ECOTONE MANAGEMENT: A COMPONENT OF HABITAT MODIFICATION FOR CONTROL OF THE LONE STAR TICK

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ECOTONE MANAGEMENT: A COMPONENT OF HABITAT MODIFICATION FOR CONTROL OF THE LONE STAR TICK

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Scope of Study: The lone star tick is an important arthropod pest affecting man, livestock and wildlife in eastern Oklahoma. The lone star tick is found in large populations in ecotonal areas surrounding pastures. Vegetative management has been shown to be an effective method for controlling the lone star tick. This study was developed to show the effects of vegetative mananagement in ecotones on the lone star tick. The objectives of this study were: 1) Determine the survivability of unfed lone star tick females. 2) Determine the oviposition success of fed females. 3) Determine the molting success of replete nymphs and larvae after the ecotonal vegetation had been subjected to a management scheme.

Findings and Conclusions: Four vegetation management strategies, unmanaged, herbicide, herbicide + controlled burn and controlled burn, were examined for their effectiveness in controlling the lone star tick in ecotones located in the northeast and southwest corners of meadows in eastern Oklahoma. Released unfed females, replete nymphs and replete larvae were effectively supressed through the use of a herbicide or a herbicide + controlled burn ($P < 0.05$) in both the northeast and southwest corners. For these reasons management of ecotonal vegetation should be an important component in an integrated tick control program.

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CHAPTER I

INTRODUCTION

The lone star tick, *Amblyomma americanum* (L), is found in great abundance in the Ozark region of eastern Oklahoma. The abundance of the lone star tick in the Ozark region directly affects the activity of man and his use of the resources in the region. Two major industries, tourism and livestock production, incur substantial losses that are traceable to the lone star tick and its control. Several methods are used to control the lone star tick: acaricides, pasture spelling, cross-bred cattle and vegetation management, with acaricide being the method of choice currently. Use of acaricide is marginally effective on livestock but is of short duration and very expensive for area control. Vegetation management has been shown to be very effective and of long duration, however, few studies using vegetation management have been done on the control of the lone star tick in its preferred habitat, "edges." For this reason a study was initiated in 1985 and 1986 to determine the effects of edge management on the lone star tick. The objectives of this study were to: 1) determine the survivability of unfed female lone star tick

2) determine the oviposition success of fed females. 3) determine the molting success of replete larvae and nymphs.

CHAPTER II

LITERATURE REVIEW

The genus Amblyomma is found around the world between the 40th parallels with almost half of the known species of this genus occuring in the Americas (Robinson 1926). The lone star tick, Amblyomma americanum (L), is a member of this genus and was the first tick species to be recorded in the United States by Thomas Salmon in 1739 (Bequaret 1946). The lone star tick is widely distributed throughout the southcentral and southeastern United States (Eddy 1940; Bishopp and Trembley 1945). The Ozark region of eastern Oklahoma lies on the western border of the lone star tick's range and supports the highest infestations known to exist. In the Ozark region the lone star tick is one of the most economically important arthropod pests to livestock producers and recreationist (Hooker et al. 1912; Bishopp and Trembley 1945; Hair and Howell 1970). The development and expansion of these two industries are severely hampered in certain areas of eastern Oklahoma because the lone star tick has reached excessive populations and has reduced the returns from these resources (Lancaster 1957; Hair and Howell 1970). Tourism is affected by ticks primarily by their attack on man and the loss of wildlife. The lone star tick has been incriminated in the transmission of several diseases affecting humans: Tularemia (Hopla and Downs 1953); Bullis Fever (Woodland et al. 1943); Tick Paralysis (Swartzwelder and Seabury 1947) and possibly Rocky Mountain Spotted Fever. The severe irritation caused by the bite of the lone star tick is reason enough for many recreationists to seek alternate vacation sites. Sportsmen lose game animals through tick parasitism. Bolte (1970) showed that more than 50% of the white-tailed deer fawn crop succumbed to lone star tick attack.

Reduced weight gains, decreased milk production, hide damage, secondary infection, disease transmission and high control costs are liabilities attributed to the lone star tick by the livestock industry (Harwood and James 1979). Reduced weight gains caused by tick parasitism have been demonstrated to decrease income by as much as $40.00 per head of preweaner calves (Barnard 1986; Barnard et al. 1986).

The problems associated with control of the lone star tick are confounded by the developmental pattern of the lone star tick with host seeking stages reaching peak populations during critical times for both tourism and livestock production (Tugwell and Lancaster 1962; Clymer et al. 1970a). Population peaks of host seeking adults, nymphs and larvae coincide with the height of the tourist season during the spring and summer and with the calving cycle for spring calving cows.

Current control recommendations for the control of the lone star tick is the use of acaricide (OSU Extension Agents' Handbook 1986). However, the use of acaricide for area control is limited by the short duration of effectiveness and high costs of the labeled chemicals (Barnard and Jones 1981; Meyer et al. 1982). Because of these problems with pesticides and the biology of the lone star tick, more effective, longer lasting methods of control are needed. In 1970 Hair and Howell postulated the use of vegetation management to exploit the lone star ticks biological requirements and use these requirements to control the lone star tick.

Experiments to elucidate the critical equilibrium humidity (CEH) for several ticks have shown that ticks have strict ambient moisture requirements, Ixodes ricinus (L) survive 4-8 days at 70% RH (Lees 1946), Boophilus microplus (Canestrini) survive 12 days at 70% RH (Hitchcock 1955). The CEH for the lone star tick is 85% (Lancaster and McMillan 1955; Sauer and Hair 1971). In addition, successful egg hatch and larval survival require RH of 73% or more (Lancaster and McMillan 1955; Sonenshine and Tigner 1969). These studies show that when ticks are held at constant temperatures and relative humidities tick survival is more dependent on relative humidity under lab conditions. If the microclimate surrounding the lone star tick could be altered by vegetation management an alternative to acaricides could be recommended.

Vegetation management has been shown to be an effective management tool in the control of the lone star tick (Clymer et al. 1970b; Semtner et al. 1971; Mount 1981; Meyer et al. 1982). Vegetation management modifies the ticks habitat by altering the microclimate and the host activity.

Microclimatological parameters altered by vegetation manipulation include relative humidity, soil moisture, ambient temperature, soil temperature and light intensity (Clymer et al. 1970b; Semtner et al. 1971; Mount 1981; Meyer et al. 1982). Hoch et al. (1971) demonstrated that by altering the vegetational structure of an area the available ambient moisture was reduced which is the most significant climatological parameter affecting tick survival.

Host activity patterns are also altered by vegetation modification. Two host types, deer and small animals, are influenced by vegetation management. Deer, the primary host for adult lone star ticks (Tugwell and Lancaster 1962; Clymer et al. 1970a), are attracted to edges by the presence of preferred browse plants. Browse plants found in ecotones such as, persimmon, sassafras, grape, winged elm, sumac and greenbriar, comprise the bulk of white-tailed deer diets during the spring and summer (Korschgen et al. 1980; Williamson and Hirth 1985). Management of ecotonal vegetation would result in less tick-host contact and force deer to utilize an alternative food source. The alternative food source could be an improved pasture, another vegetation management system for control of lone star ticks. Deer usage has been shown to increase in improved pasture situations increasing the chance of fed tick release in a harsh environment (Byford 1984; Presley unpub. data). Small animal activity, field mice and ground dwelling birds, is decreased because of the reduced cover provided by trees and shrubs (Morrison and Meslow 1983).

Management of edge vegetation should be an important component of an integrated tick control system because edges provide the lone star tick two essential requirements: (1) adequate environmental conditions and (2) host availability. Management of these areas offers the opportunity to disrupt both of these conditions.

CHAPTER III

PRELIMINARY STUDY

A preliminary study was conducted during the summer of 1985 to test the uniformity between the north, east, west and south edges. The uniformity study was conducted to concentrate the study due to time constraints and similar vegetational patterns between the north and east edges and the south and west edges. Also, these two pairs of edges are exposed to similar light and wind patterns. Therefore, the objectives of this study were to verify the visual similarities between the two pair of edges based on lone star tick responses in order to combine them into one plot.

Materials and Methods

One meadow was selected and one subplot was established on each of the four sides of the meadow. Within each of these four subplots an unmanaged area and a herbicide managed area was set up to determine the responses of lone star ticks to altered edges. The herbicide treated areas were sprayed during the first week of June 1985 with the herbicide 2,4-D [(2,4-diclorophenoxy) acetic acid] to control broadleaf vegetation.

One week post treatment fed female lone star ticks and fed nymphs were exposed to the treatment areas and monitored. Fed female lone star ticks were monitored for oviposition and egg hatch starting one week post release. Fed nymphs were monitored for survival and molting success starting one week post release.

Since this study was started in June concentrated releases of these life stages were required. Three releases of four fed females were made per arena in each treatment area with two week intervals between releases. Three releases of fifty fed nymphs were made per arena in each treatment area with a one week interval between each release.

The means to collect climatalogical data were not available for use in this study. For further details see Chapter IV.

Results and Discussion

Fed lone star tick females and fed nymphs exhibited similar survival responses within two pair of edges. Tick responses were similar in the north and east edges and tick responses were similar in the south and west edges. Fig. 1 (Appendix) shows percent oviposition and percent eggmasses exhibiting hatch for all edges. In this graph the north exposure corresponds to the south edge, the south exposure to the north edge, the east exposure to the west edge and the west exposure to the east edge. Ovipositon and egg hatch was similar in the south and west edges and in the north and east edges. Similar patterns in percent survival and percent molt were observed from fed nymphs released in these treatment areas (Fig. 2 Appendix).

Summary

The results of the preliminary study showed that responses of fed lone star tick females and replete nymphs were similar in two pairs of the edges studied. Tick responses in the north and east exposure were similar and tick responses in the south and west exposure were similar. Based on these results, a decision was made to combine the four plots located in the four cardinal directions into two plots. The north and east edges were combined and located in the northeast corner and the south and west edges were combined and located in the southwest corner.

CHAPTER IV

MATERIALS AND METHODS

Plot Establishment

Three replicates where established during the late winter of 1985 and early spring of 1986 at the Cookson Hills Wildlife Management Unit located in Adair and Cherokee counties of eastern Oklahoma. Cookson Hills was chosen because of its limited access and abundance of indigenous lone star ticks. Six plots were established around three meadows with one plot in the northeast corner and one plot in the southwest corner in the edge area surrounding each meadow (Table I and Fig. 3 Appendix).

Each plot measured 8.0 m by 124.0 m The plot was then divided into four treatment areas measuring 8.0 m by 31.0 m. The boundaries of each plot and treatment area were marked with corner stakes and foresters tape. The treatment areas were then assigned one of four different management techniques:

1) Unmanaged.
2) Herbicide.
3) Controlled burn + herbicide.
4) Controlled burn.

Treatment areas receiving a controlled burn were

TABLE I

LOCATION AND SOIL TYPE OF THE STUDY PLOTS WITHIN THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

PLOT	REFUGE LOCATION	R.T.S.[1]	SOIL TYPE
1	Food plot 5	SW 1/4, R23E, T14N, S15	Sallisaw gravelly silt loam 1-3% slope
2	Food plot 4	SW 1/4, R23E, T14N, S14	Okemah silty clay loam 1-3% slope
3	Food plot 9	NE 1/4, R23E, T14N, S15	Sallisaw gravelly silt loam 1-3% slope
4	Food plot 8	SW 1/4, R23E, T14N, S15	Okemah silty clay loam 1-3% slope
5	Jeff Bagget	SW 1/4, R23E, T14N, S11	Hector-Linker association hilly
6	Jeff Bagget	SW 1/4, R23E, T14N, S11	Hector-Linker association hilly

[1]=Range, Township and Section.

subjected to minimal mechanical clearing to provide adequate fuel for the burn. Hardwood species less than 5 cm in diameter were thinned to ca. 2 m between each tree and dead trees were felled. Fire breaks were raked around each treatment area subjected to a controlled burn prior to burning. The controlled burn was implemented during February when fire danger was at a minimum. Herbicide was applied to the respective treatment areas during green-up in early March. Due to the diversity of the plant species found in the edge areas in eastern Oklahoma a broad spectrum broadleaf herbicide was required. The combination of picloram (4-amino-3,5,6-trichloropicolinic acid) and triclopyr ([(3,5,6-trichloro-2-pyridinyl)oxy]acetic acid) was chosen as the combination most likely to control the edge vegetion per label instructions. The herbicide mixture consisted of 1.9 L picloram, 1.9 L triclopyr, 3.8 L diesel, 60 g Aura-Green®, a commercial lawn dye, and 186.2 L water. The entire herbicide application was mixed in a 209 L barrel to ensure a homogenous mixture. Picloram and triclopyr were applied at the rate of 1.81 kgs/ha and 3.62 kgs/ha, respectively. Aura-Green® was added to the herbicide mixture to ensure adequate coverage of the vegetation. Herbicide was applied using a hand pressurized 191 L Solo® 425 backpack sprayer equipped with a mister nozzle. All treatment areas receiving herbicide were sprayed on the same day to ensure consistency in application and weather conditions.

Observation Areas

Observation areas were constructed in the center of each treatment area. Two T-posts and 3.6 m of nonclimb fencing were used to construct a circle 1.1 m in diameter. The area was constructed to protect the tick releases from the local wildlife.

