Design of Livestock Shades

construction and location of shades contribute to animal comfort and maintenance of feed intake

C. F. Kelly, T. E. Bond, and N. R. Ittner

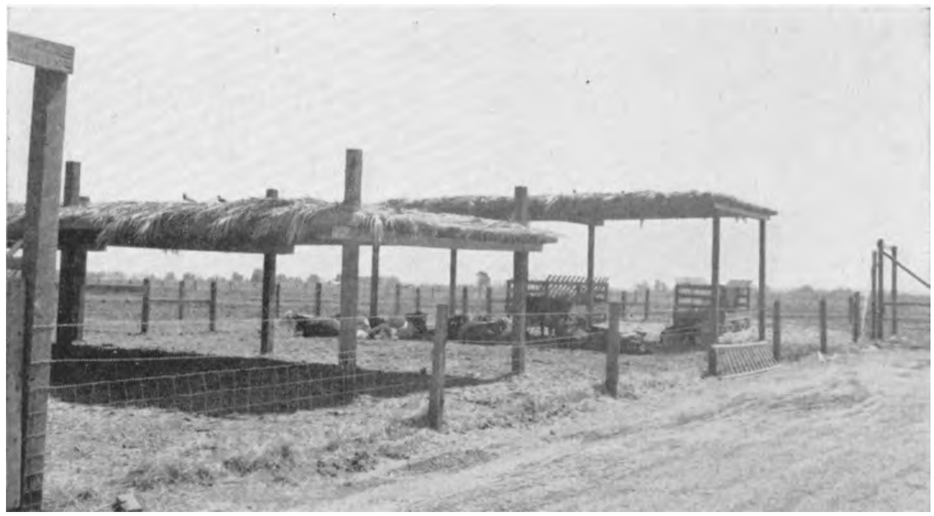
High weather temperatures at certain seasons may turn profitable livestock enterprises into losses, even though feed and labor are plentiful.

Only a relatively small part of the energy in livestock feed intake goes into milk, meat, fat, or eggs. The rest is discarded to the environment in the form of heat, feces, and urine. If not discarded, it raises the animal's body temperature, and a loss of appetite with reduced feed intake results—disastrous to profits.

The problem in a hot environment is to make it possible for the animal to lose its waste heat without changing its physiological reactions in any way that might interfere with its remaining on full feed.

In a long-term co-operative study by the United States Department of Agriculture and the University of California, the effectiveness of several types of shades—constructed and natural—for livestock was investigated.

When the wind velocity is but one mile per hour, a given volume of air will be in the shadow of a shade structure which is 36′ long—in the direction of wind travel—for only 25 seconds. Any lowering of air temperature occurs as a result of heat transfer by convection from the air to the cooler ground in the shadow or to the framework or roof of the shade—unless water is evaporated into the air from sprays or from urine and feces. Observations under several experimental shades constructed at the University of California Imperial Valley Field Station indicated that little reduction in air temperatures can be expected by convection.



Experimental shades in Imperial Valley. Notice that most of the animals are in the shadow of the 12′ shade and not under the 7′ shade.

Any small area on the surface of a shade, the ground, or other part of the surround radiates heat at a rate depending upon its temperature and emissivity—its ability to give off heat. Each part of the surround radiates in all directions but only a part of the total radiation will be intercepted or received by an animal.

The entire surround may be divided into five radiating sectors, each giving off quantities of radiant energy at different rates: *A*, the cool ground in the shadow of the shade; *B*, the unshaded hot ground around the shadow of the shade; *C*, the underside of the shade; *D*, a band about 10° high above the horizon, radiating at a high rate because of back radiation from moisture in the heated air near the ground; and *E*, the remainder of the sky not hidden by the shade or included in the horizon band.

Location of Shadow

Cattle seeking shelter from the sun's rays position themselves not by the shade but by its shadow location. Therefore, if a shade is to be designed for a season of the year, time of day, and geographical latitude, the shadow position should be calculated. The sun's rays are parallel when they reach the earth, and the size of the shadow under a thin, flat, horizontal shade is the same as the size of the shade. Furthermore, the rate at which the shadow moves—because of the sun's movement—is exactly proportional to the shade height. For example, in one hour a shadow from a shade 12′ high will move twice as far as that from a shade 6′ high.

For a given location, a shade should be designed either for the date and time of day when the solar radiation will be greatest—noon on June 22 in the northern hemisphere—or for the time of year when the average air temperature is greatest and protection from the sun's rays most important—usually in August. However, because conditions with regard to solar and sky radiation, air temperature, and other factors are never static, no one shade can be best for all conditions.

