Development of a novel walk-through fly trap for the control of horn flies and other pests on pastured dairy cows

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ABSTRACT

A prototype walk-through fly vacuum system, designed to remove horn flies *Haematobia irritans* (L.) (Diptera: Muscidae) from cattle, was developed and tested for efficacy. The study was conducted during 4 fly seasons over 17 consecutive weeks each year within the months of May through September at 1 dairy research herd in the coastal plain of North Carolina. Additional data on horn flies, as well as face flies (*Musca autumnalis*) and stable flies (*Stomoxys calcitrans*), were collected during 1 yr from 7 commercial pasture-based and organic dairy farms in the piedmont region of North Carolina. The number of flies observed on animals in the pasture was compared with the number of flies collected in the trap. Studies were initiated after horn fly densities had met or exceeded a threshold of 200 flies per animal. The vacuum trap removed between 1.3 and 2.5 million flies annually from the research station cattle. Most fly removal occurred during the first few weeks of operation and maintained densities below threshold thereafter. Cattle using the fly trap at the research farm had only about 28% the number of horn flies as untreated cattle, and reductions ranged from 67.5 to 74.5% across the 4-yr study. In addition to large numbers of horn flies, traps placed on commercial dairies during 1 yr collected stable flies, face flies, and house flies, all species with differing behavior and larger in size than horn flies. The estimated cost of running the trap is \$72 per season at commercial rates of \$0.12 per hour and an expected 4 h of daily operation during the time of milking. Use of a vacuum system as described herein has potential as a cost-effective method in reducing populations of parasitic flies in pasture-based dairy production systems without the use of insecticides.

Key words: Muscidae, *Haematobia irritans*, face fly, stable fly, organic dairy

INTRODUCTION

Biting and nuisance flies adversely affect animal health and reduce farm profitability (Kunz et al., 1991; Jones, 2002; Taylor et al., 2012). Three species represent the primary pests of pastured cattle in North America: the horn fly (*Haematobia irritans* L.), face fly (*Musca autumnalis*, De Geer), and stable fly (*Stomoxys calcitrans* L.; Figure 1). Arthropod pest damages to dairy and beef cattle in the United States have been estimated to exceed \$2.26 billion in losses annually (Byford et al., 1992).

The horn fly is a small, obligate, blood-sucking parasite of cattle and is considered the most common pest of pastured cattle in the United States (Drummond, 1987). Horn flies are most active in the spring and summer and overwinter as pupae beneath dung pats to emerge from diapause in the next spring (Lysyk and Moon, 1994; Lysyk, 1999). The reproductive potential of the horn fly is remarkable, and in untreated herds season-long horn fly numbers average about 400 to 700 flies per animal per day. On occasion, as many as 10,000 flies per animal have been observed (Watson et al., 2002; Bruce, 1964). Predilection sites for the horn fly are primarily the back, sides, and belly of cattle (Kuramochi, 2000). Adult horn flies are relatively weak flyers and tend to remain with their host animals, even as animals change pastures or come in to be milked (Bruce, 1964). Horn flies have been incriminated in the transmission of bovine mastitis (Nickerson et al., 1995; Gillespie et al., 1999; Edwards et al., 2000; Oliver et al., 2005). In North Carolina, horn flies were documented to host the same genotypes of the mastitis-causing bacterium, *Staphylococcus aureus*, in local dairy herds (Anderson et al., 2012).

Face flies are pests of pastured cattle from southern Canada to most of the United States, exclusive of the Deep South (Krafsur and Moon, 1997). Adult face flies are active from spring to autumn and overwinter in attics and out buildings (Krafsur et al., 1985). Adult face flies feed on lacrimal secretions of the eyes, mucosa of nose, and other bodily secretions of cattle (Glass et al., 1982; Krafsur and Moon, 1997). Fly annoyance causes

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Figure 1. Fly pests commonly associated with pastured cattle include horn flies feeding on the back sides and belly, stable flies feeding on the lower legs of a calf, and face flies feeding on the eyes and muzzle. Color version available in the online PDF.

cattle to elicit several defensive behaviors to avoid fly feeding, including head toss, bunching, and seeking refuge, resulting in altered grazing habits and poor pasture utilization (Hart, 1994). Fly feeding on the conjunctiva of the eye is the primary means of transmitting the bacterium *Moraxella bovis*, the causative agent of infectious bovine keratoconjunctivitis, or pinkeye (Glass and Gerhardt, 1984). Losses to the cattle industry related to face fly-induced infectious bovine keratoconjunctivitis were estimated at >\$53 million annually (Byford et al., 1992).

