REGULATING POPULATIONS OF LONE STAR TICKS BY INTEGRATED AND NON-CHEMICAL MEANS

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REGULATING POPULATIONS OF LONE STAR TICKS BY

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PREFACE

Until recently, regulating populations of lone star ticks has been mainly accomplished by the use of persistent pesticides (i.e., chlorinated hydrocarbons). However, with the increasing concern of society with the pollution of environmental resources with persistent toxicants, new short residual insecticides and non-chemical means must be developed to control ticks in our recreational, forested areas, and pastures.

Studies were initiated during the summer of 1967 in the Oak-Hickory woodlots of eastern Oklahoma. The main objective of this investigation was to determine if short residual insecticide (i.e., organophosphate) or vegetative alterations were effective in regulating populations of lone star ticks in woodlots and, or both, recreational areas. Additional observations were conducted in the test sites to ascertain possible differences in temperature, relative humidity and soil moisture which would help evaluate control methods.

Controlled burning was also investigated during the summer of 1970 as a possible method for reducing ticks in wooded areas.

Sincere gratitude is extended to the Oklahoma State Agricultural Experiment Station and the USDA, Entomology Research Division, whose financial contributions made the forementioned research possible. A great deal of indebtedness is owed to Dr. J. A. Hair, Associate Professor, Department of Entomology, who directed the research and gave untold hours in guidance and assistance in developing and completing the research. Appreciation is also extended to Dr. R. D. Eikenbary, Associate Professor; to Dr. W. A. Drew, Professor, and Dr. R. R. Walton, Professor, for serving as graduate committee members and for their constructive criticism in the preparation of this manuscript.

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The lone star tick, Amblyomma americanum (Linnaeus), has a vast range of distribution: east of central Texas to the Atlantic coast; northward to Iowa. Due to their mass numbers and blood-feeding habits on warm-blooded animals in these areas, significant economic losses and annoyance to man are of major consequence. It has recently been reported by Oklahoma entomologists, that 57% of the new-born fawns are lost annually in the Ozark region. Moreover, the potential recreational areas of this region may never be realized until the tick populations can be controlled effectively and economically.

It is well known that in the temperate and tropical regions that ticks surpass all other arthropods in the number and variety of diseases which they transmit to man and his domestic animals. The lone star tick is the vector of such diseases as Rocky Mountain spotted fever, tularemia, Q Fever, lone star virus and Bullis fever.

Previous work on the control of the lone star tick by integrated chemical or mechanical means, or both, was conducted on a limited scale during the summer of 1968. It was felt that additional data and more extensive work should be conducted in this area to determine whether long term control practices would be more effective.

Thus the present research was conducted to: (1) obtain supporting evidence that various mechanical or chemical treatments, or both, of woodlots are effective means of tick regulation; (2) determine those environmental parameters which effect the suitability of the various treatment plots as tick habitats; and (3) evaluate controlled burning as a possible means for tick control.

FURTHER OBSERVATIONS ON THE CONTROL OF LONE STAR TICKS THROUGH INTEGRATED CONTROL PROCEDURES

Little published information is available on integrated control of ticks in woodlots, and until recently the literature was essentially void of published reports on effective, short-lived pesticides that could be used for this purpose without fear of causing heavy mortality of non-target species.

Due to the complex biology and behavioral traits of most tick species, they are extremely difficult to control under woodlot conditions. Factors such as residue of acaricide, host animal utilization of the treated area, and suitability of area as tick habitat determine the long-term effects of specific treatments on a tick infestation. The severity of the lone star tick, *Amblyomma americanum* (L.), problem in Oklahoma has been outlined by Bolte, *et al*. (1970) and Hair and Howell (1970).

Although no longer acceptable for use in recreation areas, DDT has been shown to be effective against the lone star tick in wooded areas (Smith and Gouck, 1944a,b; 1945; McDuffie, *et al*., 1950; George and Stickel, 1949; McKiel, *et al*., 1967). Lindane (U.S. Dept. Agr., 1963, 1966) and other chlorinated hydro-carbons have also produced suitable results when applied for tick control.

Recent papers by Mount, *et al*. (1968), Mount, *et al*. (1970) and Clymer, *et al*. (1970) have demonstrated that a number of organic phosphate pesticides are highly effective against lone star ticks. Mount, *et al.* (1968) reported that a number of these organic phosphate materials were more effective than DDT for control of lone star ticks. In preliminary studies in Oklahoma, Gardona[R] (2-chloro-1 (2,4,5-trichlorophenyl) vinyl dimethyl phosphate) 75% wettable powder was shown to be effective against *A. americanum* when applied directly to woodlot vegetation, or when used on an integrated basis (Clymer, *et al.*, 1970). Beynon and Wright (1969) reported that the half-life of Gardona was about 1 day on the leaves of plants and 4-5 days on medium loam soil. Large scale application of Gardona to recreation areas in Oklahoma has not produced any problems with acute toxicity to birds, fishes or mammals (J. A. Hair, unpublished data).

The present studies were initiated during 1967 by Clymer, *et al.* (1970) to evaluate the long-term effects of various integrated control procedures against the lone star tick. Since their preliminary data were published, another 2 years of data have been collected and the study terminated. A summary and discussion of the 4 year study will be presented in this paper. The use of vegetative alteration for tick control or animal manipulation, or both, was reviewed by Clymer, *et al.* (1970).

Materials and Methods

Three experimental woodlot areas consisting of six 0.45ha plots were established during July, 1967 and maintained on a seasonal basis through the summer of 1970. Plots within each area received various mechanical-chemical treatments to evaluate the potential of integrated procedures for lone star tick control. Detailed methods and procedure for establishing and maintaining these experimental areas were outlined by Clymer, *et al.* (1970). In brief, one of the following treatments was applied to each of the plots in each study area: (1) mechanical clearing of all undergrowth and enough of the larger vegetation to allow penetration of 70-80% sunlight; (2) mechanical clearing as in (1) with the addition of an acaricide; (3) application of an acaricide to existing vegetation; (4) mechanical clearing as in (1) with the addition of a herbicide; (5) application of a herbicide to existing vegetation; and (6) no treatment.

Initial removal of vegetation in mechanically cleared areas was done through the use of hand equipment and chain saws. Seasonal maintenance of these plots was performed with a tractor and mower as required to keep the vegetation at a height of less than 12-14 cm. Herbicidal plots received 2,4,5-T for brush kill as described by Clymer, *et al.* (1970). Follow-up applications of 2,4,5-T were made as needed to suppress all woody-type and broad-leaf vegetation.

Study plots receiving an acaricide were sprayed with Gardona 75% WP at the rate of 1 kg of actual toxicant per ha applied in 8.3 dkl of water. Follow-up applications of Gardona were made as needed to maintain control of all stages of the lone star tick. Applications were generally made every 5-8 weeks in order to suppress populations of nymphs and adults. Gardona was not applied during 1970 to the plots normally receiving an acaricide, nor were estimates of tick populations made.

Flagging surveys were used to estimate tick populations in study areas. A heavy-duty sweep net, 37.5 cm in diam., and a drag flag consisting of heavy-weight white muslin, 90 x 180 cm, attached to a 90 cm dowel were used in estimating tick populations. The sweep net was employed in the usual sweeping method, while the drag flag was pulled behind the person taking the sample.

Each sample area consisted of an area 22.9 m x 90 cm. Four samples were taken at random in each plot, and the average or mean number of ticks per sample was counted or estimated and recorded.

Population counts were taken at 7- to 14-day intervals except when climatic conditions prohibited sampling. Average net seasonal reduction of the various tick stages was determined by comparing tick populations in treated plots during a particular year with the populations existing in the control plots that particular year. Percent net control was calculated by a modification of Abbott's formula:

$$\text{Net \% control} = \frac{\text{No. in control - No. in treated plot}}{\text{No. in control}} \times 100 \quad .$$

All counts from a given treatment during each season were averaged to obtain an average seasonal control value. This was necessary in order to summarize the voluminous quantity of weekly data collected over the 3-year period.

