Evaluation of a commercial vacuum fly trap for controlling flies on organic dairy farms

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ABSTRACT

The objective of this study was to evaluate the efficacy of a commercial vacuum fly trap (CowVac, Spalding Laboratories, Reno, NV) in on-farm organic dairy production systems to control horn flies, stable flies, and face flies. As cows walk through the trap, flies are brushed off the face, flank, and back with hanging flaps and blown off the belly, udder, and legs from one side, and then vacuumed from the air into a chamber from vacuum inlets opposite the blower and above the cow. The study included 8 organic dairy farms during the summer of 2015 in Minnesota, and herds ranged from 30 to 350 cows in size. The farms were divided into pairs by location; during the first period of the summer (June to July), the trap was set up on 1 farm, whereas during the second period of the summer (August to September) the trap was sent to its paired farm. Farms were visited once per week to collect and count flies from the trap as well as count and record flies on cows. Bulk tank milk, fat, and protein production and somatic cell count were collected on farms during the entire study period. Data were analyzed using the GLM procedure of SAS (version 9.3, SAS Institute Inc., Cary, NC). Independent variables for analyses were the fixed effects of farm, trap presence, housing scenario, and summer period. Horn fly numbers on cows were lower by 44% on farm in the presence of a trap (11.4 vs. 20.5 flies/cow-side) compared with the absence of a trap. Stable fly (5.4 vs. 7.1 flies/leg) and face fly (1.0 vs. 1.0 flies/cow) numbers were similar on farm whether the trap was present or absent on farms, respectively. Milk production was similar for farms with the trap (15.5 kg/d) compared to without (15.3 kg/d) the trap. Bulk tank milk, milk components, and somatic cell count were statistically similar in the presence and absence of the trap, so potential benefits of the trap for those measures were not evident at low fly populations observed

during the study. The presence of a trap on farm reduced horn fly population growth rates (−1.01 vs. 1.00 flies/d) compared with the absence of a trap. Cows on farms with no housing (100% pasture) tended to have reduced horn fly numbers (11.7 vs. 28.3 flies/cow-side) in the presence of a trap compared with the absence of a trap on farm. Cows on farms with housing had similar horn fly numbers (11.2 vs. 14.8 flies/cow-side) in the presence of a trap compared with the absence of a trap on farm. In summary, these results indicate the trap was effective in reducing horn fly numbers on cows and reduced horn fly growth rates during the pasture season in organic dairy production systems, but benefits in improved milk production were not evident likely because of relatively low fly populations.

Key words: organic dairy, CowVac, horn fly, stable fly

INTRODUCTION

The horn fly (*Haematobia irritans* L.) and the stable fly (*Stomoxys calcitrans* L.; Moon, 2002) are 2 biting and blood-feeding flies that attack organic grazing cattle in the upper Midwest. The horn fly develops exclusively in intact, fresh cattle manure in pastures and are pests of conventional and organically raised cattle. Unlike other kinds of flies that visit cattle for brief moments, adult horn flies reside on the host animals, making them especially vulnerable to control. Adequate horn fly control leads to increased milk production and calf growth (Jonsson and Mayer, 1999).

Stable flies are blood-feeding flies typically found on the legs of cattle, and were estimated to cause annual losses of \$360 to \$920 million to US dairy cattle between 2005 and 2009 (Taylor et al., 2012). Stable flies develop as maggots in a wide array of decomposing OM, including soiled animal bedding and soiled feed debris that accumulates wherever cattle are confined (Moon, 2002). Populations of stable flies build exponentially by continuous reproduction from spring to fall in northern temperate climates (Beresford and Sutcliffe, 2010; Taylor et al., 2012). Dairy farm surveys indicate that calf hutch bedding is a prominent source of stable

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flies around dairies (Schmidtman, 1988), and choice of bedding material can minimize stable fly production (Schmidtman, 1991). Recently, feed debris and manure accumulated during winter feeding have been documented as favorable for development of stable flies, especially where debris piles remain intact into the following summer (Talley et al., 2009; Taylor and Berkebile, 2011).

The face fly (*Musca autumnalis* DeGeer) is a nonbiting fly that feeds on liquid secretions, typically around the eyes and muzzle of cattle. These flies cause irritation and they may be vectors for parasites and pathogens of the eye.

