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Impact of Trap Design, Windbreaks, and Weather on Captures of European Corn Borer (Lepidoptera: Crambidae) in Pheromone-Baited Traps

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ABSTRACT Pheromone-baited traps are often used in ecological studies of the European corn borer, *Ostrinia nubilalis* (Hübner) (Lepidoptera: Crambidae). However, differences in trap captures may be confounded by trap design, trap location relative to a windbreak, and changes in local weather. The objectives of this experiment were, first, to examine differences in *O. nubilalis* adult (moth) captures among the Intercept wing trap, the Intercept bucket/funnel UNI trap, and the Hartstack wire-mesh, 75-cm-diameter cone trap (large metal cone trap) as well as among three cone trap designs. Second, we examined the influence of the location of the large metal cone trap relative to a windbreak on the number of moths captured. Third, we examined the relationship between nightly mean air temperature, relative humidity, wind speed, precipitation, and the number of moths captured in large metal cone traps. The number of moths captured was significantly influenced by trap design, with large metal cone traps capturing the most moths. Wing and bucket traps were ineffective. Differences among trap captures were significant among trap locations relative to a windbreak. Under strong (>14 kph) or moderate (7 < 14 kph) wind speeds, traps located leeward of the windbreak captured the most moths, but when wind speeds were light (<7 kph), traps not associated with windbreaks captured the most moths. The multiple regression model fitted to the relationship between number of moths captured per Julian date and nightly weather patterns was significant. Nightly mean air temperature was the most influential parameter in the model, and its relationship with moth capture was positive.

KEY WORDS *Ostrinia nubilalis*, pheromone traps, weather, windbreaks, corn

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European corn borer, *Ostrinia nubilalis* (Hübner), is a major pest of corn, *Zea mays* L., in most of North America east of the Rocky Mountains. Understanding its biology and ecology is pivotal for its management because control tactics are often predicated on such information (Mason et al. 1996). Insect traps are an easy-to-use device for detection and monitoring populations of some insects, including *O. nubilalis.* However, fluctuations in *O. nubilalis* populations may not be correlated necessarily with changes in the numbers of moths captured in traps, and trap performance may not be consistent across trap designs or trap locations.

Many pheromone-trap designs have been used in studies of *O. nubilalis,* including aerial water-pans (Webster et al. 1986, Thompson et al. 1987, Bartels and Hutchison 1998), aluminum-screen petri-dish cages (Showers et al. 1974), wire-mesh cone traps (Webster et al. 1986, Mason et al. 1997, Bartels and Hutchison 1998, Showers et al. 2001, Sorenson et al. 2005), nylon-mesh cone traps (Webster et al. 1986, Bartels et al. 1997), and sticky traps (Oloumi-Sadeghi et al. 1975, Kennedy and Anderson 1980, Webster et al. 1986). Pheromone-baited traps are advantageous because they are species-specific, sex-specific, portable, relatively cheap, do not require a power source, and easy to operate and maintain. However, the relative efficiency among trap designs may differ.

The location or surroundings of insect traps influences their efficiency (Wellington and Trimble 1984, Lee 1988, Mason et al. 1997, Sappington and Spurgeon 2000, Kavallieratos et al. 2005), and insect responsiveness to traps is often a function of weather (Davidson and Andrewartha 1948, Vogt 1986, Gregg et al. 1994, Mohamed-Ahmed and Wynholds 1997, Butler et al. 1999). Windbreaks such as tree lines modulate air movement, airborne chemicals, and airborne insects (Lewis and Dibley 1970), and an insect's ability to control flight is a function of wind speed. Thus, determining the sensitivity or ability of a trap to detect insect populations and their ability to monitor population changes requires knowledge of trap efficiency in different environments and conditions.