Shade Placement

In the hot sections of California, shades are commonly constructed with the long axis north and south in order to keep the total irradiation of the ground under the shade sufficient to dry

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up the urine and feces and to promote sanitation. However, an east-west orientation—placement—has an advantage over the north-south in that a greater proportion of the shadow lies to the north of the shade, providing possible exposure to the colder north sky for a larger number of cattle. Furthermore, the ground temperature under the east-west shade may be a little lower because the ground is shaded for a greater part of the day.

Increasing the size of the shade varies the shape factor of the various sections of the surround with respect to the animal. As the shade's shadow size increases, its shape factor increases and the hot ground factor decreases. At the same time, the portion of cool sky radiating to the animal is being made smaller. The net result is that the belly of the animal is cooled and the back warmed, the total being about the same.

Shade Height

As the height of a shade is increased, the animals in the shadow become exposed to a larger percentage of the cool sky, which tends to increase the cooling effect. Raising the shade does not alter the size of the shadow but the decrease in the temperature of the ground will be less because of the shadow's more rapid movement onto solar-heated ground as the sun passes overhead.

A field test on the effect of height of shade on cattle comfort was conducted at El Centro with two 18′ × 36′ hay-covered shades—one 7′ high and the other 12′. Both were located in the same corral, with eight Hereford steers having access to both shades. Neither shade was more convenient to pasture, water, or feed than the other. The 12′ shade was used almost exclusively; very seldom was an animal seen under the lower one.

Practical cattlemen object to low shades because the moisture from urine and feces does not dry out as fast as under high ones. However, the moisture does serve to lower the ground temperature by evaporation. Then, too, if high shades are used, trucks may be driven under them and range cattle may be worked by a man on a horse.

A hog or a chicken, being of less height than a cow, will be closer to the cool shadow and farther away from the hot underside of the shade roof, and therefore will receive a smaller amount of radiant energy—per unit of body surface—under usual conditions of daytime radiation.

Effect of Walls on Shades

In a study at Davis on the effect of walls on the radiation heat load under a shade, observations were made on an 8′ × 12′ three-sided shade 6′ high, open on the north, with a 2″ plank wood floor, 1″ wood walls, and a double aluminum roof. Comparative observations were made on a typical 12′ × 16′ flat aluminum shade 7′ high.

At noon, when the air temperature was 100°F and the air velocity two miles per hour, the calculated heat load under the three-sided shade was 166 btu—British thermal units—per hour per square foot of animal surface, as compared to 172 btu under the shade without walls. This difference was mainly due to cutting off radiation from the hot ground and horizon on three sides and to a lower floor temperature. On the other hand, the walls cut off a large part of the cool open sky but not enough to counterbalance the ground-radiation benefits.

The three-sided shade in this study had the disadvantage of a roof lower than the shade without walls.

Trees for Shade

Trees are often thought to be the ideal shade, but their comparative values are difficult to measure with instruments because of their irregular shapes.

A limited number of observations at Davis indicate that the radiation intensity from trees may be somewhat less than from a flat aluminum shade. A large black walnut tree averaged 138 btu per hour per square foot; a smaller catalpa tree averaged 141 btu; and an aluminum shade, 170 btu. At that time the air temperature was 83°F, with a slight breeze.

One distinct advantage of trees is the fact that because of their thickness or mass of leaves, their shadow is always larger than the vertical projected area. Therefore, the trees give a larger low temperature ground area with a given exposure to cool sky than is possible with a thin shade.

Disadvantages of trees are that in many cases the shadow is not solid because of openings between leaves and that they do not fit into a practical farming practice where it is desired to rotate pastures frequently.

Three-sided shade 6′ high for observation of effect of walls on radiation heat load.

Improving Shades

Observations made in these studies indicate that the radiant-heat load on animals can be decreased by lowering the radiating temperature of any one of the five elements of the surround, or by changing their proportions so that the low radiating elements are increased.

Lowering the temperature of the ground in the immediate vicinity of the shade offers another opportunity to decrease the heat load. Midday observations at El Centro indicated that fescue pasture might be expected to average 85 btu per hour per square foot lower in radiation intensity than the hard ground in the corral. The heat load can be further reduced by covering a shade roof made of galvanized iron with an upper roof of hay, as was done in one test when the radiant energy of the shade roof was reduced from the 200 btu per hour per square foot to 168 btu. Adding the hay will increase the thickness of shade and enlarge the shadow slightly.

In another test, raising the shade 4′, locating it in a pasture, and changing the material of construction reduced the heat load 22 btu per hour per square foot of animal surface—from 186 to 164 btu. This amounts to 1,110 btu per hour for a 750 lb. animal having a surface area of 50 square feet exposed to radiation, or the equivalent of the hourly evaporation of about one pound of water from the lungs of the animal. Each of these changes—especially the green pasture—will also tend to lower the air temperature under the shade, thereby increasing the livestock's comfort and aiding in maintaining full feed intake.

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