Observing that horn flies remained with the host, Bruce (1938) built a walk-through fly trap with 1-way fly-screen baffles on its otherwise translucent sides to remove and capture flies as the cattle passed through. That simple design is now known as the Bruce walk-through fly trap, and different versions (some using a passive trap and others with electric modification) have been studied for horn fly control in Missouri (Hall and Doisy, 1989), Florida (Tozer and Sutherst, 1996), North Carolina (Watson et al., 2002), and Ontario, Canada (Surgeoner et al., 1998). Those studies showed that walk-through traps can reduce horn fly burdens by 50 to 90%. Most recently, North Carolina State University replaced the side baffles with a system that included a blower and a vacuum (Denning et al., 2014). Bruce traps and the newer vacuum traps are compatible with organic dairying and conventional dairy grazing, because a trap can be positioned at the entrance to or exit from a milking parlor, where cows come and go twice or 3 times per day.

Organic dairy farmers rely on botanical repellents and sticky tapes to alleviate fly problems, but success of these products is limited (Sorge et al., 2015). Because horn flies spread easily among adjacent pastures, efficacy for a whole herd is modeled as the difference between the rate at which traps can remove and kill flies on cattle and the rate at which they are produced naturally in pastures. Our hypothesis was that summer growth of horn fly populations from June to August would be lowest on commercial organic dairies where a commercial vacuum fly trap (CowVac, Spalding Laboratories, Reno, NV) was used and greatest where no trap was used. Therefore, the objective of our study was to determine removal rates of a commercial walk-through fly trap, measure natural fly reproduction rates in organic dairy pastures, and then evaluate herd-level control using the trap. Furthermore, an objective was to determine the effects of production (milk, fat, protein, SCC) on farms when the trap was present or absent.

MATERIALS AND METHODS

Experimental Design and Collection of Data

This study was conducted at the University of Minnesota West Central Research and Outreach Center organic dairy (Morris, MN) and 7 other organic dairy farms in Minnesota during the summer of 2015. The study period was from June 4 to September 30, 2015. All animal procedures involving animal care, management, and the client consent forms were approved by the University of Minnesota Institutional Animal Care and Use Committee (#1508-32966A).

The organic dairy farms included in our study spanned from southeast, to central, to northwestern Minnesota, and ranged in herd size from 30 to 350 cows. The West Central Research and Outreach Center organic dairy herd had 130 milking cows. All herds had cows that were of numerous breeds of cattle and consisted of pure Holstein, pure Jersey, and crossbreds of Holstein and Jersey and European dairy breeds. The 8 herds averaged in milk production from 7 to 23 kg/cow per day. Six herds milked cows in a milking parlor twice daily; however, 2 herds had a Lely Robotic Milking system (Lely, Maassluis, the Netherlands). For all herds and cows, at least 30% of their diet consisted of high-quality organic pasture during the grazing season, which is in accordance with USDA-NOP organic regulations (USDA-NOP, 2016).

Weather data were collected for 3 weather stations in Minnesota (Fosston, Morris, and Rochester) from Weather Underground (<https://www.wunderground.com/>). Mean temperature and total precipitation for the 3 weather stations for the months of the grazing season during 2015 were 17.8°C and 7.3 cm, 20.0°C, 32.0 cm, and 20.0°C, 32.2 cm for Fosston, Morris, and Rochester, respectively. The mean temperatures for the study were similar for the 30-yr average (1985–2015) of 18.7°C. Rainfall totals were similar to the 30-yr average in Morris, but 10 cm lower in Rochester and 25.3 for Fosston compared with the 30-yr average.

Four traps were acquired during the spring of 2015 from Spalding Laboratories (Reno, NV) for use in the experiment. The trap is a novel way to control pasture flies on dairy cows. It can be placed at the entry or exit of the milking parlor or barn. Figure 1 shows the trap positioned at the entrance to the milk parlor holding area in the cattle walkway at the University of Minnesota West Central Research and Outreach Center organic dairy. The trap has 1 vacuum and 1 blower opening, and the flies are brushed off the face, flank, and back with hanging flaps in the chute and blown off the belly, udder, and legs from one side into

