, temp was around 28 °F
- Can work at 24-25 F, however may cover much less area than 30 acre.
- Fast: 29 °F to 33 °F in under 1 min
- Used for 3-4 h @ $1600/Hr. ($6400 per night)
- Availability is the challenge

Fifer Orchard, Delaware

Did not work when tried to cover 50 acres @ 26 °F

Very useful, if you don't own the ground!

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Milehighcopters.com

Cellulose crystal nano-particles

- The WSU research on cellulose particles has been very encouraging.
- The spray forms a layer that works like a woolen coat
- Currently available in a limited amount.
- A grower had used 5 gal on motorized back-pack and there were challenges of clogging.
- Currently there are an efforts to improve application using electrostatic sprayers etc.

Combination of methods

- Try at least one method on the scale that you can afford for future decisions.
- The addition of wind machines could potentially increase protection by up to 4 °F over the under-plant sprinklers alone (Olmstead, M. University of Florida).
- Heater plus wind machine – the most effective combination (Bill Mackintosh)

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