Suppression of *Rhipicephalus (Boophilus) microplus* (Acari: Ixodidae) on Pastured Cattle Using an Abamectin-Impregnated Cattle Ear Tag[1]

Ronald B. Davey[2], J. Mathews Pound[3], and Kimberly H. Lohmeyer[3]

USDA-ARS, Cattle Fever Tick Research Laboratory, 22675 N. Moorefield Rd., Bldg. 6419, Edinburg, Texas 78541

J. Entomol. Sci. 48(2): 99-113 (April 2013)

Abstract Ear tags containing 8% abamectin and 20% piperonyl butoxide were applied to pastured cattle to evaluate efficacy against southern cattle ticks, *Rhipicephalus (Boophilus) microplus* (Canestrini), during a 40-wk field study. Temperature fluctuations had an important impact on effectiveness of the tags. The first 19 wks, during spring and early summer (March-June) temperatures were optimum for tick survival, producing high tick numbers on treated animals (9 - 63 ticks) which were not different from untreated animals. During this time tags provided ≤ 53.7% control. By contrast, during the summer through midfall (July-October), high temperatures caused dramatic natural declines in the tick population, but tick numbers on treated animals were always lower (0 - 3 ticks) than untreated animals (4 - 16 ticks). Control during this period was 72 - 100%, indicating tags had a negative impact on tick survival beyond the natural attrition caused by high temperatures. During the last 9 wks (midOctober to midDecember), temperatures were again highly conducive to tick survival and tick numbers on untreated animals rebounded to previous levels (7 - 56 ticks), whereas treated animals produced significantly fewer ticks (1 - 9 ticks), resulting in 73 - 98% control. Results demonstrated that timing of ear tag application was critical to the expected efficacy. Tags applied in spring through early summer would likely provide low level control, whereas tags applied in summer through early fall would likely provide high level control. Additionally, tag application in summer through fall months would likely prevent the enormous buildup of ticks that would otherwise occur the following spring with no tag treatment.

Key words southern cattle tick, ear tag, control, abamectin, endectocide

Mandatory procedures carried out by the U.S. Department of Agriculture (USDA), Animal and Plant Health Inspection Service (APHIS), Veterinary Services (VS), Cattle Fever Tick Eradication Program (CFTEP) provide the means for eradicating cattle fever ticks, *Rhipicephalus (Boophilus)* spp., from quarantined premises where ticks have been detected. However, the potential risk of infestation associated with adjacent

---

[1]Received 01 June 2012; accepted for publication 31 August 2012. This paper reports the results of research only. Mention of a commercial or proprietary product in this paper does not constitute an endorsement by the U.S. Department of Agriculture. In conducting the research described in this report, the investigators adhered to protocol approved by the USDA-ARS Animal Welfare Committee. The protocol is on file at the USDA-ARS, Knipling-Bushland U.S. Livestock Insects Laboratory, Tick Research Unit, Kerrville, TX. 78028. USDA is an equal opportunity provider and employer.

[2]Address inquires (kim.lohmeyer@ars.usda.gov).
[3]USDA-ARS, Knipling-Bushland U.S. Livestock Insects Research Laboratory, 2700 Fredericksburg Rd., Kerrville, TX 78028.

pastures that may or may not be stocked with cattle is pointedly neglected, thus placing these uninfested areas in jeopardy of having ticks dispersed into them. During the past 50 years this risk has been heightened by the ever increasing body of evidence indicating that the presence and movement of free-ranging white-tailed deer, *Odocoileus virginianus* L., and exotic ungulate species, is linked to the dispersal and initiation of tick infestation into previously uninfested areas (Pound et al. 2010). Whereas ungulates, such as native white-tailed deer and exotic nilgai antelope, *Boselaphus tragocamelus* Pallas are not as suitable as hosts for cattle fever ticks as cattle, they can produce sufficient numbers of ticks to sustain an infestation for a period that is longer than the prescribed regulatory quarantine period (Cooksey et al. 1989, Davey 1990, 1993). This makes these mammals potentially problematic to the CFTEP in their effort to curtail the spread and eliminate these serious pest species. The risk of free-ranging ungulates dispersing ticks into uninfested areas that lie adjacent to infested premises was highlighted in recent years when the CFTEP was forced to place over 400,000 ha under quarantine as a result of tick infested ungulates traversing uninfested areas outside of the permanent quarantine zone, thus causing massive outbreaks to occur. These circumstances emphasize the critical need for investigating methods that could be used to prevent or, at the very least, limit the spread of cattle fever ticks into uninfested areas.

Although the use of acaricide-impregnated ear tags is not a new technology for controlling ticks, these devices have shown efficacy in reducing several species of ticks on cattle. Historically, the efficacy of ear tags against tick species that have a predilection for attachment in or around the ears, such as the Gulf Coast tick, *Amblyomma maculatum* Koch, and the brown ear tick, *R. appendiculatus* Neumann, has been greater (Gladney 1976, Ahrens and Cocke 1978, Rechav 1987) than against ticks that attach to other body parts, such as the southern cattle tick, *R. (B.) microplus* (Canestrini), and the tropical bont tick, *A. variegatum* (F.) (Davey et al. 1980, Owen 1985, Allan et al. 1998). Ear tags have primarily incorporated older, more traditional, acaricides, such as pyrethroids (P) and organophosphates (OP) as the main active ingredients. Nevertheless, because these devices have demonstrated the ability to suppress ticks on cattle and require little management of the cattle following application, their potential as a means for preventing, or at least reducing, the risk of dispersing ticks into areas that lie adjacent to infested premises is worthy of consideration. Recently, Y-Tex® Corp., Cody, WY received registration approval for use of a new cattle ear tag (XP 820™) containing the endectocide abamectin as the primary active ingredient as well as piperonyl butoxide as a synergist. The label for this new XP 820™ cattle ear tag contains a claim for aiding in the control of cattle fever ticks which makes it a candidate for potential use in the CFTEP as a method for limiting the dispersal of ticks into uninfested areas. The potential benefits of using endectocide-based products, such as the abamectin used in the XP 820™ ear tag over other chemical classes, including P and OP agents, are that they have broad-spectrum activity and are efficacious at extremely low concentrations (Putter et al. 1981). Additionally, there have, as yet, been no confirmed instances of acaricide resistance to any endectocides in cattle fever tick infestations detected along the Texas-Mexico border, which is not the case for P and OP acaricides.