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The objectives of this study were to examine differences in *O. nubilalis* adult (moth) captures among the Intercept wing trap, the Intercept bucket/funnel UNI trap, and the Hartstack wire-mesh cone trap (large metal cone trap). In addition, we compared capture efficiency among three cone trap designs, including the large metal, small metal, and small nylon cone traps. All of these traps are advertised by the manufacturers and venders as effective for trapping *O. nubilalis.* Second, we examined the influence of the location of the large metal cone trap relative to a windbreak on the number of moths captured. Third, we examined the relationship between the number of moths captured per Julian date in large metal cone traps and nightly mean air temperature, relative humidity, wind speed, and precipitation.

Materials and Methods

Experimental Design. Traps were established at sites in Story and Boone counties, IA, in 2003, 2004, and 2005, and they were maintained throughout the summer over both moth flights. *Ostrinia nubilalis* is bivoltine in much of the Corn Belt, including Iowa (Mason et al. 1996). The first flight usually begins in mid-May and lasts 3–4 wk, and the second flight in mid-July and typically lasts 4–6 wk. In 2003, three trap designs were deployed on 20 May at each trap site. The three trap designs used at a site were the Intercept wing trap (hereafter wing trap) (IPM) Tech, Inc., Portland, OR), the Intercept bucket/funnel UNI trap (hereafter bucket trap) (IPM Tech), and the Hartstack wire-mesh, 75-cm diameter cone trap (hereafter large metal cone trap) (Hartstack et al. 1979) (Fig. 1a–c). At each site, the traps were placed 30 m apart from one another in a line that ran east to west. The wing and bucket traps were each suspended from a 1.5-cm-diameter metal pole that was hammered into the ground. The large metal cone traps were mounted on top of the poles. Traps were equipped with a pheromone lure (Trécé Inc., Adair, OK) impregnated with a mixture of 97% *cis*-11-tetradecenyl acetate and 3% *trans*-11-tetradecenyl acetate, attracting males of the Z- or *cis*-strain of *O. nubilalis*, which is the strain inhabiting Iowa (Klun 1968, Klun and Brindley 1970). The lures were replaced biweekly and suspended 1 m above the ground. The sticky bottoms of the wing traps were replaced at least weekly. Traps were serviced 5 d/wk, and the order of the trap designs in a trap line at a site was randomly selected daily during each moth flight, so that each trap design had the same chance to capture moths at a given site (Sappington 2002). All of the traps were within 100 m of corn, and the native grasses' heights around the traps were generally <1 m.

To test the effect of windbreaks on the number of moths captured in traps, trap lines were placed away from, on the north side, or on the south side of the windbreaks. All windbreaks at the trap sites ran east to west. Lines of mature trees >100 m in length and >10 m in depth constituted a windbreak, and associated trap lines were placed within 5 m of the windbreak. Tree lines consisted predominantly of oak