Results and Discussion

Larval Control

Even though herbicidal treatment of woodlots creates an environment that is generally unfavorable for *A. americanum* larvae (Table I), it appeared to be the least effective of all treatments for control of the 3 developmental stages of this tick species. Larval populations in the herbicidal treated plots had been reduced by 82% after the third year of treatment. An additional 7% control was obtained by mechanically clearing woodlots prior to the application of an herbicide.

TABLE I

AVERAGE NET SEASONAL REDUCTION[a] OF LONE STAR TICK LARVAE IN WOODLOTS RECEIVING VARIOUS MECHANICAL-CHEMICAL TREATMENTS DURING 1967, 1968, 1969 AND 1970, CHEROKEE COUNTY, OKLAHOMA

Observations Made	Untreated	Treatment 2,4,5-T	Clear	Clear + 2,4,5-T	Gardona	Clear + Gardona
Year 1 Post-treatment[b]	0	33	47	63	85	93
Year 2 Post-treatment[c]	0	53	72	67	89	96
Year 3 Post-treatment[d]	0	82	85	89	*	*

[a] All observations in a specific treatment for a particular year were averaged to yield this figure.

[b] Six observations; July 23 through September 5.

[c] Eight observations; July 7 through August 27.

[d] Twelve observations; June 23 through September 12.

* Data not collected.

When it is impractical, aesthetically, to apply herbicides to all vegetation (i.e. recreation area), clearing or clearing with herbicides appears to hold promise as a means of suppressing larval development. From data presented in Table I, the feasibility of acaricidal applications to low-use areas that have received mechanical clearing may be questioned. In recreation areas or other high-use areas it would be highly desirable to maintain 100% control of all tick stages. Therefore, one would deem acaricidal treatments in these areas desirable since over 95% control of larvae can be obtained by Gardona treatments applied every 5-6 weeks.

Reasonable control of larval ticks can be obtained in woodlot pastures or areas peripheral to recreation areas by applying Gardona to existing vegetation. Because of reinfestation pressure due to animal utilization of uncleared areas, acaricides offer no long-term solution to the tick problem, whereas clearing may alter the behavior of tick hosts that normally depend on cover for survival.

It is of particular interest to note that plots receiving mechanical clearing, clearing plus herbicide, or only herbicide appear to become less desirable as larval habitat as treatments are continued over a span of years.

In attempts to characterize physical differences between control and vegetatively altered plots and to determine the suitability of such areas as tick habitat, Hoch, et al. (1971a) have shown that herbicidal treatment or removal of vegetation in woodlots results in higher temperatures in the tick habitat, causes a lower relative humidity in the area and reduces the available soil moisture. These workers thus concluded that changes in these parameters following alteration of the environment may be largely responsible for the reduction in tick populations within treated areas. Although actual comparisons were not made Lancaster (1958) felt that improved pastures supported fewer ticks than unimproved pastures with appreciable vegetation.

Based on the data in Tables I, II and III, larvae appear to be less tolerant than adults and nymphs of conditions resulting from habitat modification. It is possible that egg hatchability was low in some of the treated areas since Lancaster (1957) showed that eggs held at humidities below 75% RH failed to hatch. Sauer and Hair (1971) also demonstrated that lone star tick eggs are highly susceptible to desiccation, and it has previously been shown that tick longevity is correlated to relative humidity (Lees, 1946; Feldman-Muhsam, 1947).

Nymphal Control

Whereas the addition of herbicide to mechanically cleared plots appeared to give only slightly greater control of larvae, nymphal populations in cleared areas were apparently affected to a greater extent by removal of broadleaf plants with herbicide (Table II).

Nymphal populations were affected only slightly by herbicidal application to existing vegetation. Since it was noted a fair degree of larval control (Table I) by this treatment, it may be possible that host animals are responsible for the introduction of replete larvae from surrounding untreated areas. Woody vegetation continues to stand in the herbicidal treated areas for a number of years and affords some protection for wild animal hosts.

Equally effective control can be obtained by applying Gardona to existing vegetation as to cleared areas (Table II). The real necessity

TABLE II

AVERAGE NET SEASONAL REDUCTION[a] OF LONE STAR TICK NYMPHS IN WOODLOTS RECEIVING VARIOUS MECHANICAL-CHEMICAL TREATMENTS DURING 1967, 1968, 1969, AND 1970 CHEROKEE COUNTY, OKLAHOMA

Observations Made	Untreated	Treatment				
		2,4,5-T	Clear	Clear + 2,4,5-T	Clear + Gardona	Gardona
Year 1 Post-treatment[b]	0	24	29	73	96	97
Year 2 Post-treatment[c]	0	23	53	48	90	90
Year 3 Post-treatment[d]	0	24	39	58	*	*

[a] All observations in a specific treatment for a particular year were averaged to yield this figure.

[b] Seven observations; May 28 through August 1.

[c] Eight observations; May 28 through August 5.

[d] Seventeen observations; May 8 through September 12.

* Data not collected.

TABLE III

AVERAGE NET SEASONAL REDUCTION[a/] OF LONE STAR TICK ADULTS IN WOODLOTS RECEIVING VARIOUS MECHANICAL-CHEMICAL TREATMENTS DURING 1967, 1968, 1969 AND 1970, CHEROKEE COUNTY, OKLAHOMA

Observations Made	Untreated	Treatment: 2,4,5-T	Clear + 2,4,5-T	Clear	Clear + Gardona	Gardona
	Average Seasonal Reduction					
Year 1 Post-treatment[b/]	0	30	24	52	90	81
Year 2 Post-treatment[c/]	0	12	67	75	89	96
Year 3 Post-treatment[d/]	0	39	54	62	*	*

[a/] All observations in a specific treatment for a particular year were averaged to yield this figure.

[b/] Seven observations; April 30 through July 9.

[c/] Six observations; May 28 through July 7.

[d/] Eleven observations; May 8 through July 29.

* Data not collected.

for acaricidal treatment can be noted when reviewing the data in Tables II and III. It is doubtful that any of the treatments could be as satisfactory for use in high-use areas as an acaricide when large numbers of ticks exist. The data do indicate, however, that the burden to livestock in wooded pastures can be reduced considerably by non-acaricidal means, though not entirely.

Adult Control

Most treatments resulted in greater reduction of the adult than nymphal tick population (Tables II and III). Adults appeared to be little affected by herbicidal application to cleared areas since no greater control was achieved by this combination than was obtained by clearing alone.

Conclusions

On the basis of data collected over a 4-year period, one can conclude that integrated control approaches can considerably reduce all stages of the lone star tick in treated areas. Since larvae are very susceptible to the various treatments, it might be possible to reduce the resident tick population to insignificant numbers within several years. Only the incursion of wide-ranging hosts would re-infest the treated area. However, even if this did occur it may not be possible for new populations to become established since habitat conditions might be unfavorable for eggs and larvae.

The procedures as outlined above might make pesticidal applications necessary only on rare occasions.

MEASUREMENT OF SEVERAL PHYSICAL PARAMETERS TO DETERMINE THE SUITABILITY OF MODIFIED WOODLOTS AS LONE STAR TICK HABITAT

Attempts to correlate the abundance and distribution of the lone star tick with ecological habitat-type and environmental conditions have been made. Bishopp and Trembly (1945) reported that heavier infestations of lone star ticks were usually found in wooded areas as opposed to areas with less dense vegetation. Sonenshine, et al. (1966) offered support to this view by finding that medium deciduous-woody areas had more adult and nymphal ticks than grassy and herbaceous-type areas.

Researchers working on the distribution and abundance of lone star ticks in the Ozark Mountain region have also suggested a relationship between habitat-type and tick distribution. Lancaster (1958) believed that unimproved pastureland with dense brushy vegetation supported higher numbers of lone star ticks than improved pastures, and Semtner, et al. (1971a) found a close correlation between numbers of adult ticks present and the density of the vegetation.

Although several attempts to physically characterize vegetative stand-types as tick habitat have been made (Lancaster 1955, 1957), it was concluded that the data from preliminary observations presented by Lancaster were not sufficient to allow one to adequately analyze the control results obtained by Clymer, et al. (1970) and Hoch, et al. (1971a) from vegetatively modified woodlots.