The objective of the present study was to determine the long-term suppression capability of XP 820™ cattle ear tags against cattle fever ticks under natural field conditions in South Texas. Positive results from the study could be of great value to the CFTEP as a means of limiting the build-up of large numbers of ticks on cattle that might otherwise occur if no eradication procedures are being applied within premises that lie adjacent to tick-infested pastures.

Materials and Methods

The study was conducted under natural field conditions at the USDA, Agricultural Research Service (ARS), Cattle Fever Tick Research Laboratory (CFTRL), near Edinburg, TX. This location, in southernmost Texas, is referred to as the Rio Grande Plains (Hatch et al. 1990) and is characterized by short, mild winters and long, hot summers, with an annual rainfall of 550 mm, occurring principally in May-June and September-October (Everitt and Alaniz 1982). The study used 2 separate and individually maintained pastures of approx. 6.9 ha each. The vegetative composition of both pastures was similar and typical of rangeland habitat in the region, containing approx. 65% open buffel grass, *Pennisetum ciliarus* L. and approx. 35% various woody species, principally mesquite, *Prosopis glandulosa* Torr.. During the study, temperature data were obtained at the study site using a HOBO® U30 Station (Onset® Computer Corp., Bourne, MA). The unit was programmed to record minimum and maximum temperature on each day. The minimum and maximum temperatures for each day were then partitioned into 7-d intervals that corresponded to each of the weekly tick count intervals to provide weekly mean minimum, maximum, and overall mean temperatures throughout the study. Rainfall data were obtained from a standard rain gauge maintained at the study site, and the total rainfall that occurred during each 7-d interval that corresponded to each of the weekly tick count intervals during the study was determined.

Before the study was begun, both pastures were artificially infested with *R. (B.) microplus* ticks by placing 4 bovines that had been infested multiple times with larvae (approx. 15,000 total) on each pasture and allowing the cattle to range freely across the pasture as the ticks reached repletion and detached from the animals naturally. Animals were then maintained on the pastures for a period of approx. 6 mo. to allow the tick populations to develop and stabilize naturally. After this time period, and prior to treatment, these animals were removed from both pastures. The ticks used to produce the field populations were obtained from a laboratory-reared colony that had never been exposed to or challenged with any acaricidal agents, and laboratory bioassays conducted prior to study initiation demonstrated that the ticks were susceptible to all classes of acaricides.

On 15 January, when tick infestations within the pastures were deemed suitable for testing, 7 naïve heifer calves (4 Hereford and 3 Angus, each weighing approx. 220 kg) were placed in each of the 2 pastures. Working pens and squeeze chutes were installed in each pasture, so that cattle could be gathered, handled, and data collected that enumerated standard (≥ 5 mm in size) engorging female ticks present on each animal. Calves within 1 pasture were assigned as the untreated control group, hereafter designated as the UG (Untreated Group), and calves within the other pasture were assigned as the treated group, hereafter designated as the TG (Treated Group). Calves within each pasture were then allowed to range freely for a period of 28 d to acquire ticks and to establish viable infestations on each animal. Beginning on 12 February, cattle in both pastures were gathered for 5 consecutive weekly intervals to obtain pretreatment tick count data on each animal within each pasture prior to application of ear tags on the TG cattle. At each pretreatment tick count, an index of the number of ticks present on animals within each pasture was determined by counting the total number of engorging female ticks that were ≥ 5 mm in size on the entire left halves of the bodies of each animal. The criteria for counting only ticks of this size was based on information reported by Wharton and Utech (1970) stating that ticks of this size would detach within 24 - 48 h, thus providing an indication of the number of viable ticks that would likely return to the pasture to sustain the field population of ticks.

The study was designed for a 40-wk (280-d) evaluation period because this is the length of time prescribed in regulations of the CFTEP for a standard long-quarantine period when cattle are maintained on a known tick-infested premise. Thus, the study extended from 11 March (Week 0) through 17 December (Week 40). After tick counts were made at the last weekly pretreatment interval (Week 0; 11 March), a single XP 820™ cattle ear tag (Y-Tex Corp., Cody, WY) was placed in each ear (2 tags per calf) of each of the TG cattle, according to the label recommendation. Label recommendation also specified that the limit of control activity of the tags was 2 - 3 mo (approx. 8 - 12 wks). Therefore, new ear tags were applied to the TG cattle at each 10-wk interval (approx. every 2.5 mo) throughout the study, such that new tags were applied at Week 0, 10, 20, and 30 of the 40-wk evaluation period. Each ear tag contained 8% abamectin and also was impregnated with 20% piperonyl butoxide, which synergized the abamectin for maximum pesticidal activity. Ear tags were attached between the two medial cartilage ribs of the ear with a Y-Tex® Ultratagger™ application gun. Beginning at 1 wk (19 March) following the initial application of the ear tags on the TG cattle (19 March) and continuing for 40 consecutive weekly intervals, animals in both pastures were gathered and an assessment of the number of ticks on each animal was conducted. At each weekly gathering the entire left side of each animal in each pasture was carefully inspected and the total number of female ticks that were ≥ 5 mm in size were counted and recorded, as described above.