Observation Arenas

Observation arenas were constructed of 9.6 cm diameter PVC pipe and 18 mesh screen wire. These arenas prevented the escape of released ticks while allowing easy access to count the contained ticks. One arena was placed in the observation area for each release and each life stage of the tick. A pilot tool the same diameter of the arena was first driven into the ground to facilitate placement of the arena.

Weather Stations

Weather stations were constructed of window shutters and plywood. Eight of these stations were constructed and placed on stands ca. 0.5 m above the ground. Four stations were randomly placed in the northeast and southwest corners with one station in each type of management technique. Cole-Parmer® Hygrothermographs were placed in each station and continuous recordings of ambient temperature and relative humidity were obtained. Belfort® Tempscribes were placed in each station to monitor soil temperature continuously. The temperature probes from the Tempscribes were placed at the soil duff interface to obtain the soil surface temperature.

Unfed Females

Wild ticks were collected during the summer of 1985 (Wilson et al. 1972) and added to the OSU colony and reared (Patrick and Hair 1975). Subsequent nymphs from these wild females were fed and allowed to molt before each release. From this group of molted ticks 484 females were collected and placed in vials with 20 females per vial for field transfer. The vials containing the ticks were placed in an ice chest along with a small amount of water to maintain tick survival during transport. Females were then placed in the observation arenas previously described and allowed to acclimate to the environment for one wk before the first observation was made. Each observation arena was observed weekly and each live female tick was counted and recorded until the end of the study or until no live ticks remained. Four releases of unfed females were made during the period of activity of this life stage in eastern Oklahoma encompassed by this study. Releases were made on 04-05-86, 04-19-86, 04-30-86 and 06-04-86.

Fed Females

A total of 400 male and female lone star ticks were selected from the ticks trapped in 1985 to obtain fed and mated adult females to release in the managed ecotones.

From this population 100 pairs of lone star ticks were fed on sheep at the Oklahoma State University Medical Entomology Laboratory for each release of fed females. Upon completion of the feeding and mating stage 72 females were collected starting two days before release giving three days of collection. After collection from the host three fed females were placed in a vial in preparation for field transfer. Upon transfer to the field three females were then placed in each treatment area in an observation arena. These females were allowed to acclimate to the environment for one wk before the first observation was made. These observations continued on a weekly interval through the duration of the study. Fed females were observed for oviposition success. Four releases of fed females were exposed in each treatment area during the summer on four different dates, 04-19-86, 05-09-86, 06-04-86 and 07-03-86.

Replete Nymphs

Unfed nymphs were placed on a host and allowed to feed until they detached from the host. Upon completion of the feeding stage 480 ticks were chosen and placed into field transfer vials with 20 ticks per vial. Four releases of replete nymphs exposed to each treatment area during the course of the study when replete nymphs would normally be found in eastern Oklahoma. These releases occurred on 04-30-86, 05-09-86, 06-04-86 and 07-03-86. After the replete nymphs were placed into the release arenas, they were allowed one week to acclimate to the existing conditions before the first observation was made. Observation of replete nymphs was made on a weekly basis for all releases until the end of the study. Replete nymphs were monitored for successful molt at which time molted ticks were counted and removed from the arena.

Replete Larvae

Unfed larvae were placed on hosts and allowed to complete feeding. Upon completion of feeding 480 replete larvae were placed into vials with 20 larvae per vial for transport to the field. The same observation routine was used for fed larvae as was used for fed nymphs. During the course of the study three releases of replete larvae were exposed to the treatment areas with releases occurring on 05-09-86, 06-04-86 and 07-03-86. These releases correspond to the times when replete larvae would be found detaching from natural hosts in eastern Oklahoma.

Field Transfer

All ticks were transported to the field in separate vials as previously described. Prior to leaving Stillwater the vials containing the ticks were put into an ice chest containing paper towels soaked with water and packed so they would not roll around and break during transport. This procedure was done to ensure tick survival during transport until the ticks could be placed in their respective arenas.

Vegetation Measurement

The edge vegetation was measured three times during the study using a vegetation profile board (Nudds 1977; Guthery et al. 1981). The profile board was constructed of a 0.1 m wide by 2.5 m tall white pine board which was divided into 0.5 m increments, painted in alternating white and orange. Each treatment area was measured at three different locations. The profile board was placed in the back of the treatment area and the measurement was taken at a distance of 22.5 m perpendicular to the edge.

Soil Moisture

Each week soil moisture was determined gravimetrically from a single soil plug (2.5 cm x 4 cm) collected within 1 m of the observation area. The sample was deposited into a soil tin and sealed with two wraps of black electricians tape to prevent moisture loss. The sample was then weighed to determine the initial weight and the weight recorded. After the initial weight was obtained the sample was placed in an oven at 121 C. for three days. The soil sample was then reweighed to obtain a final weight and percent soil moisture was calculated on a dry weight basis.

Statistical Analysis

The experiment was conducted as a split plot withe the treatments areas laid out in a randomized complete block design. The main plot treatment factors were corner and treatment while release date was the subplot treatment factor. The GLM procedure from the Statistical Analysis System (SAS) was used to analyze the data (SAS Users Guide : Stastistics, 1985). Season means ($\bar{X}$) were compared using Duncan's multiple range test at $P > 0.05$. Error terms were specified to test siginificance of the variables and interacitons. Error A contained the mean squares for Rep*Corner, Rep*Trt and Rep*Corner*Trt. Error A was used to test for interactions between corner and treatment. Error B consisted of the mean squares for Reld*Rep*Corner, Reld*Rep*Trt and Reld*Rep*Corner*Trt. Error B was used to test the variables and interactions between release date, corner and treatment.

Environmental measurements were analyzed using analysis of variance (ANOVA) and weekly means ($\bar{X}$) compared using Duncan's multiple range test at $P > 0.05$. Ambient temperature, relative humidity and soil temperature were analyzed as a completely randomized design. Soil moisture and vegetation response were analyzed as randomized complete block design.

CHAPTER V

RESULTS AND DISCUSSION

Unfed Females

Management systems proved to be the most significant factor influencing reductions in the survival of released unfed females ($P < 0.0001$, df=3,14, F=24.55). Significant reductions in survival of released unfed females was achieved through the use of herbicides to manage ecotonal vegetation when compared to management strategies not using a herbicide (Table II). As can be seen in Fig. 4 (Appendix) the areas managed with herbicide and herbicide + controlled burn consistently reduced the survivability of unfed females throughout the study ($P > 0.05$). Reductions in female survival was similar throughout the study in the unmanaged and controlled burn treatment areas (Fig. 4). The data obtained from this study shows that the unfed female lone star ticks can be effectively controlled through the use of herbicide applied to the edge vegetation. Fifty percent control was obtained in both treatment areas where herbicide was applied to the edge vegetation compared to 28 percent and 27 percent control in the controlled burn and unmanaged treatment areas, respectively. It would seem reasonable to expect similar responses from the indigenous tick

TABLE II

PERCENT REDUCTION OF UNFED FEMALE LONE STAR TICK SURVIVAL IN EDGES MANAGED BY FOUR DIFFERENT METHODS IN THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Management System	N	% Reduction[a]
Herbicide	1536	50_a
Herbicide + Controlled Burn	1536	50_a
Controlled Burn	1536	28_b
Unmanaged	1536	27_b

% with different letters are significantly different at $P < 0.05$.

[a] = 480 unfed adult female lone star ticks were released in each treatment area during the season.

population, therefore, reducing the contact between unfed females and potential host.

Significant difference also occurred between corners with respect to survival of released unfed adult females ($P < 0.0018$, df=1,14, F=14.79). Survival of unfed adult females was significantly different in the northeast corner when compared to the southwest corner (Table III). This difference was probably caused by the harsher environmental conditions found in the northeast corner. The northeast corner recieves the afternoon sun and faces the prevailing winds of the summer season, which would produce a harsher environment.

Release date was another significant factor affecting survival of unfed adult females ($P < 0.0001$, df=3,48, F=8.77). The longer the unfed females were exposed to the environment the less chance they had for survival due to depletion of water reserves (Table IV).

Fed Females

Fed females are highly resistant to environmental changes as shown by Semtner et al. (1971). The only significant factor affecting oviposition by fed females was date of release ($P < 0.0001$, df=3,48, F=8.33). The greatest reduction in oviposition occurred in those females released on 7-3-86 with 59 percent of the females released unable to oviposit (Table V). The next females most affected were those released on 5-9-86 with 35 percent of the females

TABLE III

PERCENT REDUCTION OF UNFED FEMALE LONE STAR TICK SURVIVAL IN EDGES LOCATED IN THE NORTHEAST AND SOUTHWEST CORNERS OF IMPROVED MEADOWS AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Corner	N	% Reduction[a]
Northeast	1536	43_a
Southwest	1536	34_b

% with different letters are significantly different at $P < 0.05$.

[a] = 960 unfed adult female lone star ticks were released in each corner during the season.

TABLE IV

PERCENT REDUCTION OF UNFED FEMALE LONE STAR TICK SURVIVAL RELEASED ON FOUR DIFFERENT DATES IN EDGES LOCATED IN THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Release Date	N	% Reduction[a]
4-5-86	456	45_a
4-19-86	408	39_b
4-30-86	384	37_b
6-4-86	288	31_c

% with different letters are significantly different at $P < 0.05$.

[a] = 480 unfed adult female lone star ticks were released on each date.

TABLE V

PERCENT REDUCTION OF OVIPOSITION BY FED LONE STAR TICKS RELEASED IN EDGES ON FOUR DIFFERENT DATES AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Release Date	N	% Reduction[a]
4-19-86	408	17_c
5-9-86	384	35_b
6-4-86	288	25_c
7-3-86	192	59_a

% with different letters are significantly different at $P < 0.05$.

[a] = 72 fed females were released on each date.

unable to oviposit (Table V). There were no significant differences between those females released on 4-19-86 and 6-4-86 with 17 and 25 percent reduction in oviposition, respectively (Table V).

Management of ecotonal vegetation does not produce a microclimate severe enough to alter the biology of fed females. Reduction of fed females and subsequent eggs and larvae in ecotones would be through decreased visitation of host utilizing the area, although, no data were taken to confirm decreased visitation of host. Ecotones provide deer a primary food source and if the food source is removed deer would be forced to seek alternative sources. The control of the lone star tick through manipulation of fed females would have to depend on manipulation of the host based of the results of this study.

Replete Nymphs

Treatment areas proved to be a significant factor affecting nymphal molt ($P < 0.0001$, df=3,14, F=14.5). Percent control of nymphal molt was significantly different ($P > 0.05$) in areas managed with herbicide when compared to areas not managed with herbicide (Table VI and Fig. 8 Appendix). Ecotones managed with a herbicide or herbicide + controlled burn reduced nymphal molt by ca. 35 percent and 34 percent, respectively. However, nymphal molt was reduced by 37 percent in the unmanaged area, which was the highest reduction (Table VI).

TABLE VI

PERCENT REDUCTION IN NYMPHAL MOLT IN EDGES MANAGED BY FOUR DIFFERENT METHODS IN THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Management System	N	% Reduction[a]
Unmanaged	1272	37_a
Herbicide + Controlled Burn	1272	35_{ab}
Herbicide	1272	34_b
Controlled Burn	1272	29_c

% with different letters are significantly different at $P < 0.05$.

[a] = 480 replete nymphs were released in each management system.

Significant differences were seen when corners were compared ($P < 0.0032$, df=1,14, F=12.57). Nymphal molt was reduced by 48 percent in the northeast corner compared to 40 percent in the southwest corner (Table VII).

Nymphal molt was also significantly affected by release date ($P < 0.0001$, df 3,48, F=33.8). The replete nymphs released on 6-4-86 were affected the most with 57 percent of the unable to complete ecdysis (Table VIII). Replete nymphs released earlier in the season were more successful in completing ecdysis thah those released towards the end of the nymphal season (Table VIII).

Disruption of nymphal ecdysis in ecotones was possible through management of edge vegetation, location of release and date of release. Manipulation of these three factors to control replete lone star nymphs could allow the livestock producer to utilize his pastures more economicallly through rest-rotation grazing and management of edge areas. The reduced success of nymphs completing ecdysis could reduce the population of unfed adult ticks the following year which could increase revenue from pastures and recreational areas.

Replete Larvae

The interaction beteen treatment and release date was a significant factor reducing the success of larval molt ($P < 0.0096$, df=6,32, F=3.45) when using Error B. Responses of replete larvae to management techniques were more variable than the responses seen in unfed adults and replete nymphs.

TABLE VII

PERCENT REDUCTION OF NYMPHAL MOLT IN THE NORTHEAST AND SOUTHWEST CORNERS OF IMPROVED MEADOWS AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Corner	N	% Reduction[a]
Northeast	1272	48_a
Southwest	1272	40_b

% with different letters are significantly different at $P < 0.05$.

[a] = 960 replete nymphs were released in each corner during the season.

TABLE VIII

PERCENT REDUCTION OF MOLTING BY REPLETE NYMPHS RELEASED ON FOUR DIFFERENT DATES IN EDGES LOCATED IN THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Release Date	N	% Reduction[a]
4-30-86	408	40_d
5-9-86	384	35_c
6-4-86	288	57_a
7-3-86	192	51_b

% with different letters are significantly different at $P < 0.05$.