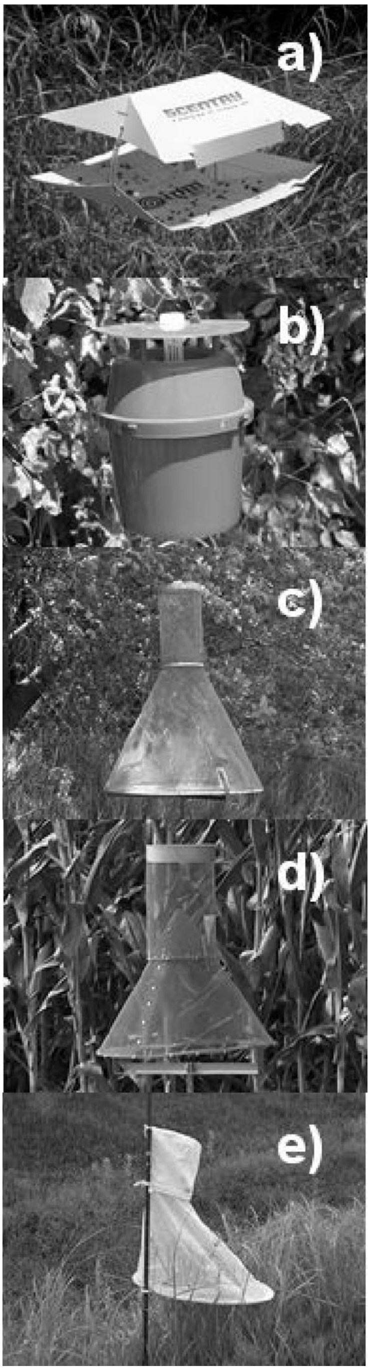

Fig. 1. Three trap designs used to examine the relative efficiency of traps in capturing *O. nubilalis* moths in 2003 and 2004. (a) Intercept wing trap (wing trap). (b) Intercept bucket/funnel UNI trap (bucket trap). (c) Hartstack wire-mesh, 75-cm-diameter cone trap (large metal cone trap) (Hartstack et al. 1979). In 2005, the large metal cone trap was compared with a modified Hartstack wire-mesh, 35-cm-diameter cone trap (small metal cone trap) (d) and the Gemplers *Heliothis*, 35-cm-diameter cone trap (small nylon cone trap) (e). All traps were baited with an Iowa-strain pheromone lure, changed biweekly.

(*Quercus* spp.) and other deciduous species along with associated underbrush, and foliage was present from ground level to >4 m. In 2003, two trap lines were located in open fields away from windbreaks, three trap lines were located north of windbreaks, and four trap lines were located south of windbreaks.

The experimental design used in 2004 was similar to 2003. The traps were deployed 17 May, and the order of the trap design in a trap line at a site was randomly selected about three times a week. Two trap lines were located in open fields away from a windbreak, three trap lines were located north of windbreaks, and three trap lines were located south of windbreaks.

In 2005, the experimental design for testing the effects of windbreaks on moth captures was akin to 2003 and 2004. However, only the large metal cone traps were deployed because data from the previous years showed that the wing and bucket traps collected few moths, as is described in *Results.* The large cone traps were deployed 26 April. Three trap sites were located in open fields away from windbreaks, three sites were located north of windbreaks, and three sites were located south of windbreaks.

We examined the effects of windbreaks and weather on moths captured in the large metal cone traps. A weather station (Campbell Scientific, Inc., Logan, UT) was used to monitor weather parameters during the moth flights, and was located within 9 km of the traps. Air temperature (Celsius), dew point (Celsius), precipitation (millimeters), relative humidity (percentage), wind direction (degrees), and wind speed (kilometers per hour) were measured every 60 s, and a mean output for each variable was calculated hourly.

The relative location of trap lines associated with windbreaks (i.e., windward or leeward) was assigned daily based on mean direction of wind relative to windbreaks during the nights of capture. Nighty mean wind directions between 337.5° and 22.5° were considered north winds, and mean wind directions between 157.5° and 202.5° were deemed south winds, where cardinal north equals 0° or 360°. Data from nights with average winds outside the indicated limits were omitted from the analyses to reduce possible confounding effects of interference among traps in a trap line at a site (Sappington 2002) and to increase the dampening effect of windbreaks on wind speed. The trap sites not associated with windbreaks were always classified as such regardless of wind direction. However, dates that were omitted from the leeward-windward sites because the wind direction was outside the indicated limits also were omitted from the no-windbreak sites, so that the comparisons were balanced. Because the moths are nocturnal, only weather data collected between 2100 and 0600 hours were used to determine the predominant nightly wind direction for assigning trap locations relative to windbreaks.

Mean nightly measurements of the weather factors also were regressed on the numbers of moths captured in the large metal cone traps. Moth capture data from Mondays were omitted from all analyses because they represented a 3-d capture. Only data that were collected during the natural moth flights were used for analyses (Fig. 2).