As with the horn fly, the stable fly is an obligate blood feeder. Feeding on the lower body and legs of the host, stable flies take 2 to 3 blood meals per day. Bovine

responses to stable fly feeding range from behaviors that denote pain and irritation, such as bunching, head throwing, and foot stamping (Wieman et al., 1992), to physiological changes, including increased body temperatures, increased urinary nitrogen output, and elevated cortisol levels (Schwinghammer et al., 1986). Stable fly pressure on cattle has increased in pastures with the use of round bale feeders when wasted hay mixes with manure and urine, creating an ideal larval development site (Broce et al., 2005; Talley et al., 2009). Face flies and stable flies are difficult to control because they are only on the host for a relatively brief amount of time (Krafsur and Moon, 1997; Taylor et al., 2010; Pitzer et al., 2011).

Producers view pasture flies as a group of insects that are difficult to control and as a cause of economic losses (Harrington et al., 1998). Pasture fly management traditionally relies on insecticides formulated as dusts, sprays, pour-on, feed additives, and insecticide-impregnated ear tags (Butler and Okine, 1999). Unfortunately, adequate control is relatively rare because of the over-reliance on insecticides of the same or similar mode of action that has led to widespread resistance among horn flies and less so for stable flies (Hogsette et al., 1991; Foil and Hogsette, 1994; Foil et al., 2010; Pitzer et al., 2010).

Noninsecticidal options for the control of pasture flies, including biological control and competition for resources, have been met with limited success (Roth et al., 1983). Fly trapping is useful for monitoring pasture fly densities and, in some cases, management of resistant populations (Bruce, 1938; Broce, 1988; Meyer et al., 1991). The first walk-through pasture fly trap consisted of a covered structure designed to brush flies from the animals as they passed through, with the fleeing flies are captured in the screened hollow walls (Bruce, 1938). Similar fly trap designs were developed and continue to be used by organic producers with mixed results, stemming from altered fly behaviors (Hall and Doisy, 1989). Moreland et al. (1995) patented a modified Bruce fly trap by adding a rigid canopy and black-lighted electrified grids on the ceiling and side-walls electrocuted the disturbed flies brushed from the surface of the animal as it passed through. Although the electrified trap significantly reduced horn fly densities initially, upkeep and the suspected development of behavioral resistance limited its adoption (Surgeoner et al., 1998; Watson et al., 2002). Targeting the horn fly as our primary pest of pasture-based dairy production, we recognized 3 key elements in developing a trap-based horn fly management system: (1) horn flies remain with the cattle when they are brought up for milking, (2) horn flies are easily disturbed from the animals when they pass through a curtain, and (3) horn flies are small and weak flyers. These factors led to the development of a vacuum-trapping system for the management of pasture flies. Our objective was to document the efficacy of a prototype vacuum system in reducing populations of parasitic flies on dairy cattle.

MATERIALS AND METHODS

A prototype walk-through fly vacuum system was developed and tested at a research dairy at the North Carolina Department of Agriculture, Center for Environmental Farming Systems (CEFS), located in Goldsboro, NC. Beginning in 2007, the study was conducted for 4 fly seasons during 17-wk periods within the months

of May through September of each year. The trap was positioned in an alleyway at the exit of an open-sided milking parlor at the research dairy (Figure 2). Cows passed through the unit in single file, twice daily, as they returned to pasture. Mounted on top of alleyway rails, the trap contained a vacuum motor within a box housing that was divided inside by a filter screen, which kept flies, hair, and debris out of the motor (Figure 2A). Curtains were attached to an upper vacuum inlet that was housed in a flexible duct that hung over and brushed along the top of the cattle's backs (Figure 2B). Fiberglass screening was attached to alleyway rails to help prevent fly escape (Figure 2C). Flies resting on the bellies, udders, and flanks were dislodged with an exhausted air pressure port that was positioned at 49 cm above the ground (Figure 2E). The dislodged flies were sucked into the lower vacuum inlet port that was positioned directly opposite the pressure port (Figure 2D). After each milking event ended, the device was switched off, which allowed a flap, held closed by vacuum pressure, to open (Figure 2F). Captured flies, attracted to the light, move from the dark housing of the trap into a translucent, screened-in, collection chamber. Flies remained in the collection chamber until death. Dead flies accumulated in a container that was affixed to the bottom of the collection chamber (Figure 2G).

