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A NOVEL TICK MANAGEMENT SYSTEM AND ITS ROLE IN REDUCING THE INCIDENCE OF LYME DISEASE

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Abstract Since first identified in the 1980's, Lyme Disease has become the most widely diagnosed vector-borne disease in the United States. Lyme Disease occurs from the infection of human and animal hosts by the bacterium *Borrelia burgdorferi*. Infection of hosts results from the bite and completion of a successful blood meal by infected black-legged ticks (*Ixodes scapularis*). In cooperation with the USCDC, Bayer Environmental Science has developed the Maxforce Tick Management System® (TMS). This product provides direct control of ticks on the most important reservoir host of Lyme disease in the disease cycle, wild rodents. TMS delivers a topical application of fipronil to rodents that enter the station. One exposure to the delivery system will keep a target animal tick free for over 40 days. In development and field trials the TMS provided reductions of tick populations 60-80% in first year placements. Trials lasting two years and longer reduced populations of *I. scapularis* between 90-100%. The infection rate in sampled populations of *I. scapularis* fell from 25% to less than 2% during a three year trial period. TMS provides a significant contribution to tick management programs provided by pest management professionals (PMP's).
Key Words Lyme Disease, Black-Legged Tick, *Ixodes scapularis*, fipronil

INTRODUCTION

Lyme disease (LD) is the most frequently reported vector-borne illness in the United States. It is an infection caused by the corkscrew-shaped bacteria, *Borrelia burgdorferi*, that is transmitted by the bite of the black-legged deer tick, *Ixodes scapularis*. This tick is responsible for transmitting Lyme disease to humans and domestic companion animals. The number of reported human cases in the United States has increased each year since the United States Centers for Disease Control and Prevention (CDC) began tracking reported cases in the 1980's. CDC reports that over 23,000 human cases were reported in 2002. Bayer Environmental Science (BES) and the U.S. Centers for Disease Control and Prevention have been working since 1996 on an innovative system designed to break the cycle of Lyme disease. The Maxforce Tick Management System® (TMS) reduces tick populations and the number of infected rodents living in treatment areas. Ultimately, the goal is to reduce the risk of Lyme disease for homeowners. The system works when rodents are attracted to a station containing an non-toxic bait. While investigating the station the rodent receives a small topical exposure of fipronil insecticide. A single dose is enough to control *I. scapularis* on rodents for over 40 days. The spread of the LD infection is prevented as treated rodents are prevented from infecting immature *I. scapularis* ticks.

The station is an approved child-resistant box with a 3-month field exposure life. The TMS station is designed with a central corridor that leads to two, non-toxic, attractive bait blocks (Figure 1). As the target animal moves through the central corridor to feed on the bait, it must pass beneath a fipronil treated wick (0.70% a.i.). Contact with the wick provides the target animal an effective acaricide dose of the active ingredient. Trained professionals place the stations outside in areas of wild rodent and *I. scapularis* activity during the spring, coinciding with the host-seeking behavior of *I. scapularis* nymphs. Boxes are recovered and replaced in mid-summer, coinciding with the host-seeking behavior of *I. scapularis* larvae. TMS stations are recovered in the fall at the end of immature *I. scapularis* host-seeking activity.

This paper will review results from five trials of TMS stations that were performed in Massachusetts, Connecticut and New Jersey.

MATERIALS AND METHODS

Trials. Since 1999, a number of development and field trials have been performed by Bayer Environmental Science both alone and in cooperation with CDC sponsored regional Lyme Disease Management projects. These trials have evaluated the effect of TMS on *I. scapularis* populations. Additionally, CDC has measured the rate of infection of *I. scapularis* by *B. burgdorferi* collected from a test site over a multi-year period. Trials were conducted in residential areas where *I. scapularis* and its representative host animal populations are established. These areas were confirmed as endemic sites of LD infection in humans and domestic animals from tick infection survey, physician disease reporting (as collected by CDC) and personal interviews with residents that have experienced disease infection personally.

Trial protocol is consistent among all the described trials in this paper. Individual property size ranged from less than 0.5 to over 3 hectares. TMS stations were placed at specified intervals in areas of rodent and tick activity. These areas, referred to as the "tick zone", occur along the border between managed landscape areas (maintained turf and planting beds with mulch ground covers) and un-maintained, wild plantscapes. Tick zones are characterized by accumulative natural leaf litter, wild grasses and low vegetation. These areas provide wild rodents food, shelter and cover from predators. The leaf litter substrate provides ticks the microclimate suitable for development. When humans and domestic animals enter these infested tick zones during the host-seeking activity period of *I. scapularis*, potential exposure to disease bearing ticks occur.

