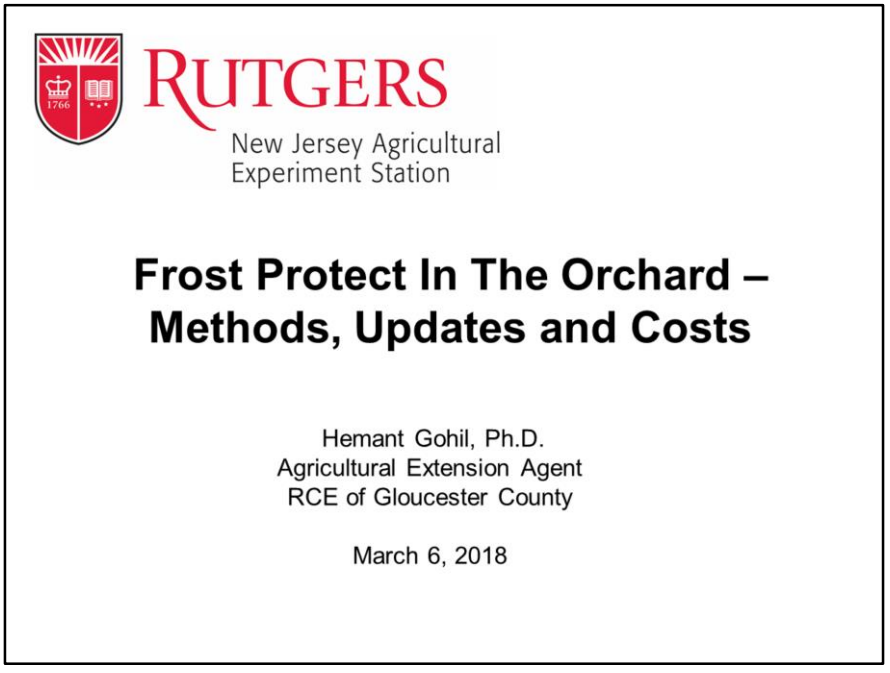
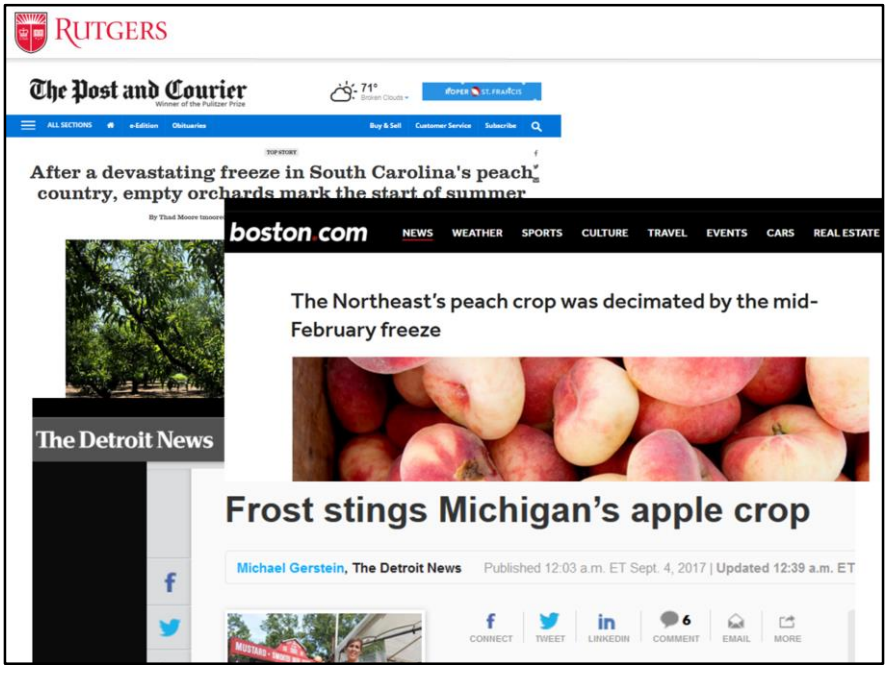
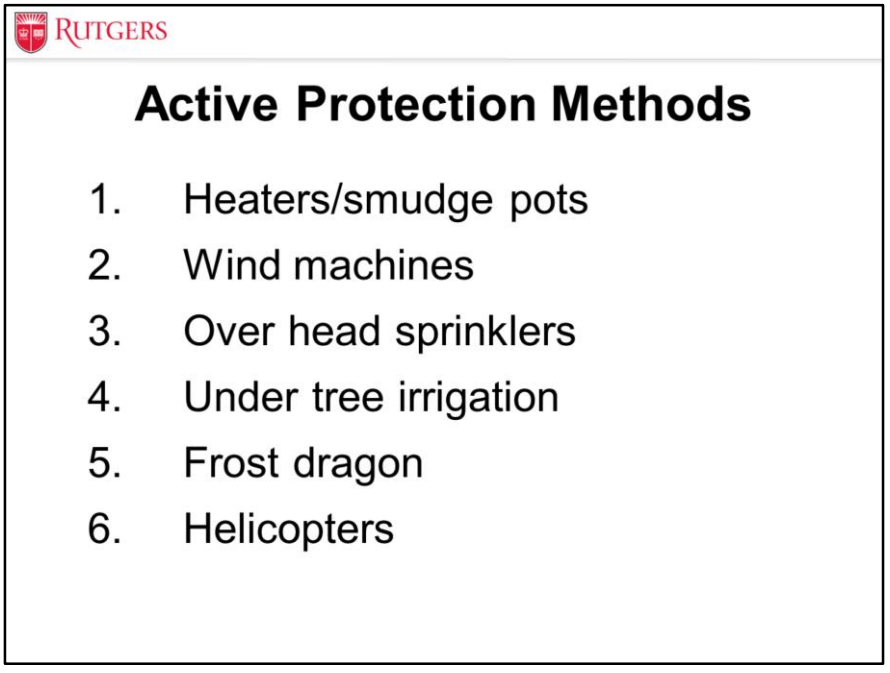


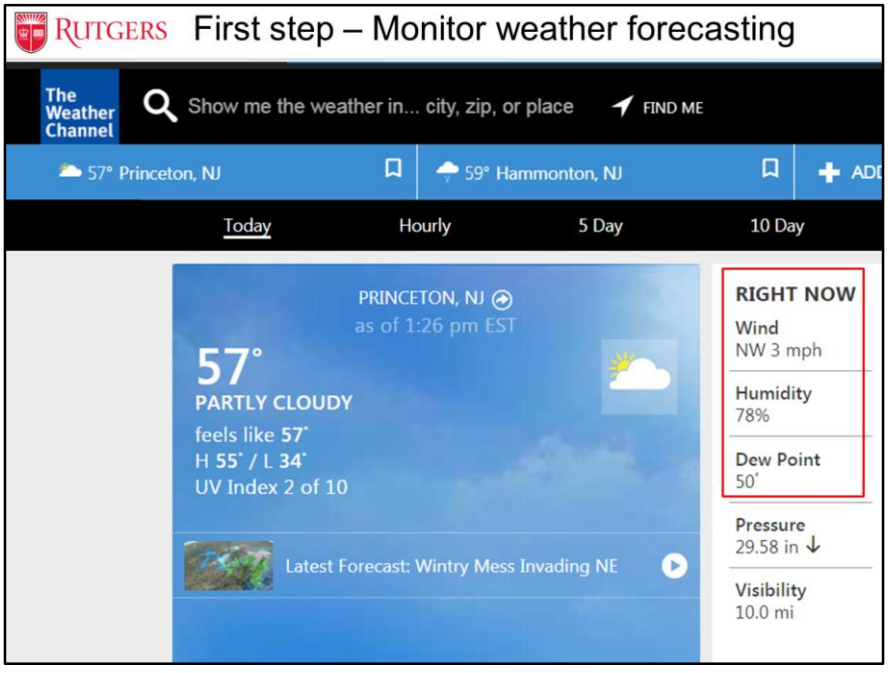
- The purpose of this presentation is to update you on recent advances in frost protection methods and various costs associated with these methods.



