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Sprinkler flow rate affects dairy cattle preferences, heat load, and insect deterrence behavior

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ABSTRACT

Sprinklers provide benefits for cattle, such as reducing heat load and possibly deterring insects. However, the use of this resource by cows varies across studies. Some of this variation may, in part, be explained by sprinkler flow rate. Higher flow rates provide greater heat abatement (desirable in warmer conditions, but perhaps not in milder weather) and generate greater spray impact, which cattle may avoid. Our objective was to evaluate the effects of flow rate on dairy cows' preferences for sprinklers and shade. We tested cows (n = 18) in a shaded arena (air temperature = 29 ± 3.8 °C, mean ± SD). To ensure they made informed choices and to measure insect deterrence behavior, we exposed cows to each treatment (flow rate = 0, 0.4, and 4.5 L/min, spray impact = 0, 1.1, and 8.9 kPa, respectively) ≥10 times in 12-min sessions. We then offered pairwise choices between 12-min treatments once daily for 8 consecutive d/pair. Cows preferred 0.4 L/min over shade alone [probability of choosing 0.4 L/min = 0.87; 95% confidence interval (CI) = 0.53–0.98]. Although cows did not prefer 4.5 L/min overall (probability of choosing 4.5 vs. 0 L/min = 0.62, CI = 0.27–0.87; vs. 0.4 L/min = 0.37, CI = 0.11–0.73), their likelihood of choosing it over shade alone tended to increase with respiration rate, body temperature, air temperature, and Temperature Humidity Index (odds ratios = 1.04, 3.57, 1.13, and 1.16, respectively). Relative to shade alone, both 0.4 and 4.5 L/min sprinklers provided the benefits of reducing insect deterrence behavior (tail flicks by 28 and 35%, respectively, and skin twitches by 32 and 48%), localized air temperature (by 0.6 and 1.1 °C, respectively, SE = 0.2 °C), and respiration rate (by 11 and 14 breaths/min, respectively, SE = 1.6 and 1.5 breaths/min). In addition, when cows chose 4.5 over 0.4 or 0 L/min, body temperature decreased by an additional 0.14 °C during treatment and stayed below starting values for 34 and 47 min longer afterward. Cows did not prefer 0.4 L/min over 4.5 L/min sprinklers, suggesting they do not avoid higher impact spray. Nonetheless, greater spray impact and heat loss may outweigh the benefits of 4.5 L/min in mild conditions, perhaps explaining why preference for this sprinkler flow rate over shade alone increased with heat load. As 0.4 L/min did not have these potential costs, this may explain why cows preferred the lower flow rate sprinkler to shade alone across all conditions tested.

1. Introduction

When dairy cows accumulate heat load, this results in production and welfare problems, including increased body temperature, decreased milk yield (Wheelock et al., 2010) and fertility (De Rensis and Scaramuzzi, 2003), and in extreme cases, mortality (Stull et al., 2008; Morignat et al., 2014). Compared to shade alone, water spray reduces body temperature, respiration rate, and localized air temperature (Kendall et al., 2007; Chen et al., 2013). Thus, this method of heat abatement is commonly used in U.S. dairies (62% of milking herds ≥500 head; USDA, 2010), and spray is often provided using sprinklers placed above the feed bunk that deliver sufficient water to wet through the hair coat to the skin. Spray cools the microclimate and dissipates heat from cows via evaporation when the water is turned off, similar to the mechanism of sweating. To allow for this evaporation, sprinklers for the entire pen of cattle are typically activated intermittently at preset intervals.

In most dairy housing systems (freestalls or drylots house three-quarters of U.S. cows; USDA, 2010) cows can choose whether or not to stand under spray. Thus, cattle behavior may moderate the heat abatement provided by sprinklers. In the literature, cattle responses to spray have been shown to vary considerably, ranging from voluntary usage (3.0 and 2.5 h/d, respectively, when water is on; Legrand et al., 2011; Chen et al., 2013) to anecdotal reports of avoidance

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(Marcillac-Embertson et al., 2009). A factor that may explain some of this variation across studies is sprinkler flow rate, which may influence cattle responses to spray through its effects on heat abatement, insect deterrence, and spray impact.

Higher flow rates (≥1.3 L/min) reduce respiration rate and body temperature more effectively than lower ones (0.4 L/min) when cows are restrained under spray (applied intermittently during 1 h; Chen et al., 2015). It is unknown whether the degree of heat abatement provided influences cattle use of spray, but weather does. When air temperature increases, cattle spend more time using spray (Legrand et al., 2011) and their preference for it over shade alone is more marked (Parola et al., 2012; Chen et al., 2013). Given that spray use increases with need for heat abatement, we predicted that in warm summer conditions, cows would prefer higher flow rates, which reduce heat load more effectively.

Besides heat abatement, spray may provide the additional benefit of deterring insects, which may explain why visits to a shower were often brief (41% of visits were <1 min long; Legrand et al., 2011). In response to flies, cattle typically display tail flicks, hoof stamps, skin twitches, or ear flicks (Dougherty et al., 1993), but when cows are under spray, they show fewer tail flicks and hoof stamps (Kendall et al., 2007; Schütz et al., 2011). If spray repels insects, we predicted behaviors associated with their deterrence would be reduced under spray, and that cows would prefer this resource, regardless of flow rate, compared to shade alone.