[a] = 480 replete nymphs were released on each date.

TABLE IX

PERCENT REDUCTION OF MOLTING BY REPLETE LONE STAR TICK LARVAE IN EDGES MANAGED BY FOUR DIFFERERNT METHODS FOR THREE DIFFERENT RELEASE DATES AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

	% Reduction[a]					
Management System	N	Rel 1[b]	N	Rel 2[c]	N	Rel 3[d]
Unmanaged	96	37_{a}	72	54_{b}	48	50_{b}
Herbicide	96	34_{ab}	72	65_{a}	48	81_{a}
Herbicide + Controlled Burn	96	35_{ab}	72	72_{a}	48	83_{a}
Controlled Burn	96	30_{b}	72	41_{c}	48	50_{b}

% with different letters are significantly different at $P < 0.05$.

[a] = 120 replete larvae released/management system/release date.

[b] = 5-9-86.

[c] = 6-4-86.

[d] = 7-3-86.

Significant differences in larval molt occured among all the treatments (Table IX). Again, as was seen in the previous life stages the treatment areas managed with a herbicide or herbicide + controlled burn were more effective in inhibiting larval molt than than the unmanaged or controlled burn treatment areas.

Again, as was seen for the other life stages the corner was a significant factor affecting the molt of the exposed replete larvae ($P < 0.0001$, $df=1,14$, $F=14.487$). The northeast corner was significantly different from the southwest corner with 57 percent and 41 percent reduction of ecdysis, respectively (Table X).

Vegetation management alone was not as successful in hindering larval molt as was the case with unfed adults and replete nymphs. The small size of replete larvae probably enable them to seek a more suitable site within the arena than replete nymphs. Location of release was a significant factor affecting the molt of replete larvae. The northeast corner was consistently more deleticious to the life stages of the lone star tick than the southwest corner.

Soil Moisture

In this study decreases in soil moisture were significantly different in the southwest corner than in the northeast corner (Table XI Appendix). Soil moisture in the southwest corner was consistently lower than in the northeast corner (Fig. 15 Appendix). No data were taken to

TABLE X

PERCENT REDUCTION OF MOLTING BY REPLETE LONE STAR TICK LARVAE IN THE NORTHEAST AND SOUTHWEST CORNERS OF IMPROVED MEADOWS AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Corner	N	% Reduction[a]
Northeast	864	57_a
Southwest	864	41_b

% with different letters are significantly different at $P < 0.05$.

[a] = 720 replete larvae released in each corner.

explain this difference but I believe soil structure and topography might account for this difference.

Hygrothermographs

It appears that the weekly average percent relative humidity in all treatment areas is below the CEH of 85% establish for lone star ticks by Hair et al. (1975). Weekly averages for percent relative humidity ranged from 57-80% in unmanaged areas, 58-81% in controlled burn areas, 58-83% in herbicide + controlled burn areas and 56-79% in herbicide areas (Fig. 16 Appendix). There were no major changes in relative humidity from week to week in all treatment areas with the largest change of 7% occurring in the herbicide treatment area during the fourth observation period. In almost all weeks during the study the weekly average of relative humidity was lower in herbicide treated areas when compared to all other treatment areas.

Values for average relative humidity are lower in the northeast corner than in the southwest corner with the greatest variation in relative humidity occurring in the herbicide treatment areas in both corners.

The data presented here does not resemble the data from previous studies involving woodlots and pastures but is intermediate to the conditions described by Semtner et al. (1971) and Hoch et al. (1971). This conclusion coincides with the type of habitat in the study. The habitat is neither a pasture nor a woodlot, it is a transitional zone between these two habitats resulting in intermediate values.

Average weekly ambient temperature was also similar in all treatment areas with no significant differences among treatments (Fig. 17 Appendix). Ambient temperature ranged from 11 to 31°C in all treatment areas. The lowest temperature occurred in April and the highest occurred in August following typical summer patterns for Oklahoma.

When treatments in contrasting corners are compared the southwest corner averaged higher ambient temperatures than the northeast corner. I'm unable to explain this difference between corners as I would have expected higher temperatures in the northeast corner. The difference might have come from weather station placement resulting in more sun exposure.

As would be expected the main factor affecting relative humidity and ambient temperature was time. As the summer progressed these factors behaved typically and relative humidtiy decreased and ambient temperature increased. Measurement of ambient conditions using hygrothermographs to record conditions in ecotones are not sensitive enough to document the actual conditions to which the tick is exposed. Measurements of the microclimate could characterize the differences in ambient temperature and percent relative humidity more accurately.

Soil Temperature

Average weekly soil temperatures showed marked differences between treatments early in the season (Fig. 18 Appendix). From May until the end of July soil temperature was higher in the herbicide and controlled burn treatment areas when compared to the unmanaged and herbicide + controlled burn treatment areas. From July until the end of the study the average weekly soil temperature in the unmanaged treatment area resembled the herbicide and controlled burn treatment areas and in some cases exceeded both.

Weekly average soil temperature is significantly different among treatments in contrasting corners (Fig. 18 Appendix). All treatments increased soil temperature markedly in the northeast corner with the herbicide treatment area exhibiting the highest average soil temperature throughout most of the season. In the southwest corner the herbicide + controlled burn produced the highest average soil temperature throughout the season.

Vegetation Response

Vegetation response was significantly different ($P > 0.05$) in the treatment areas compared to the unmanaged area (Table XII). Treatment areas receiving the herbicide + controlled burn reduced the ecotonal vegetation with only 0.41 m of the profile board screened versus 1.05 m screened in the unmanaged area.

Vegetation is significantly different ($P > 0.05$) when comparing contrasting corners (Table XII). The southwest

TABLE XII

EFFECTS OF CORNER AND VEGETATION TREATMENT ON PERCENT OF A PROFILE BOARD SCREENED BY VEGETATION AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Corner	Treatment	Percent of profile board screened[a]
Southwest	Unmanaged	56_a
	Controlled Burn	28^b
	Herbicide + Controlled Burn	20_b
	Herbicide	20_b
Northeast	Unmanaged	24_a
	Herbicide	12_b
	Controlled Burn	12_b
	Herbicide + Controlled Burn	8_b

% with the same letter within a corner are not significantly different at $P < 0.05$.

[a] = % consist of 3 replicates with 3 observations/treatment. Percent screening measured as the proportion of the 2.5 m profile board screened by vegetaion.

corner is dominated by buckbrush and winged elm whereas the northeast is dominated by grasses. Natural changes in vegetation structure occur between the northeast corner and the southwest corner due to the intensity of solar radiation directed on these exposures (Geiger 1966; Ranney 1977). Ecotonal areas in northeast corners appear to be a mixture of meadow and forest with sparse if any underbrush. Southwest corners are "typical" of meadow - forest edges composed of dense underbrush leading into forest habitat.

CHAPTER VI

SUMMARY

Vegetation management could be an important component in an integrated tick control program. Ecotones provide the greatest interaction between the tick and its host. Increased interaction is caused by the abundance of ticks in this type of habitat and the preference of this type of habitat by the primary host, white-tailed deer. The data presented here indicate that three life stages of the lone star tick are effectively hindered by vegetation management, location of release and date of release. Released populations of unfed adult females and replete nymphs were significantly suppressed when exposed to ecotones managed with a herbicide or a herbicide + controlled burn. Location of release was also an important factor affecting the success of unfed adult females, replete nymphs and replete larvae. This information could be used to base chemical control practices by concentrating these control methods in locations capable of harboring high populations of lone star ticks, such as the southwest corner. Date of release was the only factor affecting all life stages of the lone star tick. This information could allow for more efficient use of rest-rotation grazing practices by removing cattle from pastures containing abundant edge habitat during times when the lone star tick is less susceptible to climatalogical changes, such as early to late spring.

I would recommend the use of herbicide alone because of the fire hazards associated with controlled burns in this type of habitat. However, if prescribed burns are already used for pasture management, application of a herbicide to the ecotonal areas would provide the added component of tick control. The effect of vegetation management through the use of a herbicide on tick control was shown to increase during the next three years by Hoch (1971). This feature should greatly enhance the the concept of vegetation management for control of the lone star tick. In addition to actual control of the lone star tick, clearing of ecotonal vegetation would allow more effective application of timed acaricides.

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APPENDIX

Figure 1. Percent Oviposition and Hatch of Replete Females and Egg Masses in Ecotones Situated in the Four Cardinal Directions at the Cookson Hills Wildlife Management Unit During the Summer of 1985.

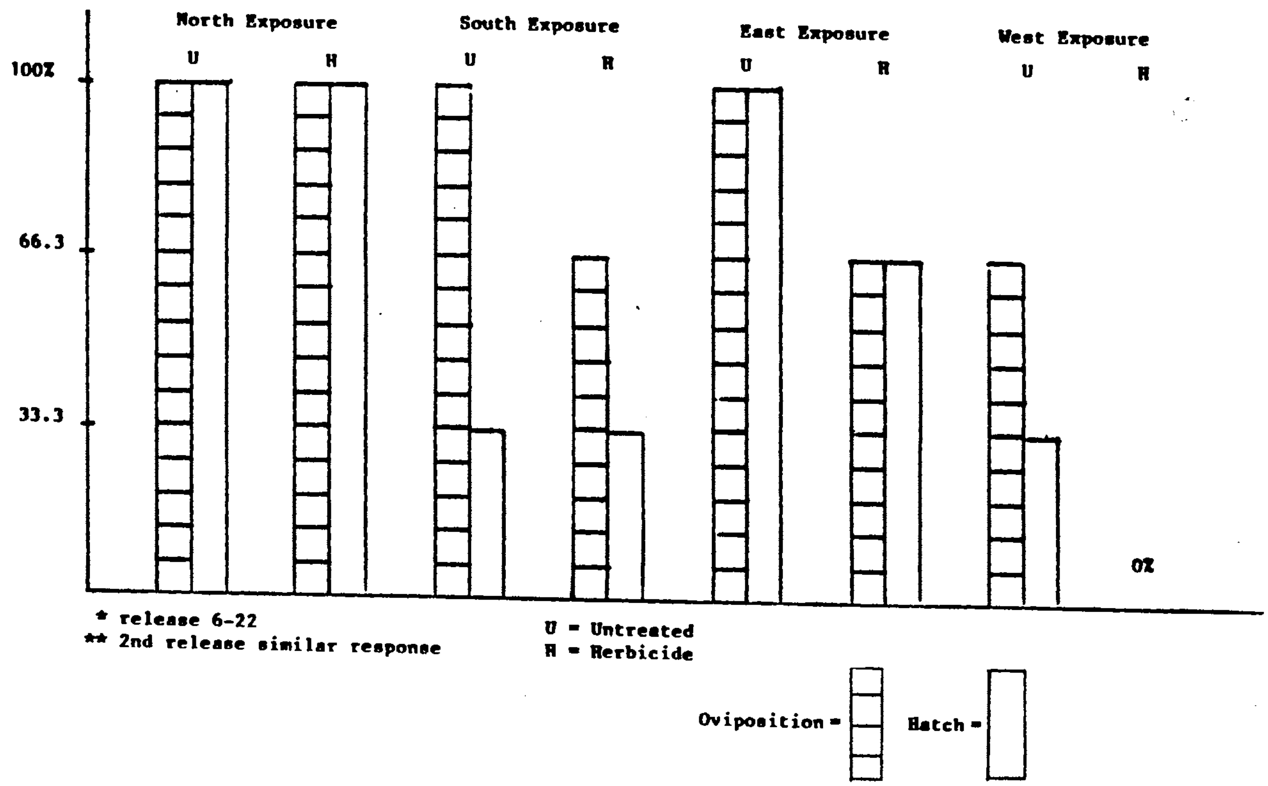

North Exposure
South Exposure
East Exposure
West Exposure
U
H
U
H
U
H
U
H
100%
66.3
33.3
0%
* release 6-22
** 2nd release similar response
U = Untreated
H = Herbicide
Oviposition =
Hatch =

Figure 2. Percent Survival and Molt of Replete Nymphs Released in Managed Ecotones Located in the Four Cardinal Directions Surrounding an Improved Meadow at the Cookson Hills Wildlife Management Unit During the Summer of 1985.