- In recent years the frequency of frost events have increased through out major tree fruit growing regions.
- In 2016 peach crop was completely wiped out of North-east while in 2017 Apple and Peach were substantially lost in southern states and in Michigan.
- There are several active frost protection methods that can be deployed to prevent or reduce the frost damage in the orchard.



- Active frost protection methods are the methods applied just before and or during the frost event to prevent bud-kill, by either preventing the loss of thermal energy or by providing additional thermal energy to living buds.
- Propane heaters, wind machines, over-head and under tree irrigation, frost dragons, helicopters are standard methods used in orchard, through out frost prone regions.



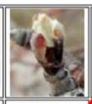
- Before starting any method, check the hour-by-hour weather forecast using on-site or the local weather station. Remember that temperature is a dynamic process which changes with the moisture content and that many methods will not work at wind speed greater than 10-12 mph.

RUTGERS

Second step:

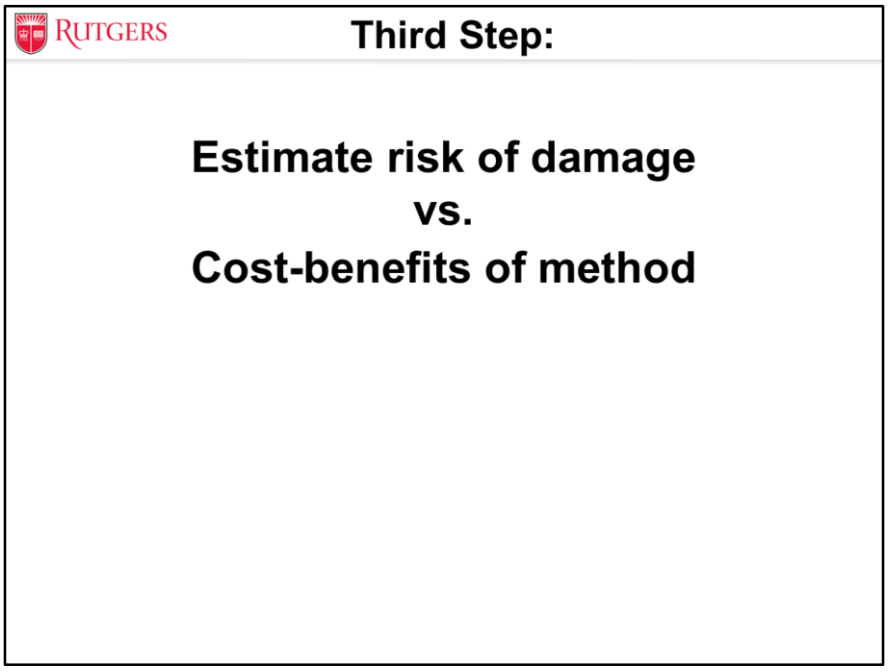
Monitoring the bud developmental stage

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.

- Second step is to monitor the bud development stage. Each stage has the critical temp. that would kill up to 10% or 90% of them. For example, if the lowest temp. in your Apple orchard is going to be 24 F and buds are at half-inch green or earlier stage, you may only see little bit of damage however the same 24 F in the first pink or later stage can kill 90% of buds.
- Also, knowing bud development stage for all varieties in the orchard will allow you to prioritize varieties or blocks that needs frost protection.

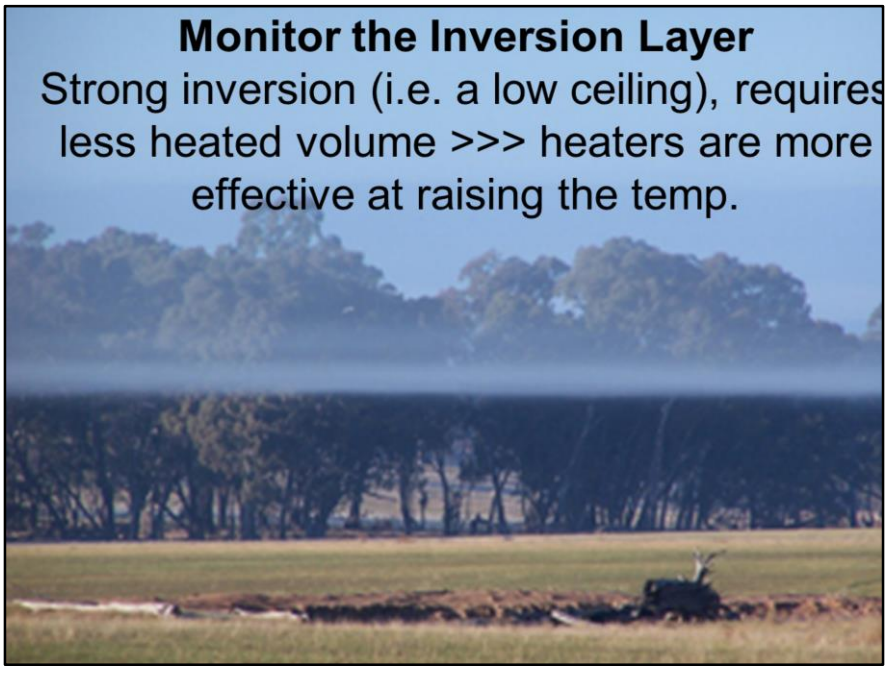


- Only after performing cost-benefit analysis, you should decide whether to employ FP method or not.
- Active frost protection methods are more effective however …doing it incorrectly – at the wrong time or under the wrong conditions is more damaging than doing nothing at all.
- Lets go one by one.