To provide insight into the efficacy of the ear tags at each weekly tick count interval, data obtained from the pretreatment tick counts and each of the 40 weekly post-treatment tick counts were subjected to 2 calculations. First, to estimate the percentage control of ticks on the TG cattle at each weekly interval, tick count data were subjected to Abbott's formula (Abbott 1925). Second, to estimate the percentage survival of ticks on the TG cattle at each weekly interval, tick count data were subjected to the following formula:

% Tick Survival = (tick count on TG cattle at a given week / ETNTGIU) X (100)

Where: ETNTGIU = Expected tick number on treated group if left untreated = ((total pre-treatment tick count on TG cattle / total pretreatment tick count on UG cattle) X tick count on UG cattle at a given week)

Whereas weekly tick counts provided a method of evaluating the effect of ear tag treatment on the TG cattle versus the UG cattle throughout the study, they did not assess the presence and/or relative abundance of ticks remaining in the field. Therefore, untreated sentinel cattle, consisting of 2 animals per pasture, were placed in each pasture at regular intervals during the study to provide insight into the density of ticks remaining in the field. Sentinel animals were allowed to range freely with the other cattle (UG and TG) for a period of 2 wks (14 d). After the 2-wk interval in the respective pastures, all sentinel animals were removed from each pasture (before any detachment of female ticks had occurred) and placed individually in 3.3 × 3.3 m stalls inside an open-sided barn. The sentinel cattle were then held for 28 d, during which all engorged females that detached were collected daily, counted, and recorded. A total of 4 groups of sentinel animals were used in each pasture during the study. The first group of sentinel animals was placed in each of the 2 pastures at Weeks 5 - 7 (15 April – 29 April) after TG cattle were initially tagged. Subsequently, a new group of sentinel cattle was placed in each pasture at 10-wk intervals throughout the remainder of the study. Thus, the second, third, and fourth group of sentinel animals were placed in each pasture at Week 15 - 17 (24 June – 8 July), Week 25 - 27 (2 September – 16 September), and Week 35 - 37 (11 November – 25 November), respectively, following the initial application of ear tags on the TG cattle.

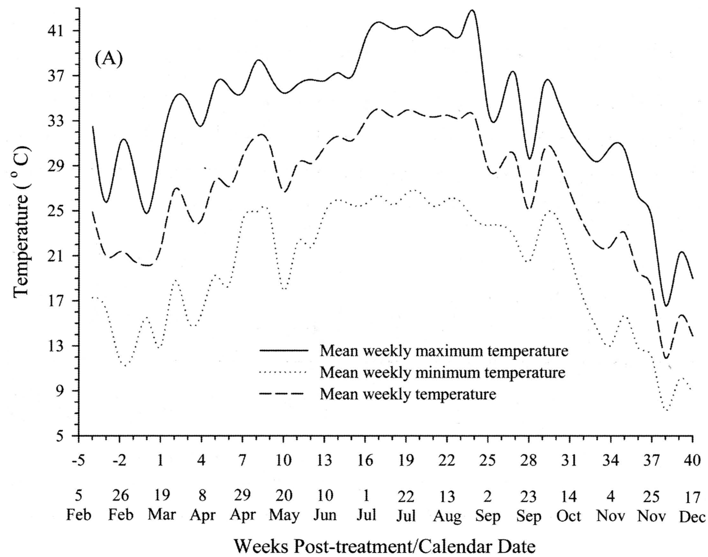
Once all tick count data from UG and TG cattle at each weekly interval were obtained, they were subjected to *t*-test analysis to determine differences between the two groups throughout the study (Systat Software 2009 - 2010). Tick count data from each of the 4 sets of sentinel cattle were first subjected to *t*-test analysis to determine differences between cattle held in the UG pasture and cattle held in the TG pasture for each group (Systat Software 2009 - 2010). Then data within each treatment group were subjected to 1-way analysis of variance (ANOVA) to determine differences in tick number through time (Systat Software 2009 - 2010).

Results

Temperature and rainfall means obtained at each weekly interval throughout the study are illustrated in Fig. 1. Mean temperatures during the first 11 weeks of the study (19 March through 27 May) ranged from 21 - 32°C, with maximum mean temperatures of 30 - 38°C. Between Week 12 (3 June) and Week 18 (15 July) mean temperatures increased to 29 - 34°C, with average maximum temperatures of 37 - 41°C. The highest mean temperatures observed during the study occurred between Week 19 (22 July) and Week 24 (27 August), reaching > 33°C throughout the 6-wk period, whereas maximum mean temperatures were 40 - 42°C throughout the period. From Week 25 (2 September) through Week 35 (11 November) mean temperatures decreased, ranging from 22 - 30°C, and maximum temperatures of 29 - 37°C. In the final 5 weeks (Week 36; 18 November through Week 40; 17 December) mean temperatures were the lowest of the study (12 - 20°C), with maximum mean temperatures of 17 - 26°C. Weekly rainfall totals showed substantial rain during May-June. Subsequently, during the last 16 wks of the study (2 September through 17 December) measurable rain occurred during 13 of the 16 weekly intervals, with substantial peaks occurring in September, October, and December (Fig. 1B).

