Evaporative Cooling to Reduce Heat Stress

Dairy Barn Cooling Factsheets

Key points

- Soak cows completely to the skin and then turn off the sprinklers
- Use fans to evaporate the moisture and cool the cows
- Start the evaporative cooling when temperature reaches 21°C (70°F) or Temperature-Humidity Index (THI) reaches 68
- Increase soaking frequency (on to wet, off to dry) as temperature increases
- Install fans over the free stall resting area first before installing over the feed manger
- Mechanically ventilated barns can reduce the humidity by exhausting humid air
- Cooling the air with high pressure misters is not recommended in the Fraser Valley due to high relative humidity

Sprinkler Cooling

Evaporative cooling is an effective method of reducing heat stress in dairy cattle and should be used in conjunction with convective cooling. Evaporative cooling involves wetting the cow's skin with sprinklers and then cooling the cow as the moisture evaporates. The cooling effect is greatly increased by using fans to blow air across the cow to increase the rate of evaporation.

The most common place to install evaporative cooling sprinklers is at the feed manger (Figure 1), but they can also be used effectively in the parlour holding area or at parlour exit lanes.

It is important to use low pressure and large water droplets to ensure wetting of the cow's skin. If a fine mist is used, it forms a thin layer of water on the cow's hair. This traps a layer of air between the water and the skin which may insulate the cow causing her to retain heat instead of releasing it and thus increasing heat stress. Fine mist can also drift onto the feed at the manger or into the stalls, which can make the bedding wet.

Figure 1. Sprinkler system with low pressure large droplet nozzles

A sprinkler system (Figure 2) consists of a:

- Controller
- Solenoid valve
- Pressure reducer
- Piping A sprin
- Sprinkler nozzles

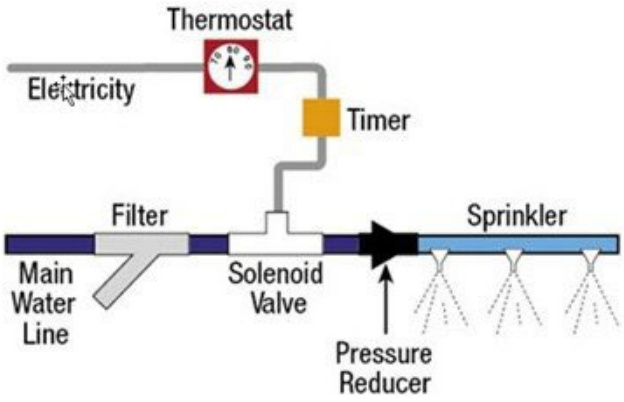

Figure 2. Schematic of sprinkler system components (KSU Extension Bulletin MF-2401)

Controller sequence

Controllers are available to automatically turn the sprinkler system on at a set temperature and to adjust the on/off sequence as the air temperature increases. Evaporative cooling works best when the sprinklers are operated with an on/off cycle, giving the sprinklers enough time to thoroughly wet the cows and then the fans enough time to evaporate the moisture. As the air temperature increases, the on/off time of the sprinklers should increase as well. The controller is usually set to turn the sprinkler system on when the air temperature exceeds 21°C (70°F).

Table 1 shows the recommended operating sequence for evaporative sprinkler cooling systems.

Temperature	Operating Time
21 to 24°C (70 to 75°C)	25 to 30 seconds every 12 to 15 minutes
28 to 29°C (82 to 85°C)	25 to 30 seconds every 6 to 10 minutes
>32°C (>90°F)	25 to 30 seconds every 5 minutes

Table 1. Operating sequence for sprinkler cooling system

The amount of time sprinklers need to run can vary depending on the nozzle size and water pressure. In many cases, it takes 1 to 2 minutes to fully soak the cow, instead of just 25 to 40 seconds.

Today's technology allows evaporative cooling sprinklers to run based on the Temperature Humidity Index (THI) inside the barn. Some systems also use visual sensors, so sprinklers only turn on when a cow is nearby. This greatly reduces the amount of excess water entering the manure system.