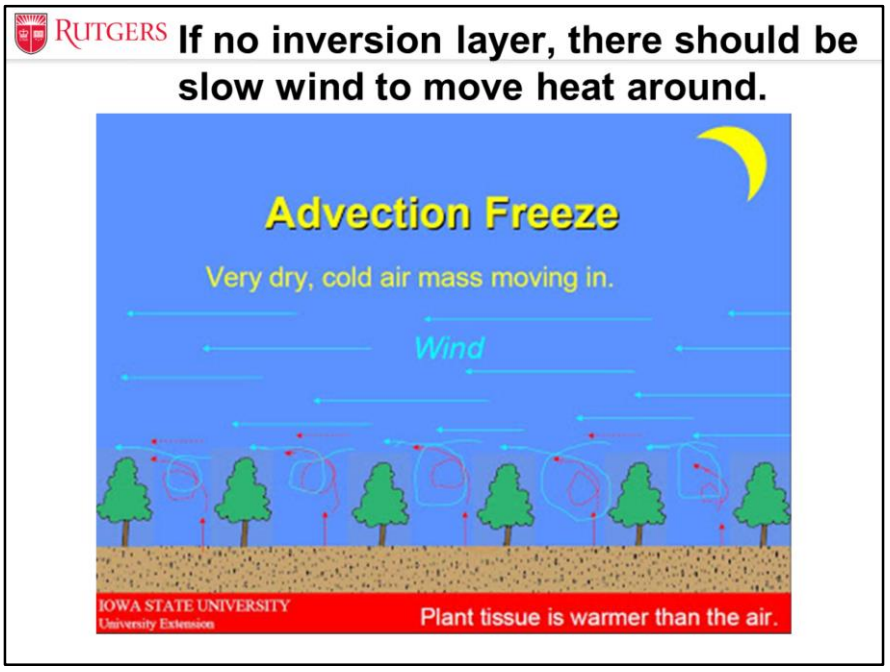
Heaters or Smudge Pots

- Heaters provide supplemental heat to help replace energy losses.
- Generally inefficient so proper design and management is necessary.

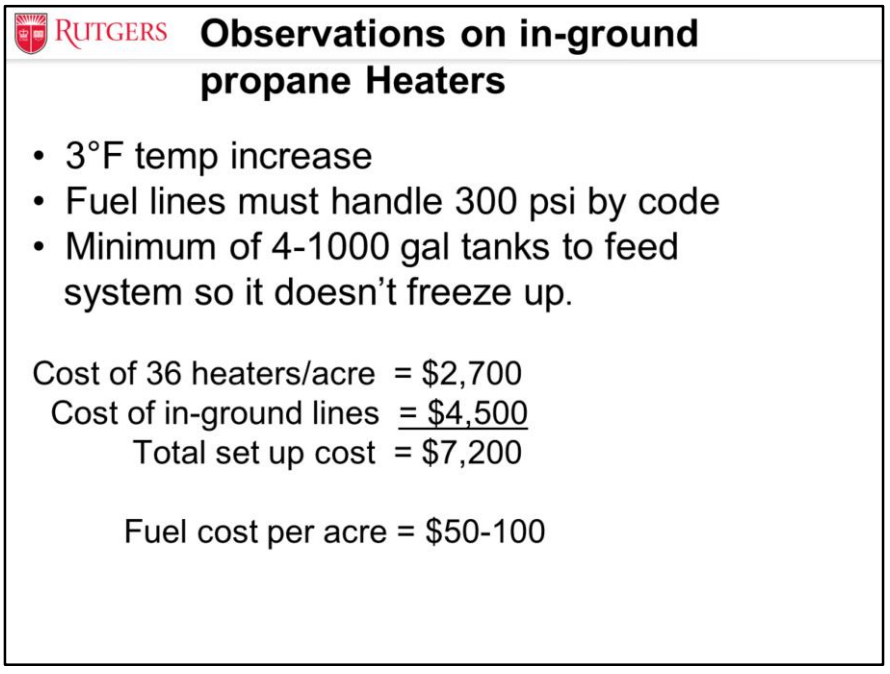
- Heating by burning fuel or woods has been one of the oldest method of FP. However Heathers are generally ineffective as most of the time heat dissipates in to above space requiring too many heathers for it to work.
- Pyramid shaped heathers with side holes and in-ground pipes are more efficient design than the smudge-pots.



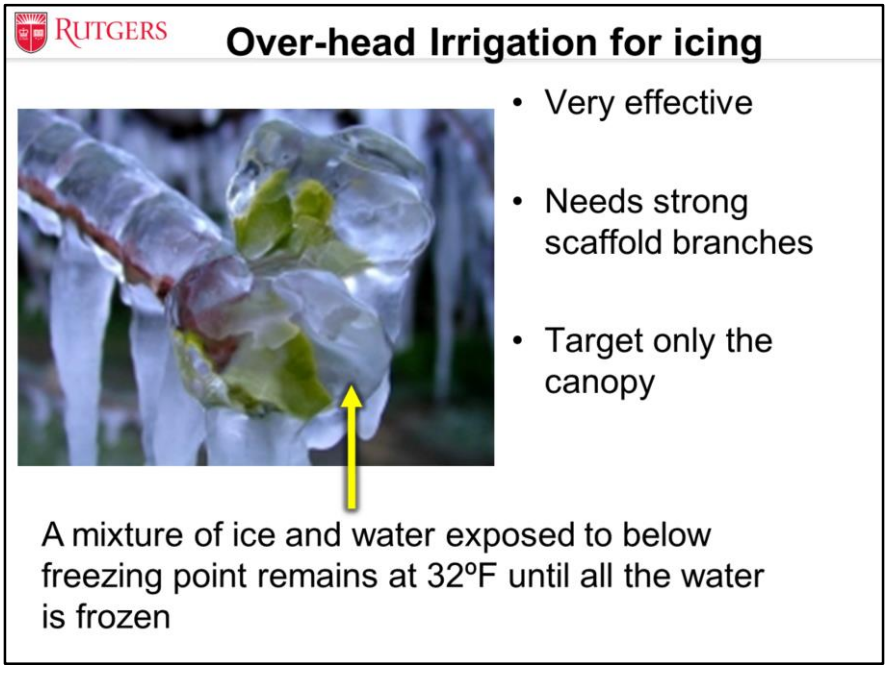
- Heaters are more effective when there is a stronger temperature inversion layer, requiring less volume of air to heat.
- Lets say the ceiling of an inversion layer is more than 100 feet, a weak inversion, you may need too much of fuel to heat up the orchard space so that heat dissipation is reduced. That can be cost prohibitive and less effective.