Results of the 5 weekly pretreatment tick counts (Week -4; 12 February through Week 0; 11 March) showed all cattle, in both pastures, were harboring active infestations of *R. (B.) microplus* at the time ear tags were applied to TG cattle (Fig. 2). Analysis of the pretreatment tick counts showed no differences ($P > 0.05$) in the mean number of ticks infesting the 2 groups of cattle (UG and TG). Thus, it appeared that at the time the tags were applied (Week 0; 11 March) the infestation level of the TG was equal to, if not greater than, that of the UG.

During the first 11 posttreatment weekly tick counts (19 March through 27 May), the mean tick numbers on calves in both pastures (UG and TG) remained > 25 ticks per animal, except on Week 3 (1 April) and Week 4 (8 April), when tick numbers on UG cattle showed an unexplained and significant ($P < 0.05$) decrease (< 10 tick per animal), as compared with TG cattle (Fig. 2). Otherwise, there were no differences ($P > 0.05$) in mean tick numbers between the 2 groups. The percentage control of ticks



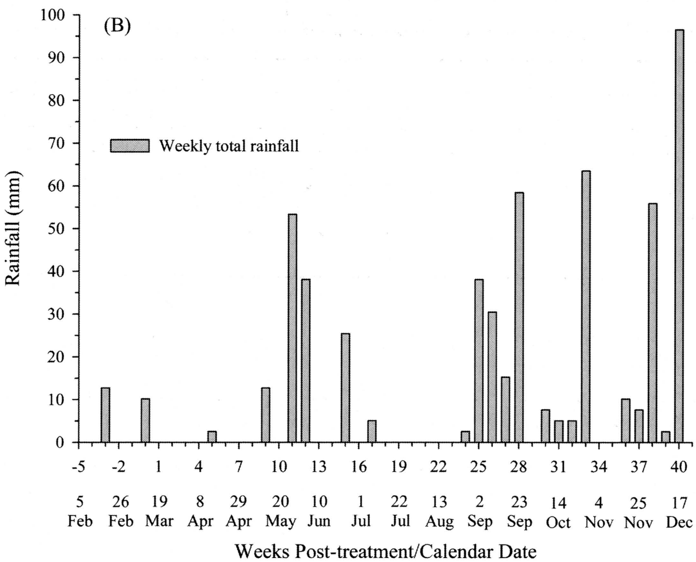


Fig. 1. Mean weekly maximum, minimum, and overall mean temperature (A) and total weekly rainfall (B) during a 40-wk period where untreated cattle and cattle treated continuously with XP 820 ear tags were held in separate pastures during the study.

on the TG at all intervals was ≤ 50.8%, and 7 of the 11 intervals showed 0.0% control during this time period (Table 1). Conversely, the percentage survival of ticks on TG animals during the first 11 wks was > 60% in 9 of the 11 weekly tick counts, meaning

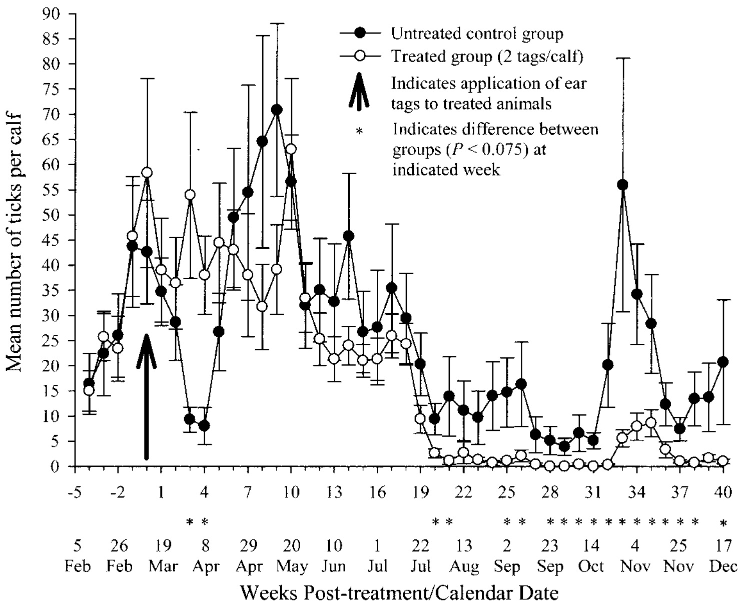


Fig. 2. Mean (±SEM) number of female *Rhipicephalus (Boophilus) microplus* (≥ 5 mm in size) counted on one side of each animal at weekly intervals on untreated calves maintained in one infested pasture and calves treated with XP 820 ear tags (1 tag in each ear) maintained in another infested pasture during a standard 9-mo (40-wk) quarantine period.

that the majority of the ticks on the TG animals returned to the pasture to sustain the field population.

Between Week 12 (3 June) and Week 19 (22 July), the mean number of ticks on cattle in both pastures (UG and TG) was lower than was observed during the initial 11 wks (Fig. 2). The mean number of ticks on UG calves was ≥ 27 on 7 of the 8 intervals, whereas the remaining interval (Week 19; 22 July) produced 20 ticks per animal. Conversely, the mean number of ticks per calf counted on TG calves during this 8-wk period ranged from 9 - 26 ticks per animal, but was ≤ 25 ticks per animal on 7 of the 8 counting periods. However, analysis at each weekly interval during this period showed no differences ($P > 0.05$) in the mean number of ticks per animal between groups (UG and TG). The lower numbers of ticks on the UG, as compared with the first 11 wks, coupled with the increase in temperature, suggested that both temperature and the presence of the ear tags were factors in the decline of the TG tick numbers during this 8-wk period. Whereas the percentage control of ticks on TG cattle during these 8 wks was always < 55%, there were no instances of 0.0% control, as was frequently observed during the first 11 wks (Table 1). The percentage survival of ticks in the TG between Week 12 and Week 19 was > 65% on 5 of the 8 count intervals, with a low percentage survival rate of 41.6% (Week 19; 22 July). Again, for the most part, this reflected that a majority of the ticks on TG animals were returned to the pasture each week to sustain the population.