Since Clymer, et al. (1970) and Hoch, et al. (1971a) showed distinct differences in tick population numbers in woodlots receiving different mechanical or chemical treatments, or both, it was assumed that field populations of lone star ticks would be regulated to a great extent by such factors as temperature, soil moisture and relative humidity.

Numerous laboratory studies have been conducted on the effects of relative humidity and temperature on various species of ticks. The value of laboratory studies is limited because under field conditions many other factors, including unrestricted behavior, may influence the survival and behavior of an organism. On the other hand, certain laboratory data have helped to establish that low humidities or high temperatures are very important to the survival and longevity of various tick species. For example, the southern cattle tick, Boophilus microplus (Canestrini) appears to oviposit a maximum number of eggs when held within a temperature range of 24 to 26.5°C and egg laying diminishes at temperatures above or below this range (Hitchcock, 1954). This worker also noted that a 2 hr exposure to a temperature of 52°C resulted in a mortality rate of ca. 92%.

Hyalomma savignyi Gerv. larvae held at 17.5°C and 20% RH had a mean life span of 13.7 days, whereas at the same humidity and higher temperatures, survival time was greatly reduced. Rhipicephalus sanguineus (Latreille) females apparently have a "preferred" temperature range since higher mortality occurred at 5 or 15°C than at 10°C. Temperatures above 35°C and below 15°C were not suitable for egg production (Sweatman, 1967).

Perhaps the proper relative humidity is more important than the proper temperature to the survival and longevity of ticks. Observations on the influence of relative humidity on the various life stages of the lone star tick have been made by a number of researchers (Sonenshine and Tigner, 1969; Lancaster and McMillan, 1955; and Sauer and Hair, 1971). These studies indicate that lone star tick eggs fail to hatch when held below a specific relative humidity (Sonenshine and Tigner, 1969; Lancaster and McMillan, 1955; and Sauer and Hair, 1971), and that the Critical Equilibrium Humidity (C.E.H.) for adults is ca. 85% RH (Sauer and Hair, 1971). These data suggest that low humidities desiccate the eggs and that it is necessary for unfed adults and probably other stages as well to periodically "seek out" and find temperatures of sufficiently high relative humidity to insure survival.

The critical equilibrium humidity varies from species to species of tick (Knulle, 1965). Larvae of Dermacentor variabilis (Say) held at 53 and 60% RH died within 5 days, while larvae of Amblyomma cajennense (Fabricius) survived longer than 6 days under the same conditions.

Clymer, et al. (1970) and Hoch, et al. (1971) suggested that the marked reduction of ticks obtained in vegetatively altered woodlots was due to changes in the physical environment. Parameters such as exposure to radiation, temperature, relative humidity and soil moisture change considerably after habitat modification. The objective of this study was to characterize vegetatively altered woodlot plots as to existing temperatures, relative humidity, and soil moisture and to compare the findings with those of undisturbed woodlots. In addition, it was desired to correlate changes of these parameters with tick abundance within the study areas.

Materials and Methods

The vegetatively altered woodlot plots used as study areas were set up and maintained from 1967-70 (Clymer, et al., 1970; Hoch, et al., 1971). Although procedures for establishment and maintenance have been given by the above workers, a short resume of treatments follows.

Two experimental woodlot areas consisting of six 0.45ha plots were established in Cherokee Co., Oklahoma during July of 1967 in order to evaluate a number of integrated treatments on lone star tick populations. Within each of the 2 woodlot areas the following treatments were applied: (1) mechanical clearing of undergrowth and enough of the larger vegetation to allow for 70-80% sunlight penetration; (2) mechanical clearing as in (1) with the addition of a herbicide; (3) application of an herbicide to existing vegetation; (4) no treatment; and (5) and (6) involved the use of acaricides, but these 2 treatments were not pertinent to this study.

The flagging method described by Clymer, et al. (1970) was used to estimate tick populations in the study areas so that comparisons could be made between tick abundance and the physical characteristics to be measured in this study.

Within plots receiving the treatments outlined above (treatments 1-4), 3 physical parameters, including temperature, relative humidity and soil moisture, were measured weekly in order to determine the influence of habitat modification on these parameters and in turn to determine the relative importance of these parameters in maintaining tick populations within woodlots.

Relative Humidity Determinations

Relative humidity measurements were taken at 3 elevations in each plot under study in the 2 experimental woodlot areas from May 27 through September 12, 1970. An Atkins^R Psychometer[1] (Figure 1,A) was employed to measure the RH at the following heights: (1) soil surface; (2) 15.2 cm above soil surface; and (3) 45.7 cm above the soil line. Measurements were made at 3 different randomly selected sites in each plot on a weekly basis, and an average weekly value for each height was derived by averaging the 3 readings in each plot. Weekly readings collected from the different treatments within the 2 woodlot areas were averaged in order to minimize area differences.

Temperature Measurements

Temperature measurements were taken in the 2 study areas on a weekly basis and were made at the same time that the relative humidity data were collected. A YSI Teletherometer^R [2] with a 6 channel probe system (Figure 1,B) was used to measure the temperature simultaneously at 6 different elevations. Five replicates of temperature readings were made in each plot and averaged to get a weekly temperature measurement at each of the 6 different heights. Temperature readings from the 2 different woodlot areas were averaged to get replicated temperature values for each treatment.

Temperature readings were taken in each plot at the following levels: (A) 2.5 cm below soil surface; (B) soil surface; (C) 15.2 cm

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[1]Cole Parmer Instrument Co., 7425 No. Oak Park Ave., Chicago, Ill.

[2]Yellow Springs Instrument Co., Inc., Yellow Springs, Ohio.

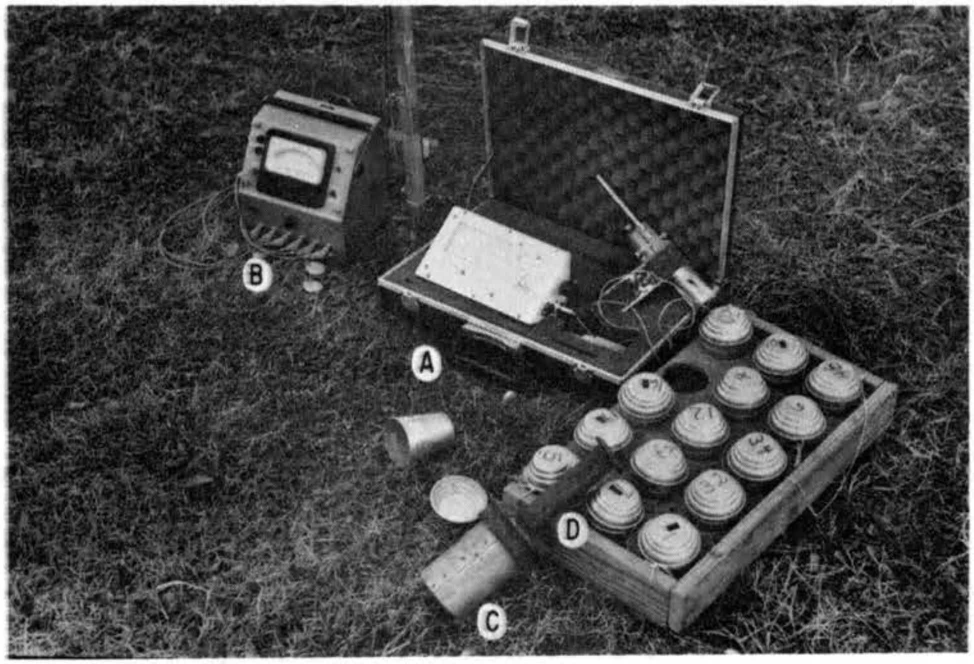

Figure 1. Equipment Used for Determining the Physical Environment in Experimental Study Areas. (A) Atkins[R] Psychometer; (B) YSI Telethermometer[R]; and (C-D) Soil Sampler.

above soil level; (D) 30.5 cm above soil surface; (E) 45.7 cm above soil surface; and (F) 60.9 cm above soil surface.