Sprinkler nozzles

Sprinklers should be operated at a low pressure of 103 to 130 kPa (15 to 20 psi) and set to provide 1.1 litres of water per square metre (0.03 gallons per sq. ft.). Select nozzles that will provide 1.9 to 3.8 litres per minute (0.5 to 1 gallons per minute).

Nozzles on the water line are typically suspended 1.8 to 2.1 m (6 to 7 ft.) above the scrape alley to avoid cow reach. They should also be positioned to avoid spray drift that would wet the cow's feed.

Nozzles should be adjusted to cover a 180° pattern of 1.8 to 2.4 m (6 to 8 ft.) wetted area in the scrape alley (Figure 3). The goal is to wet the cows and not the feed in the manger or have any spray drift into the free stalls along the scrape alley. Nozzles should have check valves so that they do not drain after each cycle.

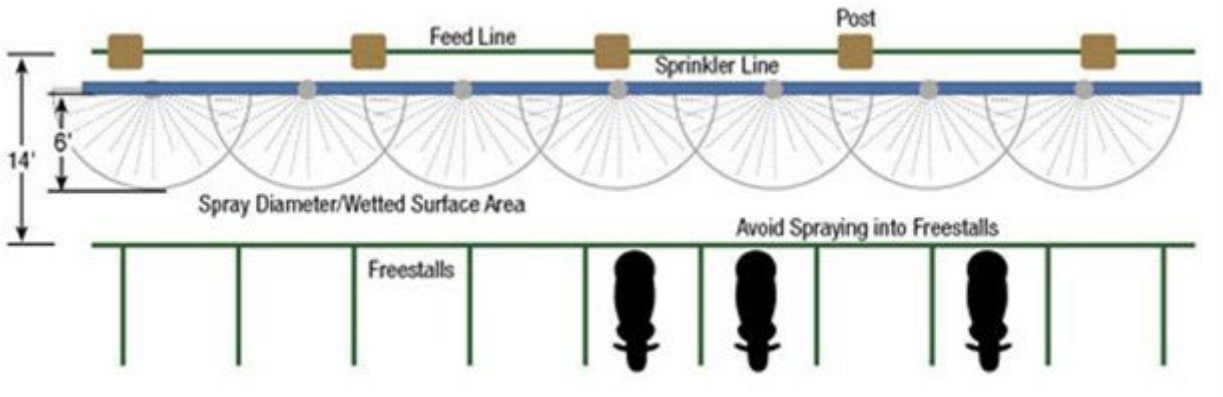

Figure 3. Top view of sprinkler system at Feed Manger (KSU Extension Bulletin MF-2401)

Using fans to speed up evaporation

Evaporative cooling works best by evaporating the moisture from the cow's surface with fast moving air. Berman (2008) found that the best air speed was 1 to 2 m/s (200 to 400 fpm) to evaporate moisture from the sprinklers. This air speed cooled the cow for up to 10 minutes. His research showed that evaporative cooling was not optimized with air speeds of 0.5 m/s (100 fpm) or less.

The priority is to install fans over the free stalls to provide cooling in the resting area, and this encourages them to lay down. If fans are only installed at the feed manger, it will cause cows to stand and not lie down. Along with fans over the free stalls, it's also important to install fans over the feed manger. These should be aimed to blow air across the cows' backs while they're eating, helping with evaporative cooling.

The most effective way to reduce heat stress is to install fans in both places however evaporative cooling is still beneficial even without fans at the feed manger.

Sprinkler cooling in the holding area

Evaporative cooling needs to be considered in the milking parlour holding area. Two to three times a day, cows are crowded into areas where they have only about about 1.4 m2 (15 ft2) of space or less. This makes it very difficult to release body heat. Research by Smith et al. (2000) has shown that without cooling, the body temperature of the cow increased 1.7C (3°F) within 20 minutes of entering the holding area. However, the cow's body temperature was lowered by 2°C (3.5°F) during the time the cows were in the holding area with an overhead sprinkler system and fans.

