Northern New York Agricultural Development Program
2016 Project Report

The Effectiveness of Heat Stress Abatement Systems on Behavior and Performance of Lactating Dairy Cows in NNY

Project Leader(s):

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Background:

Summer can be the most detrimental season for dairy cows because of the heat stress caused by high temperatures and humidity. In the United States, dairy cows spend an average of 14.1% of hours per year heat-stressed. In New York State alone, dairy cows undergo heat stress for an estimated average of 8.2% hours per year, resulting in a total economic loss for New York of $23.193 million per year even when using abatement systems with fans and sprinklers (St-Pierre et al., 2003).

The temperature humidity index (THI) is an efficient method for measuring the amount of thermal stress exerted on an animal by the surrounding climate and is calculated using $THI = (1.8 \times T + 32) - (0.55 - 0.0055 \times RH) \times (1.8 \times T - 26)$ where T is dry bulb temperate in Celsius and RH is relative humidity (NOAA, 1976). Original studies reported the threshold for heat stress of dairy cows to be 72 or greater (Armstrong, 1994; Ravagnolo et al., 2000). However, these studies measured the productivity of low-yielding cows.

In an updated look at THI, Collier et al. (2012) found that cows producing greater than 77 lbs. (35 kg)-per-day yield nearly 5 lbs./day less when the average THI is 68 or higher for more than 17 hours a day.

Purwanto et al. (1990) showed that lactating cows yielding an average of 70 lbs. (31.6 kg) per day and 41 lbs. (18.5 kg) per day produced 48% and 27% more heat than non-lactating cows, a relationship that was unrelated to body weight.

Furthermore, the heat stress threshold is further complicated by the gradual effects of THI. West et al. (2003) observed that the THI and average air temperature have the greatest effect on milk yield and dry matter intake two days after the heat stress event.

Lying behavior of cows is also greatly affected by thermal stress. It has been found that cows spend up to three hours a day less resting during heat events in order to maximize evaporative cooling by increasing the surface area through which heat can radiate from their body (Overton et al., 2002; Cook et al. 2007). This is a significant consequence because cows typically spend 12 to 14 hours a day lying and for every 1.5 hours spent restricted from lying, there is an estimated decrease in eating time by 45 minutes (Metz, 1985; Grant, 2007).

However, Solano et al. (2016) suggests that too many hours spent resting can be an indication of lameness, showing that cows that lay over 14 hours a day have 3.7 higher odds of being lame. Many other factors can also contribute to the amount of time a cow spends lying including the parity of the cow, stage of lactation, and many environmental factors (Solano et al., 2016).

Because of the severe consequences of heat stress, heat abatement systems are necessary to keep milk production stable during the summer months. **Shading** is the most basic part of a heat abatement system and can reduce heat load by 30 to 50% by reducing direct solar radiation without actually effecting overall ambient temperature (Bond and Kelly, 1955). Cows with access to shade show milk production and fertility benefits when compared to those with no shade (Roman-Ponce et al., 1977).

Fans are also common and beneficial to an effective heat abatement system. Fans do not affect the ambient air temperature, but instead replace the hot, humid air coming off the cow as a result of cooling processes with drier and cooler air from the environment. Fans are most commonly used in combination with **water spray**, a system which has been found to increase lying time while decreasing core body temperature (Igono et al., 1987).

There are two main types of **water systems**: those that cool the cow and those that cool the air. Evaporative cooling systems use a finer mist that evaporates quickly and dissipates the heat from the air. Soakers or sprinklers are used on intervals to wet the cows with course droplets of water and improve evaporative cooling of the cow (Chen et al., 2016). Chen et al. (2016) found that sprinklers at the feed bunk increased milk yield and decreased core body temperature.

While many aspects of heat stress and heat abatement systems have been examined, there are still some areas that are lacking. Many current studies have begun to study high-producing cows (greater than 65 lb./day (~30 kg/d)), and yet this still isn't comparable to the top-producing cows (greater than 100 lb./day (~45 kg/d)). Furthermore, the effects of cyclical summer climates, such as that of Northern New York, are unknown, although there is evidence to suggest that it may take weeks for the cow to adapt physiologically to the effects of heat (Collier et al., 2006). Igono et al. (1992) found that when cows have 3-6 hours of relief from heat stress, such as during nighttime cooling, there is less of a decline in milk yield.

