ABSTRACT. We investigated the capability of transfluthrin on US military camouflage netting to reduce collections of tabanid biting flies in a warm-temperate field environment on the Gulf Coast of Florida. We found that transfluthrin significantly reduced collections of a variety of medically and veterinarily important tabanids inside protected areas by up to 96% upon initial treatment and up to 74% after 20 days posttreatment. These results suggest that transfluthrin could be an effective element in the US Department of Defense integrated pest management system and leveraged in civilian scenarios to protect livestock and humans from potential mechanical transmission of pathogens and disruption of activities caused by painful bites.

KEY WORDS Integrated vector management, military operational entomology, passive control, residual pesticide, resistance management

Tabanid biting flies such as Tabanus petiolatus Hine and Tabanus lineola Fabricius can mechanically transmit an array of pathogens to livestock and humans (Foil 1983, Taioe et al. 2017) and cause painful bites that severely disrupt US military field activities (Mehr et al. 1997, Suh et al. 2015). Residual pesticide treatment of US military materials that effectively repel or kill tabanids could be leveraged in military integrated vector management (IVM) because materials such as camouflage netting or tents are found ubiquitously among US military personnel in the field (Britch et al. 2010). However, widespread resistance of tabanids to organophosphates and pyrethroids (Showler 2017) limit efficacy for control of tabanids in field environments with standard residual pesticides such as λ-cyhalothrin. Fortunately, spatial repellent properties of some pyrethroids such as transfluthrin (TFL; USEPA 2018) have come to light that may interfere with host-seeking behavior of hematophagous arthropods (Achee et al. 2012, Ogoma et al. 2012) and reduce biting pressure in protected areas. Recent work has demonstrated that mosquito biting pressure can be reduced with transfluthrin on US military materials such as camouflage netting in field scenarios (Britch et al. 2020). In this study we adapted the technique used in Britch et al. (2020) to investigate the effect of camouflage netting treated with transfluthrin on reducing the number of tabanids collected in a protected area in a warm-temperate environment.

In September 2018, we investigated woodland pattern radar scattering Ultra Lightweight Camouflage Netting System (ULCANS; Britch et al. 2010) material treated with TFL and placed in a woodland site in the Lower Suwannee Wildlife Refuge (LSWR) on the Gulf Coast of Florida (Fig. 1) to reduce collections of natural populations of biting tabanid flies in small protected areas. This site has been previously described in Kline et al. (2018), and natural populations of tabanids were present at the time of the study. Before fielding we treated the ULCANS outdoors at Camp Blanding Joint Training Center, Starke, FL, with a Bayer proprietary formulation of Bayothrin™ transfluthrin (Bayer Environmental Science, Research Triangle Park, NC) diluted in water and applied to the interior and exterior sides of the material at the maximum rate recommended by the manufacturer of 1 g Al/m² using a 3 gallon (11.4 liters) hand pressurized portable sprayer (268131; H. D. Hudson Mfg. Co., Chicago, IL). We cut the ULCANS into 6 strips, each approximately 8 in. (0.2 m) by 15 ft (4.6 m).

We deployed a series of 6 H-traps (Bite-Lite, LLC, Bethel, CT) arranged in 3 pairs along an approximately 1-km stretch of unimproved dirt road in a section of woodland in the LSWR closed to vehicular traffic (Fig. 1). On 14 September (Day 0) we surrounded each H-trap with an octagonal wall fashioned from 2 HESCO MIL blast wall cells (Hesco Bastion, Inc., North Charleston, SC) cut open and partially stripped of geotextile fabric that formed a narrow slit on opposite sides revealing the large black ball visual attractant of the H-trap (Fig. 1 inset). We chose 1 of each pair of traps that had historically shown the highest collection numbers of tabanids and fastened 2 TFL-treated ULCANS strips around the Hesco wall as shown in the Fig. 1 inset photo, leaving the other trap in each pair as an untreated control with no ULCANS present.

We supplied each H-trap with a 30-day octenol lure (Bite-Lite Insect Lure, Bite Lite, LLC, Bethel, CT) throughout the study period, but could only...
supply CO₂ (approximately 2 kg dry ice) to the traps on certain days indicated in the graph shown in Fig. 2. Each lure consisted of 3.72 g 1-octen-3-ol (racemic mix) and other inert ingredients and was hung to either the H-trap hook or the ball loop such that the lure hung just below the bottom of the green hood of the H-trap. We retrieved collection cups 24 h after deploying CO₂ and replaced with a new collection cup for 1 or more days until the next opportunity to deploy CO₂ and a new collection cup. We identified all collections to species using the keys of Jones and Anthony (1964) and Goodwin et al. (1985) and the reference collection at the Florida Department of Plant Industry, Gainesville, FL, and graphed the results (Fig. 2). We used a t-test to compare means of TFL-treated and control H-trap collection numbers for each posttreatment collection period, and instances of $P < 0.05$ significance are marked on the graph shown in Fig. 2.