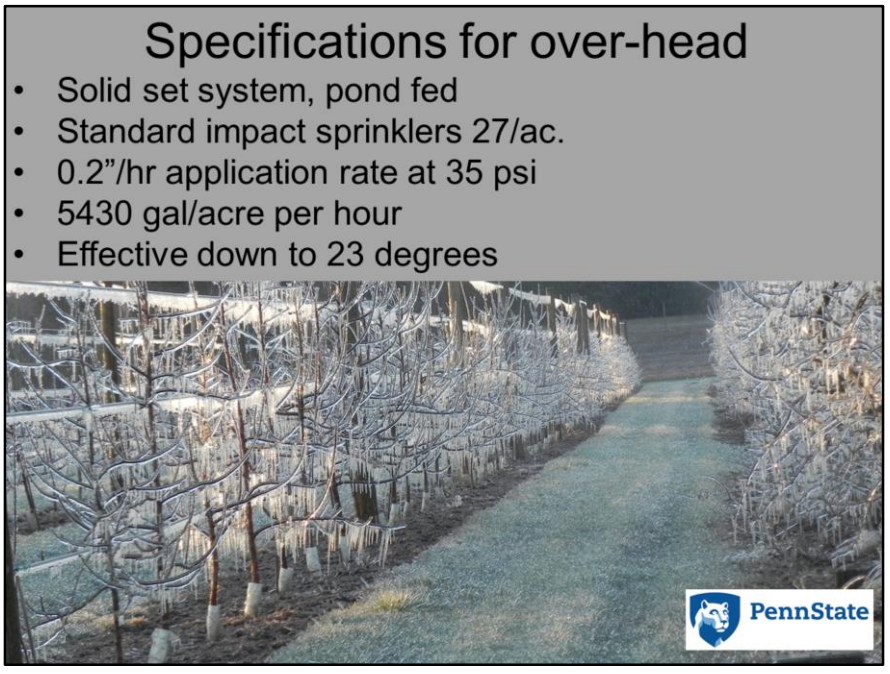
- If there is no inversion layer, there should be slow moving wind.
- In the event of Advection freeze or polar vortex moving-in, refrain from using heaters or any other methods.



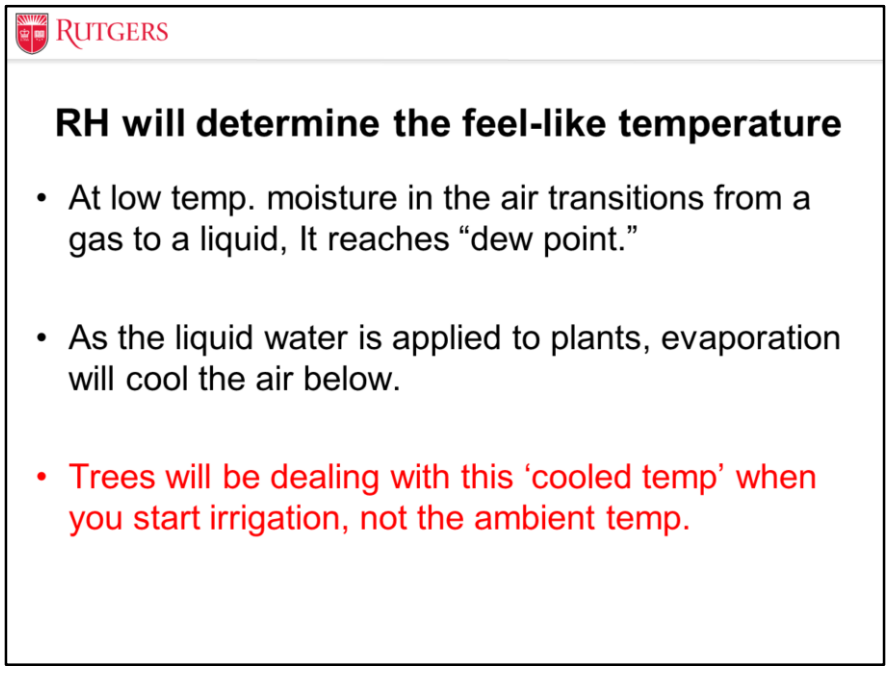
- Few observations, that are very important to know that, Heathers typically only raise up to 3F temperature.
- In most states, code requires that installed fuel lines must handle 300 psi pressure.
- Keep additional fuel, running out of fuel mid-operation can be disastrous for any method that requires fuel.
- Its costs around $7,200 per acre which includes the cost of heaters and in-ground lines.
- Fuel cost per acre could be anywhere between $50-100 depending on gas prices.



- Over-head irrigation for icing is a very effective method which targets only the canopy, however young trees branches do break under the weight of ice loading, so may not work in very young orchard.
- It works on the principle of heat-of-fusion – that is when the water changes from liquid to solid phase, it release thermal energy which then protect the underneath tissues.

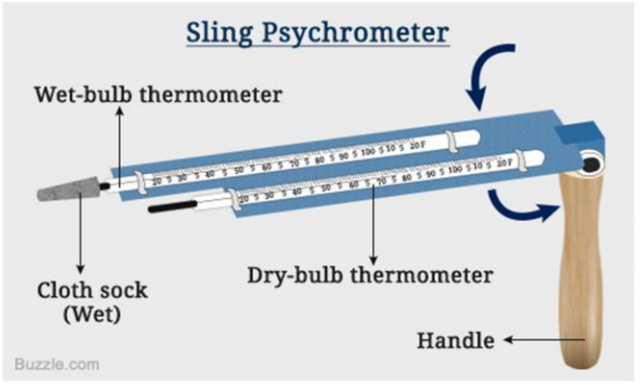


- The energy consumption of sprinklers is considerably less than that used in heaters, however it consumes lots of water, if you don’t have the capacity like 5430 gal/acre/hour than don’t go for over-head. Other disadvantages with using sprinklers are the high installation cost.
- The Most important aspect of the over-head for frost protection is the right temperature so that when you start the irrigation, a layer of water immediately forms clear ice.

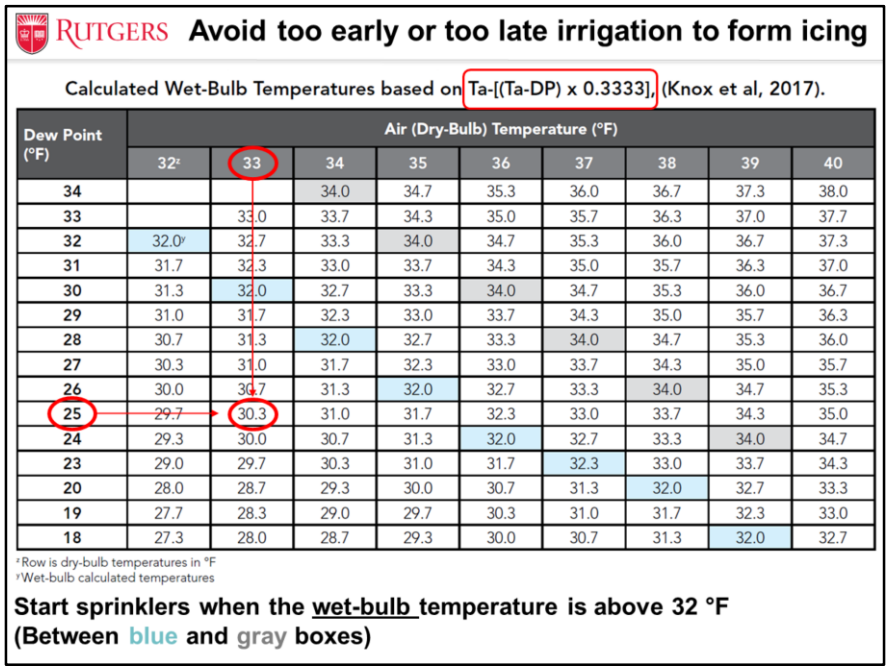


- Growers typically start irrigation system at around freezing point, however it may be bit too late.
- Though water turn ice at 32F, the existing moisture plus irrigation moisture can bring down the **wet-bulb** temperature, which is the feel-like temperature for tissues!
- Wet bulb temp. are generally few to several degree lower than the air temp. depending on the relative humidity of air.