The collected flies were removed from the container weekly and air dried. After drying, the collection was weighed and mixed thoroughly. A sample of 0.5 to 1.0 g was taken, weighed, separated by fly species, and the insects were counted to determine the total weekly collection of each target species. The total numbers of flies captured per week were calculated by extrapolation from samples as sorted by species.

Weekly horn fly densities for the treatment group were assessed by estimating the total number of horn flies on 10 randomly selected animals in the herd (Watson et al., 2002). Horn fly densities were determined by a trained observer estimating the number of horn flies on the entire animal at a distance of about 2 to 4 m. Horn fly densities were also determined on a second group of 8 to 10 cull cows, kept on the same farm but not allowed to pass through the device, as the untreated control animals. Traps were started when mean horn fly densities on cattle reached about 200 flies or more (Hogsette et al., 1991). Horn fly trapping continued for 17 wk each year in 2007, 2008, 2009, and 2011. Data from 2010 were not used in the current study because a different vacuum trap was being tested during that year.

To gather data on trap efficacy for stable flies and face flies, traps were also placed on 4 pasture-based commercial dairy farms with significant populations of stable flies and face flies in addition to horn flies. For

Figure 2. Vacuum fly trap mounted to an exit chute at the Center for Environmental Farming Systems (Goldsboro, NC). Components include (A) vacuum box housing, (B) upper vacuum inlet, (C) fiberglass screening, (D) exhausted air pressure port, (E) lower vacuum inlet port, (F) fly collection chamber, and (G) dead fly container. Color version available in the online PDF.

the commercial dairy farms, control cows on the same farms were not available, but 3 commercial dairies not using the fly trap were added as controls for a total of 7 test farms. Horn fly densities were estimated as described previously. Face flies were counted on 10 animals randomly selected from each commercial herd per week. Flies resting on the muzzle, eyes, forehead, and cheeks of the animal were counted from a distance of 2 to 4 m (Ode and Matthyse, 1964). Similarly, stable flies were counted on the forelegs of 10 animals (Lysyk, 1993). Collected flies from the 4 trap farms were removed weekly, dried, and quantified to species as described previously. Stable flies and face flies were not monitored on the CEFS farm in eastern North Carolina because of typically low populations of those species in that herd.

Percent reduction was calculated using Abbott's formula (Abbott, 1925). Comparisons between treatment groups were analyzed using one-way ANOVA (SAS, 2013). The linear relationship between weekly fly counts on animals was regressed against trap catches using simple regression. The current study was conducted under the Institutional Animal Care and Use

Committee protocol 10-154-A, following recommendations outlined in Guidelines for the Care and Use of Agricultural Animals in Research and Teaching.

RESULTS AND DISCUSSION

The fly vacuum was started on June 1, 2007, and within 1 wk of operation the device had removed 410,000 horn flies from the cattle. During the second week, an additional 457,000 horn flies were trapped (Figure 3). Mean horn fly densities were reduced from 775 to 263 per cow the first week, and by the third week of trap operation fly densities were reduced to 150 flies per cow. The number of flies trapped by the third week had dropped to 216,000, and a 70% reduction in horn fly densities was observed compared with the control. By September 2007, over 2.4 million flies had been removed from 136 cows (Table 1). In 2007, the mean number of horn flies 107.1 ± 22.2 and 387.8 ± 47.6 ($F_{1,32} = 28.5$, $P = 0.0001$) on treated and control cows, respectively. In 2008, 1.97 million horn flies were removed from the herd, resulting in a seasonal mean fly density of 105.1 ± 15.2 per animal for those using the trap, whereas the

Figure 3. Total number of horn flies trapped (columns) and the mean number of horn flies per animal for treated and untreated cows at the Center for Environmental Farming Systems (Goldsboro, NC). Trap was started on d 0. A different vacuum trap was tested in 2010 and those data were not included.

untreated cattle had a density of 411.2 ± 53.9 flies per animal ($F_{1,30} = 29.8$, $P = 0.0001$). The trap removed 2.57 million horn flies in 2009, which resulted in mean horn fly densities per animal of 178.5 ± 25.7 on treated cattle and 669.3 ± 89.8 for the control group through August ($F_{1,30} = 27.6$, $P = 0.0001$). For 2011, the trap collected 1.31 million horn flies, resulting in a season-long fly density of 101.7 ± 28.1 and 309.5 ± 73.6 for the treated and untreated control cattle, respectively ($F_{1,30} = 7.3$, $P = 0.011$).