Objective:

The objective of this NNYADP-funded study was to assess the impact of different heat abatement systems on behavior and performance of dairy cattle from May through September in Northern New York.

Methods:

The study took place from June 10, 2016, to August 28, 2016 using Holstein cows housed in 3 pens located in 4-row free-stall barns at the William H. Miner Agricultural Research Institute in Chazy, NY, and was approved by Miner Institute's Animal Care and Use Committee.

Pens:

The three pens had the following heat abatement systems:

1) Minimal heat abatement with fans only over the free-stall beds (**FB**): four 52-inch fans located 8-ft over the center of the beds spaced 40-48 ft. apart. The fans were activated when the temperature was 70°F or higher. The beds were arranged head-to-head, with two sections of 34 beds separated by 2 water troughs, for a total of 68 beds. The beds were covered in Animattresses (Ani-mat, Inc, Sherbrooke, QC, Canada) and bedded with sawdust. This pen housed mid/late-lactation animals which averaged 251 ± 65 days in milk and 85 ± 13 lbs. milk/day at the start of the study. Over the course of the study stocking density averaged ~112%.

2) Moderate heat abatement (**FBA**): Four 52-inch box fans were located 8-ft over the center of the beds spaced 40-48 ft. apart and five 52-inch box fans were located over the feed alley spaced 40-ft apart. The fans were activated when the temperature was 70°F or higher. This pen had deep sand beds arranged head-to-head, with one section of 40 beds and an additional 6 beds available in another section, for a total of 46 beds, until July 14 at which point access was restricted to the second section, due to management practices. This left a total of 40 beds for the remainder of the study. This pen housed peak-lactation animals which averaged 158 ± 85 days in milk and 123 ± 20 lbs. milk/day at the start of the study. Over the course of the study stocking density averaged ~108%.

3) High (maximal) heat abatement (**FBAS**): four 52-inch box fans located 8-ft over the center of the beds spaced 40-48 ft. apart and five 52-inch box fans located over the feed alley spaced 40-ft apart. The fans were activated when the temperature was 70°F (21°C) or higher. CowKuhlerz (KühlerZ, LP, Duluth, GA) evaporative cooling system was used with water nozzles attached to all the fans. Three settings were utilized. During mild heat stress (THI of 68), the spray would be on for 45 seconds for an interval of 4.5 minutes. During moderate heat stress (THI of

72), the spray would be on for 1 minute for an interval of 3.5 minutes. During dangerous heat stress, the spray would be on for 1.5 minutes for an interval of 2.5 minutes. The beds were arranged head-to-head, with two sections of 34 separated by 2 water troughs, for a total of 68 beds. The beds were covered in Animattresses (Ani-mat, Inc, Sherbrooke, QC, Canada) and bedded with sawdust. This pen housed peak-lactation animals which averaged 95 ± 59 days in milk and 123 ± 23 lbs. milk/day at the start of the study. Over the course of the study stocking density averaged ~118%.

All pens were provided the same heat abatement in the holding area of the parlor three times each day. The holding area was equipped with 4 box fans and a water spray system that was activated at different ranges. The low range was activated at 75°F, with the sprinklers on for 1.5 minutes on an interval of 4 minutes. The high range was activated when the temperature reached 90°F and the sprinkler was on for 2.5 minutes on an interval of 2.5 minutes.

Measurements:

Environmental: Temperature and humidity were recorded every 15 minutes for each pen using HOBO U23 Pro v2 Temperature/Relative Humidity Data Loggers (Onset Computer Corporation, Bourne, MA) from June 10 – August 28. These measurements were used to calculate the THI ($THI=(1.8 \times td + 32) - [(0.55 - 0.0055 \times RH)(1.8 \times td - 26)]$ where td is the dry bulb temperature in °C and RH is the percent relative humidity). Wind speed was measured using an anemometer (Kestrel 3000). The average wind speed was measured in the feed alley and beds for each pen.

Resting Behavior: Fifty multiparous cows were used as focal animals for the lying time data with 20 cows selected from FB and FBAS and 10 cows from FBA. Resting behavior (lying time and bouts) was continuously measured July 2–July 31 using HOBOware Pendant G loggers (Onset Computer Corporation, Bourne, MA) that measured the tilt along the y-axis to distinguish the time cows spent lying versus standing. Total minutes lying was measured as well as lying bouts, which was defined as more than 3 consecutive minutes spent lying.