a chamber from 2 vacuum inlets, 1 opposite the blower and 1 above the cow. Once airborne, the flies are vacuumed from the air into a chamber from vacuum inlets opposite the blower and above the cow. From that chamber, the flies move toward a collection bag on one side (Denning et al., 2014). Six herds had the trap positioned at the entry into the milking parlor. One trap at a robotic herd was placed in the entry to the barn from the pasture so cows could move in both directions through the trap. The other robotic dairy had the trap placed into the Lely Grazeway gates to allow for one direction movement through the trap from pasture into the holding area of the robotic barn. Both traps set up on robotic dairies were running 24 h/d, 7 d/wk during the experimental period. Four farms had freestall barn access for cows and 4 farms did not have any facilities or shade for cows in the pasture (cows were on pasture for at least 22 h/d except for milking). Adjustments were made to the trap for proper height of cows at each specific farm to ensure proper airflow and capture of flies depending on the different breeds of cows at each farm. For the cows at each dairy, cows were accustomed to going through the trap from 2 to 5 d after training by university researchers.

The farms were divided into pairs by location in Minnesota; during the first period of the summer (June 4 to July 18) the trap was set up on 1 farm, whereas during the second period of the summer (July 20 to September 30) the trap was sent to its paired farm. The time between July 18 and 20 was the time the traps were moved to the other 4 farms. During moving, the traps were inspected for mechanical function and cleaned of any excess flies left in the system. The 2 treatments were operated in a crossover design among farms and months (June, July, August, and September), such that each farm received both treatments (trap or no trap) within the summer. Farms with the trap on their farm had the machine's filters cleaned weekly by removing them from the inside of the trap and lightly brushing them off to ensure all the fly debris and cow hair was removed. The inside of the trap was cleaned and cleared of any excess flies that did not make it to the collection chamber bag for removal. The machine and generators (2 farms used generators for power) were also checked to ensure they were in proper working order.

Farms were visited once per week to collect flies from the trap, as well as count and record horn flies, stable flies, and face flies on cows. Farms that did not have

Figure 1. Commercial walk-through fly trap (foreground) placed before entrance to the milk parlor holding area at the University of Minnesota West Central Research and Outreach organic dairy (Morris, MN). In the background is a Bruce fly trap (Bruce, 1938) used at the organic dairy. Color version available online.

traps were also visited to count and record fly numbers. Numbers of flies on cows in each herd were counted by trained observers once per week during the 2015 grazing season. Flies were counted on all the cows in the herd or, if more than 100 cows were in the herd, half of the herd's cows were counted for flies. Fly identification and counting methods were similar to those used by Denning et al. (2014). Observers distinguished horn flies from face flies and stable flies. Horn flies were counted individually or in groups of 10 on one side of each cow. Face flies were counted on the animals' faces viewed head on, from poll to jawline and muzzle. Stable flies were counted on the visible faces of front and rear legs separately. For stable flies, the front leg and back leg counts were added together for analysis; counts were made from a distance of 2 to 4 m (Watson, et al., 2002; Denning et al., 2014).

Furthermore, for farms that had the trap, the trap was emptied weekly to determine the number of flies captured. The flies collected from the chamber bags were separated by date and farm, and then individually counted to see what types of flies were being caught in the trap. Flies from individual bags were counted using a method that required the plastic bag of flies to be emptied into petri dishes. The petri dishes were equally filled by weight until the bag was empty; if the last dish was not filled in a similar way, the dish was labeled as a leftover dish. Two petri dishes, along with the leftover dish, if applicable, were chosen at random using a random number generator and were counted for individual fly numbers. The petri dishes were divided into piles of horn, stable, and face flies and other insects caught in the trap. The mean, standard error, and variance of the 2 petri dishes were calculated and evaluated to ensure another petri dish did not need to be counted. The variance in fly numbers between the 2 dishes needed to be below 0.10; if this did not occur, another petri dish was counted. After the correct variance was found, the mean of the petri dish was multiplied by the total number of dishes filled from the bag of flies from each farm. The leftover dish was then added to that extrapolated number to get an estimated number of horn, stable, and face flies collected on farm for each specific week.

Additionally, bulk tank production records (milk, fat percentage, protein percentage, and SCC) along with weekly cow numbers on farm were collected from each of the 8 organic dairy farms. Daily milk production was calculated as total bulk tank production divided by the average number of cows on farm.