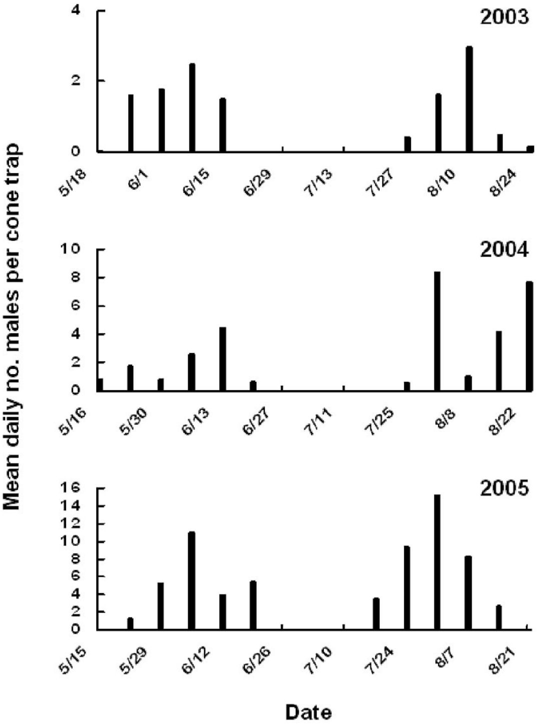

Fig. 2. Mean number of *O. nubilalis* moths collected daily in Hartstack wire-mesh, 75-cm-diameter cone traps per week.

In 2005, numerous trap sites were set up along two transects across Iowa and into adjoining states to collect moths for a population genetics study. Because we recorded the numbers of moths collected per trap per location, and because three types of cone traps were used, the data provided an opportunity to test different cone trap designs on capture efficiency. The trap designs evaluated in this experiment were the large metal cone trap (Fig. 1c), a modified Hartstack wire-mesh, 35-cm-diameter cone trap (hereafter small metal cone trap) (Fig. 1d), and the nylon-mesh *Heliothis,* 35-cm-diameter cone trap (hereafter small nylon cone trap) (Gemplers, Madison, WI) (Fig. 1e). Traps sites were established in late June and early July before the onset of the second flight. All traps were positioned along roadsides within 5 m of a cornfield. At each site, there were five traps, located within ≈2 km of each other. The spatial arrangement of the trap designs deployed at a site was arbitrarily chosen, and the number of each trap design at a site varied. The trap sites were spaced at 80-km intervals along two transects in the cardinal directions centered on Ames, IA. Nested within two of the 80-km intervals along the east-west transect in central and eastern Iowa were trap sites spaced at 16-km intervals. The traps were serviced about twice weekly, and lures were replaced biweekly.

Statistical Analyses. An analysis of variance (ANOVA) (restricted maximum likelihood estimates; REML-ANOVA) was used to determine whether trap designs tested in 2003 and 2004 (wing, bucket, and large metal cone traps) influenced the number of moths captured (PROC MIXED, SAS Institute 2001). The dependent variable of the model was the mean number of male moths collected daily, and trap design was the fixed effect. The random effects in the model were dates nested in year and trap site. Treatment means were separated using the LSMEANS option with the Tukey–Kramer adjustment, and the degrees of freedom were estimated using the Satterthwaithe's approximation (SAS Institute 2001). A similar model was used to assess the influence of the large metal cone trap, the small metal cone trap, and the small nylon cone trap on the number of moths captured. The dependent variable in the model was the mean number of moths collected daily, and the independent variable was trap design. The random factors were date, trap site, and their interaction.

A REML-ANOVA was used to determine whether trap location relative to a windbreak influenced the number of moths captured in the large metal cone traps (PROC MIXED, SAS Institute 2001). Separate models were fitted to moth capture data under various wind speed categories because the difference in speed between windward and leeward locations presumably increases as wind speed increases (Sappington and Spurgeon 2000). Winds were considered strong, moderate, or light when nightly mean wind speeds were >14, 7–14, or <7 kph, respectively. The dependent variable of the model was the mean number of moths captured, and trap location relative to a windbreak was the fixed effect. The random effect in the model was date. Treatment means were separated using the LSMEANS option with the Tukey–Kramer adjustment, and the degrees of freedom were estimated using Satterthwaithe's approximation (SAS Institute 2001).