The stall standing index (SSI) was assessed from July 6 to August 28 using a Moultrie camera with panoramic view (M-880 Gen2 MP Digital Game camera, Ebsco Industries, Inc.). The camera was set to capture an image of a group of stall beds at 10-minute intervals. Six time points were selected throughout each day: 2 hours before and 2 hours after each of the 3 daily milkings. The pictures captured closest to each of these time points were examined in order to calculate the SSI. The SSI was calculated by dividing the number of cows standing by the total number of cows in contact with a bed.

Milk Production: Milk yields for all cows in the study pens were recorded electronically at each milking from June 10 – July 31. Milk samples from 3 consecutive milkings for each cow were collected weekly over the same period. The milk samples were analyzed for fat, true protein, lactose, solids nonfat, and urea nitrogen by mid-infrared procedures and somatic cell count was analyzed by flow cytometry. Weekly milk samples were mathematically composited after analysis in proportion to milk yield at each sampling.

Statistical Analysis*:* Proc Reg (SAS, 9.2; SAS Institute Inc., Cary, NC) was used to evaluate the relationships between lying time, SSI, and THI. Proc GLIMMIX (SAS, 9.4; SAS Institute Inc., Cary, NC) was used to evaluate the effect of THI at low (<68), medium (68-72), and high (>72) ranges on lying time and lying bouts. The fixed effect was the THI range and the random effect was the cow.

Results:

Pen Conditions:

Over the course of this study, there were many days when the average THI was greater than 68 which provided opportunities to evaluate the efficacy of three levels of heat abatement: minimal, moderate, and maximum. Minimal heat abatement was fans only over the free stalls (FB), moderate abatement was fans over both the stalls and feed alley (FBA), and maximum heat abatement included fans and sprinklers over both the stalls and the feed alley (FBAS).

An episode of heat stress was defined as THI ≥68. As expected, the average THI was similar across the study pens (Figure 1). The wind speed measured when fans were engaged over the feed alley and the freestall beds averaged 4.9 kt and 3.5 kt for FB, 6.7 kt and 2.9 kt for FBA, and 6.5 kt and 3.7 kt for FBAS, respectively.

Heat Stress and Milk Production:

Figures 2-4 show the relationship between episodic heat stress experienced between June 10 and July 31, 2016 and milk yield.

With minimal heat abatement (Figure 2) milk yield declined with the first heat episode and then remained fairly constant until the third episode when a prolonged period of heat stress resulted in a 6% decrease in milk yield.

With moderate heat abatement (Figure 3) milk yield gradually declined from 123 lb./d to about 113 lb./d for the first two heat episodes, recovered slightly to 117 lb./d then dropped precipitously to about 107 lb./d during the prolonged heat period (7/8 to 7/29/16). This pen of cows was earlier lactation than the cows in the minimal heat abatement treatment and much of this loss in milk likely reflects the fact that higher producing cows are more sensitive to heat stress.

With maximal heat abatement (Figure 4), the cows held fairly steady in milk production through the first two episodes of heat, but dropped from about 125 lb./d to 118 lb./d during the prolonged period of heat stress, < 6% decrease. As with the cows on the moderate abatement, these cows were high producing and more sensitive to heat stress, however the degree of impact was less for this high producing group of cows.

Overall, comparing moderate to maximum heat abatement with cows at similar milk production, it appeared that supplying fans and sprinklers over stalls and feed alley led to less loss of milk yield.

Heat Stress and Milk Fat Percentage

Milk fat response to heat stress is shown in Figures 5-7. With minimal heat abatement (Figure 5), milk fat percentage dropped below 4% from 4.15% following the first heat episode and remained below 4% until the final week when it rose slightly to 4.05%. Overall, milk fat % did not change much for this pen of cows with minimal heat abatement.

With moderate heat abatement (Figure 6) milk fat percentage dropped from 3.86 to 3.70% with the first heat episode, but it rebounded to 3.76 and 3.87% as the heat stress continued.

With the maximum heat abatement (Figure 7), milk fat remained steady through the first episode of heat stress and then it dropped to 3.68 from 3.76% and remained steady throughout the heat stress periods and rebounded by the final week to 3.72%.

Overall, cows that experienced moderate and maximum heat abatement had less change in milk fat percentage than cows under minimal heat abatement.