RUTGERS Sling Psychrometers costs ~ $100



- Sling Psychrometers are cost effective way of determining on-site wet-bulb temp. You need to wet the clock sock on the wet bulb thermometer and then sling it for few minutes.



RUTGERS **Avoid too early or too late irrigation to form icing**

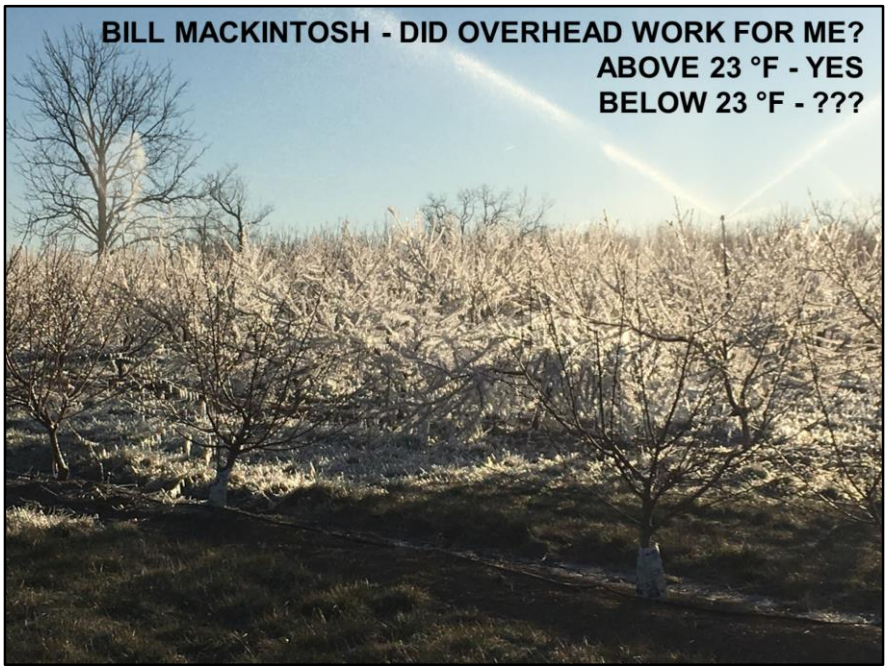
Calculated Wet-Bulb Temperatures based on Ta-[(Ta-DP) x 0.3333], (Knox et al, 2017).

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

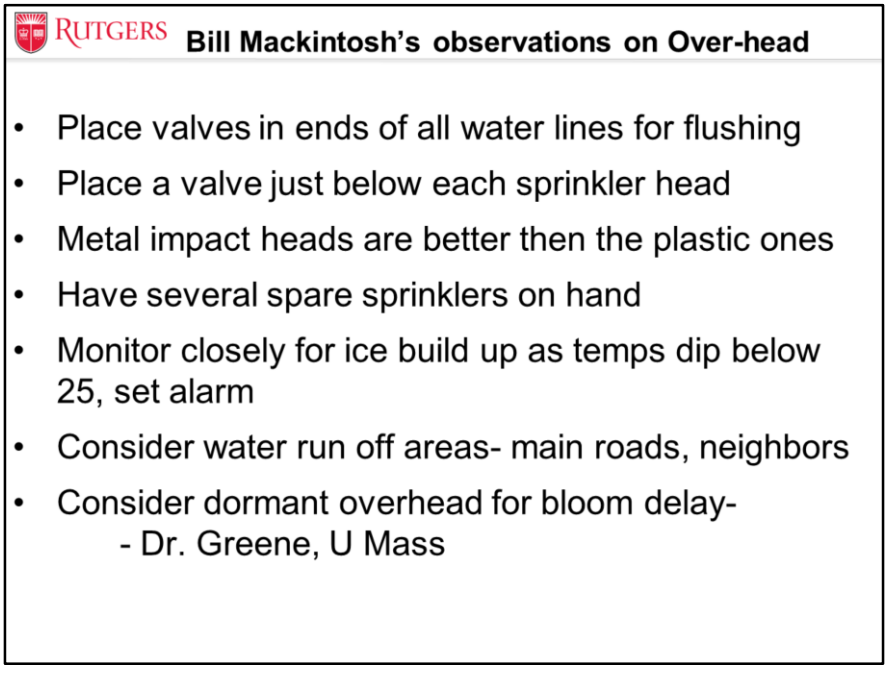
[z] Row is dry-bulb temperatures in °F
[y] Wet-bulb calculated temperatures

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

- Fortunately, in 2017 Pam Knox and her group at University of Georgia came with an easy formula to calculate wet bulb temp. All you need is air temp. and Dew point which are easy to get from field or nearby weather station.
- Subtracting the one-third the difference between air temp. and dew point for the air temp. gives you the wet bulb temperature.
- You have this table, start sprinklers when wet bulb is between 32F and 34F.
- Starting too early can lead to unnecessary loss of water and staring late may result in the frosting.



Bill Mackintosh, a VA based fruit grower and orchard consultant, who has used over-hear for years, agreed with other's observation that over head is less effective below 23F.



- Placing valves in the end of water lines and at the end of each sprinkler head will help in flushing as well as stabilizing the pressure.
- The plastic impact heads are cheaper however metal ones can resist the ice formation on it, through its high inertia force.
- You don't want to fix the non working impact-heads in the middle of night, just replace them, that means you need to keep extra ones.
- Monitor ice build-up specifically at under 25F, that is when impact-head begins to get stuck.
- Water run-off can be sticky issue with neighbors!
- You might as well use over-head during warm spring days to delay bud-break.