Over the 20-day period of the study we collected 8 species: *Tabanus atratus* Forster (N = 4), *Tabanus imitans* Walker (N = 102), *Tabanus gracilis* Wiedemann (N = 47), *Tabanus lineola* Fabricius complex (N = 2,740), *Tabanus petiolatus* Hine (N = 166), *Diachlorus ferrugatus* (Forster) (N = 11), *Chrysops vittatus* Wiedemann (N = 156), and *Chlorotabanus crepuscularis* (Bequaert) (N = 44), for a total of 3,291 specimens. We also collected an unidentified *Tabanus* species (N = 10) and an unidentified *Chrysops* species (N = 7) that were not included in analyses. Mean collection numbers of all species combined shown in Fig. 2 represent 1 collection day for all data points, except for Day 4 posttreatment that includes collections from 5 collection days (i.e., Day 0–Day 4), Day 10 posttreatment (3 collection days, Day 8–Day 10), and Day 20 (6 collection days, Day 15–Day 20). With few exceptions, nearly every sample period for each species showed a pattern of lower collection numbers in traps protected by the TFL-treated camouflage netting barrier (Figs. S1–S8; Supplementary Materials available at https://ars.usda.gov/cmov/mfru/tfl). We found that transfluthrin could significantly reduce collections of a variety of medically and veterinarily important tabanids into protected areas by up to 96% upon initial treatment and up to 74% after 20 days posttreatment (Fig. 2), compared with untreated control areas.

A severe storm passed through the study area following the Day 20 collection and destroyed all but 2 of the H-traps (H-4 and H-5), which remained intact and carried on collecting tabanids for approximately 1 month. Analysis of this unplanned continuous ~30-day collection revealed that 3,571 specimens (99% *T. lineola* complex) had been collected in the untreated H-5 trap compared with 1,865 specimens (97% *T. lineola* complex) in the treated H-4 trap, a reduction of 47.8% where TFL was present. Traps H-5 and H-4 had previously collected 850 and 373 tabanid specimens, respectively, during the original 20-day study period before the storm—a reduction of 56.1% in the presence of TFL. These data imply that the TFL treatment on the ULCANS material was persistent and continuously effective at reducing tabanid incursion into a protected area for more than 7 weeks posttreatment, and suffered an arguably minimal loss of approximately 8% efficacy (i.e., the difference between 56.1% and 47.8%) after severe weathering with wind and rain.
Results from this investigation suggest that transfluthrin-treated materials could be an effective element in the US Department of Defense integrated pest management system to protect personnel in the field from nuisance and disease vector tabanid biting flies and could theoretically be leveraged in civilian scenarios to similarly protect livestock as well as humans. This study is the first known study investigating effects of a spatial repellent on tabanids in the field, and the first specifically with any US military material as a substrate for spatial repellents targeting tabanids. Owing to resource limitations, TFL replicates were not rotated to different positions to eliminate possible bias from spatial effects. However, results from preliminary trials in other study areas (SCB, KJL, unpublished data) pointed to transference of TFL to trap parts or surrounding materials that would require rotation of the entire setup of each replicate to new positions in future investigations. Future studies with tabanids should investigate effects of transfluthrin or a variety of other spatial repellents applied to other military materials such as the HESCO geotextile itself and other common substrates such as shade cloth or vegetation in a range of ecological regions, across different seasons, and possibly combined with or compared to materials treated with standard residual pesticides.

A clear pattern that emerged with the variation in the presence of CO2 across the collections was that significant reduction in collections from TFL-treated H-traps compared with untreated controls was observed only when CO2 was absent. One possibility is that the stimulus of a simulated vertebrate host (CO2) at the H-traps overwhelmed the potential repellent effect of the TFL. Octenol bait was present throughout the experiment and on its own did not appear to overwhelm the effects of TFL, but 2 previous studies with tabanids—1 conducted at this site—showed that CO2 was significantly more attractive to members of the Tabanidae (Diptera) movement between hosts.

The Nzi, Horse Pal and Bite-Lite are different seasons, and possibly combined with or compared to materials treated with standard residual pesticides.

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