The relationship between the number of moths collected in the large metal cone traps and weather was assessed by multiple regression (PROC REG, SAS Institute 2001). The dependent variable in the model was the number of moths collected per Julian date, and the initial fixed effects were a linear term for Julian date, a quadratic term for Julian date, year, flight, nightly mean air temperature (Celsius), nightly mean relative humidity (percentage), nightly mean wind speed (kilometers per hour), nightly precipitation (millimeters), the interactions of linear Julian date with the weather parameters, and the interactions of flight with the weather parameters. The orthogonal polynomial functions of Julian date helped model the natural rise and fall cycle of moth populations over time (Davidson and Andrewartha 1948). Model construction was conducted in a stepwise manner. The inclusion and exclusion levels of α for parameters were relatively liberal ($P = 0.15$), so if a given parameter was not included in the final model, it had very little to no predictive power with regard to the dependent variable. Only data from the windward cone traps and the cone traps not associated with windbreaks were used because the leeward cone traps presumably experienced wind speeds less than those recorded by the weather station.

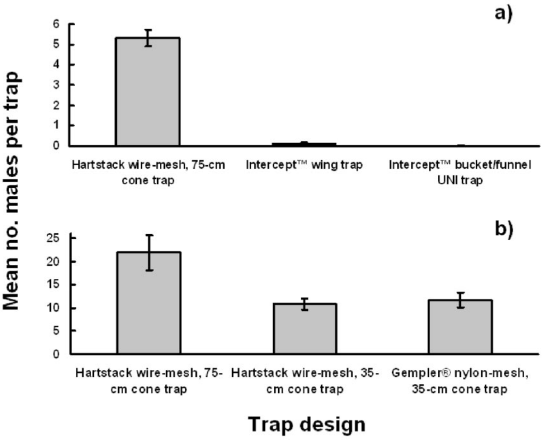

Fig. 3. Mean ± SE number of *O. nubilalis* moths collected daily with different pheromone-baited trap designs in 2003 and 2004 (pooled) (a) and 2005 (b).

The dependent data used to analyze trap design and in the multiple regression were transformed to $\ln(\bar{X} + 0.5)$ to meet model assumptions of homoscedasticity and normality (Fry 1993, Ott and Longnecker 2001). All REML-ANOVA and multiple-regression model assumptions and fits were assessed with residual and normal plots.

Results

Figure 3 shows the mean number of moths collected daily among the trap designs. The REML-ANOVA model used to examine the relationship between moth captures and trap design was significant in 2003 and 2004 ($F = 635.21$; df = 2, 1,612; $P < 0.0001$). Least-squares differences of means between the bucket trap and the large metal cone trap and between the wing trap and the large metal cone trap were significant ($P < 0.0001$). However, the least-squares difference of means between the wing trap and the bucket trap was not significant ($P = 0.1279$). The large cone traps averaged 5.3 moths daily over the two natural moth flights of both years of the study ($n = 564$; Fig. 3a). The average daily trap counts of the wing traps ($n = 564$) and the bucket traps ($n = 564$) was <0.1 daily (Fig. 3a), and on most dates these trap counts were zero.

The REML-ANOVA model used to examine the relationship between moth capture and cone trap design was significant in 2005 ($F = 14.47$; df = 2, 131; $P < 0.0001$). Least-squares differences of means between the large metal cone trap and the small nylon cone trap, and between the large metal cone trap and the small metal cone trap, were significant ($P < 0.006$). However, the least-squares difference of means between the small cone trap and the nylon cone trap was not significant ($P = 0.0588$). In this case, the large metal cone traps averaged 21.9 moths daily from mid-

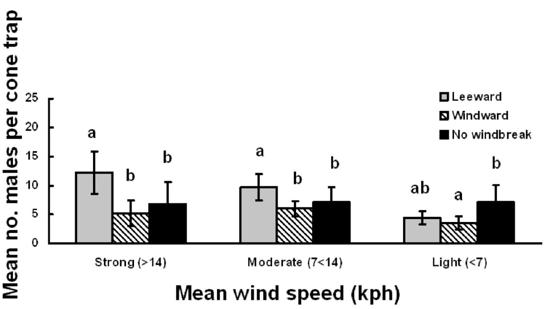

Fig. 4. Mean ± SE number of *O. nubilalis* moths collected daily in pheromone-baited, Hartstack wire-mesh, 75-cm-diameter cone traps in different locations relative to a windbreak at different wind speeds in 2003, 2004, and 2005. Captures at different trap locations within wind speed category with different letters were significantly different based on least-squares differences of means ($P < 0.05$).