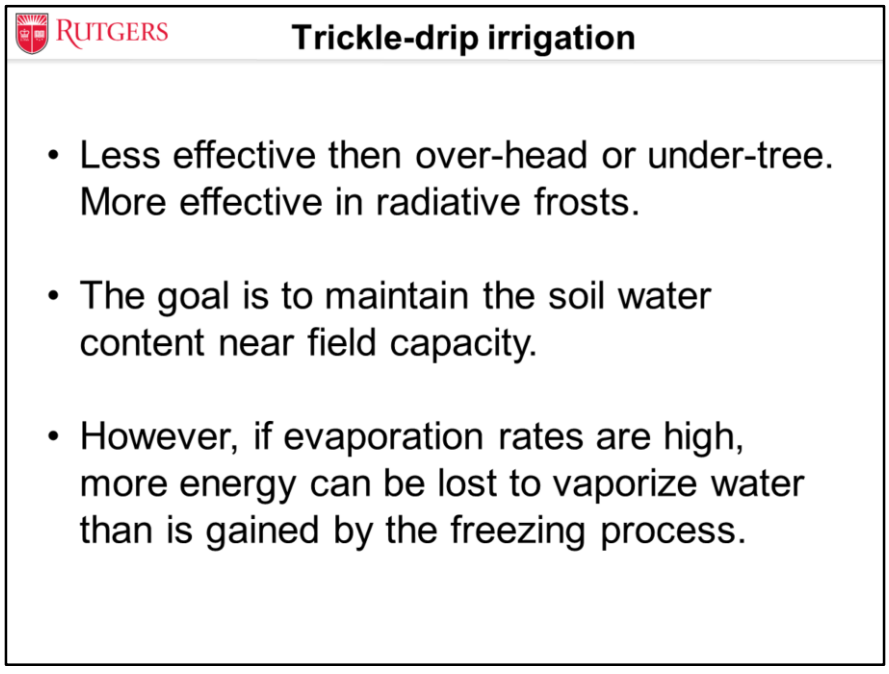
RUTGERS

Cost of the set-up – Mackintosh Orchard, VA

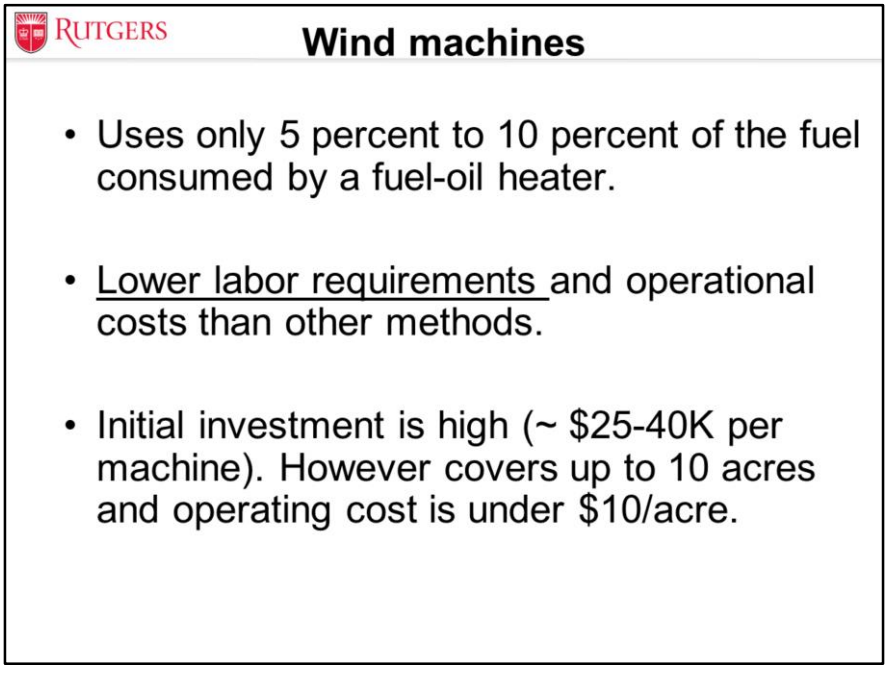
		Cost of equipment per acre	Cost of operation per acre
Overhead			
	Cost from pond to orchard	**6184**	
	2" lay flat sprinkler line 1000' per acre	353	
	V-Rain brass sprinklers(5gpm@35psi)x20/A, spacing 44'x50',100gpa	338	
	1" x 8' PVC stem, 1" T, metal T support post (20/A)	300	
	Bushings, T's, clamps,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

- The cost of pipes and pump to move water half a mile from the pond to orchard was around $6,000 for Bill.
- Cost of laying sprinklers in-orchard was around $1,100 per acre. However the cost of operation is just $17 per acre.

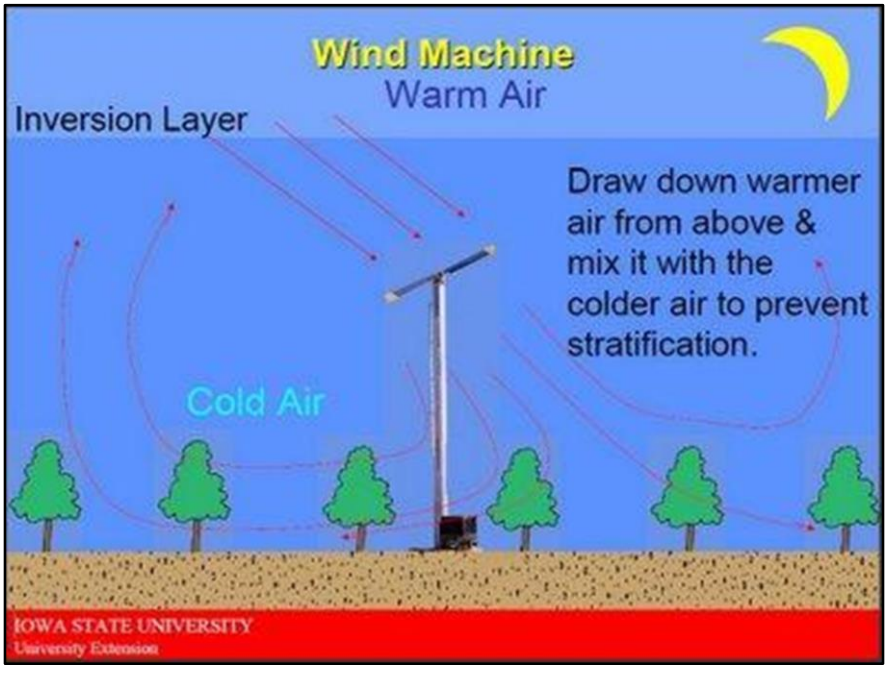
- Gaining popularity with growers for irrigation and frost protection, however costly if only use it for frost control.
- Same principle as over-head irrigation, latent-heat of the fusion protecting lower tissues. Also, icing on the grass surface and lower branches raising temp. by few degrees.
- Not as effective below 26F, however uses only half the water compared to over-head and lower pressure (20-25 psi).



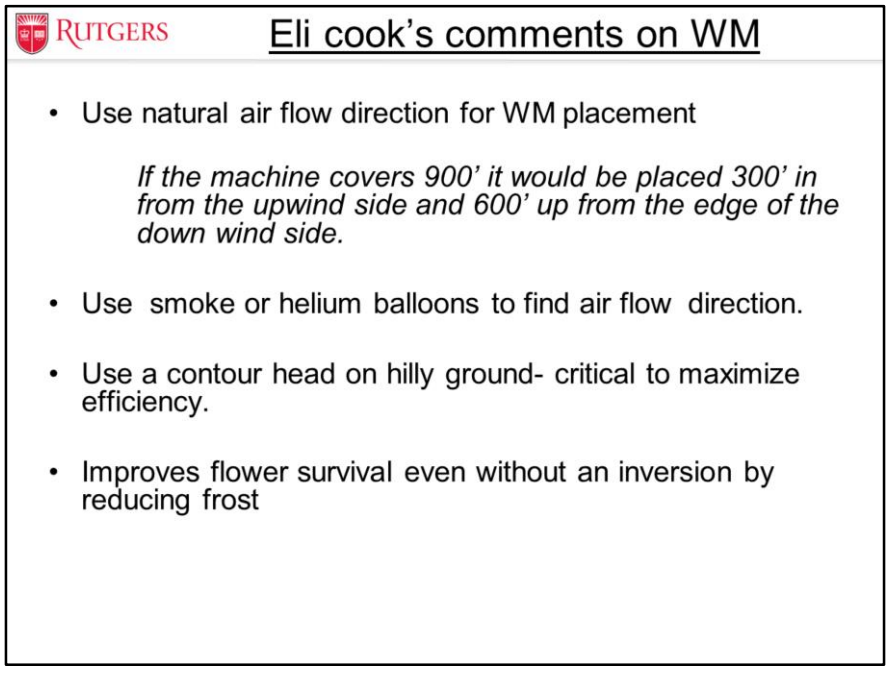
- Most of us use trickle drip irrigation for all its practicality and benefits, but not as effective compared to over-head or under tree.
- When soils are dry, there are more air spaces, which inhibit heat transfer and storage. Therefore, in dry years, frost protection is improved by wetting dry soils.
- The goal is to maintain the soil water content near field capacity. Also, wetting the soil will often make it darker, and increases absorption of solar radiation.
- Make sure wind is not to pick up above 12 mph, evaporative cooling can be disastrous.