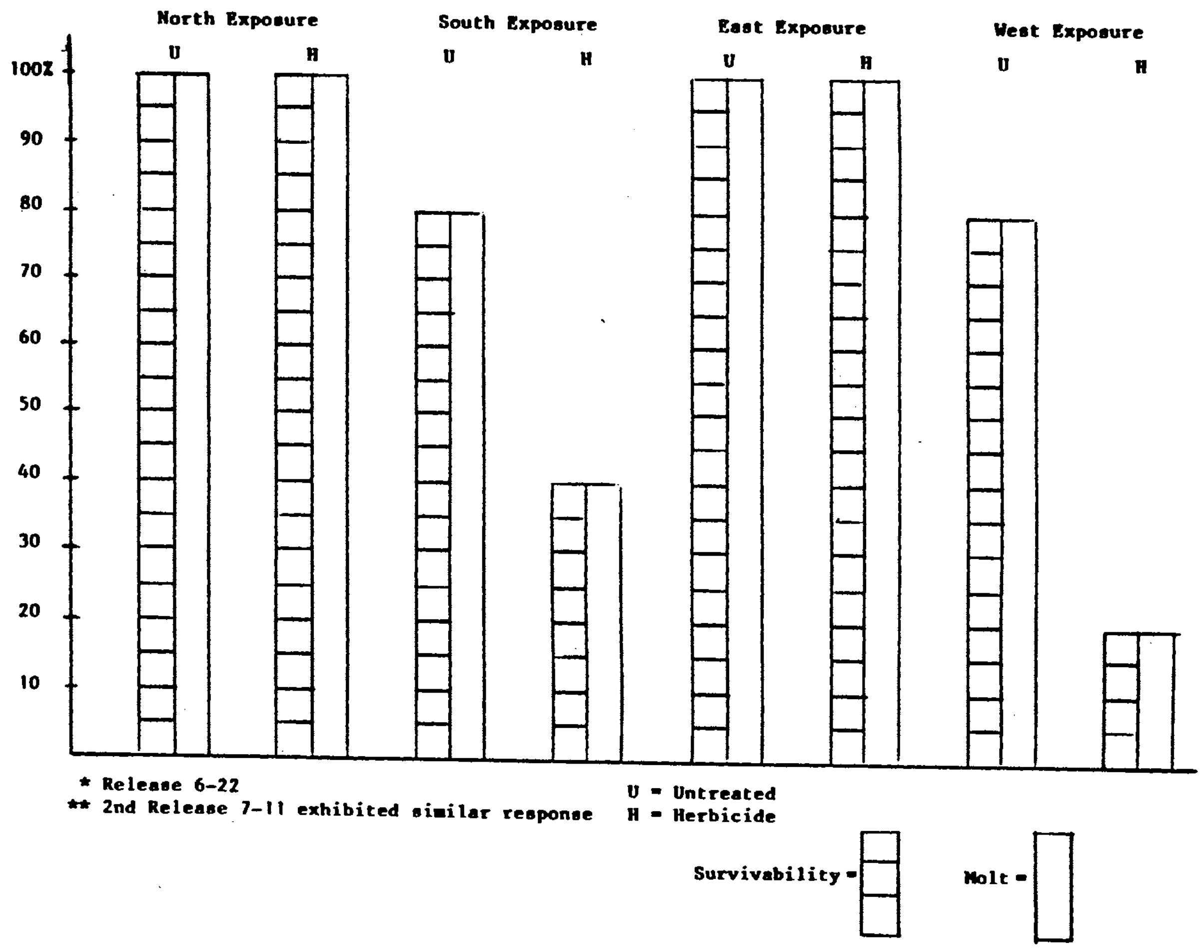
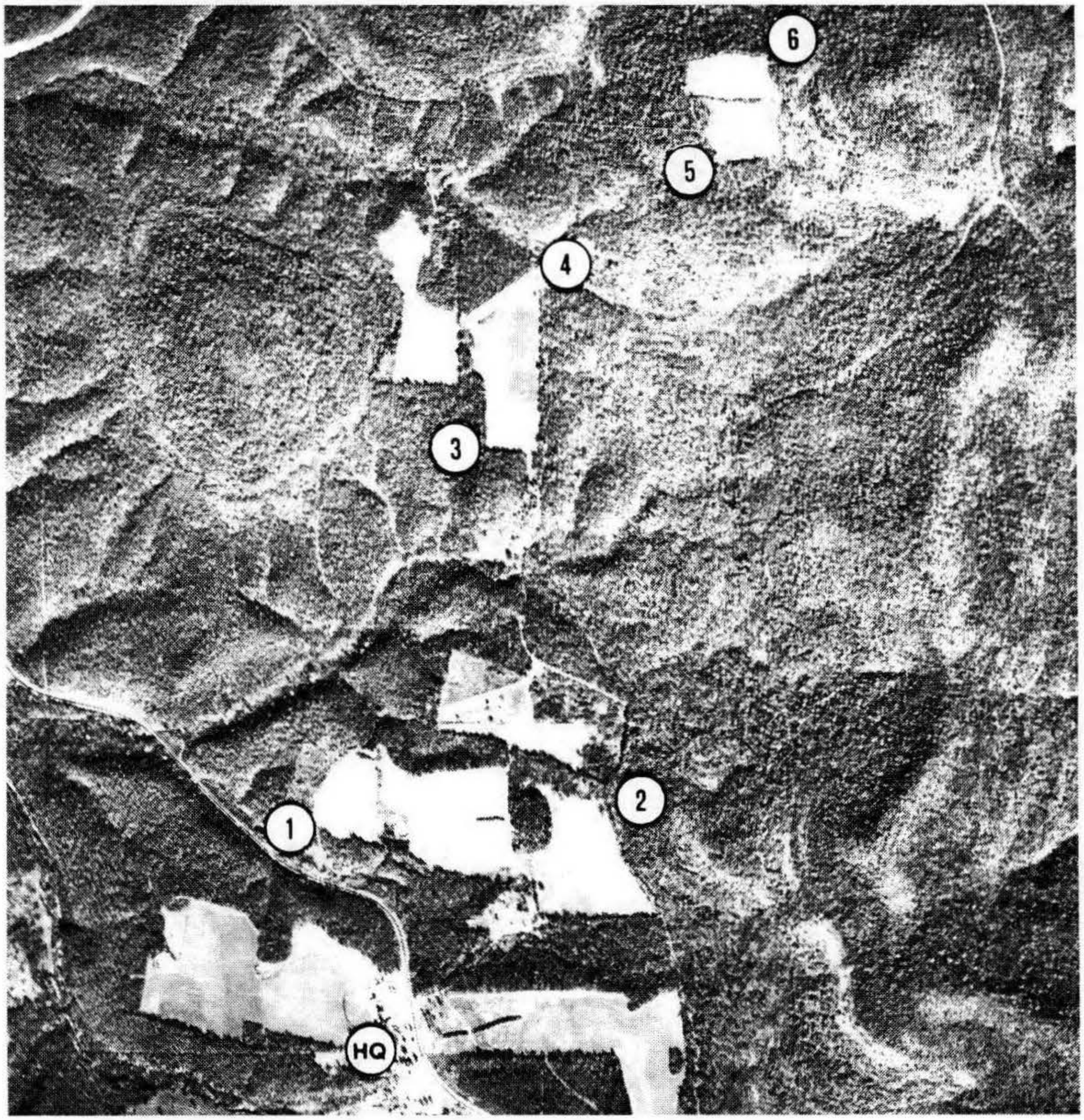

North Exposure
South Exposure
East Exposure
West Exposure
U
H
100%
90
80
70
60
50
40
30
20
10
* Release 6-22
** 2nd Release 7-11 exhibited similar response
U = Untreated
H = Herbicide
Survivability =
Molt =

Figure 3. Map of the 1986 Study Area at the Cookson Hills Wildlife Management Unit.



Scale - 1:24000

U.S. Soil Conservation Service, Aerial Photograph BQH-IFF-65, Cherokee County, Cookson Hills Wildlife Management Unit 11-12-64. Salt Lake City, Utah.

Figure 4. Mean Survival of Unfed Lone Star Tick Females in Ecotones Managed by Four Different Strategies in the Cookson Hills Wildlife Management Unit During the Summer of 1986.

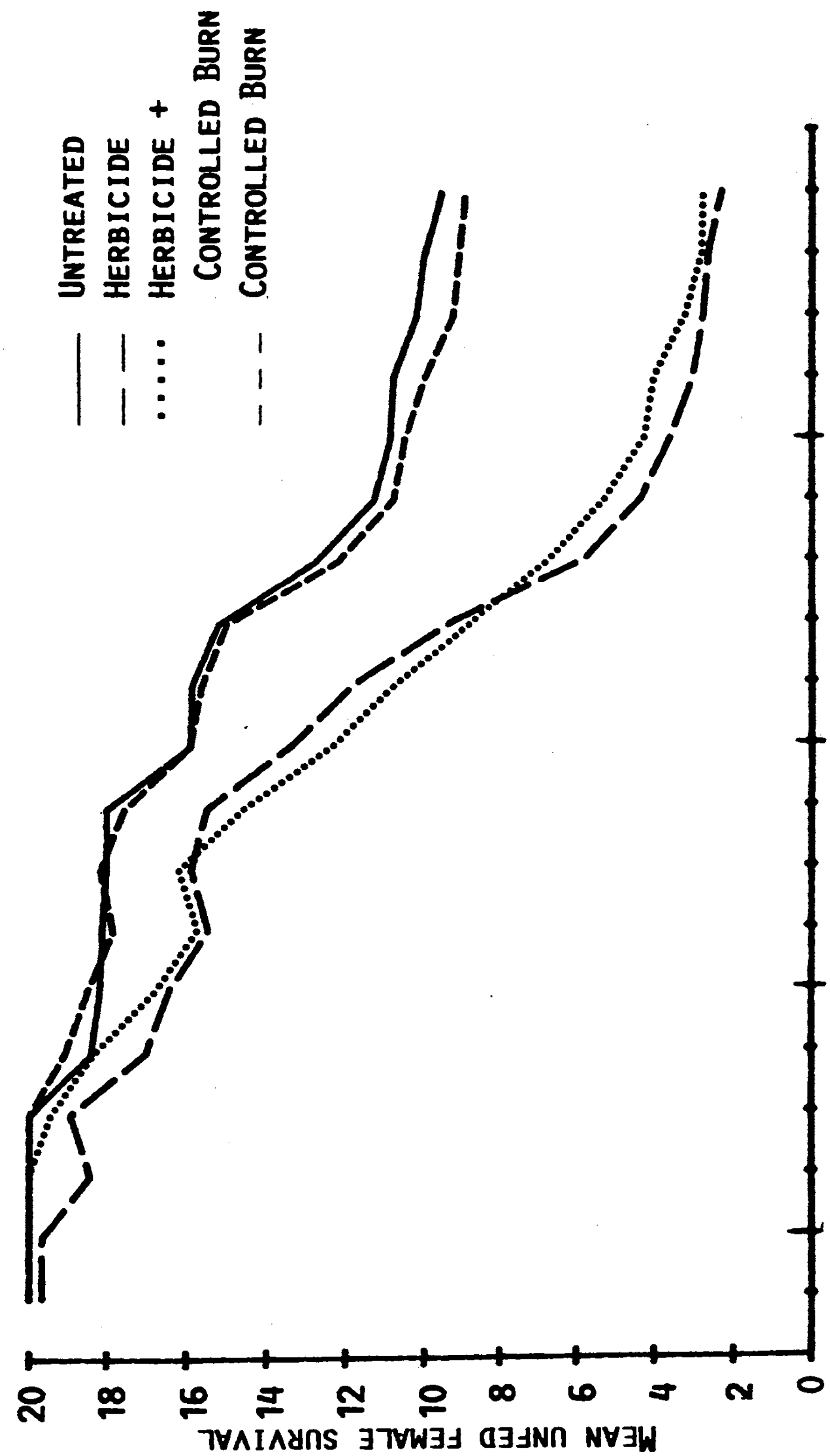
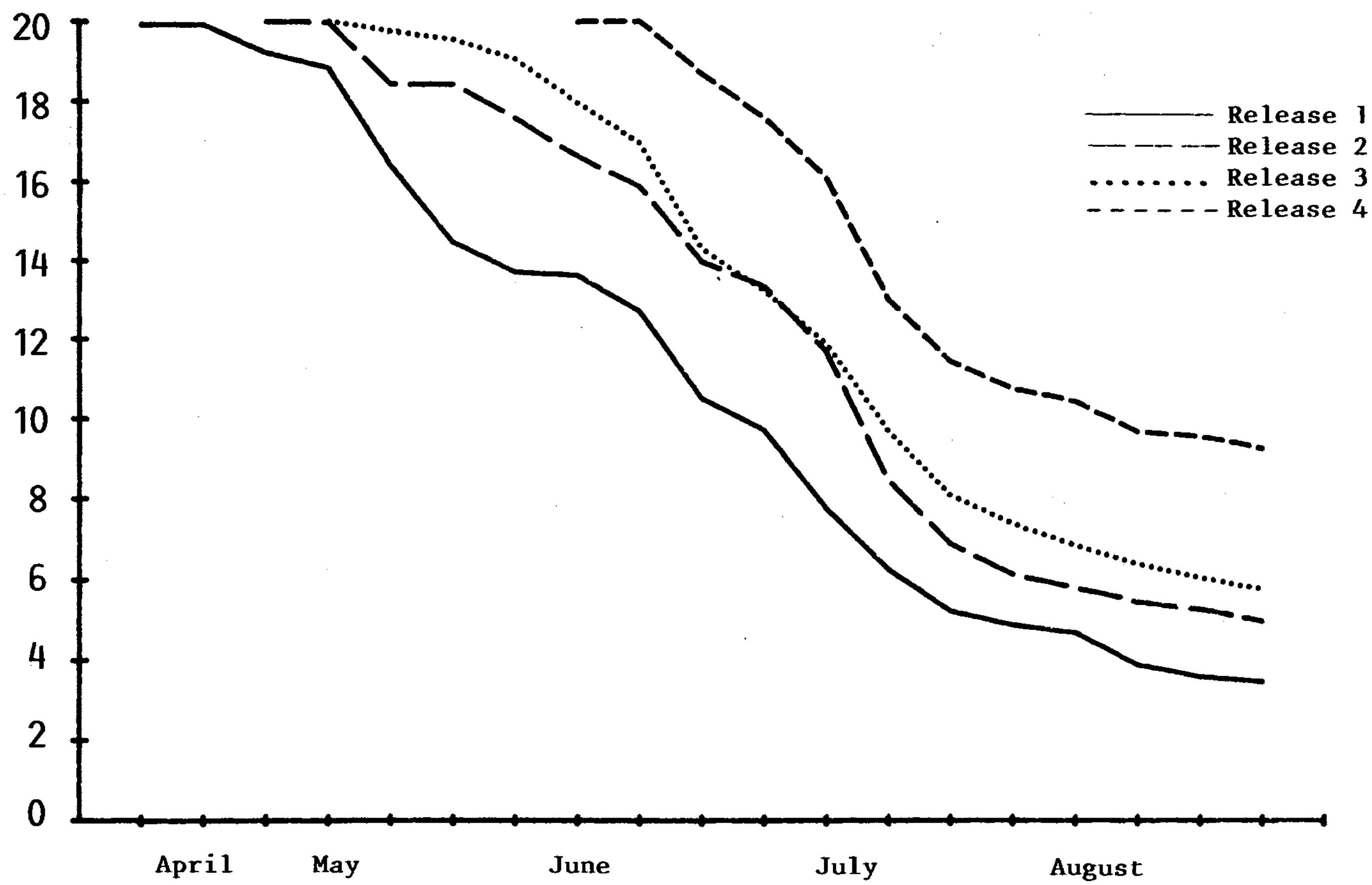