TMS station placements were made to coincide with the host-seeking activity periods of *I. scapularis*. First station placements were made in May during nymph tick host-seeking. May-deployed stations were recovered and replaced in July to coincide with the period of host-seeking activity by *I. scapularis* larvae. Stations were recovered at the end of the season. Stations were placed at specified intervals (9-14 m) at a 1.5-3 m depth from the border of the managed lawn/landscape. In some properties, additional rows of boxes were placed deeper into the woodland portion of properties where frequent use by people and/or domestic animals was indicated. A typical treated property would have between 10-12 stations installed. Adjacent, untreated properties and/or undeveloped areas were used as controls to compare tick populations against treated properties. These untreated controls included public parks, conservation forests and wildlife refuge areas.

Tick population survey data and TMS efficacy were measured using two methods. Environmental surveys were performed by "flagging". A white, cotton twill cloth measuring approximately 12 square feet (~ 1.1 m^2) was dragged at normal walking speed through tick/rodent habitat for periods of 10 minutes. Visual counts of *I. scapularis* attached to the "flag" were recorded for both treated and control sites. Tick species identification and developmental stage were recorded. Animal surveys were performed to compare the difference in "tick-loads" (i.e. parasitization) on hosts between treated and control areas. Target host animals: white-footed mice (*Peromyscus leucopus*) and eastern chipmunks (*Tamias striatus*); were live-trapped using Sherman box traps (H.B. Sherman, Tallahassee, FL) and lightly anesthetized for examination. The number, developmental stage and species of attached ticks were recorded. Animals were released after examination at the point of capture. Data were reported using various statistical models based on cooperators preference.

Dolan et al. (2004) performed a trial over three years in Connecticut. The trial site was located on Mason's Island (town of Mystic, Connecticut). Thirteen properties were treated in 1999. The trial in 2000 added an additional 31 properties and in 2001, 110 more new properties had TMS installed and were included in the study. The accumulative trial totaling 154 properties allowed an evaluation of TMS impact over a three-year treatment period as well as comparing the impact of TMS on tick populations being added to local new areas each season. Maupin (2003) performed a three-year trial using TMS in Norwood, Massachusetts, a suburban community located southwest of Boston. This trial was performed with the cooperation of a professional pest management company. Eighteen properties were treated seasonally from 2001-2003. A one-year trial was performed by Maupin on Martha's Vineyard, an island off the coast of Massachusetts in 2004. In this trial eighteen properties were treated with 400 stations (combined nymph and larvae exposure periods).

Schulze and Jordan (2004) evaluated TMS impact on a LD management program in Monmouth County, New Jersey. Monmouth County is located in central New Jersey east of Trenton. Thirteen properties were treated with a combined total of 350 TMS stations for the duration of this trial. Barile (unpublished data) performed two trials to evaluate TMS efficacy at two deployment densities in Massachusetts in 2004. One trial was performed in a residential neighborhood in Walpole, Massachusetts (30 miles southwest of Boston). At this site, ten properties were treated with a total of 160 stations throughout the season. The second Massachusetts trial site was located in Brewster, located on Cape Cod. This treatment site differed from other tests in that the stations were placed along a recreational footpath located on a private condominium complex. The footpath was approximately 2000 feet (610 m) long through a wooded area. In this site 170 stations were utilized for the 2004 trial season.

RESULTS

Utilizing modified rodent bait boxes and prototypes of the production TMS station Dolan et al. (2004) found tick burdens on white-footed mice were reduced by 68% (nymphs) and 84% (larvae) on Mason's Island. After treatment, surveys of questing *I. scapularis* adults were reduced by 77%. The infection rate of collected *I. scapularis* nymphs was reduced by 67% after 2 years of treatment. In Maupin's (2004) three-year study in Norwood, Massachusetts on-animal tick, surveys indicated a 92-100% reduction of tick attachment in the third year of the trial. During the single-season trial performed on Martha's Vineyard, Massachusetts in 2004, on-animal counts of *I. scapularis* were reduced 73% during the nymph activity period and 76% during the larval activity period (Figure 2).

Table 1. Summary of nymphal tick burdens on live-captured small mammals before and after bait box deployment within the Fox Hill, New Jersey treatment area, May-June 2004.