Table 1. Percentage control and survival of ticks at 40 weekly intervals (calendar dates shown) after XP 820 ear tags were applied to cattle (2 tags/animal) maintained in a pasture infested with *Rhipicephalus (Boophilus) microplus*, as compared with untreated cattle held in a separate tick infested pasture.

Wk posttreatment	Date	% Tick Control*	% Tick Survival**
1	19 Mar	0.0	100
2	25 Mar	0.0	100
3	1 Apr	0.0	100
4	8 Apr	0.0	100
5	15 Apr	0.0	100
6	22 Apr	13.0	78.2
7	29 Apr	30.2	62.8
8	6 May	50.8	44.2
9	13 May	44.8	49.6
10	20 May	0.0	100
11	27 May	0.0	93.8
12	3 Jun	27.7	65.0
13	10 Jun	34.9	58.6
14	17 Jun	47.5	47.2
15	24 Jun	21.3	70.7
16	1 Jul	22.8	69.4
17	8 Jul	26.8	65.8
18	15 Jul	17.3	74.3
19	22 Jul	53.7	41.6
20	29 Jul	72.3	24.9
21	5 Aug	92.1	7.1
22	13 Aug	75.7	21.8
23	19 Aug	86.6	12.1
24	26 Aug	95.0	4.5
25	2 Sep	92.5	6.7
26	9 Sep	87.1	11.6
27	16 Sep	93.7	5.7
28	23 Sep	100	0.0
29	30 Sep	100	0.0
30	7 Oct	93.9	5.5

Table 1. Continued

Wk posttreatment	Date	% Tick Control*	% Tick Survival**
31	14 Oct	100	0.0
32	21 Oct	98.5	1.3
33	28 Oct	90.0	9.0
34	4 Nov	76.9	20.8
35	11 Nov	69.6	27.3
36	17 Nov	73.2	24.1
37	25 Nov	86.5	12.1
38	2 Dec	94.8	4.7
39	10 Dec	88.3	10.5
40	17 Dec	95.2	4.3

* % Tick Control = ((Number of ticks on untreated calves – Number of ticks on treated calves) / Number of ticks on untreated calves) X 100.
** % Tick Survival = ((Mean pretreatment tick count on untreated calves X weekly tick count on treated calves) / (Mean pretreatment tick count on treated calves X weekly tick count on untreated calves)) X 100.

Analysis of tick numbers on the 2 groups of cattle from Week 20 (20 July) through Week 31 (14 October) showed that TG cattle had substantially fewer ticks per animal than UG cattle at all intervals, and differences were significant ($P < 0.075$) on 8 of the 12 tick count intervals (Fig. 2). Weekly tick counts obtained from cattle in both pastures during this period were considerably lower than counts obtained during the first 19 wks, ranging from 4 - 16 ticks per animal in the UG and 0 - 3 ticks per animal in the TG. The lower tick numbers obtained from UG cattle, coupled with the fact that the highest temperatures of the study were observed during this period (Fig. 1A), again suggested that the decline in tick numbers was, to some extent, temperature related. However, because the decline in number of ticks on TG cattle during this time was significantly greater than for UG cattle in a majority of intervals, results suggested that the presence of ear tags on TG cattle may have had an additive adverse effect on the ticks beyond the attrition caused by the high temperatures. The percentage control of the ticks during this 12-wk period remained > 72% at all weekly intervals and exceeded 86% control in 10 of the 12 intervals, whereas providing 100% control on 3 occasions (Table 1). Consequently, the percentage survival of the ticks on the TG cattle during the period was always < 25%, and was < 10% in 7 of the 12 weekly intervals, thus showing that a low percentage of ticks were returned to the field to sustain the population.

Tick count data obtained during the final 9 wks of the study (Week 32; 21 October through Week 40; 17 December) perhaps provided the best evidence of the efficacy of the ear tags in suppressing ticks on TG cattle. During this time period, substantially fewer ticks were counted on TG cattle than on UG cattle at all intervals, and differences were significant ($P < 0.075$) in 8 of the 9 weekly counts (Fig. 2). In the UG cattle, tick counts rebounded dramatically during this period, averaging ≥ 13 ticks per animal, except for 1 interval which produced 7 ticks per animal (Week 37; 25 November). In fact, during the 4-wk period between Week 32 (21 October) and Week 35 (11 November) tick counts were strikingly higher than all counts obtained throughout the final 21 wks of the study (Week 20; 29 July through Week 40; 17 December), averaging 20 - 56 ticks per animal. In stark contrast, tick counts on the TG cattle remained at ≤ 3 ticks per animal, except for the 3-wk period between Week 33 (28 October) and Week 35 (11 November), when tick counts increased slightly to 6 - 9 ticks per calf. Percentage control of ticks during the final 9 wks was > 86%, except during the 3-wk interval between Week 34 (4 November) and Week 36 (18 November), when control was 69.6 - 76.9% (Table 1). Conversely, tick survival remained > 28%, with 5 intervals producing a survival rate of ≤ 10.5%, showing that a low percentage of ticks were returned to the pasture to sustain the population.