UNTREATED
HERBICIDE
HERBICIDE + CONTROLLED BURN
CONTROLLED BURN
MEAN UNFED FEMALE SURVIVAL
0
2
4
6
8
10
12
14
16
18
20
APRIL
MAY
JUNE
JULY
AUGUST

Figure 5. Mean Survival of Unfed Lone Star Tick Females Released on Four Different Dates in the Cookson Hills Wildlife Management Unit During the Summer of 1986.



20
18
16
14
12
10
8
6
4
2
0
April
May
June
July
August
Release 1
Release 2
Release 3
Release 4

Figure 6. Mean Survival of Unfed Lone Star Tick Females in Contrasting Corners of Edges in the Cookson Hills Wildlife Management Unit During the Summer of 1986.

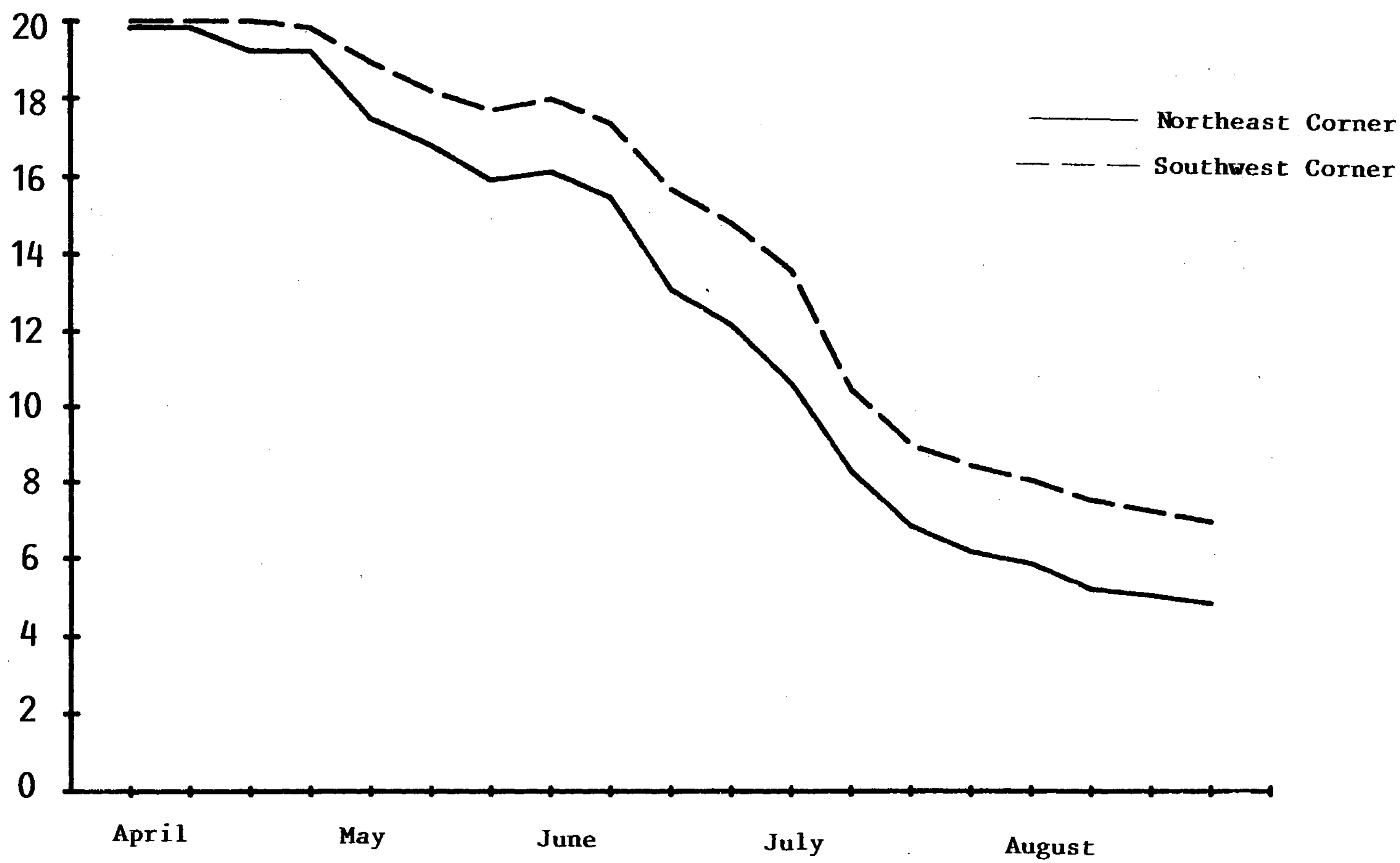

20
18
16
14
12
10
8
6
4
2
0
Northeast Corner
Southwest Corner
April
May
June
July
August

Figure 7. Mean Oviposition of Lone Star Tick Females Released on Four Different Dates in Edges at the Cookson Hills Wildlife Management Unit During the Summer of 1986.

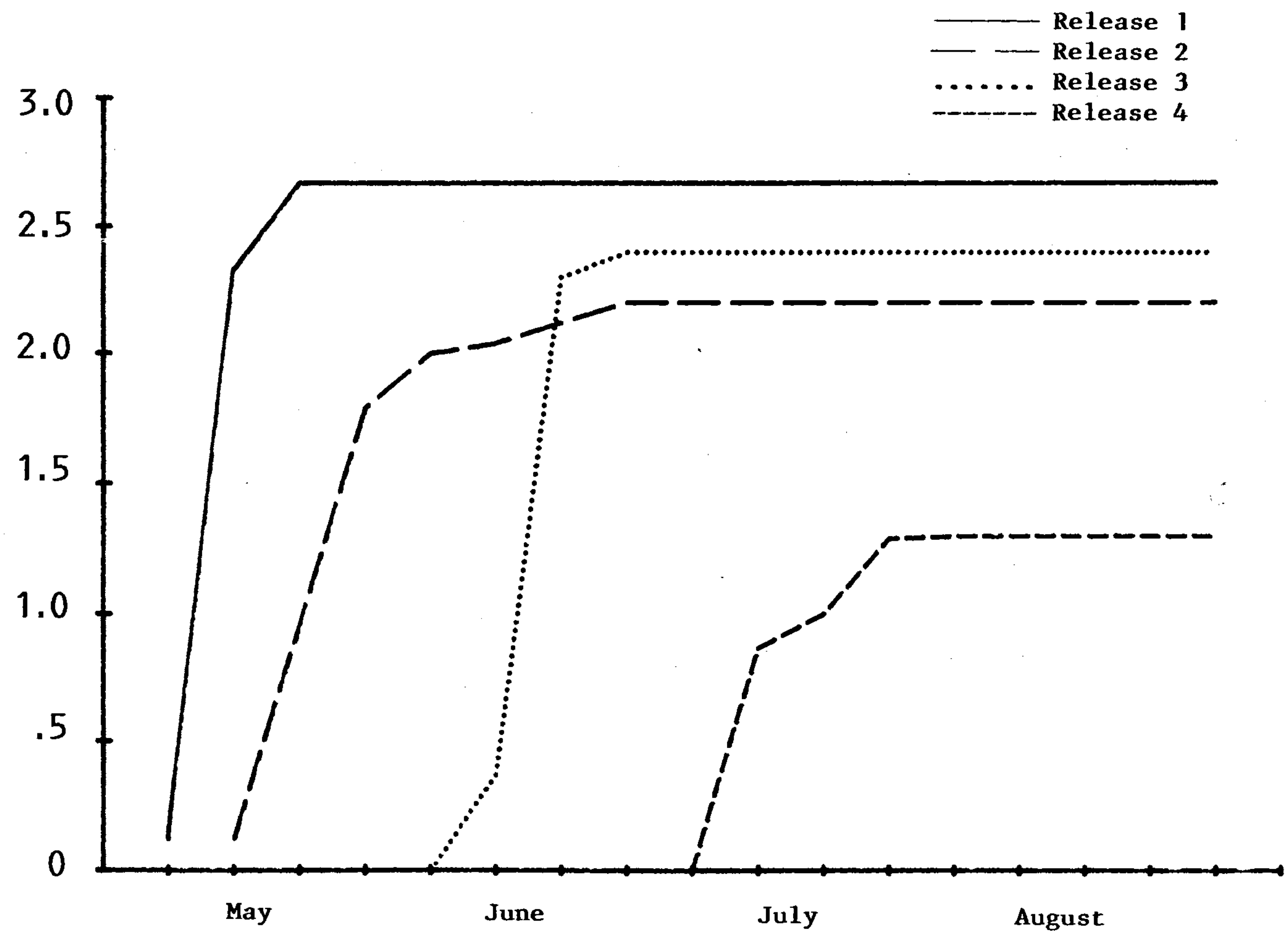

Release 1
Release 2
Release 3
Release 4
3.0
2.5
2.0
1.5
1.0
.5
0
May
June
July
August

Figure 8. Mean Molting Success of Replete Nymphs Released in Ecotones Being Managed by Four Different Methods at the Cookson Hills Wildlife Management Unit During the Summer of 1986.

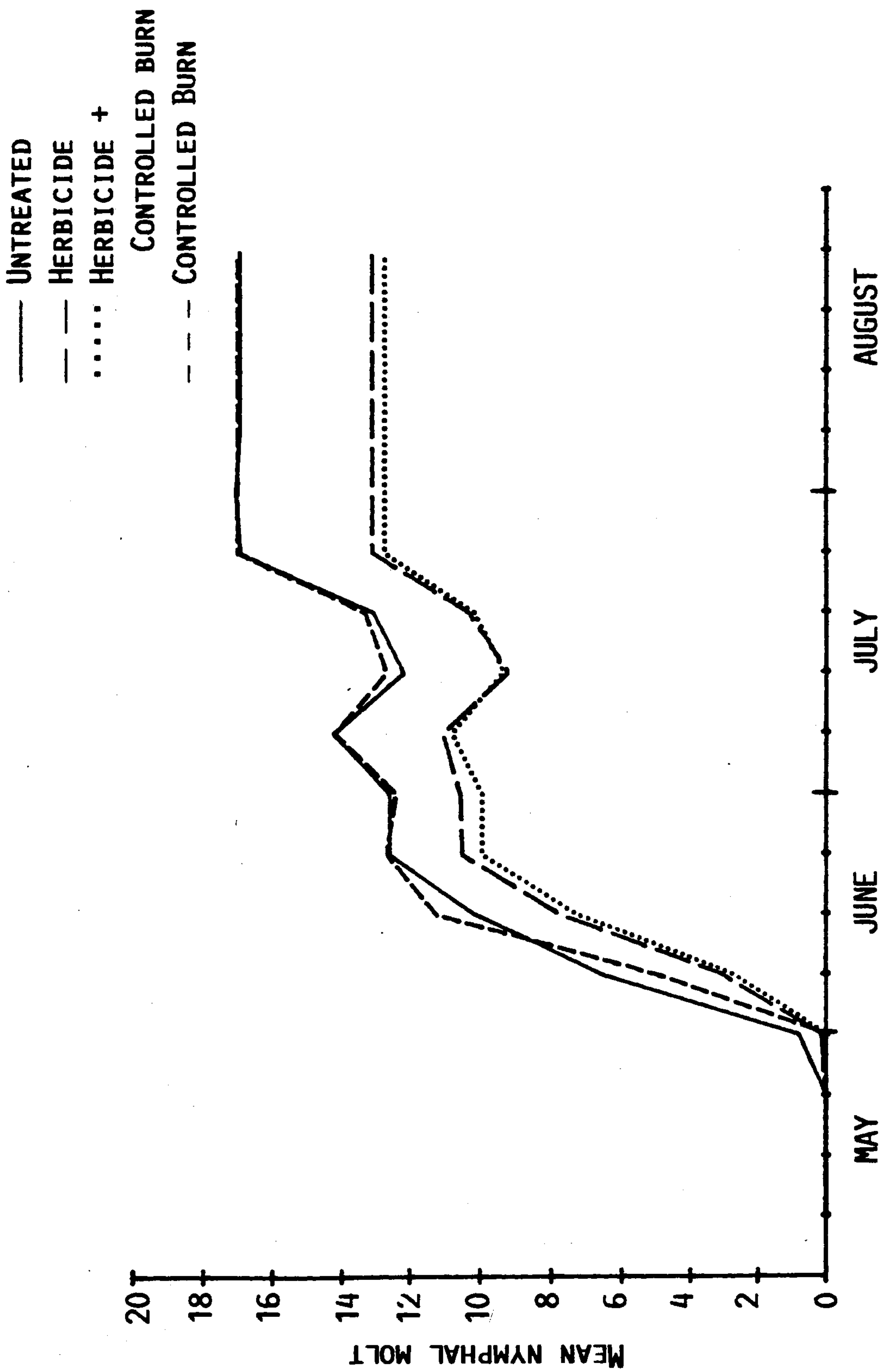

UNTREATED
HERBICIDE
HERBICIDE + CONTROLLED BURN
CONTROLLED BURN
MEAN NYMPHAL MOLT
0
2
4
6
8
10
12
14
16
18
20
MAY
JUNE
JULY
AUGUST

Figure 9. Mean Molting Success of Replete Lone Star Tick Nymphs Released on Four Different Dates in Edges at the Cookson Hills Wildlife Management Unit During the Summer of 1986.