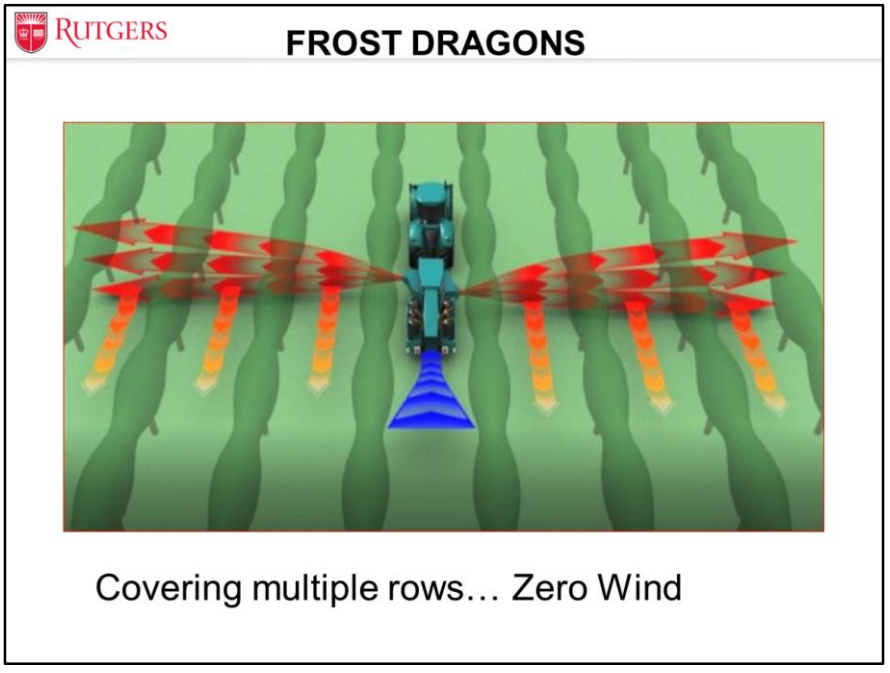
- Wind machines are the fastest adopted method of FP in Pacific North-west, Michigan and Mid-Atlantic region. Part of the reason is, though the initial cost are very high, it covers up top 10 acres and the cost of operation is just around $10 per acre. It dose not require labors or much physical work on the part of the grower, once the system is set-up.



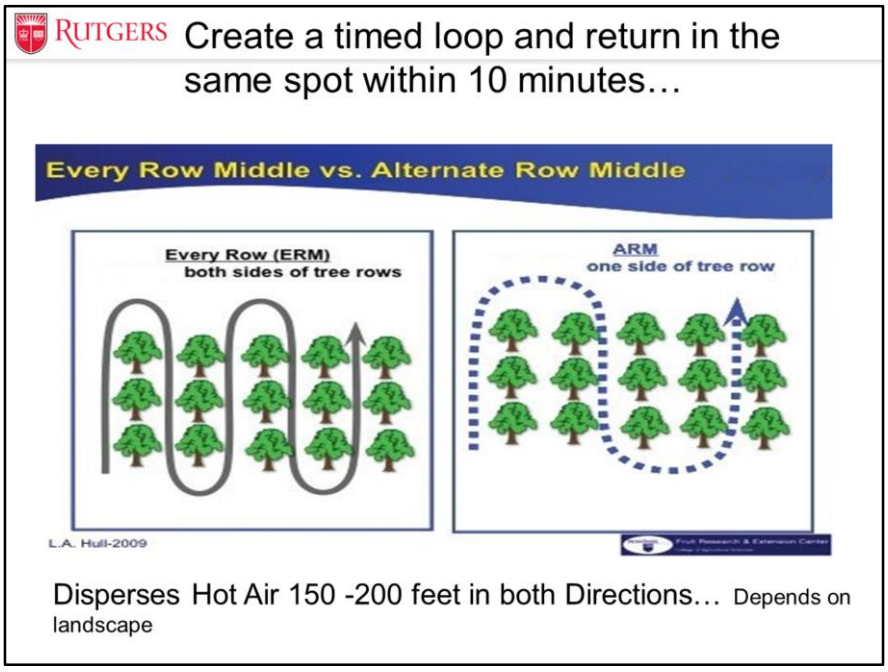
- Latest wind machines have Auto Start feature - A probe located inside of the protection area continuously measures the ambient temperature in the orchard or growing field. When the temperature drops to a pre-set level, a safety alarm sounds before the system starts the wind machine. When the temperature rises to the pre-set shutdown temperature, the system automatically shuts down the wind machine.
- Wind machines do not work under cold, windy conditions, because the wind usually mixes the atmosphere enough to prevent an inversion layer from developing.
- If no warm layer, you can fire up the heater at the base and channel the heat the pipe and thru blow it downward thru the fan.



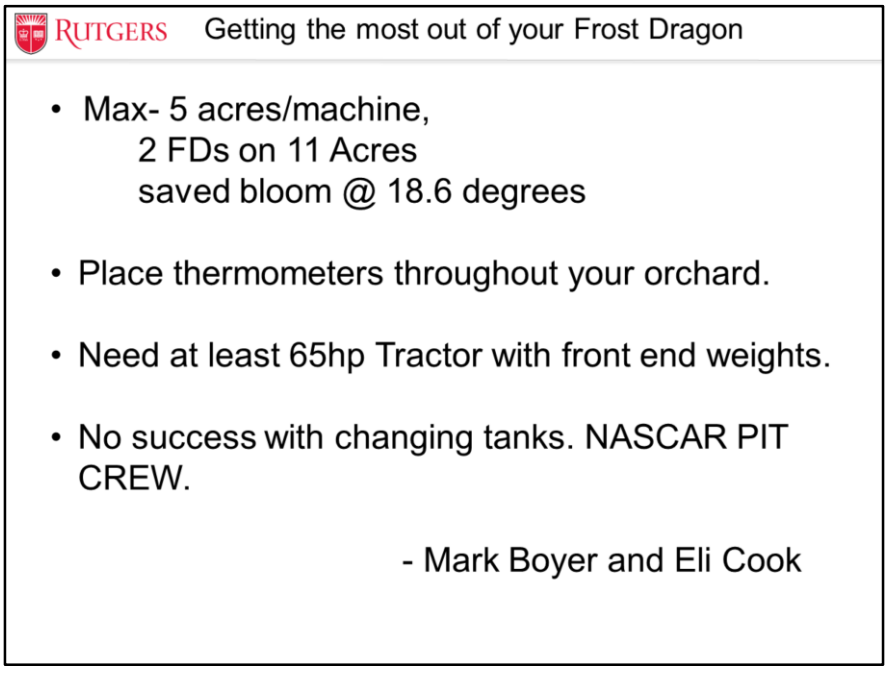
- Here are the observations from Eli Cook from VA, who has effectively used wind machines for decades.
- Basically you want to use the natural wind flow direction to get the maximum out of wine machine. Just use the balloons or smoke to know the natural air flow direction.
- Place it on the top of the hill of you have rolling site.