Soil Moisture Determinations

Soil samples were collected from each plot within the 2 study areas in order to determine the influence of habitat modification on available soil moisture. Three samples were taken from each plot within the 2 study areas. A soil sampler was fabricated of 22 ga. galvanized metal. During sampling, a cylinder (Figure 1,C) 11.2 cm x 16.3 cm was forced into the soil ca. 2.5 cm with the aid of a metal driver (Figure 1,D). The samples (ca. 200 gms.) were then transferred to air-tight aluminum containers and transported back to the laboratory for weighing prior to determination of net soil moisture by oven drying the samples.

After recording the wet weight of the samples, all samples were placed in an oven at 100-107^{o}C and allowed to dry until several successive weighings of each sample showed no appreciable loss in weight. Net percent moisture was calculated by a modification of Abbott's formula:

$$\text{Net percent moisture} = \frac{\text{wt. of wet-wt. of dry}}{\text{wt. of wet}} \times 100$$

Soil moisture averages for each treatment were derived by averaging the 6 soil samples obtained from a given treatment in study areas 1 and 2.

Results and Discussion

Considerable differences in average seasonal temperatures, relative humidities and soil moistures occurred between woodlot plots which had been subjected to various integrated treatments from 1967 through 1970

(Table IV). It is believed that the differences shown between treatments is of major significance in the marked reduction of lone star ticks on a seasonal basis by Clymer, et al. (1970) and Hoch, et al. (1971a).

The average seasonal temperature data in Table IV indicate that plots which had received mechanical clearing plus herbicide had the highest temperature of the various areas treated. An average seasonal difference of 7^{o}C between the soil temperature of the "herbicide + clear" and control plots was recorded while a 3.5^{o}C difference was recorded at the surface of the soil. It is likely that these differences occurred because of the removal of under- and overstory vegetation that allowed more sunlight to penetrate to the forest floor.

Average seasonal temperatures in plots receiving either "herbicide" or "clearing" were approximately the same at all levels measured. However, when mechanical clearing was followed by application of herbicide, an increase in soil temperature of several degrees centigrade was noted as compared to those receiving only "clearing" or "herbicide". The probable explanation for these differences is the fact that many broad-leaf herbaceous plants less than 15 cm high remained in the mechanically cleared plots after mowing and offered some protection in the area from the impinging sun rays and could have helped prevent the evaporation of moisture. On the other hand, when only herbicide was applied to the woodlot area, many grasses (i.e., broom-sedge) grew tall and possibly served to prevent sun rays from reaching the soil surface. When both of these treatments were applied to the same area, broad-leaf plants were controlled and mowing of grasses allowed the sunlight to penetrate to the ground surface. One might assume that this was responsible for

TABLE IV

SEASONAL TEMPERATURE, R.H., AND SOIL MOISTURE AVERAGES IN WOODLOTS RECEIVING VEGETATIVE ALTERATION, CHEROKEE CO., OKLAHOMA, SUMMER 1970

Observation Level (cm)	Treatment			
	Cont.	Herb.	"Herb. + Clear"	Clear
	Temp. (^{o}C.)			
Soil	30.7	34.1	37.3	35.2
Surface	36.0	39.2	40.5	39.2
30.5	33.8	35.2	35.2	34.4
	Relative Humidity			
Surface	55.1	48.7	48.9	51.0
15.2	55.9	52.1	53.4	54.1
45.7	56.6	54.2	55.0	55.8
	Net % Soil Moisture			
Soil	12.3	12.5	9.6	11.0

the higher average seasonal temperatures at the soil and surface levels (Table IV). Very little variation in temperature occurred in the various treatment areas at heights of 30.4 cm or above. For this reason, only data on measurements below a height of 30.4 cm are presented in Table IV.

There was a positive correlation between the relative humidity measurements in the various treatment areas and the temperatures of the soil and soil surface. As expected, the relative humidity in the "herbicide + clearing" treatment area was much lower than in the untreated area. Semtner, et al. (1971b) have reported that undisturbed woodlots usually have a higher relative humidity and lower temperature than unprotected areas such as meadows.

In addition to a lower seasonal relative humidity, soil temperature and soil surface temperatures, the areas receiving "clearing + herbicide" shoed a lower soil moisture content than the other treatments or untreated areas. A reduction of 22% in available moisture could have considerable significance on the development of tick eggs (Lancaster, 1958; Sonenshine and Tigner, 1969; Sauer and Hair, 1971). Hixon (1940) has indicated that Ambylomma maculatum Koch eggs were often deposited directly on the soil surface or within a shallow excavation prepared by the female. Since the behavioral traits of replete lone star females as they relate to oviposition is not known, one can probably assume that the eggs are laid in close association with the soil. In view of previous laboratory studies (Lancaster, 1958; Sauer and Hair, 1971) it appears that hatchability is reduced when the ambient moisture is insufficient. The relationship between soil moisture, relative humidity and egg hatchability under field conditions is an important experiment that should be done in the near future. It is believed that the data presented in Table IV suggest a possible correlation between soil moisture and soil surface relative humidity.

Certain relationships between the 3 parameters discussed above and tick populations seemed to exist in our study areas. Since the "herbicide + clearing" treatment changed the 3 parameters measured the most, it was decided to compare the seasonal distribution of larvae and nymphs in this treatment area with those in the control area. As noted in Figures 2 and 3, populations of nymphs and larvae were greatly reduced in the "herbicide + clearing" plots. Since larval populations appeared to be affected the most, it is possible that low egg hatchability may have been the cause.

These findings have possible significance when considered in conjunction with the reported findings of Lees (1946) and Feldman-Muhsam (1947). Lees (1946) showed that another hard tick, Ixodes ricinus L. lost 50% of its original weight within a period of 24 hrs if kept in an environment of 0% relative humidity, and died with 24 hrs. At 50% relative humidity, only 10% of the original weight was lost per day and the arthropod generally lived for 3-5 days. Rearing in 70% relative humidity caused a 5% weight loss per day and survival increased to 4-8 days. Significantly, ticks survived for 2-3 months at 90% relative humidity. Feldman-Muhsam (1947) noted that Hyalomma savignyi Gerv. ticks survived only a few days at 20% relative humidity and 17.5^{o}C, but were alive after approximately 7 months when held in an atmosphere of 95% relative humidity.

Lees (1946) and Feldman-Muhsam (1947) also suggested that hard ticks are more sensitive physiologically to humidity changes than to