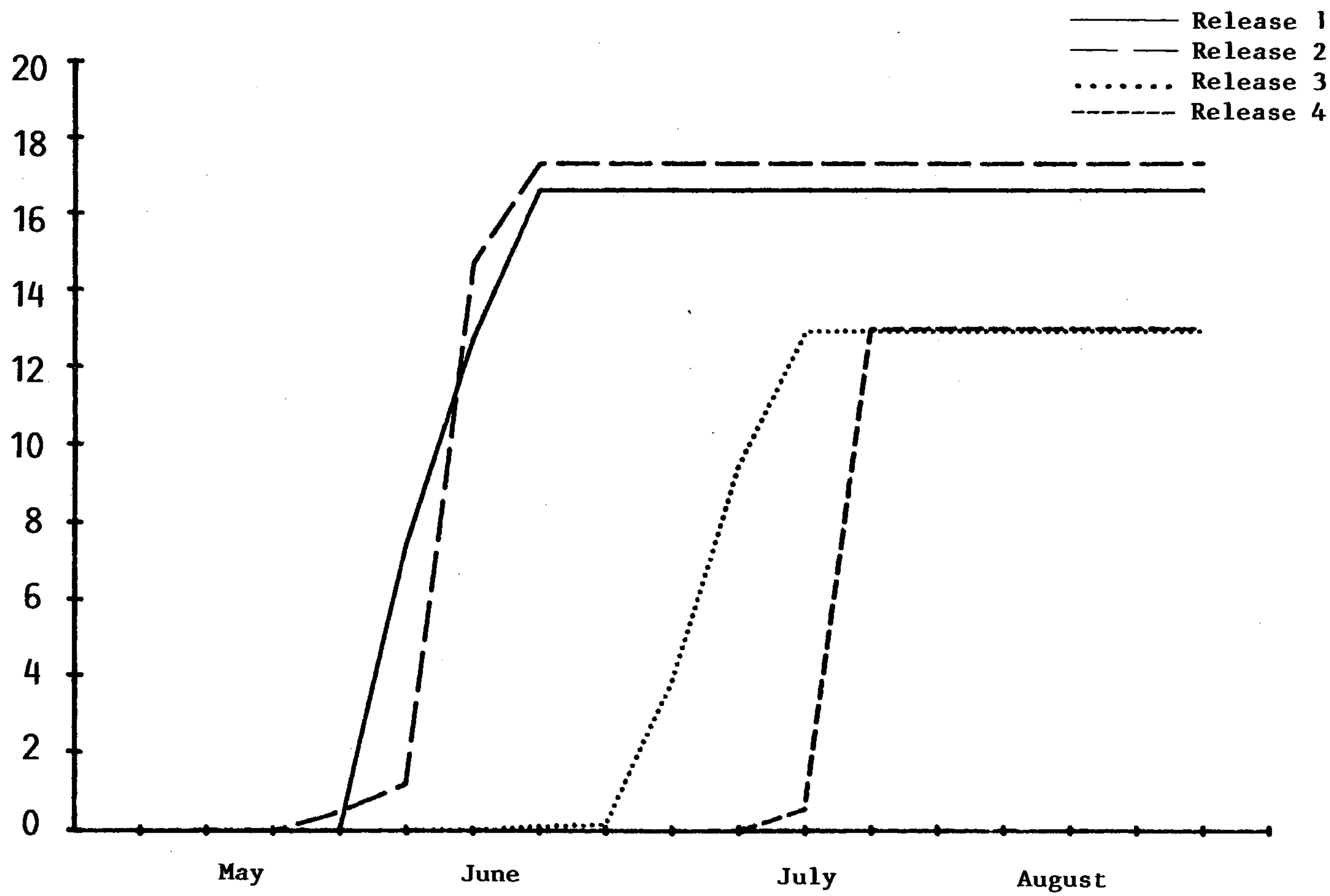

Release 1
Release 2
Release 3
Release 4
20
18
16
14
12
10
8
6
4
2
0
May
June
July
August

Figure 10. Mean Molting Success of Replete Lone Star Tick Nymphs in Contrasting Corners at the Cookson Hills Wildlife Management Unit During the Summer of 1986.

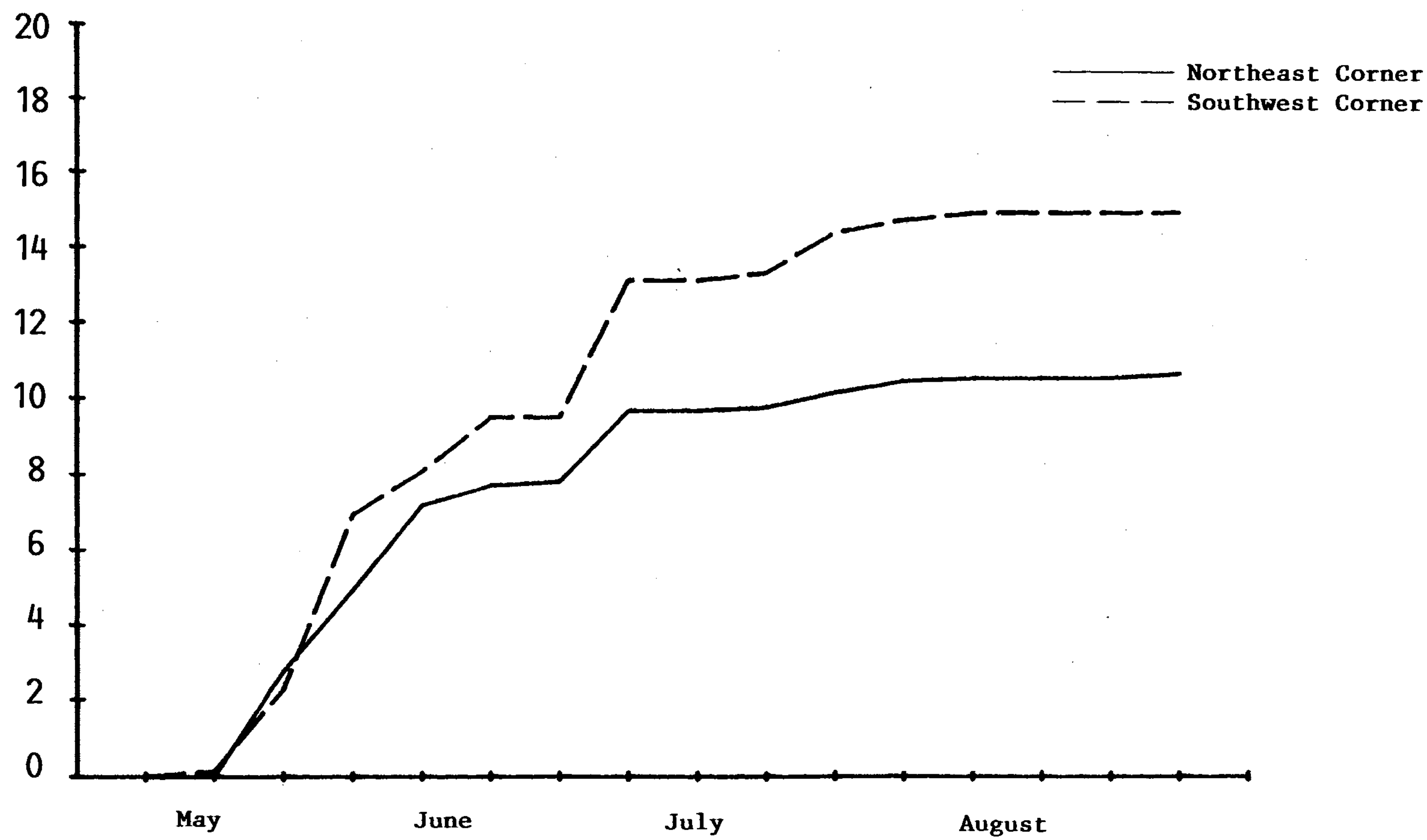

20
18
16
14
12
10
8
6
4
2
0
Northeast Corner
Southwest Corner
May
June
July
August

Figure 11. Mean Molting Success of Replete Lone Star Tick Larvae Released on May 9, 1986 in Edges Managed by Four Different Methods at the Cookson Hills Wildlife Management Unit.

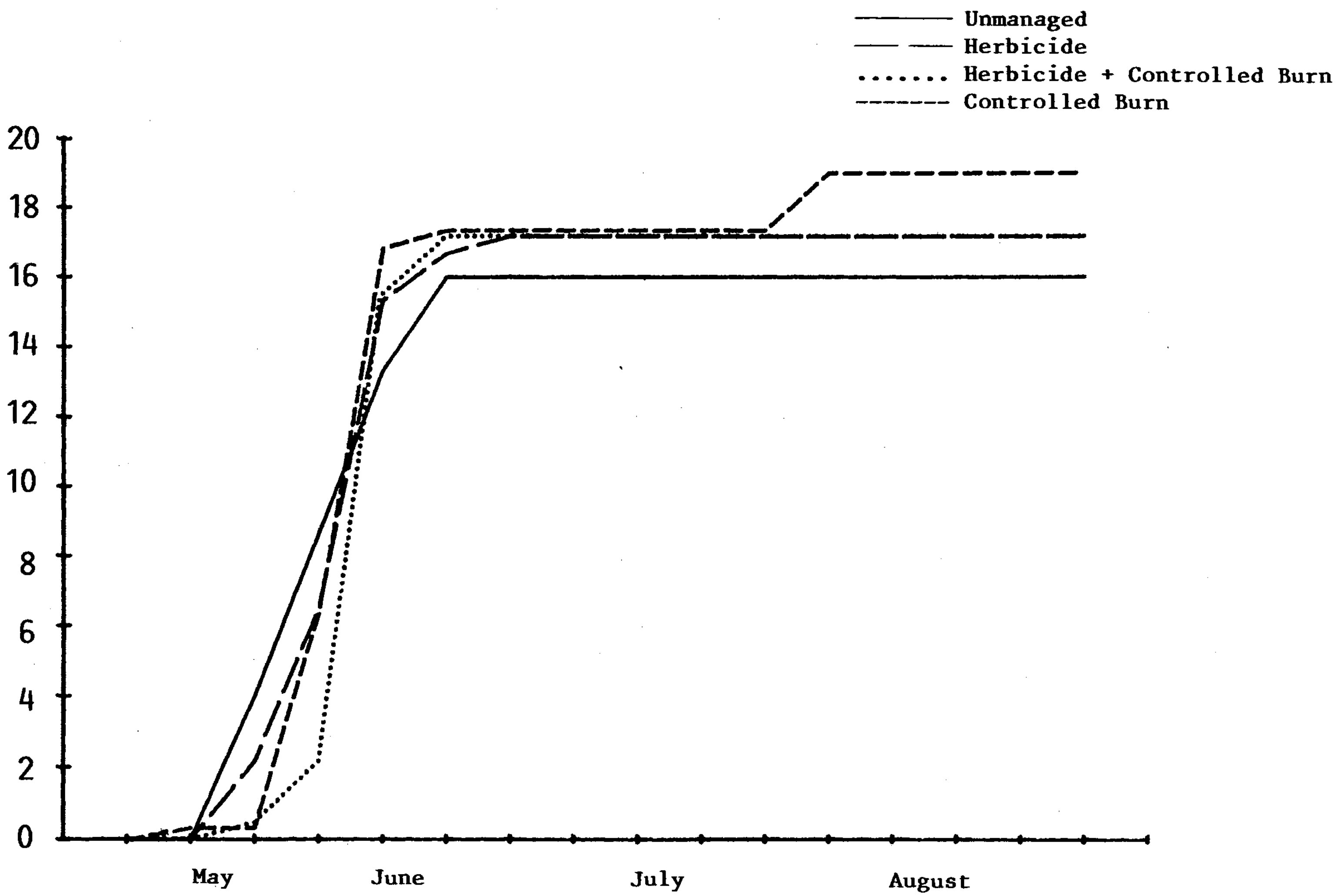

Unmanaged
Herbicide
Herbicide + Controlled Burn
Controlled Burn
20
18
16
14
12
10
8
6
4
2
0
May
June
July
August

Figure 12. Mean Molting Success of Replete Lone Star Tick Larvae Released on June 4, 1986 in Edges Managed by Four Different Methods at the Cookson Hills Wildlife Management Unit.