The mean number of ticks recovered from cattle in each of the 4 groups of sentinel calves placed in each pasture (UG and TG) at various intervals during the study is shown in Table 2. The first set of sentinel cattle was placed in each of the pastures at 5 - 7 wks after the application of the ear tags (15 April through 29 April). Sentinels placed with UG cattle produced 11,847 ± 1206 ticks per animal, whereas those placed with TG cattle produced 4,511 ± 650 ticks per calf, which was the highest number of ticks recovered from all sentinel groups placed in each respective pasture during the study. Although tick numbers on sentinel cattle placed with UG cattle was approx. 2.6-times greater than the number recovered from sentinels placed with the TG cattle, statistical analysis showed no difference ($P > 0.05$) between the 2 groups.

Whereas the second group of sentinel animals, placed in each pasture (UG and TG) at 15 - 17 wks after application of ear tags (24 June through 8 July), both produced fewer ticks than the first set of sentinels, the numbers still remained high in both pastures (Table 2). Analysis again showed no difference ($P > 0.05$) in tick numbers between sentinels placed in the UG pasture (8,008 ± 867 ticks per calf) and those placed in the TG pasture (4,129 ± 287 ticks per calf), although sentinels in the UG pasture still produced 1.9-times more ticks than sentinels in the TG pasture. The decline in tick numbers obtained from sentinels in the UG pasture was consistent with the decline observed during weekly tick counts on the UG cattle during the same time period, which supported the assumption that the higher temperatures at this time were responsible, at least in part, for the decline in ticks beyond the control afforded by the ear tag treatment.

The third group of sentinel cattle, placed in pastures at 25 - 27 wks (2 September through 16 September) after application of ear tags, produced the fewest number of ticks of all sentinel groups placed in each respective pasture (Table 2). Comparison of the third sentinel group in each pasture with the second sentinel group in each pasture showed a 76.8% decrease in tick numbers in the sentinels in the UG pasture, whereas the decrease in tick numbers on sentinels in the TG pasture was 99.5%. However, even though sentinels in the UG pasture produced approx. 93-fold more ticks (1855 ± 440 ticks per calf) than sentinels in the TG pasture (20 ± 0 ticks per calf), there was no difference ($P > 0.05$) in tick numbers between the 2 groups. Once again, the decline in tick numbers on cattle in the UG pasture was consistent with the decline observed on UG cattle during weekly counts at the same time period, thus supporting the assumption that the higher temperatures at this time were a factor in the dramatic decline. However, the proportionately greater reduction in tick numbers on cattle in the TG pasture supported the assumption that ear tags produced an adverse effect beyond the natural attrition caused by higher temperatures.

Table 2. Mean (± SEM) number of engorged female *Rhipicephalus (Boophilus) microplus* per calf recovered from sentinel calves placed in pastures at various intervals with untreated calves and calves treated with XP-820 ear tags (2 tags/calf) during a 40-wk evaluation period.

Group No.	Calves in pastures at indicated weeks after ear tag application	Inclusive dates calves were in the pastures	Mean no. of female ticks recovered from calves held with indicated treatment group		Results of Paired *t*-test on untrted and trted grp
			Untreated	Treated	
1	5 - 7	15 Apr - 29 Apr	11847 ± 1206 a	4511 ± 650 a	NS
2	15 - 17	24 Jun - 8 Jul	8008 ± 867 b	4129 ± 287 a	NS
3	25 - 27	2 Sep - 16 Sep	1855 ± 440 c	20 ± 0 b	NS
4	35 - 37	11 Nov - 25 Nov	8390 ± 448 b	137 ± 105 b	*

Means within Column 4 and Column 5 followed by the same letter are not significantly different ($P > 0.05$); Tested by 1-way ANOVA; Differences among means were determined by the Holm-Sidak all pairwise method.

Column 6: Paired *t*-test comparison between untreated and treated within each sentinel group; NS indicates no significance ($P > 0.05$); * indicates difference ($P < 0.05$) between groups.

The fourth group of sentinel cattle, placed in the pastures at 35 - 37 wks (11 November through 25 November) after application of ear tags, produced increases in tick numbers in each of the pastures, as compared with the third group of sentinels, although cattle in the UG pasture produced significantly ($P < 0.05$) more ticks (8,390 ± 448 ticks per animal) than sentinels placed in the TG pasture (137 ± 105 ticks per animal) (Table 2). The dramatic rebound in tick numbers obtained from cattle in the UG pasture was slightly higher than the number recovered from the second group of cattle placed in the UG pasture. On the other hand, even though cattle in the TG pasture produced more ticks than the third set of TG sentinels, nevertheless, the numbers were far below the number recovered from the first 2 groups of sentinels placed in the TG pasture.

Analysis of the 4 groups of sentinel cattle placed in the UG pasture across the 4 time intervals showed significant ($P < 0.05$) decreases in tick numbers for each of the first 3 sentinel groups, whereas numbers of ticks recovered from the fourth group of cattle was not significantly ($P > 0.05$) different from that of the second group of sentinel animals (Table 2). Analysis of the 4 sentinel groups in the TG pasture at the 4 intervals showed no difference ($P > 0.05$) in tick numbers recovered from the first 2 sentinel groups placed in the pasture during the first half of the study. Similarly, there also was no difference ($P > 0.05$) in tick numbers recovered from the third and fourth group of sentinel cattle placed in the pasture during the last half of the study. However, significantly ($P < 0.05$) more ticks were recovered from the first 2 groups than were recovered from the last two groups placed in the TG pasture.