Statistical Analyses

For analysis of farm data, fly numbers and milk production were averaged for each period (with or without

trap) for each farm. We created one average value across cows for each farm for each period for analysis. Log-transformations of fly counts were used as needed to satisfy analytical assumptions of equal variance and normal distribution of errors. Fly population growth rate was the estimated slope of a regression line for the average fly counts for periods with and without the trap. Growth rate of horn, stable, and face fly populations were compared between the 2 periods.

Independent variables for statistical analysis of milk (kg/d), fat (kg/d), protein (kg/d), and horn, stable, and face fly numbers and population growth rates were effects of summer period (with or without trap) and farm. For statistical analysis of horn, stable, and face fly weekly counts from the collected traps (reported as flies/cow per day removed), the independent variable was period and farm for separate analysis.

Independent variables for the statistical analysis of comparing trap location during the season included milk and horn, stable, and face fly. The effects of season (traps on farms during the first or second half of the summer) and trap presence were analyzed as dependent variables.

Farms were also characterized as to whether they had barns for cattle to enter during the day for shade or for hot and humid weather or no housing facilities in a low-input production system, with cows on pasture at least 22 h/d during the grazing season. For this analysis, the independent effects in the statistical model included housing facility (housing versus no housing), trap (with or without trap on farm), and the interaction of housing facility and trap. For all statistical analysis listed above, the MIXED procedure (SAS Institute, 2016) was used for the output and used to conduct the ANOVA for the experiment. All treatment results were reported as least squares means, with significance declared at $P < 0.05$ and trends at $P < 0.10$.

RESULTS AND DISCUSSION

Production and Fly Numbers

For all results and following tables, horn flies are reported as the number of flies for one side of the cow, stable flies are reported as the number of flies per leg of a cow, and face flies are reported as the number of flies per cow. Least squares means and standard errors for milk, fat, protein production, SCC, and horn, stable, and face fly numbers for each of the 8 farms are in Table 1. The table is separated based on the period of the summer in which the trap was placed on the farm (first or second period).

Horn fly numbers were quite variable across the farms. A few farms had very low numbers of horn flies

Table 1. Least squares means and standard errors for daily milk production and fly numbers by farm for organic dairy cows across the entire 16 wk of the grazing season¹

Farm	Trap presence ²	Milk (kg/d)		Fat (kg/d)		Protein (kg/d)		SCC (cfu/mL)		Horn fly (flies/side)		Stable fly (flies/leg)		Face fly (flies/cow)	
		Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE	Mean	SE
A	First	22.7 ^a	2.9	1.7 ^a	0.2	1.5 ^a	0.1	568 ^a	27.6	14.1 ^{abcd}	1.2	1.1 ^a	1.6	0.4 ^{ab}	1.2
B	First	16.0 ^b	2.9	1.3 ^{ab}	0.2	1.1 ^{ab}	0.1	270 ^{cde}	27.6	9.2 ^{cd}	1.2	4.4 ^a	1.6	1.4 ^{ab}	1.2
C	First	11.3 ^c	2.9	0.9 ^{bc}	0.2	0.8 ^{bc}	0.1	385 ^b	27.6	17.8 ^{abc}	1.2	6.2 ^a	1.6	0.9 ^{ab}	1.2
D	First	6.7 ^d	2.9	0.6 ^c	0.2	0.4 ^c	0.1	246 ^{de}	27.6	24.1 ^{abc}	1.2	4.2 ^a	1.6	1.6 ^a	1.2
Average		14.2		1.1		0.9		367		16.3		4.0		1.1	
E	Second	20.1 ^{ab}	2.9	1.6 ^a	0.2	1.3 ^a	0.1	295 ^{bcd}	27.6	27.5 ^{ab}	1.2	7.1 ^a	1.6	1.4 ^{ab}	1.2
F	Second	18.8 ^{ab}	2.9	1.6 ^a	0.2	1.2 ^a	0.1	270 ^{cd}	27.6	10.3 ^{bcd}	1.2	1.6 ^a	1.6	0.7 ^{ab}	1.2
G	Second	16.3 ^b	2.9	1.7 ^a	0.2	1.4 ^a	0.1	176 ^e	27.6	6.1 ^d	1.2	2.9 ^a	1.6	0.3 ^b	1.2
H	Second	11.4 ^c	2.9	0.9 ^{bc}	0.2	0.8 ^{bc}	0.1	351 ^{bc}	27.6	29.5 ^a	1.2	3.5 ^a	1.6	1.4 ^{ab}	1.2
Average of farms		16.6		1.4		1.2		273		18.3		3.8		1.6	