In contrast, Schütz et al. (2011) observed more skin twitches when cows were under spray, and speculated this was a reaction to droplets hitting the skin. Spray impact is proportional to flow rate, and for this reason, higher flow rates could perhaps be less attractive to cattle. Consistent with this idea, heifers anecdotally avoided 30 L/min sprinklers altogether (Marcillac-Embertson et al., 2009) and some cows rarely used a 7.3 L/min shower (i.e., <1 h/d; Legrand et al., 2011). Likewise, steers did not prefer feed bunks with 2.6 L/min sprinklers compared to those without spray except in warmer weather, but clearly preferred 1.3 L/min to shade alone across weather conditions (Parola et al., 2012). If cattle respond to spray impact, we predicted skin twitches would increase with higher flow rates, and cows would prefer lower flow rates overall.

Our objective was to evaluate the effects of sprinkler flow rate on preferences, insect deterrence behavior, and heat load in dairy cattle.

2. Materials and methods

2.1. Animals and housing

The study was conducted during the summer (June–September, 2012) at the University of California-Davis (UC Davis) dairy facility, with all procedures approved by the Institutional Animal Care and Use Committee. Eighteen lactating, pregnant Holstein-Friesian dairy cows were used, with average parity 1.8 ± 0.6, days in milk 213 ± 55, daily milk yield 42 ± 5.5 kg, and body weight 700 ± 80 kg (mean ± SD).

Cows were tested in two consecutive cohorts of nine cows each. Each cohort was kept in a concrete-floored home pen with three water troughs (automatically refilled to 378 L) and 16 shaded, sand-bedded freestalls with three fans (36-DMCH; Future Products Corp., Mosinee, WI, USA). The shaded feed bunk was fitted with six soaker nozzles (TF-VP7.5 Turbo FloodJet wide angle flat spray tip, 4.9 L/min; Spraying Systems Co., Wheaton, IL, USA) that delivered 3 min of continuous spray, followed by 10 min off. The bunk was replenished twice daily during milking at 07:00 and 18:00 h with total mixed ration formulated to National Research Council (1989) requirements using the PC Dairy system (Bath and Strasser, 1990).

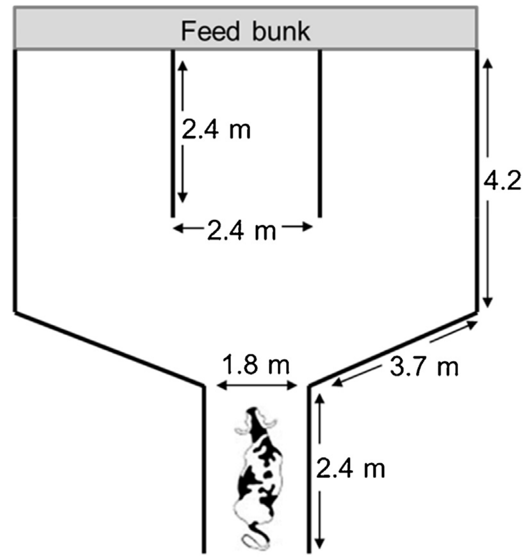

Fig. 1. Dairy cow (n = 18) preferences for heat abatement resources were tested in a shaded arena (diagram not to scale) with three treatment locations abutting a feed bunk, which were separated with solid barriers to minimize spray drift. During preference testing, cows began in the starting lane (as depicted) behind a chain, then chose between two locations; access to the third location was blocked using portable livestock fencing (not shown).

Between 07:00 and 18:00 h daily, the home pen was divided into thirds with portable livestock fencing (Powder River, Provo, UT, USA) to separate the three groups (three cows each) within each cohort assigned to a different testing hour (10:00, 12:00, and 14:00 h). Each group had one water trough and two sprinkler nozzles, which were turned off 3 h before and 3 h after each group's daily testing hour (i.e., 07:00–14:00 h, 09:00–16:00 h, and 11:00–18:00 h). This ensured that observed responses were due to the treatments, because sprinklers can lower body temperature for at least 2 h after a 1-h treatment (Chen et al., 2015). At night (18:00–07:00 h), each cohort of nine cows was allowed to intermingle, and had access to an additional 808 -L water trough near the testing arena.

2.2. Treatments

Treatments were administered to individual cows in an area separated from the home pen, shaded by a portable structure (9.8 × 6.1 m × 3.4-m-high) with a waterproof polyethylene cover that blocked 88.4 ± 1.2% (mean ± SD) of solar radiation (**SR**). Portable livestock fencing was used to construct three treatment locations (left, center, right), separated from a starting lane by a chain (Fig. 1), and abutting an unshaded concrete feed bunk, 35 m from the home pen feed bunk. The treatments were separated with 2.4-m-wide × 2.4-m-tall plywood partitions to prevent spray drift from the nozzles, which were controlled manually with a ball valve, mounted on a water line 1.9-m-high, and angled such that the spray wetted the entire floor of each treatment.

There were three treatments: a shade-only control in which no water was applied (0 L/min), and two sprayed options. The sprayed treatments were delivered by soaker nozzles (TK-FloodJet wide angle flat spray tips; Spraying Systems Co., Wheaton, IL, USA) differing in flow rate: 0.4 L/min [model TK-0.75, 138 kPa (20 psi, 1.4 kg/cm^2) operating water pressure, 370 μm average droplet size], and 4.5 L/min [model TK-12, 69 kPa (10 psi, 0.7 kg/cm^2) operating water pressure, 975 μm average droplet size]. We selected these two from the six nozzles evaluated in a previous study (Chen et al., 2015), to maximize the chance cows could discriminate between the options based on theoretical total spray impact (F_i),