Heat Stress and Stall Standing Index:

The stall standing index response to heat stress is shown in Figures 8-10. With minimal heat abatement, there was a positive relationship between THI and stall standing index (Figure 8). In contrast, with either moderate or maximum heat abatement (Figures 9-10) there was no relationship between THI and stall standing index. **These results indicate that, with adequate heat abatement, higher THI does not result in more standing in the stalls. With greater THI, cows with minimal abatement stood more in an effort to cool themselves.**

Heat Stress and Lying Time:

Table 1 shows how lying time changed with increasing THI for cows experiencing three degrees of heat abatement. For cows with minimal heat abatement, lying time decreased once THI exceeded 72. Similarly, lying time was reduced above THI 72 for the moderate and maximum abatement treatments as well. But, the extent of the reduction in lying time increased from maximal to moderate to minimal heat abatement. Cows with minimal heat abatement lost the greatest amount of lying time. It is also interesting to note the much greater lying time for cows in the pen with moderate abatement; this pen had sand-bedded stalls compared with mattresses for the other two pens. Most studies have found lying time to be greater for sand versus mattress systems.

Conclusions/Outcomes/Impacts:

The main conclusions from this study are:

- Higher producing cows appear to be more sensitive to bouts of heat stress.
- Maximal heat abatement system (fans and sprinklers over stalls and feed alley) held milk production better than moderate abatement (fans over stalls and feed alley).
- Milk fat percentage was minimally affected by heat stress when cows had maximal heat abatement.
- With minimal heat abatement, standing time increased with greater THI as cows tried to cool themselves.
- For moderate and maximal heat abatement, as THI increased stall standing index did not change. In other words, cows were more comfortable and did not need to stand in the stall in order to cool themselves.
- Lying time was depressed for all abatement systems above THI 72, but the extent of reduction in lying time was less with more aggressive heat abatement.

Outreach:

The results of this study will be shared through the Miner Institute Farm Report, presented at multiple dairy producer meetings, and made available on Miner Institute's website. An abstract will also be submitted at the national meeting of the American Dairy Science Association 2018.

Next Steps:

The farmer-driven Northern New York Agricultural Development Program is continuing to support research evaluating heat stress on Northern NY dairy farms in 2017,using commercial farms to evaluate the impact of heat stress when various heat abatement systems are used.

Acknowledgments:

Thank you to the farm and research staff at Miner Institute for their hard work and dedication throughout this study. Also, thank you to the farmers of the Northern New York Agricultural Development Program for financial grant support of this study.

For More Information:

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Northern New York Agricultural Development Program
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The Effectiveness of Heat Stress Abatement Systems on Performance, Behavior & Lameness of Lactating Dairy Cows in NNY

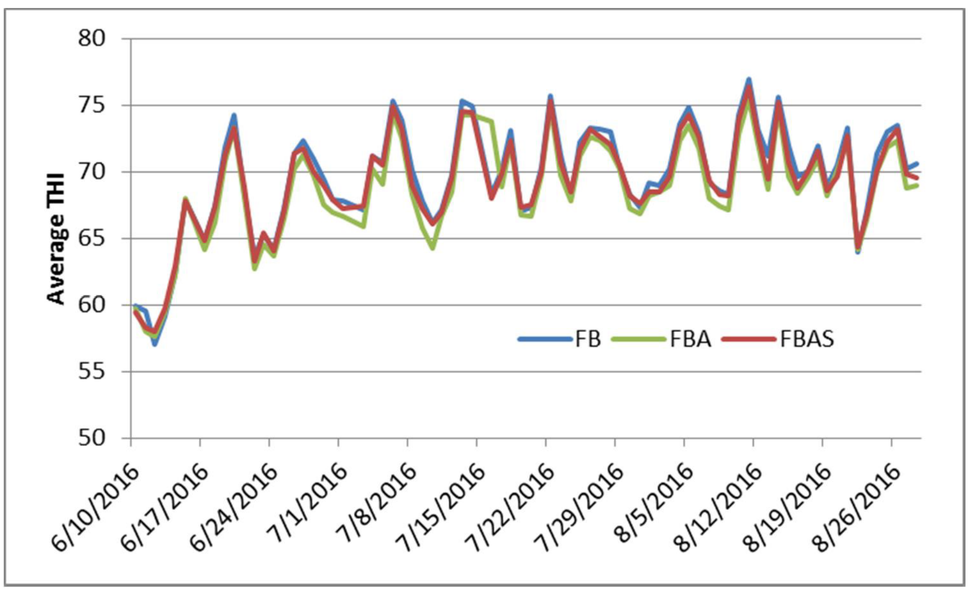

Figure 1. Average THI across study pens from June 10 through August 28, 2016. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