In 2007 and 2008, the weekly percentage reduction in horn flies corrected for the control was above 80% for 7 and 6 wk, respectively, whereas the season reduction in horn flies was 72 and 75% (Figure 4; Table 1).

Similarly, in 2009 and 2011, the season-long percentage reductions were 73 and 68%, with 6 and 5 wk above 80% reduction for both seasons (Figure 4, Table 1).

The CEFS dairy is a seasonal calving operation with calving beginning in October. Proportionally more of the herd was dried off in August for fall calving and fewer cattle were being milked; therefore, fewer cattle used the trap. End of season horn fly numbers trended upward, both in trap catch and on the cattle during the dry-off period (Figure 3). By wk 17 in 2007, only 42% of the cattle used the trap because dry cows were not being brought up to the parlor, and the decision was made to conclude the study for each season. To reduce horn fly densities on the dry cows and late season

Table 1. Total number of horn flies trapped and season mean (SE) horn fly numbers per animal for treated and untreated cattle for years 2007, 2008, 2009, and 2011 at a research site in the North Carolina coastal plain¹

Year	Total horn flies trapped (no.)	Treated cattle (season mean number; horn flies/animal)	Untreated cattle (season mean number; horn flies/animal)	Season horn fly reduction (%)
2007	2,402,100	107 (21.7)	388 (61.1)	72.4
2008	1,969,600	105 (21.6)	411 (70.2)	74.5
2009	2,579,700	178 (27.0)	688 (116.3)	74.1
2011	1,312,400	102 (44.0)	314 (71.0)	67.5

¹Data for 2010 are not presented because a different trap was evaluated that year.

Figure 4. Weekly reduction in the number of horn flies on cattle using the vacuum fly trap over 4 yr at the Center for Environmental Farming Systems (Goldsboro, NC). Percentage reduction was calculated using Abbott's formula, where percentage total = $100 \times [1 - (\text{treatment mean})/(\text{control mean})]$.

horn fly populations on the farm, dry cows were walked through the trap once daily, 5 times per week, during seasons 2008 through 2011.

The economic threshold level of 200 flies per animal has been the accepted standard for over 20 yr (Schreiber et al., 1987; Hogsette et al., 1991). We allowed fly populations to develop unimpeded before activating the fly trap to demonstrate that we could reduce horn fly densities to an acceptable level. Trapping studies performed in areas densely populated with cattle can be confounded because of the potential for horn flies to disperse substantial distances when necessary (Kinzer and Reeves, 1974). In our study, other sources of horn flies were obvious. The control cattle were located on the farm and within sight of the treatment group. The dry cows carried horn flies and the adjacent pasture-based beef cattle facility also included about 200 head of beef cows and young stock that were also carrying horn flies.

Regardless of these outside pressures, it was clear that on-animal fly numbers were declining in the treatment herd and somewhat in the control group (Figure 3). To examine this trend, we used linear regression

to compare the weekly mean number of flies on the animals to the number of flies collected in the trap. The weekly mean number of flies on the control cattle was positively correlated ($F_{1,63} = 16.6$, $P = 0.0001$) to the number of flies captured in the trap ($R^2 = 0.208$; trap catch = $54,216.319 + 137.591 \times \text{mean number of flies}$). Similarly, the weekly mean number of flies on the treated cattle was positively correlated ($F_{1,63} = 41.11$, $P < 0.0001$) to the number of flies captured in the trap ($R^2 = 0.394$; trap catch = $45,178.177 + 577.524 \times \text{mean number of flies}$). These data suggest that the depletion effect of removing horn flies from the environment decreased the number of flies on the treated cattle at a greater extent than the control herd. Presumably, fewer flies were reproducing and laying eggs in the dung pats, leading to an overall decline in the number of replacement flies over time. The observed decrease in horn flies on the cattle and the decline in number of flies trapped indicated a need for confirmation studies.