July through mid-August 2005 ($n = 67$; Fig. 3b). The average daily trap count of the small metal cone traps ($n = 132$) was 10.7, and for the small nylon cone traps ($n = 171$) was 11.7 daily (Fig. 3b).

The location of the large metal cone traps relative to windbreaks significantly influenced the number of moths captured under all wind conditions (Fig. 4). Under strong winds (>14 kph), the location of the traps significantly influenced moth capture ($F = 6.01$; df = 2, 127; $P = 0.0032$). The same was true under moderate winds (7 < 14 kph) ($F = 7.43$; df = 2, 370; $P = 0.0007$). The traps located leeward of a windbreak captured the most moths at strong or moderate wind speeds. Conversely, trap location significantly influenced moth capture during light winds (<7 kph) ($F = 4.69$; df = 2, 199; $P = 0.0102$), but the traps not associated with windbreaks captured the most moths.

When the number of moths captured in the large metal cone traps was regressed on the weather parameters, the fitted model was significant ($F = 30.11$; df = 5, 814; $P < 0.0001$; $r^2 = 0.16$). The independent terms included in the final model were the y-intercept, a quadratic term for Julian date, year, mean nightly air temperature, mean nightly relative humidity, and mean nightly wind speed (Table 1). The range of the nightly means in 2003 and 2004 for the air temperature was 9.7–25.4°C, for the relative humidity was 44.1–100%, and for the wind speed was 1.6–22.7 kph. The range of the nightly precipitation sum was 0–15.2 mm.

Table 1. Parameter coefficients (± SE) for the multiple regression model fitted to the relationship between the number of *O. nubilalis* moths collected per Julian date in pheromone-baited, Hartstack wire-mesh, 75-cm-diameter cone traps and weather

y-intercept	Yr	Quadratic[a]	Air temp	Relative humidity	Wind speed
−198.79 (107.65)	0.10 (0.05)	−1.47 (0.19)	0.11 (0.01)	0.01 (0.003)	−0.02 (0.01)

[a] Orthogonal polynomial function of Julian date to model the natural rise and fall cycle of moth populations over time (Davidson and Andrewartha 1948).

The influence of all weather parameters on the number of moths captured per Julian date in the large metal cone traps was positive except for wind speed, which was negative. The nightly mean relative humidity and nightly mean wind speed parameters in the model only accounted for <1% of the observed variation in moth captures. The nightly mean air temperature was the most influential weather parameter in the multiple regression model ($r^2 = 0.08$).

Discussion

In our experience, the large metal Hartstack-cone pheromone traps have consistently performed well for collecting *O. nubilalis.* However, these traps are expensive to build, and to our knowledge they are no longer commercially available. So, we were interested in testing different traps in a search for a suitable and affordable substitute. Wing traps and bucket traps are relatively inexpensive and commonly advertised as being effective for capturing *O. nubilalis.* Similarly, the modified smaller Hartstack cone traps, both metal and nylon designs, are advertised as less-expensive substitutes for the conventional large metal cone traps.