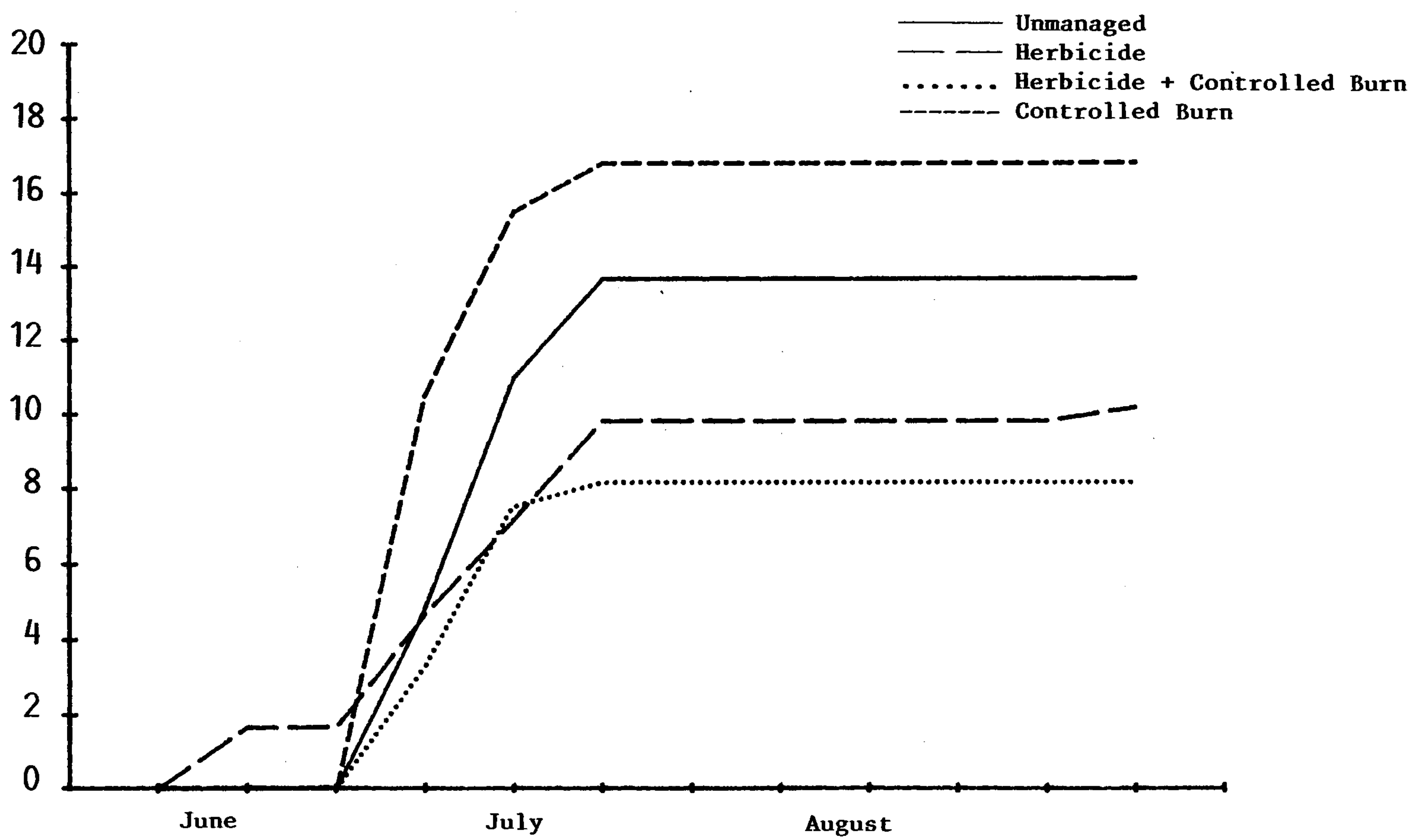
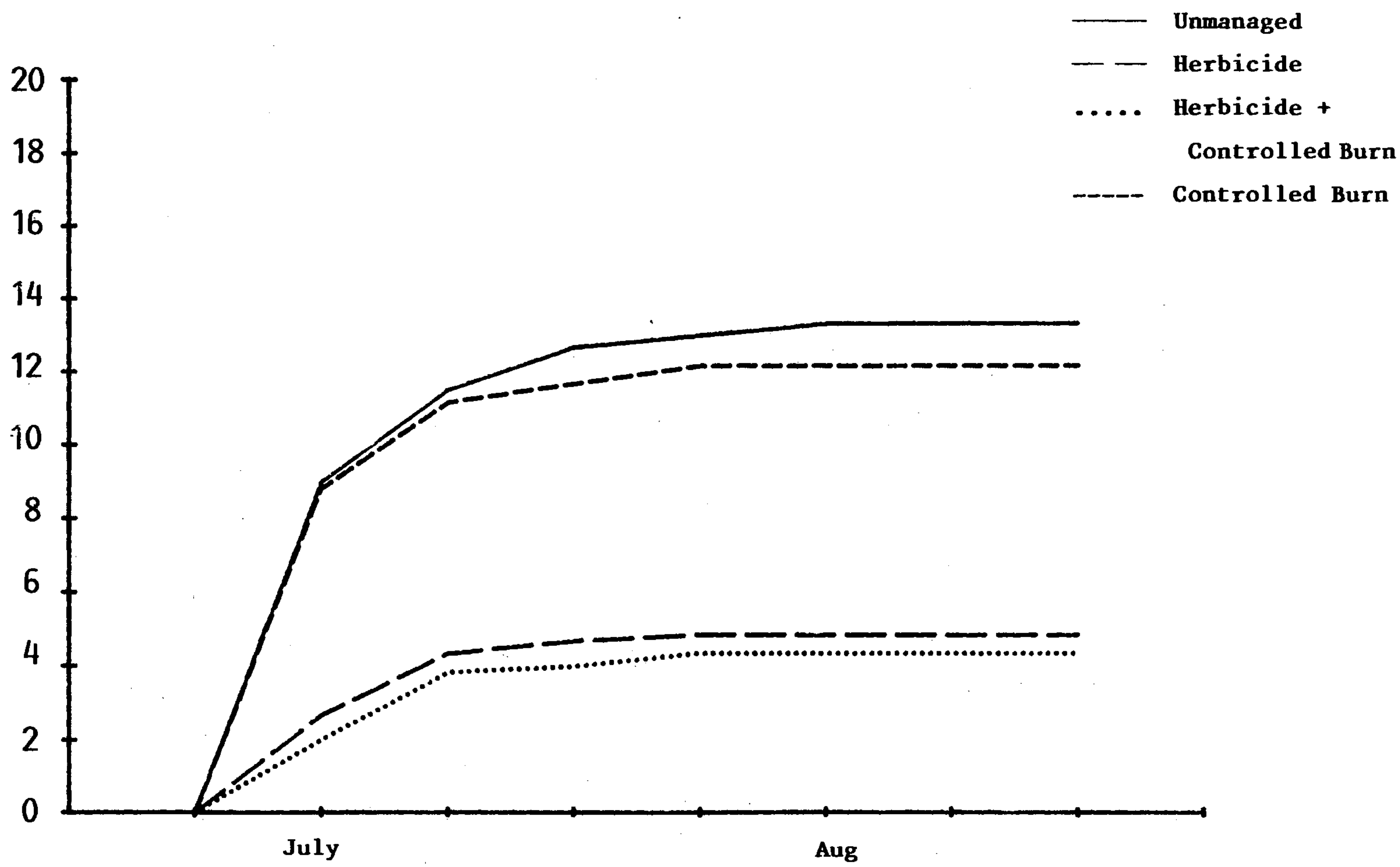

Unmanaged
Herbicide
Herbicide + Controlled Burn
Controlled Burn
20
18
16
14
12
10
8
6
4
2
0
June
July
August

Figure 13. Mean Molting Success of Replete Lone Star Tick Larvae Released on July 3, 1986 in Edges Managed by Four Different Methods at the Cookson Hills Wildlife Management Unit.



Unmanaged
Herbicide
Herbicide + Controlled Burn
Controlled Burn
20
18
16
14
12
10
8
6
4
2
0
July
Aug

Figure 14. Weekly Average Soil Moisture in Ecotones Managed by Four Different Methods in the Cookson Hills Wildlife Management Unit During the Summer of 1986.

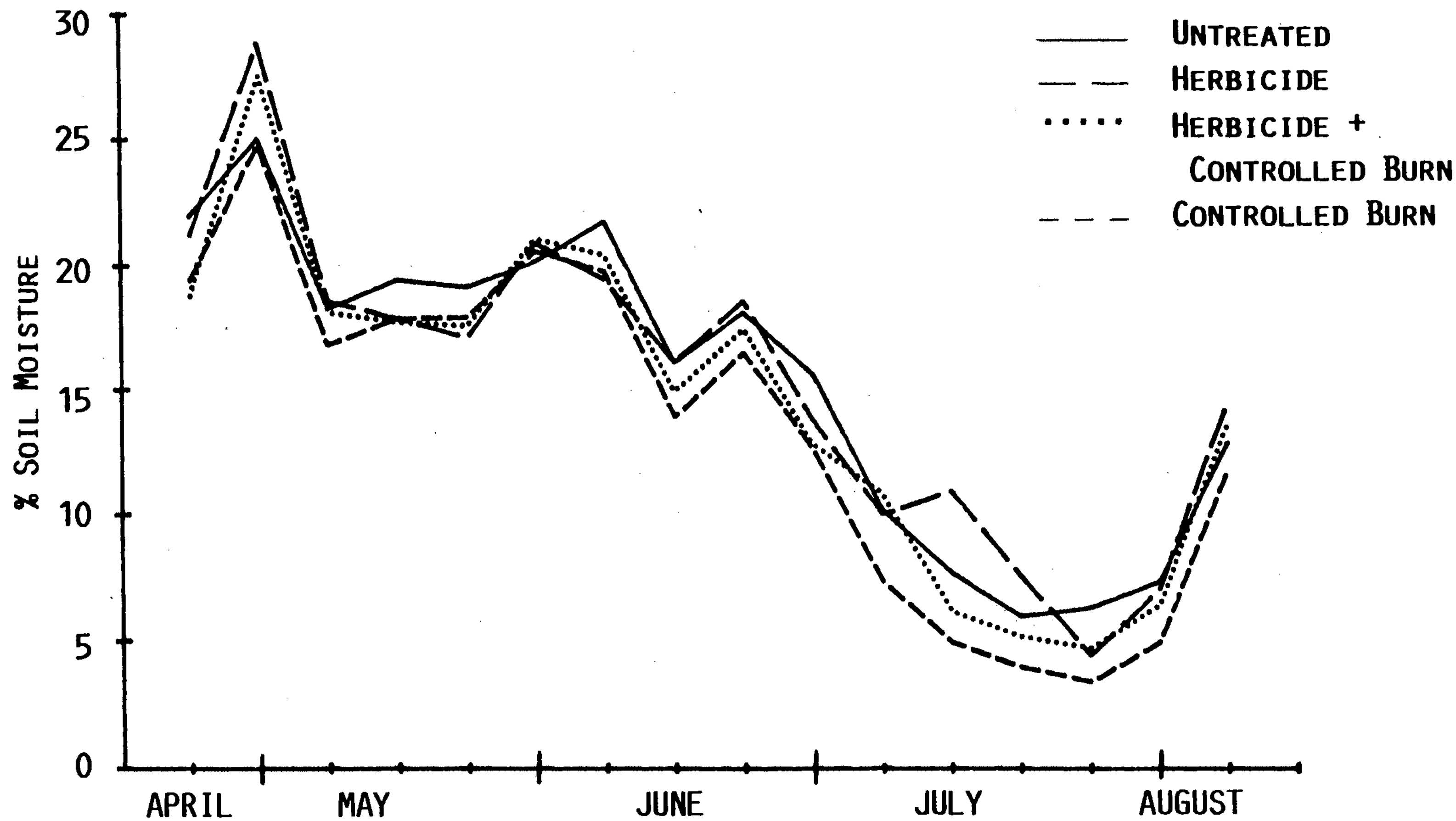
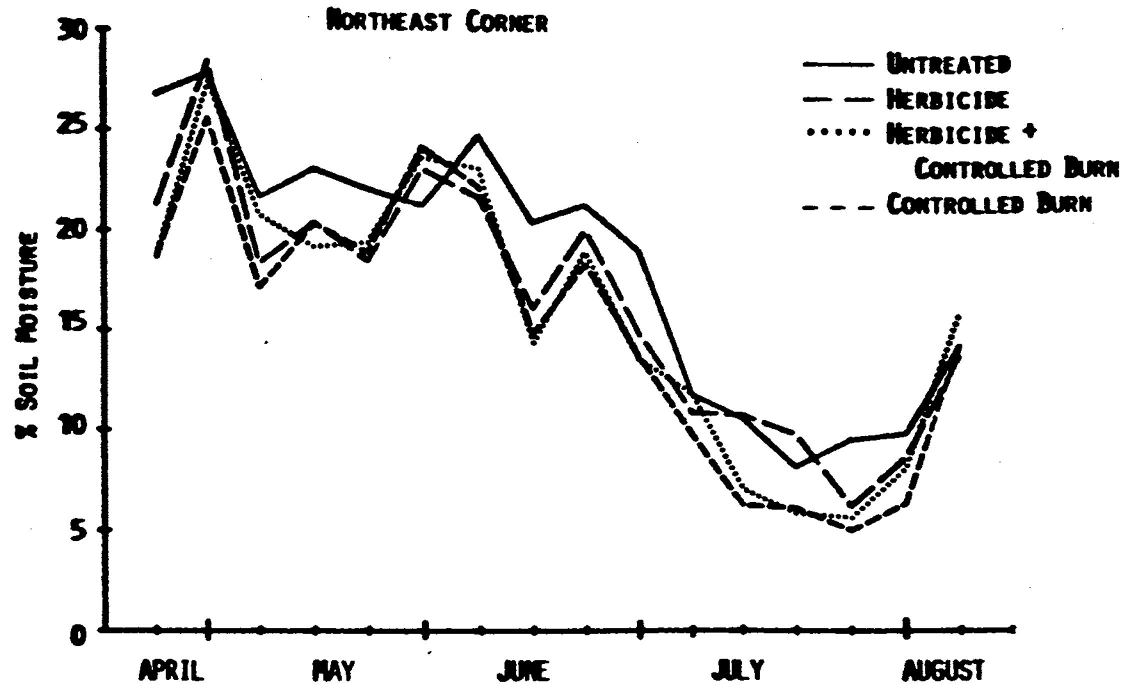