Discussion

Results of the study demonstrated that the efficacy of the XP 820 ear tags was influenced by several factors that operated both independently and in combination with each other, making assessment of the efficacy of the ear tag treatment complex. The 3 factors that appeared to have the greatest impact on efficacy of the treatment were (1) the temperature at different periods during the study, (2) the intensity of the tick challenge to which cattle were subjected at a given time, and (3) the timing of the application of the ear tags to the treated cattle.

Temperatures during the study were consistent with historical records, as well as previous studies reported for the area (National Oceanic and Atmospheric Administration 1983, Davey et al. 1994). Weekly rainfall totals, showing peaks in May-June and September-October, also compared favorably with peak rainfall reported for the region (Everitt and Alaniz 1982). Thus, the impact of weather, as it related to the efficacy of these ear tags, could be expected to produce similar results anywhere within the South Texas region where these ear tags were applied.

The high tick numbers, low percentage of control, and high percentage of tick survival during the first half of the study (11 March through 22 July) was influenced, in large part, by 2 interacting factors. First, the study was initiated precisely during the time of year that the phenomenon known as the "spring rise" in tick density occurred. This annual phenomenon takes place in the spring of the year, which in South Texas occurs in March to midJune, during which the tick population generally attains maximum density as a result of the delayed hatch of overwintered eggs and increased activity of larvae that have survived from the previous fall and winter when climatic conditions curtailed tick development and activity (Snowball 1956). The second factor that influenced high tick numbers and low percentage control during the first half of the study was the moderate temperatures that occurred during this time, which provided optimum conditions for tick fecundity and survival. Previous investigations reported mean temperature ranges between 20 and 30°C, with maximum temperatures of < 35°C, were optimum for fecundity, fertility, and survival of the cattle fever ticks (Davey 1988), and that the highest egg production and hatch rate of eggs occurs between March and June in South Texas (Davey et al. 1994). As a consequence of the relatively high tick numbers on TG cattle during the first 19 wks, which produced no significant differences as compared with untreated cattle, any adverse impact afforded by the ear tags was not readily apparent. However, tick counts obtained from the first 2 groups of sentinel cattle, placed in the pastures at 5 - 7 and 15 - 17 wks after ear tags were applied, indicated that the presence of the ear tags on TG cattle may, in fact, have had an adverse impact on ticks in the TG pasture. Considering that all pretreatment tick counts indicated the tick populations in both pastures were similar at the initiation of the study, the fact that the first 2 groups of sentinel cattle placed in the UG pasture produced approx. 2 times more ticks than sentinel cattle placed in the TG pasture strongly implied that the presence of the ear tags on the treated cattle had a mitigating effect on the tick population in the TG pasture, otherwise tick numbers on sentinel cattle in the TG pasture would have been much higher.

Similarly, low tick numbers, high percentage control, and low percentage survival of ticks during the last half of the study (29 July through 17 December) was again influenced by temperature. The peak in temperatures during August and September resulted in a dramatic natural decline in the tick populations, as reflected by the decline in tick numbers in the UG cattle and sentinel cattle placed in the UG pasture during this time period. Again, these results compared favorably with previous studies that reported mean temperatures > 30°C, with maximum temperatures exceeding 40°C, which was the case throughout August and September, were highly detrimental to the fecundity, fertility, and survival of the cattle fever ticks (Davey 1988), producing the lowest egg production and egg hatch of the year during July-September in South Texas (Davey et al. 1994). However, unlike results in the first half of the study, the decline in ticks on the TG cattle was frequently significantly greater than that of the UG cattle during the last half of the study. This indicated that the presence of ear tags on the TG cattle magnified the decline in tick numbers to an extent that was well beyond the natural attrition caused by the high temperatures. Furthermore, the presence of the ear tags on the TG cattle prevented the tick numbers from rebounding to previous high levels during the last 8 wks of the study when temperatures were more conducive for tick survival, as was observed in the UG cattle and the fourth sentinel group placed in the UG pasture.

Because results of the study indicated that temperature played a substantial role in the suppression capability of the XP 820 ear tags against ticks on the animals, it emphasized that the timing of the application of the ear tags would be critical to the level tick suppression that could be expected. Application of ear tags in the winter, spring, or early summer months (December through midJune), when tick populations generally attain maximum density levels in the field, would almost certainly result in a very low and/or unapparent suppression of the ticks, at least in the short-run. On the other hand, application of ear tags in the summer through midfall months (July through October), when the high temperatures have caused a dramatic natural decline in the tick population, would very likely result in a high-level suppression of the ticks. Thus, the application of the XP 820 ear tags in the summer or early fall would control a high percentage of the ticks on the animals, thereby preventing a high percentage of the ticks from returning to the pasture as a source for sustaining the field tick population. Consequently, during the subsequent "spring rise," when temperatures are again conducive to tick survival, the risk of having a massive increase in tick numbers that would normally occur would be much less likely.

From the perspective of the potential for use of XP 820 ear tags in the CFTEP, whereas the ear tags would not eradicate a natural tick population, nevertheless, their use, in a timely manner, would likely reduce the tick population. If the ear tags were applied at the proper time (summer through early fall) the use of this treatment technology, as a means of suppressing cattle fever ticks, could certainly be beneficial by reducing the risk of dispersing ticks into uninfested areas resulting from the unrestricted movement of wild ungulate hosts. Also, if the timing of ear tag application was carefully coordinated, it would likely prevent the massive build-up of the tick population to unmanageable levels prior to the implementation of traditional systematic dipping procedures. In addition, use of carefully timed applications of the ear tags would have distinct advantages over other suppression technologies, such as antitick vaccines, because they provide immediate and long-lasting effects and they target not only cattle fever ticks, but flies, ear ticks, lice, and mites. By contrast, vaccines require 2 or more months to become effective, provide comparatively short-term protection during which tick numbers on vaccinated animals increase dramatically between booster treatments, and they are highly specific for control of only cattle fever ticks (Frisch 1999).

