COMMON FLORIDA SHADE MANAGEMENT SYSTEMS
TO REDUCE HEAT STRESS

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The radiant heat load that an unshaded cow receives during the day from the sun and surroundings is often greater than the cow's metabolic heat production. A simple shade structure can effectively reduce the radiant heat load on the cow by 30% or more by intercepting the direct solar radiation. As shown in Table 1, this reduction in solar radiation markedly reduces rectal temperatures and respiration rates of cows compared to unshaded control animals. This reduction in heat load improves lactation and reproductive performance of dairy cattle in a subtropical environment, Roman Ponce et al., 1977, J.D.S. 60:104.

Table 1. Responses of animals to environment.

<table>
<thead>
<tr>
<th>Black Globe Temperature (°C)</th>
<th>Shade 29.84</th>
<th>NS-S 8.11*</th>
<th>No Shade 37.95</th>
</tr>
</thead>
<tbody>
<tr>
<td>Holstein</td>
<td>Jersey</td>
<td>Holstein</td>
<td>Jersey</td>
</tr>
<tr>
<td>Rectal Temp (°C)+</td>
<td>38.75</td>
<td>38.53</td>
<td>1.02*</td>
</tr>
<tr>
<td>Respiration Rate (per min)</td>
<td>77.48</td>
<td>78.62</td>
<td>35.73*</td>
</tr>
<tr>
<td>Rumen Contraction+ (per min)</td>
<td>2.20</td>
<td>2.63</td>
<td>-0.70*</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.44</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.96</td>
</tr>
<tr>
<td>n</td>
<td>188</td>
<td>130</td>
<td>243</td>
</tr>
</tbody>
</table>

*Significant treatment difference P<.001.
+Significant breed within treatment difference P<.001.

In addition to lowering fertility heat stress also reduces uterine blood flow, Roman Ponce et al., 1978, J. Anim. Sci., 46:175. This reduction of uterine blood flow during pregnancy is of importance to the dairy farmer. Chronic reduction in uterine blood flow may retard growth of the fetus. The fetal placenta produces hormones stimulating mammary growth during pregnancy. The degree of mammary development establishes the potential of the cow to produce milk.
In order to determine if heat stress during pregnancy reduces calf birth weight and/or milk yield in the next lactation we ran the following experiment. Thirty-one pregnant cows were placed in either the shade (n=16) or no shade (n=15) areas in June 1978. At four day intervals from day 190 of pregnancy to term we measured environmental temperatures, cow rectal temperature, heart rate, and respiration rate and took a blood sample for analysis of hormones. At parturition all cows were removed from treatment and placed in the milking herd. Calf birth weights and milk yield of the dam were also recorded.

As shown in Table 2, pregnant cows in the no shade area were exposed to higher environmental temperatures and had higher rectal temperatures, respiration rates and heart rates.

Table 2. Effect of shade during pregnancy on maternal physiological parameters.

<table>
<thead>
<tr>
<th></th>
<th>Shade</th>
<th>No Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Black Globe Temperature (°C)</td>
<td>29.5**</td>
<td>36.9</td>
</tr>
<tr>
<td>Rectal Temp (°C)</td>
<td>39.2**</td>
<td>39.8</td>
</tr>
<tr>
<td>Respiration Rate/min</td>
<td>61 **</td>
<td>89</td>
</tr>
<tr>
<td>Heart Rate/min</td>
<td>78 **</td>
<td>83</td>
</tr>
</tbody>
</table>

n>700
*P<.05
**P<.001

As shown in Table 3 the cows which calved in the shade area gave birth to larger calves (ave, 3 kg) and produced more milk in the subsequent lactation, (ave 407, 168, projected 305 day ME).

Table 3. Effect of shade during pregnancy on calf birth weight and dam's milk yield.