In this study, trap design significantly influenced the number of *O. nubilalis* moths collected in pheromone-baited traps. The large metal cone traps captured the most moths consistently throughout the experiment (Fig. 3a and b). In contrast, the wing and bucket traps captured very few moths during the same period. Because of the paucity of moths captured with the wing and bucket traps during the same period that the large metal cone traps captured moths, we conclude that the former two trap designs are not effective detection or monitoring devices of *O. nubilalis,* manufacturers' and distributors' claims notwithstanding. Although the pheromone in the wing and bucket traps presumably attracts males to the vicinity, the traps are ineffective at collecting and holding moths of *O. nubilalis.* Similarly, previous studies showed that sticky wing traps baited with pheromone are inefficient and not adequate for monitoring *O. nubilalis* (Oloumi-Sadeghi et al. 1975, Kennedy and Anderson 1980, Webster et al. 1986, Athanassiou et al. 2004). Goodenough et al. (1989) found, conversely, bucket traps to be superior over large metal cone traps when collecting southwestern corn borer, *Diatraea grandiosella* (Dyar) (Lepidoptera: Crambidae). In that study, most of the moths captured were still alive when the traps were serviced, but kill strips impregnated with dichlorvos were placed in the base of the trap and may have improved retention of captured moths. However, Ngollo et al. (2000) found that the small nylon cone traps captured more *O. nubilalis* than bucket traps containing a kill strip. An impetus to our study was that we had hoped to be able to deploy the inexpensive bucket traps to collect moths for population genetics studies, and live-traps are more desirable than kill-traps because DNA degradation will be less between collection dates.

Although not compared directly, the small metal and small nylon cone traps captured relatively more moths in 2005 than the wing and bucket traps in 2003–2004. Nonetheless, the small metal and small nylon cone traps consistently captured fewer moths than the large metal cone traps in direct comparisons in 2005 (Fig. 3b). The discrepancy among the moth captures in the 2005 cone traps may be a result of the differences in the diameter at the base of the cone, which is more than twice as great in the large metal cone trap. Bartels and Hutchison (1998) similarly found that the large metal cone traps were superior to other pheromone-baited traps tested, including the small nylon cone trap. Moreover, although the large metal cone traps began to capture moths at the onset of moth flights, as did blacklight traps, the latter detected the peak flight of moths ≈2 wk before the large cone traps (Bartels and Hutchison 1998). Blacklight traps are indiscriminant trapping devices, whereas the pheromone-baited traps mimic female-produced pheromone. Females are most abundant during peak flight and may be superior competitors over the pheromone-baited traps (Thompson et al. 1987). It is important to accurately know when peak flight occurs when scouting fields for management decisions (Mason et al. 1996). In situations where it is important to sample *O. nubilalis* moths when the population levels are low, using traps that are sensitive enough to detect moths is imperative. The large metal cone traps were the most efficient traps assessed in this experiment because they consistently captured the most moths at both low and high population levels.

The location of the large metal cone traps relative to a windbreak significantly influenced the number of moths captured. When winds were strong or moderate, most moths were collected in traps located leeward of a windbreak, and there were no significant differences between the windward cone traps and traps located away from windbreaks (Fig. 4). However, under light winds, the most moths were captured in traps located away from windbreaks. Likewise, Sappington and Spurgeon (2000) showed that when winds were >10 kph captures of boll weevils (Coleoptera: Curculionidae) were greater in pheromone-baited traps located leeward of a windbreak compared with windward traps. When wind speeds were light, there was no difference in captures in leeward and windward traps. Because windbreaks alter wind speeds, the large metal cone traps located leeward of windbreaks were presumably exposed to the calmest winds. Under strong and moderate wind speed conditions, male moths following pheromone plumes may have better control of their flight at traps located leeward of the windbreak, which may result in an increased number of moths captured. Alternatively, the pattern of the winds near a windbreak may direct airborne insects to the leeward side of a windbreak, increasing the number of moths flying in the vicinity of a leeward trap. For example, Lewis and Dibley (1970) showed that windbreaks create a sheltered zone leeward of the windbreak where flying insects tend to accumulate. The magnitude of this influence is proportional to the angle and speed of the incident wind and the permeability and dimensions of the windbreak (Lewis and Dibley 1970). Although we did not directly quantify the effect of the windbreaks on wind movement, we chose tree lines typical of the Iowa landscape. They were tall and thick enough to reasonably assume they had a substantial dampening effect on winds striking it at an angle <22.5° of perpendicular.