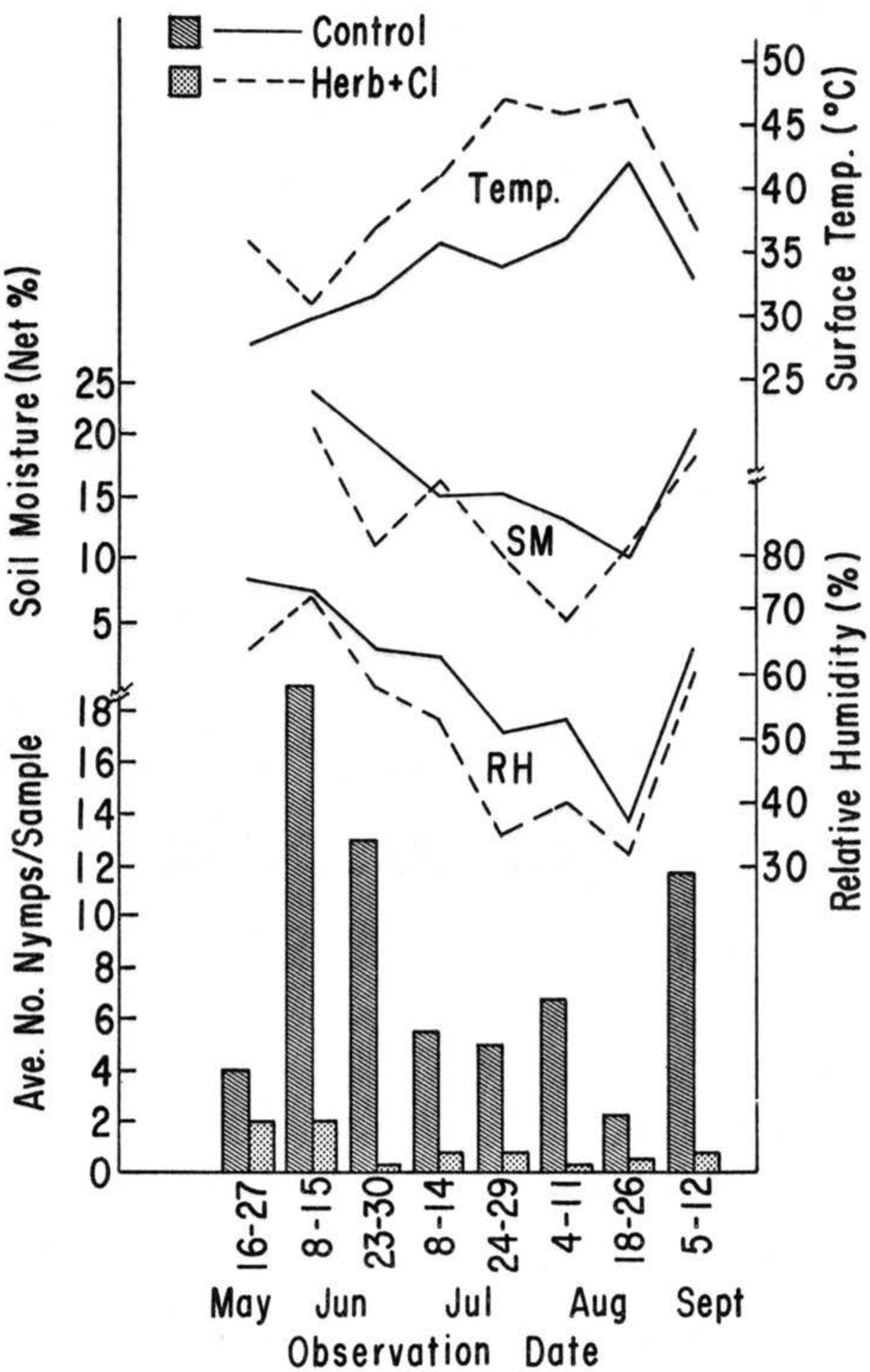

Figure 2. Seasonal Temperature, Soil Moisture, Relative Humidity and Nymphal Lone Star Tick Prevalence in a Vegetatively Altered and Undisturbed Woodlot, Cherokee Co., Oklahoma, Summer 1970

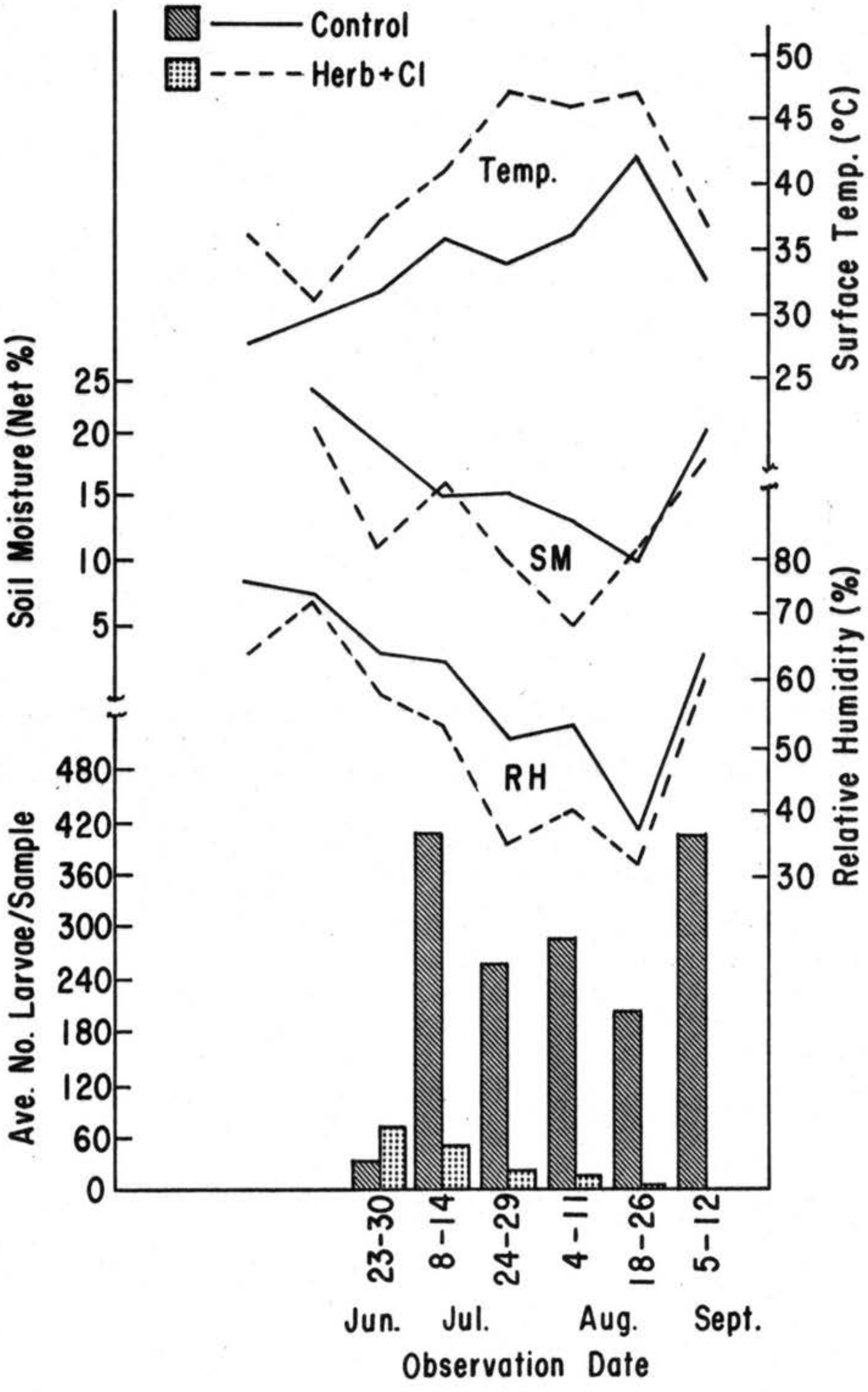

Figure 3. Seasonal Temperature, Soil Moisture, Relative Humidity and Larval Lone Star Tick Prevalence in a Vegetatively Altered and Undisturbed Woodlot, Cherokee Co., Oklahoma, Summer 1970.

temperature fluctuations. For example, the ability of the sheep tick to reabsorb water was influenced more by humidity gradients than temperature gradients (Lees, 1946). Larvae and nymphs of *Hyalomma savignyi* appeared to be more sensitive to humidity than to temperature within the range studied (Feldman-Muhsam, 1947).

Based on the data reported here, it seems that populations of the lone star tick within woodlots can be reduced by vegetative modification. Although the ensuing factors responsible for the reduction of ticks are probably complex, soil moisture and relative humidity seem to be the most important. Higher temperatures in the treated areas are factors which also seem to be of importance in that a correlation between this parameter, humidity and soil moisture normally exists.

PRELIMINARY OBSERVATIONS ON CONTROLLED BURNING FOR LONE STAR TICK CONTROL IN WOODLOTS

To develop and maintain an adequate tick control program has been the goal of researchers for many years. Such efforts have met a superficial degree of realization. Until recently the most effective method of area tick control was through the use of chlorinated hydrocarbons (Smith and Gourck, 1944; McDuffie, et al., 1950). Pesticides are quite expensive in area control programs and are currently of major concern with regard to environmental pollution. George and Stickel (1949) reported that DDT was quite lethal to brush-feeding birds and insectivorous reptiles. Rudd (1964) has also outlined the potential detriment of persistent pesticides to non-target species.

From data obtained in the oak-hickory forest of eastern Oklahoma, Clymer, et al. (1970) and Hoch, et al. (1971a) found that environment alteration by mechanical or chemical treatment, or both, of woodlots resulted in effective lone star tick control. Hoch, et al. (1971a) reported that woodlots receiving treatment of mechanical clearing plus a herbicide gave 54% and 58% reduction of adults and nymphs, respectively. It was noted by these workers (Hoch, et al., 1971b) that higher temperature and lower relative humidity were obtained in the vegetatively modified woodlots. These researchers postulated that vegetative modification changed certain environmental factors (temperature and humidity) which are very important in the survival and longevity of lone star ticks.