^aMeans within a column for milk production and fly numbers without common superscripts are different at $P < 0.05$.¹Fly counts were analyzed on a log scale and transformed back to the arithmetic scale.²The presence of the trap (commercial walk-through fly trap) during the first 8 wk or second 8 wk of summer.

(6.1 to 9.2 flies/side) on cows, whereas some farms had higher numbers of horn flies (27.5 to 29.5 flies/side); however, no farm averaged more than 100 flies per cow. Stable and face fly numbers were also variable across the 8 farms, but they were not as prevalent on cows as horn flies. Denning et al. (2014) reported a wide range of values for horn flies on cows across 7 commercial dairy farms, which is in agreement with our study. Those authors found considerably more horn flies on cows than what was found in the current study. However, Denning et al. (2014) found fewer stable flies and similar face fly numbers per cow as the current study. Climate differences between North Carolina and Minnesota could contribute to varying numbers of the different fly species per cow; however, Lysyk (2000) reported mean numbers of horn flies per animal from 65 to 150 in grazing cattle in Alberta, Canada, which is also greater than the number reported in the current study.

Two hundred horn flies per animal has been the accepted economic threshold level for many years (Hogsette et al., 1991). The meta-analysis study of Jonsson and Mayer (1999) noted that horn fly populations below 30 flies per animal would likely have no detrimental effect on productivity of dairy cattle; however, they reported that moderate levels of horn flies (200 horn flies per cow) would result in lost milk production of 0.50 kg/d per cow. Recently, Mullens et al. (2017) reported that cattle exhibit fly defensive behaviors (head throws, leg stomps, tail flicks) at less than 100 horn flies per cow. Few studies have reported on the effects that horn flies have on milk production; however, Oyarzún et al. (2008) reported a 4 to 12% reduction in milk production, depending on the number of flies observed on cattle.

For stable flies, Campbell et al. (1987) observed reduced weight gains and decreased feed efficiency in beef cattle when stable fly populations were between 3 and 7 per leg, and concluded that the economic threshold for stable flies is less than 2 stable flies per leg. The current study reported 5 to 7 stable flies per leg, which may have created economic losses and visible irritation to dairy cows. However, Mullens et al. (2006) reported that at low to moderate stable fly pressures milk yield was not affected, but cattle exhibited fly defensive behaviors at these low stable fly numbers. Arends et al. (1982) did not find any difference in total weight gained for beef heifers, but reported that 12 to 17 face flies per animal was irritating to heifers.

For milk production, farms ranged from 6.7 to 22.7 kg/cow per day, and some farms were different ($P < 0.05$) from one another. The differences in milk production for herds was because of the management and nutritional program of the organic dairy. Some of the

herds fed a partial TMR during the summer grazing period that consisted of more grain, whereas some herds fed very little grain and thus had lower production. Fat and protein production and SCC followed milk production and were variable across the 8 herds.

Results for milk production and fly counts in the presence or absence of the trap across the summer season are in Table 2. Milk production (15.5 vs. 15.3 kg/d) and SCC (315 vs. 322) were similar ($P > 0.10$) for farms when the trap was present compared with when the trap was absent on farms, respectively. Horn fly numbers were reduced ($P < 0.05$) by 44% when the trap was on the farm versus when the trap was removed from the farm (11.4 vs. 20.5 flies/side). Stable fly (5.4 vs. 7.1 flies/leg) and face fly (1.0 vs. 1.0 flies/cow) counts were similar when the trap was present or absent. Reductions in horn fly numbers for the current study were less than those reported by Denning et al. (2014), who saw a 68 to 75% reduction in horn fly numbers across a 4-yr study; however, the number of horn flies observed in the North Carolina study were generally much higher than those observed in our study in Minnesota. The lower numbers of flies of various species observed in the current study likely were not sufficient to affect milk production in contrast to other studies. Horn fly numbers can vary greatly among cows on farm, with some cows hosting large numbers of flies whereas others attract very few flies (Steelman et al., 1993; Jensen et al., 2004). Numerous factors may influence horn fly attraction to a particular cow, including color (Ernst and Krafur, 1984; Schreiber and Campbell, 1986), breed (Steelman et al., 1991), time of day (Schreiber and Campbell, 1986; Kuramochi, 2000), and season of the year (Lysyk, 2000).