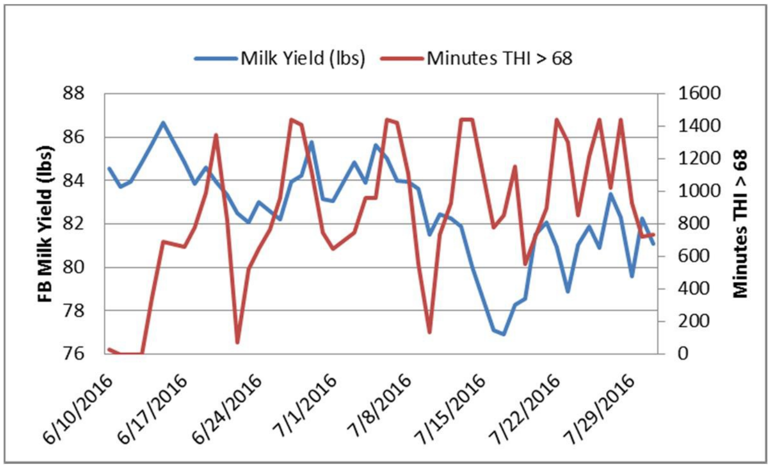

Figure 2. Milk yield relative to minutes THI ≥ 68 for cows housed in freestall pen with fans over stall beds only – minimal heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

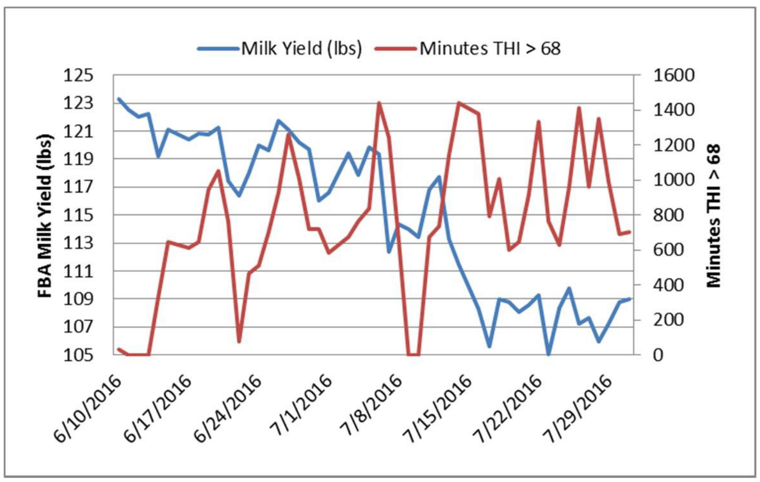

Figure 3. Milk yield relative to minutes THI ≥ 68 for cows housed in freestall pen with fans over stall beds and feed alley – moderate heat abatement, Heat Stress Abatement Project, Miner Institute, NNY, 2016.

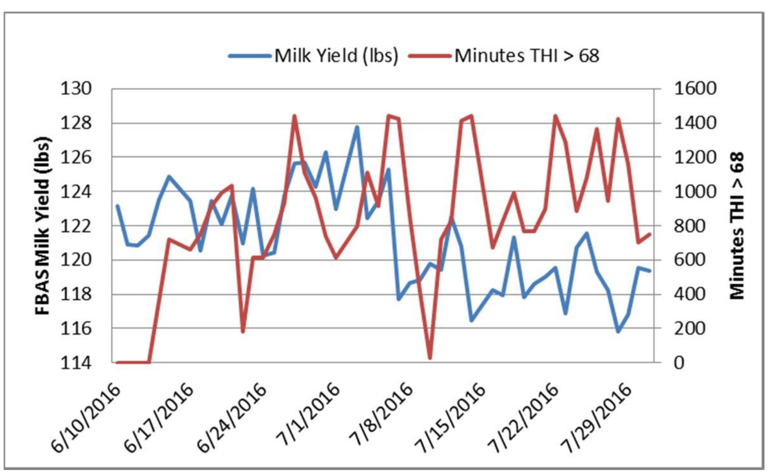

Figure 4. Milk yield relative to minutes THI ≥ 68 for cows housed in freestall pen with fans and sprinklers over stall beds and feed alley – maximum heat abatement, Heat Stress Abatement Project, Miner Institute, NNY, 2016.