Dedication

The work conducted during this study and data presented in this report are dedicated to the memory of Joe D. Kellerby, an outstanding friend and colleague. He will be greatly missed.

Acknowledgments

The authors thank Michael G. Moses, Caesar Agado, James K. Hellums, Rueben Ramirez, Jr., and Homero Vasquez (USDA, ARS, CFTRL) for technical assistance, data collection, and maintenance of calves during the implementation of this study. The authors also thank Joe Kellerby (Y-Tex Corp.) for supplying the ear tags and applicator used in the study, as well as providing technical advice.

References Cited

Abbott, W. S. 1925. A method for computing effectiveness of an insecticide. J. Econ. Entomol. 18: 265-267.

Ahrens, A. H. and J. Cocke. 1978. Comparative test with insecticide-impregnated ear tags against the Gulf Coast tick. J. Econ. Entomol. 71: 764-765.

Allan, S. A., N. Barre, D. E. Sonenshine and M. J. Burridge. 1998. Efficacy of tags impregnated with pheromone and acaricide for control of *Amblyomma variegatum*. Med. Vet. Entomol. 12: 141-150.

Cooksey, L. M., R. B. Davey, E. H. Ahrens and J. E. George. 1989. Suitability of white-tailed deer as hosts for cattle fever ticks (Acari: Ixodidae). J. Med. Entomol. 26: 155-158.

Davey, R. B., E. H. Ahrens and J. Garza Jr. 1980. Control of the southern cattle tick with insecticide-impregnated ear tags. J. Econ. Entomol. 73: 651-653.

Davey, R. B. 1988. Effect of temperature on the ovipositional biology and egg viability of the cattle tick, *Boophilus annulatus* (Acari: Ixodidae). Exp. Appl. Acarol. 5: 1-14.

Davey, R. B. 1990. Failure of white-tailed deer, *Odocoileus virginianus* L. to sustain a population of cattle ticks, *Boophilus annulatus* (Say), through successive generations. J. Parasitol. 76: 356-359.

Davey, R. B. 1993. Stagewise mortality, ovipositional biology, and egg viability of *Boophilus annulatus* (Acari: Ixodidae) on *Boselaphus tragocamelus* (Artiodactyla: Bovidae). J. Med. Entomol. 30: 997-1002.

Davey, R. B., J. M. Pound and L. M. Cooksey. 1994. Comparative reproduction and nonparasitic development of *Boophilus microplus* and hybridized *Boophilus* ticks (Acari: Ixodidae) under natural field conditions in subtropical South Texas. Exp. Appl. Acarol. 18: 185-200.

Everitt, J. H. and M. A. Alaniz. 1982. Nutrient content of grasses growing on four range sites in South Texas. USDA, ARS, Agric. Res. Results. ARR-S 11: 20.

Frisch, J. E. 1999. Towards a permanent solution for controlling cattle ticks. Internatl. J. Parasitol. 29: 57-71.

Gladney, W. J. 1976. Field trials of insecticides in controlled-release devices for control of the Gulf Coast tick and prevention of screwworms in cattle. J. Econ. Entomol. 69: 757-760.

Hatch, S. L., K. N. Gandhi and L. E. Brown. 1990. Checklist of vascular plants of Texas. Texas Agric. Exp. Sta., Bull. No. MP-1655. 158 pp.

National Oceanic and Atmospheric Administration. 1983. Climatic atlas of the United States. Wash. D.C.; Reprinted from: U.S. Dept. Commerce, Environ. Sci. Svc. Admin. Environ. Data Svc. (1968). 88 pp.

Owen, I. L. 1985. Field efficacy of ear tags impregnated with insecticide against the cattle tick, *Boophilus microplus.* Aust. Vet. J. 62: 24-25.

Pound, J. M., J. E. George, D. M. Kammlah, K. H. Lohmeyer and R. B. Davey. 2010. Evidence for the role of white-tailed deer (Artiodactyla: Cervidae) in the epizootiology of cattle ticks and southern cattle ticks (Acari: Ixodidae) in re-infestations along the Texas/Mexico border in South Texas – A review and update. J. Econ. Entomol. 103: 211-218.

Putter, I., J. G. MacConnell, F. A. Preiser, A. A. Haidri, S. S. Ristich and R. A. Dybass. 1981. Avermectins: Novel insecticides, acaricides, and nematicides from a soil micro-organism. Experientia 37: 964-965.

Rechav, Y. 1987. Use of acaricide-impregnated ear tags for controlling the brown ear tick (Acari: Ixodidae) in South Africa. J. Econ. Entomol. 80: 822-825.

Snowball, G. J. 1956. Ecological observations on the cattle tick, *Boophilus microplus* (Canestrini). Aust. J. Agric. Res. 8: 394-413.

Systat Software. 2009-2010. SigmaPlot® 11.2 User's guide – Part 2 – Statistics, San Jose, CA.

Wharton, R. H. and K. B. W. Utech. 1970. The relation between engorgement and dropping of *Boophilus microplus* (Canestrini) (Ixodidae) to the assessment of tick numbers on cattle. J. Aust. Entomol. Soc. 9: 171-182.