In the past it has been the practice for residents of the Ozark region to employ burning to reduce tick infestations in wooded areas. Considering the effects of mechanical and chemical treatment on the tick population in wooded areas (Clymer, 1970; Hoch, et al., 1971a), it was postulated that prescribed burning might significantly alter the vegetative habitat of the lone star tick and thus render the microhabitat unfavorable for tick survival by increasing temperature and lowering humidity.

Following personal communications with biologists in Cherokee County, Oklahoma, it was surmised that ticks in post-burned areas were still quite abundant after uncontrolled fires. It is believed that ticks might decend into the forest floor duff during fires and consequently avoid exposure to excessive temperatures. If this behavioral response was possible, one could assume that a considerable portion of the population might survive. Since it was believed that a behavioral response was possible, it was desirable to determine the temperature obtained at the different levels in the forest fuel and the amount of leaf litter and duff consumed during controlled fires. Such information would perhaps allow the survival of ticks in a burned woodlot to be explained.

Materials and Methods

During the summer of 1969 and 1970, controlled burning was conducted in 2 experimental areas located in the oak-hickory forest of eastern Oklahoma. In June, 1969, three 1-acre woodlot plots were established in the first study site. Only 2 of the three woodlot plots were burned; the third plot served as a control area. Fire breaks were established around the periphery of the 2 areas to be burned.

Within a few days after burning, surveys of tick populations were conducted in all 3 sites and continued on a 7-12 day basis. A heavy-duty sweep net, 90 x 180 cm, and a drag flag consisting of heavyweight white muslin, 90 x 180 cm, attached to a dowell one meter long were used in estimating tick populations. Tick surveys were also conducted during April to August, 1970, in the areas burned during 1969.

The second experimental area was established and burned in the summer of 1970. Three 1/3 ha plots were established, 2 were burned, and the third area served as a control area.

Temperature and relative humidity were measured weekly in post-burned plots in order to determine the possible influence of vegetative alteration by fire on these parameters and to determine the relative significance of these 2 factors in maintaining tick populations within post-burned areas.

Relative Humidity Measurements

Relative humidity measurements were taken at 3 height levels in each post-burn plot from July 8 to August 19, 1970. An Atkins Psychometer (Figure 1) was employed to measure the RH at the following heights: (1) soil surface; (2) 15.2 cm above soil surface; and (3) 45.7 cm above the soil line. Measurements were made at 3 randomly selected sites in each plot on a weekly basis, and an average weekly value for each height was derived by averaging the 3 readings in each plot. Weekly readings collected from the 2 post-burned areas were averaged in order to help characterize the area which had been burned.

Temperature Measurements

Temperature measurements were taken in the 2 post-burn areas on a weekly basis and were made in conjunction with the relative humidity data. A YSI Telethermometer with a 6-channel probe system was used to measure the temperature at 6 different heights simultaneously. Three replicates of temperature readings were made in each plot, and the 2 post-burn temperature measurements averaged to get a weekly temperature average at each of the 6 different levels.

Temperature readings were taken in each plot at the following levels: (A) 2.5 cm below soil surface; (B) soil surface; (C) 15.2 cm above soil level, (D) 30.5 cm above soil surface; (E) 45.7 cm above soil surface; and (F) 60.9 cm above soil surface.

Forest Floor Fuel Determination

The forest floor fuel was placed in one of 2 categories: (1) duff; or (2) leaf litter. Leaf litter was considered to be the upper portion of the forest floor fuel consisting of a loose arrangement of herbaceous plant leaves and tree leaves. A major portion of the leaf litter was composed of leaves from the previous fall. Duff was identified as being the lower, and more compact, decaying forest litter.

Available forest floor fuel and fuel moisture were determined by the dry weight technique. A 360 cm^2 metal frame, constructed from 3.75 cm angle iron, was used in taking litter and duff samples. The metal frame was randomly placed on the forest floor litter and the leaf litter and duff contained within this square foot was removed and placed in separate light-weight aluminum baking pans measuring 30 cm x 20 cm x 8.75 cm deep. Twenty pre-burn and 20 post-burn samples were collected from the areas to be burned or immediately after burning. After collection, each sample was placed in a drying chamber maintained at 100°C - 104°C. Samples were checked periodically and weights were recorded when additional weighings showed no further reduction in sample weights. The weight readings from the 20 samples were averaged in order to obtain an average duff and leaf litter sample for each plot to be burned and after burning in order to determine fuel consumption at the duff level as well as at the litter level.

Maximum Temperature Evaluation at Various Forest Fuel Levels

In order to evaluate the maximum temperatures obtained at various levels in the leaf litter and duff, heat sensitive solid organic compounds and Tempilaq[R] [3] were used. Tempilaq is a liquid in its original form but results in a dull, opaque film when applied to well-aerated surfaces. When the specific temperature of Tempilaq is exceeded, the heat sensitive coating will liquify. After cooling, the Tempilaq will resolidify, but its appearance will be distinctively different from that of the original coating. After exposure above its melting point, Tempilaq will become glossy and fuse. In these studies, 14 different Tempilaq compounds with melting points ranging from 41.1°C to 260°C were used. Microcapillary tubes were dipped in the various Tempilaq liquid compounds and allowed to dry before being transferred to study areas. The coated microcapillary tubes were held vertically above the forest fuel and forced through the leaf litter and duff until the lower end reached the soil surface. It was assumed that this approach would allow

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[3] Hamilton Boulevard, So. Plainfield, N.J.

one to measure heat penetration since sensitivity of the tubes ranged from 41.1 - 260°C, and since the thin walled capillary tubes would not allow for undue heat transfer. In the immediate vicinity of the coated glass tubes, duff and leaf depths were recorded. After burning of the study areas and using the above information, the depth at which specific temperatures were reached by measuring the unaltered Tempilaq film above the known soil surface level could be estimated. Two replicates were conducted in each pre-burn plot.

Another technique employed to measure maximum forest fuel temperatures was the use of specific melting point solid organic chemicals. Five different organic compounds were used which had a temperature range from 57.7 to 110°C. The chemicals were placed in a microcapillary glass tube and arranged horizontally at the following forest fuel depths: (1) ca. .5 cm below soil surface level; (2) between soil and duff; (3) between duff and leaf litter; and (4) mid-way in leaf litter.

Immediately after the burn, the capillary tubes were inspected to determine if any of the crystaline organic compounds had been altered in form.

Evaluation of Tick Mortality in Controlled-Burn Woodlots

To ascertain the capability of lone star tick adults to survive controlled burns in forest areas, 200 marked ticks were released in each of the 2 plots to be burned and the control area. Lone star tick adults were marked by spraying them with Day Glo® [4] florescent pigments dissolved in an acetone solvent (Kinzer, *et al.*, 1971). Marked ticks

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[4]Color Corp., 4732 St. Clair Avenue, Cleveland, Ohio, 44103.

were released in each of the 3 plots 24 hrs prior to burning the 2 treatment areas. Within a short time after the fire had subsided, carbon dioxide traps (Kinzer, et al., 1971) were placed in the general vicinity of the pre-burn release points in order to attempt to recapture any marked ticks and native ticks of the burned areas which were able to survive the fire. Carbon dioxide traps were operated daily and tick collections were recorded until no additional marked ticks were obtained. The same procedure for tick recapture was also conducted in the control plot.

Another technique used in determining tick mortality in burned areas was to confine 10 adult female ticks in cages which were placed at various depths in the forest fuel. The tick cages were constructed from 16 x 18 mesh screen wire which had been rolled into a cylinder 3.7 cm long and 0.6 cm in diameter. The caged ticks were then placed horizontally in the forest litter at the following levels: (1) .62 cm below soil surface; (2) between soil and duff; (3) between duff and leaf litter; and (4) on the surface of the leaf litter. After the burn, the cages were examined for live ticks. If any of the ticks were still mobile, it was recorded as a non-kill.