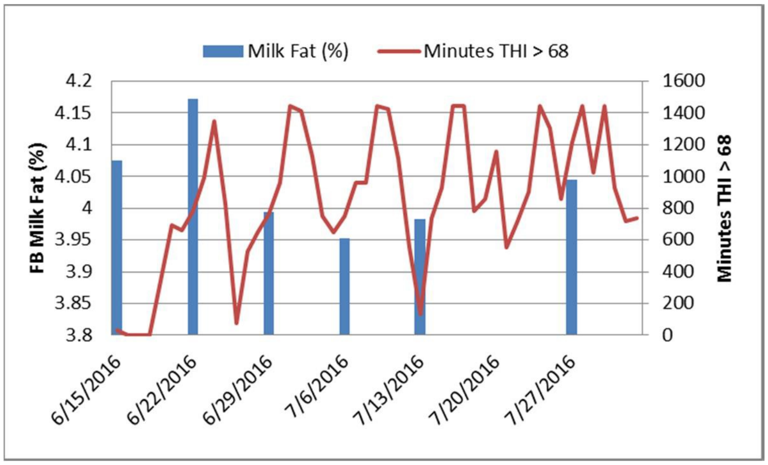

Figure 5. Milk fat (%) relative to minutes THI > 68 for cows housed in freestall pen with fans over stall beds only – minimal heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

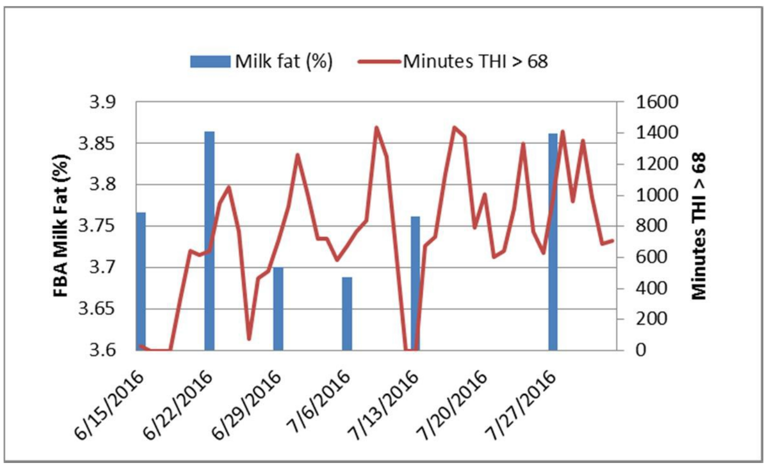

Figure 6. Milk fat (%) relative to minutes THI > 68 for cows housed in freestall pen with fans over stall beds and feed alley – moderate heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

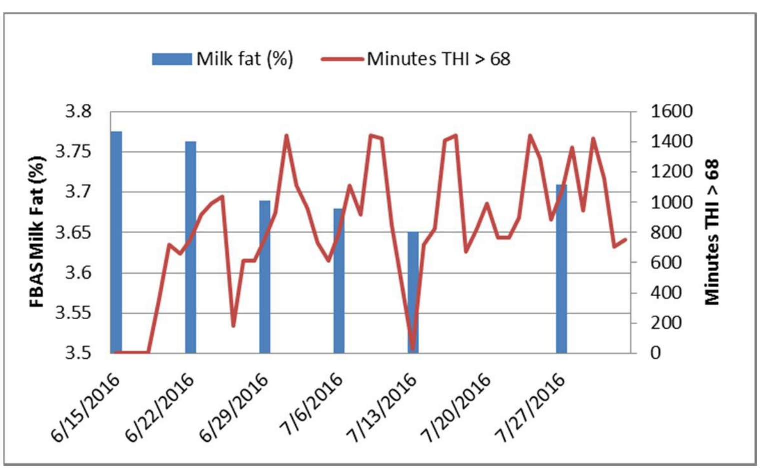

Figure 7. Milk fat (%) relative to minutes THI > 68 for cows housed in freestall pen with fans and sprinklers over stall beds and feed alley – maximum heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