	Pre-Treatment		**Post-Treatment**		
Location/Species	n	Mean ± SE	n	Mean ± SE	Mann-Whitney tests
Fox Hill Area					
P. leucopus	4	4.5 ± 1.3	5	0	
T. striatus	27	5.5 ± 0.5	74	0.4 ± 0.1	$U_{(27,74)} = 38.0$; $P = 0.01$
Total captures	31	5.4 ± 0.5	79	0.3 ± 0.1	$U_{(31,79)} = 51.0$; $P < 0.01$[1]
Assunpink WMA					
P. leucopus	13	6.1 ± 0.7	22	2.8 ± 0.5	$U_{(13,22)} = 52.0$; $P = 0.01$
T. striatus	1	11	0	-	
Total captures	14	6.4 ± 0.7	22	2.8 ± 0.5	$U_{(14,22)} = 52.0$; $P = 0.01$

[1]Percent control (modified Henderson's equation) = 89.5%

Schulze and Jordan demonstrated that 14 m spacing the TMS system provided reductions of 80% (nymphs) (Table 1) and 77% (larvae) (Table 2). Barile (2004) recorded first-year suppression of tick populations from 70-75% for both nymphs and larvae at 14 m spacing in the two Massachusetts trial sites utilizing the 2004 production TMS stations.

Table 2. Summary of larval tick burdens on live-captured small mammals before and after bait box deployment within the Fox Hill, New Jersey treatment area, July-August 2004.

	Pre-Treatment		**Post-Treatment**		
Location/Species	n	Mean ± SE	n	Mean ± SE	Mann-Whitney tests
Fox Hill Area					
P. leucopus	1	2.0	24	0.1 ± 0.1	
T. striatus	73	1.6 ± 0.2	43	0.3 ± 0.1	$U_{(73,43)} = 736.5$; $P < 0.01$
B. brevicauda	5	48.6 ± 22.0	6	0.7 ± 0.4	
Total captures	79	4.6 ± 1.8	73	0.3 ± 0.1	$U_{(79,73)} = 1191.0$; $P < 0.01$[1]
Assunpink WMA					
P. leucopus	19	7.8 ± 0.9	28	6.9 ± 0.6	$U_{(19,28)} = 236.5$; $P = 0.52$
T. striatus	0	-	1	6.0	
B. brevicauda	1	3.0	1	5.0	
Total captures	20	7.6 ± 0.9	30	6.8 ± 0.6	$U_{(20,30)} = 275.5$; $P = 0.63$

[1]Percent control (modified Henderson's equation) = 92.7%

Figure 1. Maxforce TMS Station, internal detail

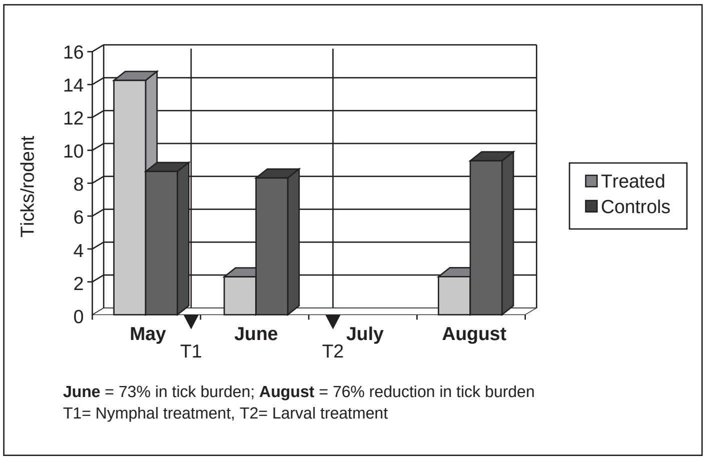

Figure 2. Comparison of tick attachment between Maxforce TMS treated and untreated rodents, Martha's Vineyard, MA 2004

DISCUSSION

Field trial data indicates that control of *I. scapularis* ticks utilizing treatment of rodent hosts with a topical acaricide is effective. Tick populations as measured both in environmental and on-animal surveys are significantly reduced in treated versus non-treated areas. Targeted treatment of rodent hosts offers consumers an attractive alternative to area-wide treatment of properties with acaricides. This system provides reduced hazard to non-target animals and property owners as well as added convenience eliminating restrictions of re-entry after application. Compared to traditional applications of acaricides as liquid sprays and/or contact granules the TMS offers pest management professionals a low-profile, passive component of an integrated tick management program.

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