Results

Figure 4 shows a 2 year population trend of the 3 stages of the lone star tick in an unburned and burned woodlot. Following the burn in June of 1969, adult activity had subsided and population measurements could not be made. Observations in 1970 revealed no real differences in adult populations in the burned and unburned areas.

Nymphal and larval populations were apparently reduced during 1969

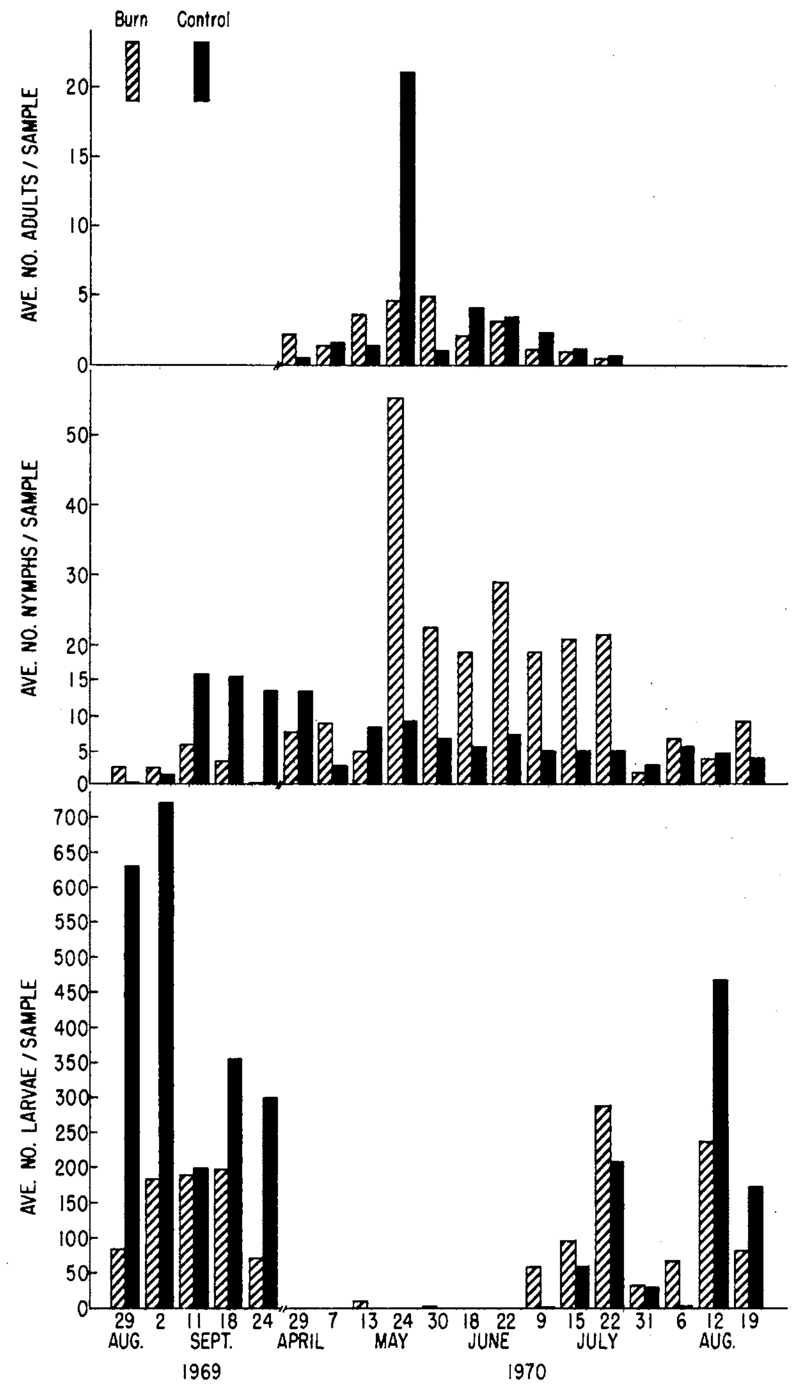

Figure 4. Seasonal Occurrence of Lone Star Tick Larvae, Numphs and Adults in Woodlots Following Controlled Burning in August, 1969

by the burn made earlier in that year, and larval populations were not significantly greater during 1970. However, Figure 4 shows that a tremendous increase in nymphal tick numbers occurred during 1970.

Tables V and VI present data which show that a sizeable percentage of the indigenous, released, and confined lone star tick adults were able to tolerate temperatures existing in the tick habitat during controlled burns. Surveys with CO_2 traps indicated that 65 and 33 percent of the released ticks survived in burned areas 1 and 2, respectively (Table V). The data in Table V also suggest little effect of fire on the indigenous tick populations in woodlots during burns.

Ticks in the lower duff near the soil, or those occupying a habitat in the upper portion of the soil, have a good chance for survival during woodlot burns (Table VI). In these studies only 1 of 4 cages of ticks in the soil surface was seriously affected by the controlled burns, and only 2 of 4 cages showed significant mortality at the soil-duff interface. Caged ticks were killed when placed on the leaf litter surface and at the duff-leaf litter interface.

The data given in Table VII show the percent consumption of forest floor fuel during controlled burns conducted in this study. These data show that under similar conditions one can expect most leaf litter to be consumed by controlled burns. However, it is also quite obvious from the data presented that one cannot expect a high percentage of the duff to be consumed since only 1 and 19.4 percent consumption of duff in areas 1 and 2, respectively, occurred during these studies.

In reviewing the data presented in Table VIII, a slightly greater depth penetration of heat in burn area 2 was noted than was achieved in area 1. The data collected would allow the reader to assume that under

TABLE V

SURVIVAL OF DAY GLO[R] MARKED TICKS AND INDIGENOUS TICK POPULATION IN WOODLOTS FOLLOWING CONTROLLED BURNS

Treatment	No. Marked Ticks Released	No. Marked Ticks Recovered	Net % Mortality (Est.)	No. Indigenous Ticks Collected
Burn 1	200	55	35	571
Burn 2	200	28	67	260
Control	200	84	0	267

TABLE VI

SURVIVAL OF CONFINED ADULT TICKS AT VARIOUS LEVELS IN THE FOREST FLOOR FULE DURING CONTROLLED BURNING

Exposure Level	Burn #1		Burn #2	
Surface leaf litter	+[a/]	+	+	+
Between duff-leaf litter	+	+	+	+
Between soil-duff	-[b/]	+	-	+
1.2 cm in soil	-	-	-	+

[a/] Caged ticks were dead.

[b/] Caged ticks were alive.

TABLE VII

NET PERCENT CONSUMPTION OF LEAF LITTER AND DUFF DURING CONTROLLED BURNS OF OAK-HICKORY WOODLOTS, CHEROKEE CO., OKLAHOMA, 1970

Burn Area #	% Consumption of Leaf Litter	% Consumption of Duff
1	70.5	1.0
2	98.0	19.4

TABLE VIII

TEMPERATURE READINGS RECORDED AT VARIOUS DEPTHS IN THE FOREST FLOOR FUEL OF OAK-HICKORY WOODLOTS, CHEROKEE CO., OKLAHOMA, 1970

Level Measured	°C Burn #1 58	82	91	96	110	Burn #2 58	82	91	96	110
Mid-way leaf litter		+++[a]	+++	+++	+++		+++	+++	+++	+++
Between duff-leaf litter	++-[b]		-+-		---	+++		+++		+++
Between soil-duff	---	---				-+-	---			
1.2 cm below soil surface	---					-+-				

[a] Organic compound reached M.P.

[b] Organic compound did not reach M.P.

conditions similar to those in these studies, one could expect that temperatures would generally not exceed 58°C at the soil surface and that they would be 60°C and above at the duff and leaf litter interface. The data show that temperatures in excess of 110°C were always achieved within the leaf litter.

Very little difference was detected between seasonal averages of temperature and humidity measurements taken in the burned and unburned woodlots following the controlled burns (Table IX). Table IX shows the average values for the 2 burned plots and comparative data taken from the control area.