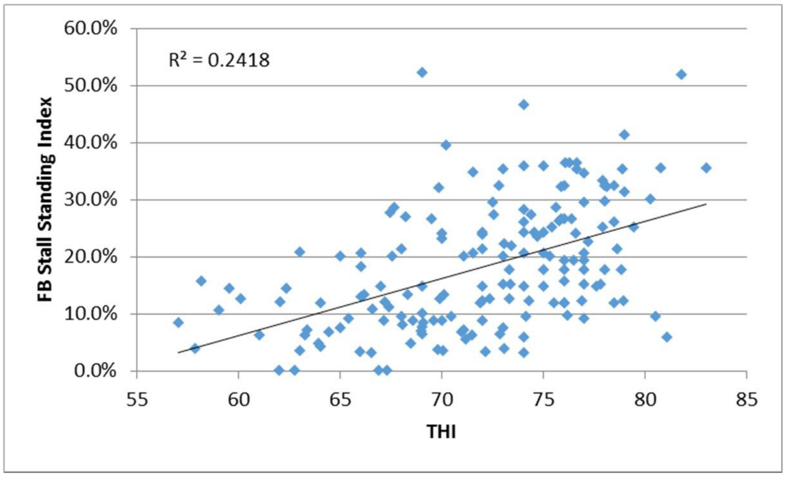

Figure 8. The relationship between stall standing index and THI in pen with fans over stall beds only – minimal heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

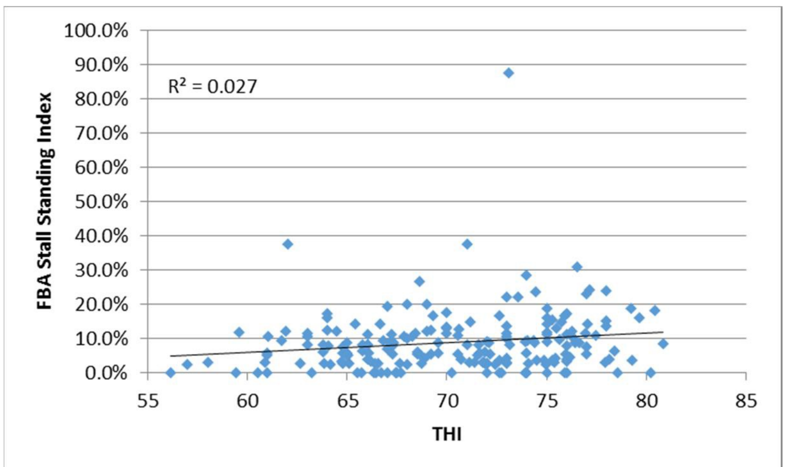

Figure 9. The relationship between stall standing index and THI in pen with fans over stall beds and feed alley – moderate heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

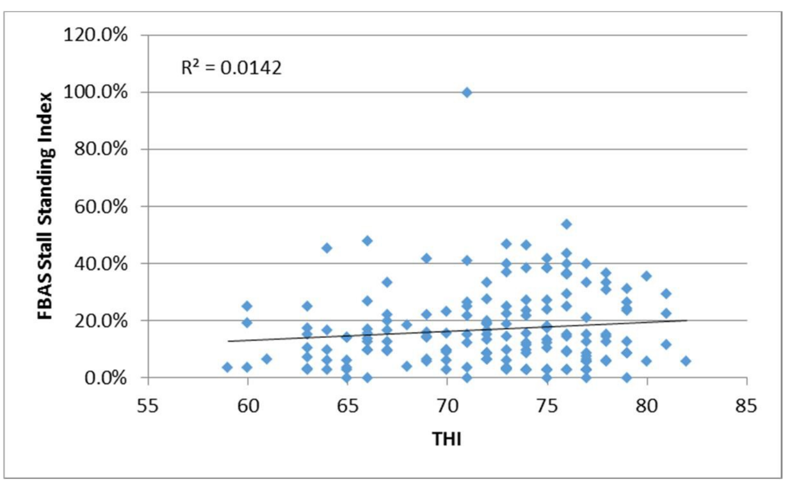

Figure 10. The relationship between stall standing index and THI in pen with fans and sprinklers over stall beds and feed alley – maximum heat abatement. Heat Stress Abatement Project, Miner Institute, NNY, 2016.

Table 1. The effect of THI level on lying time (minutes/day) by pens with differing heat abatement strategies, Heat Stress Abatement Project, Miner Institute, NNY, 2016.

Pen	n	THI <68	THI 68-72	THI >72	SE	*P*-Value
FB	20	681[a]	671[a]	631[b]	25	<0.001
FBA	10	817[a]	804[a]	776[b]	53	<0.001
FBAS	20	642[a]	644[a]	611[b]	22	<0.001