Table 3 has least squares means and standard errors for milk production and fly counts in the presence or absence of the trap for the first half and second half of summer for organic dairy cows. Milk production and horn fly and face fly numbers were similar for the first half of the study compared with the second half of the

study whether the trap was present or absent on farms. Stable fly numbers were not different for the first half compared with the second half of the study; however, stable fly numbers tended ($P = 0.08$) to be less during the second half of the study when the trap was present versus when the trap was absent.

Horn fly population growth rates mirrored that of the horn fly results and are found in Table 4. Although present on organic dairy farms, the trap reduced ($P < 0.05$) the growth rates of horn flies compared with when the trap was not on farms (−1.01 vs. 1.00). Horn flies observed on cows on farm (Table 2) indicated that the traps were removing horn flies faster than they could reproduce in pastures. Stable and face fly growth rates were not affected ($P > 0.10$) by the presence or absence of the trap on farm and mirror the results of the number of those specific fly species on cows.

Housing and Trap

Means and standard errors for daily fly counts and milk production across the summer season for organic housing systems and trap presence are in Table 5. For organic dairy farms without barns, the presence of a trap tended to ($P < 0.10$) reduce horn fly numbers on cows by 59% (28.3 to 11.7 flies/side) and tended to ($P < 0.10$) reduce face fly numbers on cows (1.7 to 1.0 flies/cow). Stable fly numbers were not affected by the presence or absence of the trap on farms without barns. Furthermore, milk production was not different for farms that had no housing system in the presence or absence of the trap. For organic dairy farms with barns, milk production, face fly, and stable fly numbers were similar when the trap was present or absent on farms. Explanations for the number of face flies on farm with the presence of a trap tending to be greater ($P < 0.10$) compared with the absence of the trap are unknown. Horn fly and face fly numbers were reduced on farms with no housing facilities with the use of the trap. Horn flies develop in undisturbed, fresh manure and nowhere

Table 2. Least squares means and SE ($n = 8$) for milk production and fly counts in the presence or absence of the commercial vacuum trap across the summer season for organic dairy cows

Item	Trap absent		Trap present	
	Mean	SE	Mean	SE
Milk (kg/d)	15.3 ^a	1.4	15.5 ^a	1.4
Fat (kg/d)	1.3 ^a	0.08	1.3 ^a	0.08
Protein (kg/d)	1.1 ^a	0.06	1.0 ^a	0.06
SCC (cfu/mL)	322 ^a	13.8	315 ^a	13.8
Horn fly (flies/side)	20.5 ^b	1.1	11.4 ^a	1.1
Stable fly (flies/leg)	7.1 ^a	7.0	5.4 ^a	7.0
Face fly (flies/face)	1.0 ^a	1.1	1.0 ^a	1.1

^{a,b}Means within a row without common superscripts are different at $P < 0.05$.

Table 3. Least squares means and SE for milk production and fly counts in the presence or absence of the commercial vacuum trap for the first and second half of summer for organic dairy cows

Variable ¹	Period	Trap absent (n = 16)		Trap present (n = 16)		P-value of difference ²
		Mean	SE	Mean	SE	
Milk	First half	13.0	2.8	15.4	2.8	0.55
	Second half	17.7	2.8	15.6	2.8	0.69
Horn fly	First half	19.1	1.4	12.5	1.4	0.40
	Second half	22.0	1.4	10.5	1.4	0.15
Stable fly	First half	5.3	1.2	9.0	1.2	0.43
	Second half	9.0	1.2	3.0	1.2	0.08
Face fly	First half	1.5	1.2	0.6	1.2	0.25
	Second half	0.6	1.2	1.0	1.2	0.22

¹Overall number of observations was 16 for trap absent or present. Comparisons for first half vs. second half are based on 8 observations each.