The sprinkler system should be designed to operate at a low pressure of 103 to 138 kPa (15 to 20 psi) and set to provide 1.1 litres of water per square metre (0.03 gallons per sq. ft.). The sprinkler nozzles should be selected to provide a 2.4 m diameter (8 ft.) 360° spray pattern and installed in a grid to completely cover the holding pen area.

The fan system in the holding area should be capable of providing 1,700 m^3/h per cow (1,000 cfm/cow). The ventilation rate is based on the total number of cows in the holding area.

In a holding area it is recommended to run the sprinklers at a shorter cycle of 1 minute on and 6 minutes off. To save water, the system can be set up to run in zones. As fewer cows remain in the holding area, the sprinklers at the back can be turned off automatically. Another option is to place sprinklers only at the front of the holding area to encourage cows to move forward.

Sprinkler cooling in the parlour exit lanes

Another location to install sprinklers is in the exit lanes from the parlour. This ensures that every cow gets wet. The sprinkler should be controlled to operate only when cows are exiting the parlour to save on water use.

High pressure misting

The other method of evaporative cooling is to use high pressure misters to lower air temperature by evaporating water into the air. However, this increases the relative humidity in the barn.

High pressure misters can be installed in front of fans to cool the air coming out of the fans. They can also be installed at the air intake of tunnel-ventilated or cross-ventilated barns to cool the incoming air. These systems only work well under conditions of low relative humidity.

When the relative humidity (RH) is below 55%, high-pressure misters can cool the air by up to 5°C (10°F). But when humidity is higher than 55%, the cooling effect drops to as little as 0.5°C (1°F).

If the relative humidity is consistently above 60%, it's better to use large-droplet sprinklers at the feed manger or holding area because they cool cows more effectively than misters in humid conditions.

Figure 4 shows the average daily relative humidity for Abbotsford from 2021 to 2024 was 72%. It's clear that most humidity readings are above 55%, and many are even higher than 60%. That is why cooling by high pressure misting or drawing air through evaporative cooling panels is not as effective as sprinkler cooling for the Fraser Valley.

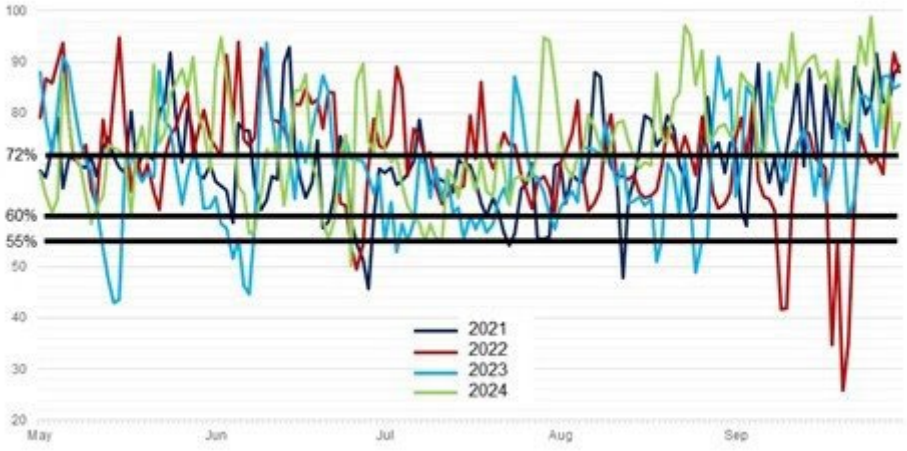

Figure 4. Average relative humidity for Abbtosford, B.C. from 2021 to 2024

The THI chart (Figure 5) provides an indication of how increasing relative humidity at a given temperature will increase the level of heat stress. In the Fraser Valley, where the average relative humidity is around 72%, cows start to feel mild to moderate heat stress when temperatures go above 24°C. At 30°C, if the relative humidity rises to 80%, cows can experience moderate to severe heat stress.