Conversely, the traps not associated with windbreaks captured the most moths when the wind speeds were light, but they did not differ significantly from the number captured in leeward traps (Fig. 4). The windward traps captured the fewest number of moths when wind speeds were light. Under light winds, the windbreaks have the least effect on wind speed. The pheromone plumes emitted from traps located at sites not associated with windbreaks are free of obstruction in all directions, whereas traps associated with windbreaks may be effective only on one side of the windbreak, limiting the area from which the trap is attracting moths. Early in the moth flight, Ngollo et al. (2000) found that more *O. nubilalis* moths were collected in cone traps located at cornfield borders and in bordering grasses, whereas traps in the middle of the cornfield captured the most moths during peak flight. Mason et al. (1997) indicated that more moths were collected in large metal cone traps when the openings were placed within the grass canopy instead of above the canopy, perhaps because a mixture of pheromone with plant volatiles is more attractive. Furthermore, the moth counts from traps embedded in the grass canopy were less variable, which may improve the use of traps in estimating moth population changes. Because trap location influences the number of moths collected, it may be best to use a combination of trap locations near and away from windbreaks given the difference in sensitivity depending on wind speed on a given night.

The numbers of *O. nubilalis* moths captured in the large metal cone traps were significantly influenced by weather, and the fitted multiple regression model accounted overall for 16% of the observed variation in nightly captures. The nightly mean air temperature was the most influential parameter in the model and was positively related to moth capture, but only explained 8.3% of the observed variation. Other studies have indicated that air temperature is the most important weather parameter to describe moth captures in traps. Butler et al. (1999) collected the most Lepidoptera in blacklight traps on warm nights compared with cool nights and noted that there was a negative relationship between precipitation and moth captures in blacklight traps. Mohamed-Ahmed and Wynholds (1997) found that the temperature was the most important weather variable that influenced (positively) tsetse fly, *Glossina fuscipes fuscipes* Newstead (Diptera: Glossinidae), captures in traps. Vogt (1986) noted that temperature was the most influential, and positive, factor in captures of the fly *Musca vetustissima* Walker (Diptera: Muscidae) in traps.

Relative humidity and wind speed were both included in the multiple regression model, and their relationship with moth capture was positive and negative, respectively. However, both mean nightly relative humidity and mean nightly wind speed only accounted for <1% of the observed variation. Sappington and Spurgeon (2000) demonstrated a negative relationship between wind speed and captures of boll weevils in pheromone-baited traps. Apart from air temperature, easily measured weather parameters seem to be overwhelmed by other unknown factors, potentially both abiotic and biotic in determining fluctuations in nightly trap captures, and are not likely to be of much aid in improving their interpretation.

Although the effect of weather on trap captures seems intuitively to be important, identifying and quantifying such effects is notoriously difficult to accomplish. Sappington and Showers (1983) explored the effect of a number of weather variables on *O. nubilalis* captures in blacklight traps. When wind speeds were >30 kph, blacklight captures of *O. nubilalis* decreased, and the size of the reduction may be further increased by precipitation. Similarly, when nightly air temperatures fell below ≈10°C, blacklight trap captures decreased. There are many potential factors that can hinder detection of any relationships between moth captures and weather parameters, such as crop phenology, moth immigration and emigration, predation, parasitization, pathogen load, local farming practices, and microclimatic differences not reflected by measurements at weather stations located outside the trap sites.

If pheromone-baited traps are to be used to detect and monitor *O. nubilalis* populations, it is important to recognize that trap design, surroundings, and the weather influence the number of moths captured on any given night, in addition to changes in the population numbers themselves. How numbers of moths captured in traps relates to the actual or relative size of *O. nubilalis* populations remains an elusive goal. However, when moth population levels are low, it is essential that devices used to detect and monitor their presence are as sensitive as possible to reduce false-negative measurements. In this study, we learned that the large metal cone traps were the most sensitive pheromone-baited trap evaluated. But because they are no longer commercially available, the small metal or nylon cone traps are the next best alternative, though clearly inferior, being about two-fold less sensitive.

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