<table>
<thead>
<tr>
<th></th>
<th>Shade</th>
<th>No Shade</th>
</tr>
</thead>
<tbody>
<tr>
<td>Birth weight (kg)</td>
<td>39.68</td>
<td>36.64</td>
</tr>
<tr>
<td>1st 100-Day Milk Yield (kg)</td>
<td>2672.4*</td>
<td>2556.1</td>
</tr>
<tr>
<td>Projected 305-Day Milk Yield (kg)</td>
<td>6518.0*</td>
<td>6051.0</td>
</tr>
</tbody>
</table>

*Corrected for age, body weight, sire and real producing ability of dam.
Shade management during the dry period appears to be much more important than previously suspected. Benefits gained from shade management during the dry period are in addition to benefits of shade during lactation and shade effects on reproductive efficiency.

Since many large dairies do not have adequate natural shade available, artificial shades need to be provided in order to increase the productive and reproductive performances of dairy cows. The man-made shades, however, must be well-designed and engineered in order to obtain the maximum benefits that can be realized from shade structures.

The major design parameters for shade structures are: 1) orientation, 2) floor space, 3) height, 4) ventilation, 5) roof construction, 6) feeding and water facilities, and 7) waste management system.

The orientation of a shade structure is very crucial. The preferred orientation is east-west. This means the long axis of the building runs in an east-west direction. Figure 1 shows the shading patterns under shade structures for three different times during the day of June 21. It is important to notice that a larger percent of the shadow from the shade structure lies under the shade structure itself with the east-west orientation. The same relationship is true in September 21 as seen in Figure 2.

In Figure 2, it is also important to point out that there is no place where a feed and watering facility could be placed under the shade structure that would not be in the sun during a portion of the day. Having feed and water available under the shade is extremely important so that the cows are able to keep cool and have access to feed and water simultaneously.

Figure 3 shows the shading patterns under the shade structures for December 21. During the winter, a larger percentage of the floor under the shade will be sunlit when the structure is oriented east-west. This means that the floor will be drier.

Because cows position themselves in the shadow rather than under the shade itself, the area around some shade structures becomes a "mud-hole." Such conditions pose serious problems, especially in low lying areas with high rainfall. Under such conditions, it is advisable to fence the cows under the shade on a concrete pad. However, the area fenced needs to be larger than the floor area of the shade structure because the shadow will not always be under the structure. For a 12 ft high shade structure with an east-west orientation in central Florida, the fenced area should extend at least 8 ft on the north, east, and west sides of the shade. No extension is needed on the south side. This entire extended floor area should be concreted.
The size of a shade structure should allow at least 50 ft$^2$ of floor space per cow. A more preferable floor area per cow is 65 ft$^2$. Facilities for feed and water for the cows should be provided under each shade structure to maximize the benefits that can be realized. Feed and water should be supplied under the shade so that animals can take advantage of the comfortable conditions under the shade and still consume feed and water. If feed and water are supplied in an unshaded area, animals will reduce feed consumption and take an increased heat load during feeding resulting in lowered milk production.

Shade structures tend to have length to width ratios ranging from about 2:1 up to over 10:1. When the width of a shade structure exceeds about 40 ft the air movement under the shade structure is sharply reduced, especially in the center of the shade. For flat-roofed structures with a width of 100 to 125 ft, the environmental conditions under the center of the shade are most undesirable because of high temperature, high humidity and high concentrations of ammonia and respiratory gases. If a wide structure is desired, it is recommended to have several continuous openings in the roof to allow better circulation of air. To enhance natural ventilation in shade structures, the site should be selected so that there will be no obstructions, trees or other buildings, within at least 50 ft of all sides of the structure. Also, any gable-roofed structure should have a continuous open ridge to enhance natural ventilation, as shown in Figure 4.

The height of a shade structure needs to be selected with two opposing criteria in mind: 1) the higher the shade, the greater the air movement under the shade and 2) the lower the shade, the smaller the diffuse and reflected radiation loads on the cows. For Florida conditions, a minimum height of 12 ft from ground level to lowest point of the roof is recommended.

Various types of roofing materials can be used for shade structures. The most effective in terms of reducing heat load on the animals under the shade is an aluminum or white galvanized metal roof with about 1 in. of insulation directly beneath the metal roofing. No air space should exist between the roofing material and insulation, otherwise the insulation becomes very vulnerable to damage by birds and rodents. The insulation serves the purpose of practically eliminating the infrared heat load on the animals. The infrared heat load from the underside of a bare metal roof can be as high as 1000 BTU/hr to a cow.