- Frost dragons are increasingly used in the orchard in Pacific North West, Michigan and Mid-Atlantic regions.
- Basically, there are propane tanks latched on the back of the tractor and when burned, it raise the air temperature as well as that of tree surface.



- In the past many growers tried and immediately stopped using them, as they could not get enough heat. Now we know that one has to create a timed loop so that you get back to the same spot under 10 min.

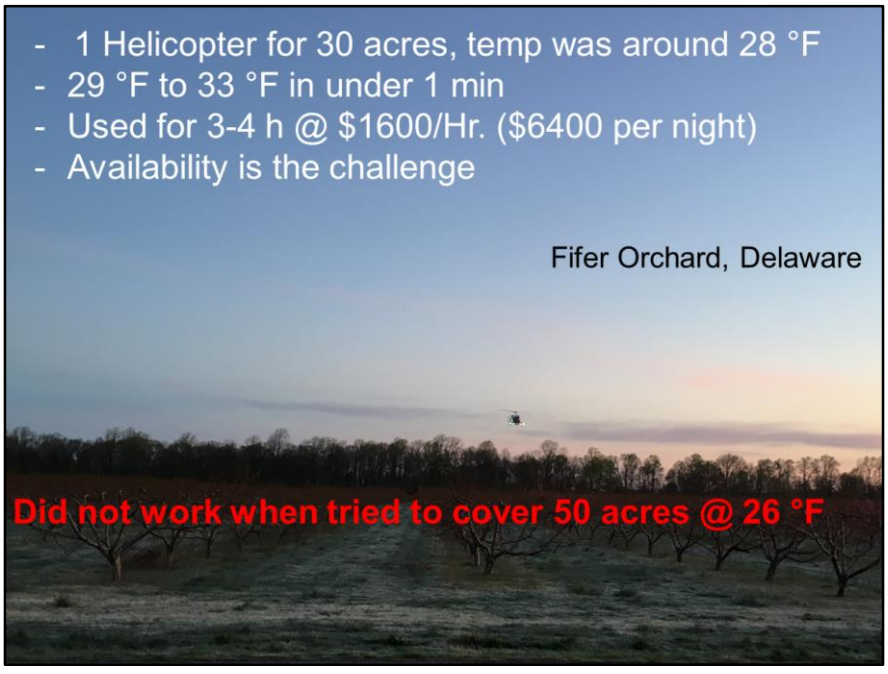


- Here are the observations of growers, Mark Boyer and Eli Cook who made frost dragon work for their orchards.
- Frost dragon does not work for more than 5 acres per machine.
- It can save bloom down to 18.6 F which is the lowest temp. controlled by any F.P. methods.
- Monitor temperature distribution in your orchard, if it has varied topography.
- To counter balance the weight of propane tanks, you need at least 65hp tractor with front end weights.
- Just like it was mentioned for heaters, you need extra fuel ready.

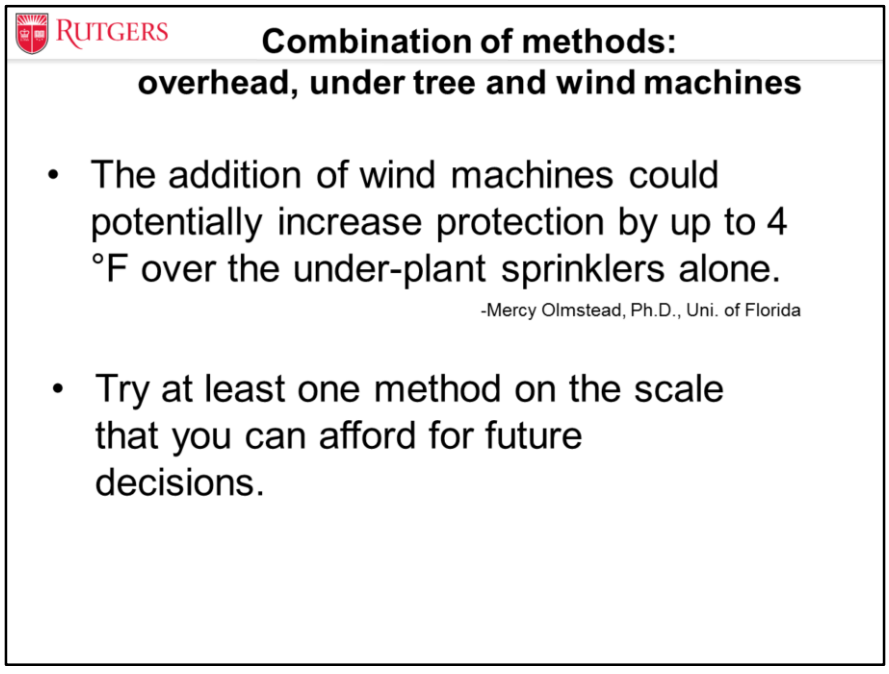
Frost Dragon – costs

		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**

- Newer wind machines costs up to $25,000 and comes out around $2,400 per acre.
- Cost of operation will depend on the fuel price, but on average it was $54 per acre for Eli Cook.
- Frost dragon are worth, specifically for high value retail orchards.



- According to Bobby Fifer of Fifer Orchards, DE, Helicopters can cover up to 30 acres/hour/night. In this video, as you can see temp came down 4 F within a min.
- It costed Bobby $6,400 per night, for 30 acres –comes to $240 per acre, however you don't have ANY capital cost!
- Only problem is availability. The Helicopter service company will charge holding fees, even if you don't use it. Its worth considering, if the cold front is definitely moving in.
- It did not work for 50 acres @ 26 F so there is a limit on acres and temperature for effective frost protection.



- According to Dr. Mercy Olmstead, Uni. of Florida, in the event of harsh temperature dip, combining two methods can assure the frost protection. She found that, adding wind machines to under-tree sprinklers raised 4 F compared to under-tree sprinklers alone.
- Typically, start the lower cost sprinklers first and then turn on the wind machines if more protection is needed.
- Its worth trying at least one method to get used to it, and then scale it up based on affordability and level of confidence.

Thanks a lot and wish you a very successful 2018!
I would like to thank AAANJ for funding this project.

Any questions?