Air Temp		Relative Humidity (%)							
°C	°F	20	40	50	60	70	80	90	100
42	108	86	91	94	97	99	102	105	108
40	104	84	89	91	94	96	99	101	104
38	100	82	86	89	91	93	96	98	100
36	97	80	84	86	88	90	93	95	97
34	93	78	82	84	85	87	89	91	93
32	90	76	79	81	83	84	86	88	90
30	86	74	77	78	80	81	83	84	86
28	82	72	74	76	77	78	80	81	82
26	79	70	72	73	74	75	77	78	79
24	75	68	70	70	71	72	73	74	75
22	72	66	67	68	69	69	70	71	72
20	68	64	65	65	66	66	67	67	68
18	64	62	62	63	63	63	64	64	64

72% 80% 30°C 24°C

Stress Threshold (68)
Mild-Moderate Stress (72)
Moderate-Severe Stress (80)
Severe Stress (90)

Figure 5. THI chart showing how increasing humidity can lead to increasing heat stress

Concerns with water usage

One of the biggest downsides of using evaporative cooling at the feed manger or in the holding area is the extra water that ends up in the manure system. Any water that doesn't land on a cow—or runs off her body—adds more liquid that needs to be managed.

Joe Harner (2015) stated from his research that a 30 to 50% water savings on a dairy farm could occur if technology was available to operate evaporative cooling sprinkler systems with controllers that used THI instead of just temperature. Today's technology lets evaporative cooling sprinklers run based on the THI inside the barn. Some systems also use visual sensors, so the sprinklers only turn on when a cow is nearby. This greatly reduces the amount of excess water entering the manure system (Figure 6).

On average, evaporative cooling uses about 5,700 litres (1,500 gallons) of water per cow each year. Using THI-based controllers can reduce that amount by around 30%.

Figure 6. Soakers can sense whether a cow is within range (Agpro® Smart Soaker)

A study by Drwencke et al. (2019) compared four innovative cooling strategies for water and energy use.

1. The Baseline consisted of a fan over the free stalls with a sprinkler line at the feed manger. This strategy had a sprinkler on time of 1.5 minutes and off time of 6 minutes.
2. The Optimized Baseline positioned the fan over the feed manager with a sprinkler on time of 0.5 minutes and an off time of 4.5 minutes.
3. The Targeted Air treatment used a fabric duct to deliver evaporatively cooled air with jets targeted at the cows in the free stalls and the feed manger.
4. The Mat treatment used conductive cooling through a plastic mat buried beneath the sand bedding in the free stall with a chilled water sources circulating through it.

Extra cooling was needed for the Targeted Air and Mat treatments because they weren't as effective as other methods at reducing heat stress when temperatures rose above 30°C (86°F). The Optimized Baseline setting – sprinklers on for 0.5 minutes and off for 4.5 minutes – was the most effective at reducing heat stress while also saving energy and water.

Concerns with high humidity

One challenge with evaporative cooling is that it can raise humidity levels in the barn, especially if there isn't enough ventilation to remove the moisture. As humidity increases, the benefit of evaporative cooling decreases due to reduced evaporation. It is important to avoid the "tropical jungle" effect that will only increase heat stress. High levels of humidity can lead to cows panting and other respiratory problems such as pneumonia. The system must work together to thoroughly wet the cow but also provide time to evaporate the moisture and to remove the evaporated moisture from the barn with the ventilation system.

Novel applications of evaporative cooling

In emergency situations with periods of high heat stress a few temporary solutions can be employed. One is to spray the roof with an irrigation gun. Water sprayed on the roof will evaporate with the suns energy to effectively cool the roof and consequently cool the building environment.

Another temporary solution is to use a parlour wash-down hose to soak cows in the holding area, offering a quick form of evaporative cooling.

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