The top of the roof should always be painted white if aluminum is not used. The white color serves to reflect a significant portion of direct solar radiation that would otherwise be absorbed and eventually place a greater heat load on the cows. Aluminum is more reflective than white paint; therefore, no paint should be applied to an aluminum roof.
Modifications of the shade structures with metal-clad roofs are the galvanized metal-cable roofing systems for flat-roofed shades, Figure 5. The metal-cable system consists of sheets of galvanized roofing sandwiched between cables under high tension. The sheets are spaced with a gap of 4-8 in. between them. The advantage of such a system is a lower initial investment; however, it is not known how well such a roof would withstand strong winds.

Shade cloth fabrics with various weave openings providing actual shade from 30% up to 90% are available for use as animal shades. Most commonly used are fabrics with about 80% actual shade. The shade cloth used as a roofing material is definitely cheaper than any other roofing system commonly used. However, the shade cloth does not provide as much protection from solar radiation for the cows. Shade cloth is quite durable if it is installed properly under tension so that the wind cannot freely whip it. It is necessary to maintain the tension in the fabric in order to realize many years of service from the material. Research is currently being conducted at University of Florida to assess how significant the differences might be between a well-designed shade structure and a structure utilizing the shade cloth in the roof.

The floor of a shade structure in Florida needs to be made of at least 4 in. or reinforced concrete on a 1/2 - 2% slope. An earthen floor cannot be used under Florida's hot and humid conditions, because such a floor would soon evolve into a "mud-hole."

A waste management system must be planned as an integral part of any shade structure. The concrete floor of a shade can be cleaned by flushing with dump tanks, hosing manually with high pressure water, or scraping manually or with a small tractor. An efficient system used in Florida involves flushing a 30 ft. by 80 ft. shade with three 300 gal. dump tanks. The flush water, along with water from holding pens and milking parlor, is then channelled into a lagoon system. The lagoon system consists of two lagoons with gravity flow from the first to the second. The first lagoon is anaerobic, while the second one is aerobic. Water from the second lagoon can then be used as irrigation water on crop lands. The plants will utilize the nutrients in the water and the soil will filter the water as it percolates into the ground water supply.

A promising new type of shade structure is a quonset shaped structure, using vinyl coated dacron with polyester fiber as the covering, Figure 6. This covering material is reflective on the exterior and appears to be very durable. The only disadvantage with this type shade structure is the high capital investment required. The high cost is attributed not only to the materials but also high erection costs involving a crane.

During August 1977, dairy producers in California experienced critical heat stress for a period of about a week after a tropical storm
hit their area. During this period of critical heat stress, the daily maximum temperature was 88-96°F and daily minimum temperature was about 70°F. Relative humidity during the afternoon averaged 40-50% and during the late evening and early morning hours was 90-95%. During this period, approximately 700 dairy cows died because of the heat stress and the milk production of all the dairy cows was substantially reduced.

It is interesting to note that the climatic conditions of the critical heat stress in California are very similar to what is frequently experienced through the period of May 15 to September 15 in Florida. In fact, many Florida summer days are even more heat stressing. In California, the cooling systems evaluated for their performance in terms of reducing death losses and milk production losses were shades, foggers, several different barn types, and washing systems. The main conclusion reached by the researchers was "shades were much more effective than any other method for reducing production and death losses."

To summarize, the major factors that need to be considered in the design of a shade structure are: 1) east-west orientation, 2) minimum of 50 sq. ft. of floor space for a cow, 3) minimum height of 12 ft., 4) roof ventilation openings, 5) a white insulated roof or aluminum roof to reflect incoming solar radiation, 6) feed and water available under the shade structure, and 7) a waste management system.
Figure 1. Shading patterns on June 21 under shade structures oriented north-south and east-west.
Figure 2. Shading patterns on September 21 under shade structures oriented north-south and east-west.
Figure 3. Shading patterns on December 21 under shade structures oriented north-south and east-west.
Figure 4. Gable-roofed shade structure with continuous open ridge

Figure 5. Shade structure with galvanized metal-cable roofing system

Figure 6. Quonset shade structure with vinyl coated dacron surface