TABLE IX

MEAN TEMPERATURE AND RELATIVE HUMIDITY MEASUREMENTS TAKEN IN TWO OAK-HICKORY WOODLOT HABITATS, 1970

Area Sampled	Level Measured						
	Soil	Surface	15.0 cm	30.4 cm	Surface	15.0 cm	45.7 cm
	°C				% RH		
Control	29.5	34.1	33.8	33.7	51.2	51.8	52.1
Burned	30.6	34.9	34.1	33.9	50.6	51.5	52.9

Discussion

From the preliminary data presented in Tables V and VIII, several generalizations can be drawn concerning the use of fire to manipulate lone star tick populations: (1) since these studies were conducted during mid-summer when the forest fuel contained below normal moisture, one could hardly expect greater consumption at other times of the year; (2) even though high temperatures may be obtained at the leaf litter level, one could normally expect considerable variations in temperature to occur in the duff and duff-soil zones, depending on depth, compaction and moisture of duff in these areas; (3) based on data presented in Tables V and VI it was surmised most controlled fires, and especially in uncontrolled fires, most adult ticks are able to tolerate conditions to which they are exposed. This may be accomplished by behavioral movements on the part of the tick or they may normally occupy a resting habitat near or in the upper soil region; and (4) controlled fires used under conditions similar to those in these investigations will not significantly alter the environmental conditions in the tick habitat of oak-hickory forests. Consequently, significant habitat modification will not likely occur as a result of controlled burns and one would not expect favorable, long-term results to occur from controlled burning practices.

Observations in 1970 on a woodlot burned in 1969 showed a marked increase in nymphal ticks. Adult and larval populations were little affected.

The increase in nymphal ticks can perhaps be attributed to one or two factors. Although quantitative data are not available, the first item to be considered is what appeared to be a significant increase in vegetative sprouts following the 1969 burn. Increased browse for deer was noticed during July, August, and September of 1969. One can, therefore, conclude as a possibility the fact that deer visiting the area in the late summer of 1969 introduced large numbers of replete larvae which molted into nymphs prior to the 1970 surveys.

Another item to consider is that the flagging technique of sampling was more efficient in the burned area than in the non-burned control. When the data of Semtner, et al. (1971) and Kinzer, et al. (1971) are compared, there is evidence to suggest that quantity and quality of ground cover affects the sampling efficiency of the drag flag as a sampling tool.

These preliminary observations suggested that considerable variation in burn uniformity is common in most woodlot fires. It was assumed that a number of factors such as atmosphere, relative humidity, air temperature, forest floor fuel moisture, quantity of fuel and wind speeds, could influence burn uniformity, heat depth penetration, and consequently tick mortality.

Smith and Sparling (1966) and Heyward (1938) noted that wind speeds greatly influenced burn uniformity. For example, these workers found that fast winds caused the flames to move over the fuel faster and resulted in a partial burn. In addition, these workers obtained cooler temperature at the soil level when flames were moving rapidly. In the studies reported herein, attempts were made to burn the fuel in such a manner as to achieve a slow uniform burn over the experimental areas. It can, therefore, be assumed that a greater consumption of leaf litter and duff (Table VII) occurred in these studies than normally occurs in uncontrolled burns. In addition, temperatures achieved at various depths (Table VIII) in these studies could represent higher estimates of temperatures than normally occur during uncontrolled burns.

Data in Table VIII show that a lack of uniformity existed between the physical make-up of forest fuel in study areas selected within what appeared superficially to be a uniform woodlot. Differences of temperature penetration shown between the 2 burned areas were possibly due to one or more factors such as litter compaction and soil drainage. It has been reported that the highest fire temperatures of the soil level occur where relative humidity and moisture content of the litter is highest (Smith and Sparling, 1966). Heyward (1938) has also concluded that thermal conductivity of soil increases with moisture in most cases.

It is not surprising that temperatures above 110°C were frequently not obtained in the duff of woodlots utilized in these studies since Bently and Fenner (1958) concluded that temperatures above 93°C were not reached below ca. 1 cm of leaf litter. However, it is felt that heat generation and depth of penetration can be attributed to quality and quantity of combustible fuel and fuel compactness.

Data given in Tables V and VI suggest certain behavioral traits of lone star tick adults which protect them from most woodlot fires. From these data, one can postulate that a large percentage of the adult tick population quickly moves to the soil-lower-duff levels of the forest floor during fires. Another good possibility, of course, is that a certain percentage of the indigenous population normally occupies this habitat region when they are not seeking a host.

Data in Tables VI and VIII suggest that temperatures below 58°C are sufficient to produce mortality. Data in Table VIII indicate that in only one case did the temperature exceed 58°C between the soil and duff, yet mortality of caged ticks occurred at this depth (Table VI).

It is interesting to note that an estimated 65 and 33 percent of the 200 marked ticks released in areas 1 and 2, respectively, survived the controlled burns. If these data are compared with that given in Table VII, it can be noted that the greatest percent of tick survival was obtained in the area having the least litter and duff loss (area 1). Numbers of indigenous ticks collected following the burns were also greater where the least fuel consumption occurred.

Although long-term effects of these burns on habitat cannot be predicted, it is not believed that the tick habitat was altered significantly immediately following the burn since temperatures and humidity measurements were comparable to the unburned control area. Since kill of overstory did not occur exposure will likely not be significantly greater in the next few years.

SUMMARY

In order to evaluate the effectiveness of various mechanical or chemical treatments, or both, of woodlots on A. americanum populations, studies were initiated in Cherokee Co., Oklahoma during 1967 and continued through 1970.

Six 0.45ha plots were replicated 3 times and received one of the following treatments: (1) mechanical clearing of all undergrowth and enough of the larger vegetation to allow 70-80% sunlight penetration; (2) mechanical clearing with the addition of an acaricide; (3) mechanical clearing with the addition of a herbicide; (4) application of an acaricide to existing vegetation; (5) application of a herbicide to existing vegetation; or (6) no treatment.

Gardona[R] (2-chloro-1(2,4,5-trichlorophenyl) vinyl dimethyl phosphate) 75% wettable powder, was used as the acaricide and applied at 1 kg toxicant per ha in the test plots. The herbicide used was 2,4,5-T, OS, which was applied at the recommended rate.

It was observed that the experimental plots receiving applications of an acaricide to existing vegetation or mechanical clearing with the addition of an acaricide demonstrated the greatest reduction of tick populations. The treatment which showed least promise for controlling tick numbers was applications of a herbicide to existing vegetation.

Larval populations of ticks were more susceptible than nymphs or adults to the various treatments involving mechanical clearing or herbicidal application. All developmental stages could be effectively

controlled through the use of Gardona.

It would appear that modification of existing vegetation, when compatible with other area uses, could result in economical, long-term control of lone star ticks, especially if practiced on a fairly large scale.

Additional studies were initiated during 1970 to determine the effect of mechanical clearing or chemical, or both, treatment of woodlots on the relative humidity, temperature and soil moisture in the lone star tick habitat.

Application of an herbicide to mechanically cleared woodlots accounted for an average seasonal increase in temperature of 6.6^{o}C at the soil surface. Correspondingly, a reduction in relative humidity of 6.2% was noted and soil moisture was lowered by 22% as a result of this treatment.

Larval tick populations were most significantly affected by changes in the physical make-up of woodlot habitats. After 3 years of treatment, the "herbicide + clearing" treatment reduced larval populations by 90% on a seasonal basis when this treatment was compared to a control area. Other treatments also showed some promise as tick control measures on an integrated basis.

Preliminary investigations on controlled burning for the control of lone star tick populations were conducted in three 1-acre oak-hickory woodlots in eastern Oklahoma. In the 2 post-burn test plots, more than 70% of the leaf litter was consumed by fire while only 19.4% and 1% of duff was destroyed by fire. Due to the protection provided by the intact duff, 65% and 33% of marked released ticks in the 2 burned areas survived. Large numbers of indigenous ticks were collected in the burned areas following treatment. Caged ticks in the vicinity of the soil were frequently not susceptible to the heat produced by a controlled burn.

Temperatures were measured at the various depths in the forest fuel and it was found that temperatures during a burn generally did not exceed 58°C at soil surface and that temperatures reached 60°C and above at the duff and leaf litter interface.

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VITA

2

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