Traps placed on 4 commercial dairies collected stable flies, face flies, and house flies in addition to horn flies (Table 2). The fly community composition on these farms was dissimilar; for example, treatment farm D had few horn flies but an abundance of stable flies. Collectively, horn flies were the most abundant pest on the treatment farms, and trapping removed about 1.1 million flies. The vacuum trap also collected 100,675 stable flies, 66,057 face flies, and 62,198 house flies. Season-long (17-wk) horn fly densities were below the horn fly threshold for all farms except control E, with 289 flies per animal on average. Stable fly densities were greatest on treatment farm D. No farm exceeded the threshold of 10 stable flies per leg. Face fly densities exceeded the 10 flies per face threshold on treatment farms B and C, but not on other farms. Collectively, the number of flies removed from the animals reflected the composition and relative densities of the fly community.

Although face flies are a problem in parts of North Carolina, they are rarely seen at CEFS, where this primary study was conducted, and were not found in the trap samples. House flies and stable flies were not monitored in the environment and were only a small percentage of captured flies at CEFS.

The national average price for electricity (residential customers) is \$0.1215 per kilowatt-hour, with commercial and industrial rates at \$0.1034 and \$0.0686, respectively (EIA, 2013). Using the commercial rate to calculate the cost to operate the trap, the fly trap motor draws $1.15 \text{ kW} \times \$0.1034 \text{ per kilowatt hour} = \$0.12/\text{h}$. Based on the CEFS twice daily milking procedures, the trap is running approximately 4 h/d. At $\$0.12/\text{h} \times 4 \text{ h/d} \times 30 \text{ d} \times 5 \text{ mo}$, we estimate the cost of running

Table 2. Seasonal means (SE) for each of 4 fly species observed on cattle and the total number of each captured using the vacuum fly trap in 2012 on commercial pasture-based dairy farms in the piedmont region of North Carolina

Farm	Horn flies		Stable flies		Face flies		House flies	
	Mean	Trapped	Mean	Trapped	Mean	Trapped	Mean	Trapped
Treated A	52.5 (15.0)	445,500	2.4 (1.0)	12,600	6.8 (1.6)	2,400	*	16,500
Treated B	36.7 (13.3)	253,000	2.1 (0.7)	37,200	11.9 (1.9)	21,400	*	15,160
Treated C	50.8 (14.7)	383,100	1.1 (0.6)	17,700	11.7 (2.5)	38,800	*	11,200
Treated D	7.7 (3.2)	30,531	9.2 (1.9)	33,175	2.3 (0.7)	3,457	*	19,338
Control E	289.3 (44.6)	NA ¹	0.7 (0.3)	NA	1.2 (0.5)	NA	*	NA
Control F	78.4 (21.9)	NA	1.7 (0.6)	NA	2.3 (0.6)	NA	*	NA
Control G	94.8 (25.0)	NA	3.8 (0.9)	NA	3.7 (1.4)	NA	*	NA

¹NA = not applicable, no fly traps were placed on the control farms.
*House flies were not monitored on animals or on the premises but were captured in the trap.

the trap is \$72 per season at commercial rates. Energy rates vary significantly among states and any estimate of cost should reflect regional and state differences.

The CEFS dairy farm, because of its southern geographic location and its close proximity to a beef cattle herd with traditionally high horn fly densities, at times exceeding 1,000 per animal, has heavy horn fly pressure every year, making it difficult to maintain horn fly densities under threshold limits throughout the season. With routine use of a vacuum fly trap by all lactating cattle on the farm, a reduction of horn fly densities to below threshold has been achieved as of 2007 without the use of insecticides. Presumably, with few or no other cattle in close proximity, cattle routinely using the trap would have horn fly densities reduced to very low levels, thereby reducing the prevalence of horn fly-mediated mastitis (Anderson et al., 2012). In the absence of fly pressure, producers could see a potential increase in milk yields, up to 2.6 mL/d per fly removed (Jonsson and Mayer, 1999). To date, no suggestion of behavioral resistance has been observed with this trap over the course of the study.

CONCLUSIONS

Twice daily use of a vacuum-powered, walk-through fly trap kept horn fly populations below a threshold of 200 flies per animal without the use of insecticides. Although other pest flies, including the stable fly, face fly, and house fly, were captured in the trap, the effect was most significant on the horn fly. The number of flies removed from the cattle represented the on-animal and on-farm population. Other factors influencing the trap efficacy was the frequency of use, the amount of time the fly spends on the host, and the potential for immigrating flies to colonize the herd from adjacent farms. The vacuum fly trap is a viable alternative for the management of horn fly, especially where insecticide-resistant populations occur or on dairies operating under organic standards.

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