²P-value of difference within periods when trap was absent or present for the first half and second half of the study.

else, and, therefore, cows that come into housing facilities to consume a partial TMR or to find shade from the heat and humidity are defecating in the housing facilities where horn flies will not reproduce. Thus, our results indicate that cows who remain outside on pasture for most the day and evening would benefit from the presence of a trap on farm compared with farms that having housing facilities for grazing cows.

Weekly Fly Numbers Collected from Traps

For horn, stable, and face flies (flies/cow per day) collected from traps during the 8 wk that traps were on farm, farms that had traps during the first period of the summer did not differ ($P > 0.10$) for number of flies captured per cow per day compared with farms that had traps during the second period of the summer (61.4 ± 19.9 vs. 29.1 ± 23.0 , 34.9 ± 18.8 vs. 39.0 ± 21.7 , and 0.10 ± 0.64 vs. 1.4 ± 0.78 flies/cow per day for horn, stable, and face fly), respectively. The traps captured a greater ($P < 0.05$) number of horn flies (71.9 ± 14.4 vs. 15.1 ± 16.7 flies/cow per day) for farms that had

no housing compared with farms that did have housing, respectively. Stable fly (49.9 ± 16.4 vs. 18.9 ± 19.0 flies/cow per day) and face fly (1.06 ± 0.72 vs. 0.10 ± 0.83 flies/cow per day) capture rates from traps were not different ($P > 0.10$) for farms that had no housing versus farms that had housing. Numbers of flies captured were substantially less than those reported by Denning et al. (2014). Perhaps, low fly numbers were observed because of the cooler climate conditions and precipitation observed in Minnesota compared with North Carolina.

Sanitation should be the primary control option on any organic dairy farm for stable flies. Because synthetic pesticides are not allowed on organic dairies, proper sanitation is of the utmost importance. Manure and feed provide the ideal habitat for stable fly production; thus, manure and old feed should be removed daily, or at least twice a week, from calf pens, holding areas, feed areas, and milking areas. To ensure success on the organic dairy, producers need to properly identify key pests, understand their biology and habitat, monitor their populations, and then reduce the fly population through mechanical or biological management techniques. Ultimately, producers can try many tactics on their own farm.

CONCLUSIONS

We found that horn fly numbers on cows and horn fly population growth rates were reduced with the use of a trap on organic dairy farms in Minnesota. However, the trap did not reduce stable fly or face fly number on individual cows. Organic producers who do not have a shelter for their cows during the summer would benefit from a trap on farm. Benefits of improved milk produc-

Table 4. Regression coefficients for fly population growth rates during periods with presence or absence of the commercial vacuum trap across the summer season for organic dairy cows

Flies per day	Trap absent		Trap present	
	Mean	SE	Mean	SE
Horn fly	1.00 ^a	1.01	-1.02 ^b	1.01
Stable fly	-1.01 ^a	1.01	-1.02 ^a	1.01
Face fly	-1.00 ^a	1.01	1.01 ^a	1.01

^{a,b}Means within a row without common superscripts are different at $P < 0.05$.

Table 5. Least squares means and SE for daily fly counts and milk production across the summer season for organic housing systems and commercial vacuum trap presence for organic dairy cows

Trap and housing scenario ¹	Milk production (kg/d, n = 16)		Horn fly (flies/side, n = 16)		Stable fly (flies/leg, n = 16)		Face fly (flies/face, n = 16)	
	Mean	SE	Mean	SE	Mean	SE	Mean	SE
No housing								
With trap	14.3	2.7	11.7	1.2	7.9	1.2	1.0	1.1
No trap	12.7	2.7	28.3	1.2	10.9	1.2	1.7	1.1
P-value of difference	0.7		0.07		0.5		0.1	
Housing								
With trap	16.6	2.7	11.2	1.2	3.6	1.2	0.9	1.1
No trap	17.9	2.7	14.8	1.2	4.4	1.2	0.4	1.1
P-value of difference	0.7		0.6		0.7		0.1	

¹Overall number of observations was 16 for trap absent or present. Comparisons of specific housing and TRAP combinations were based on 4 observations each.

tion with the trap were not evident on a herd-basis in this study, so it remains to be determined if the use of the vacuum trap will improve dairy farm profitability particularly at low populations of blood-feeding flies.

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