UNTREATED
HERBICIDE
HERBICIDE +
CONTROLLED BURN
CONTROLLED BURN
% SOIL MOISTURE
30
25
20
15
10
5
0
APRIL
MAY
JUNE
JULY
AUGUST

Figure 15. Response of Percent Soil Moisture in Ecotones Being Managed by Four Different Methods Located in Contrasting Corners in the Cookson Hills Wildlife Management Unit During the Summer of 1986.


NORTHEAST CORNER
30
25
20
15
10
5
0
% SOIL MOISTURE
UNTREATED
HERBICIDE
HERBICIDE +
CONTROLLED BURN
CONTROLLED BURN
APRIL
MAY
JUNE
JULY
AUGUST

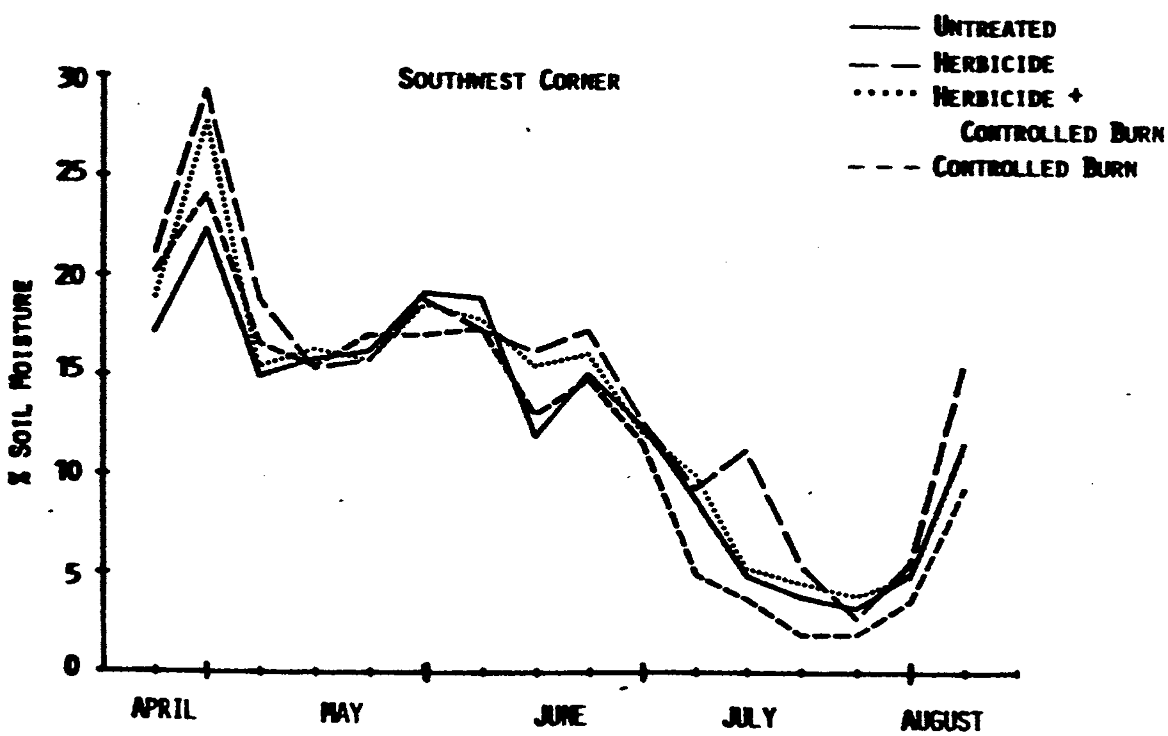
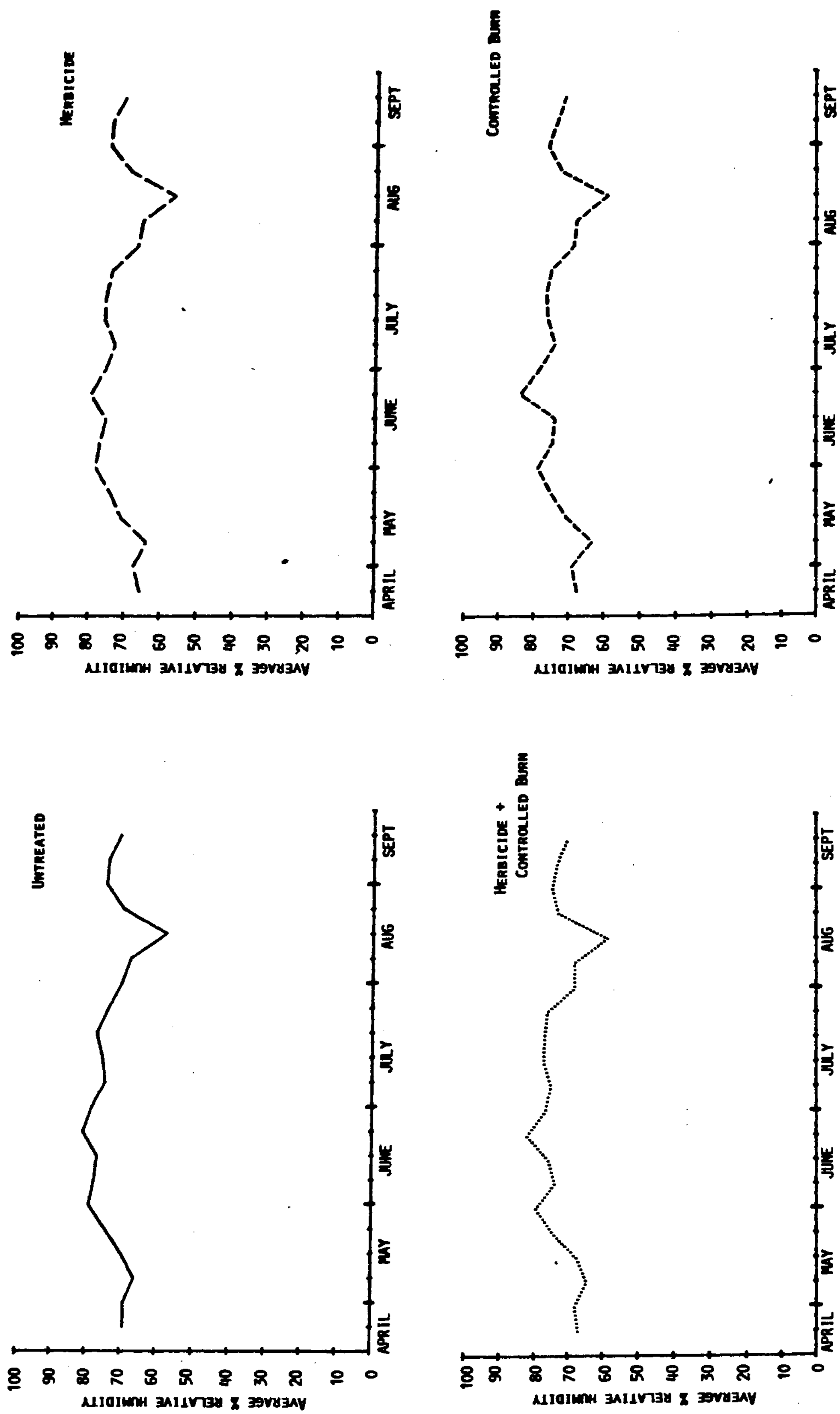
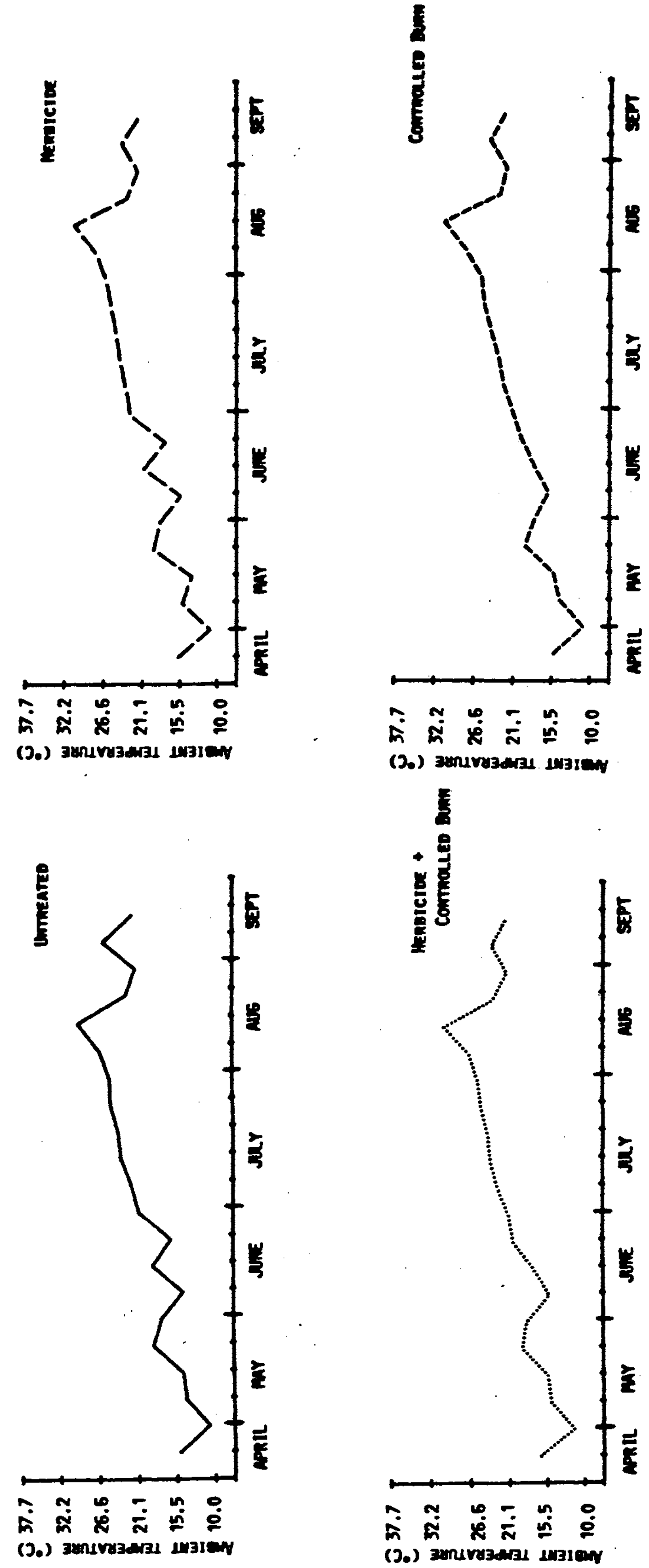

SOUTHWEST CORNER
UNTREATED
HERBICIDE
HERBICIDE +
CONTROLLED BURN
CONTROLLED BURN
30
25
20
15
10
5
0
% SOIL MOISTURE
APRIL
MAY
JUNE
JULY
AUGUST

Figure 16. Weekly Average Percent Relative Humidity in Edges Managed by Four different Methods at the Cookson Hills Wildlife Management Unit During the Summer of 1986.



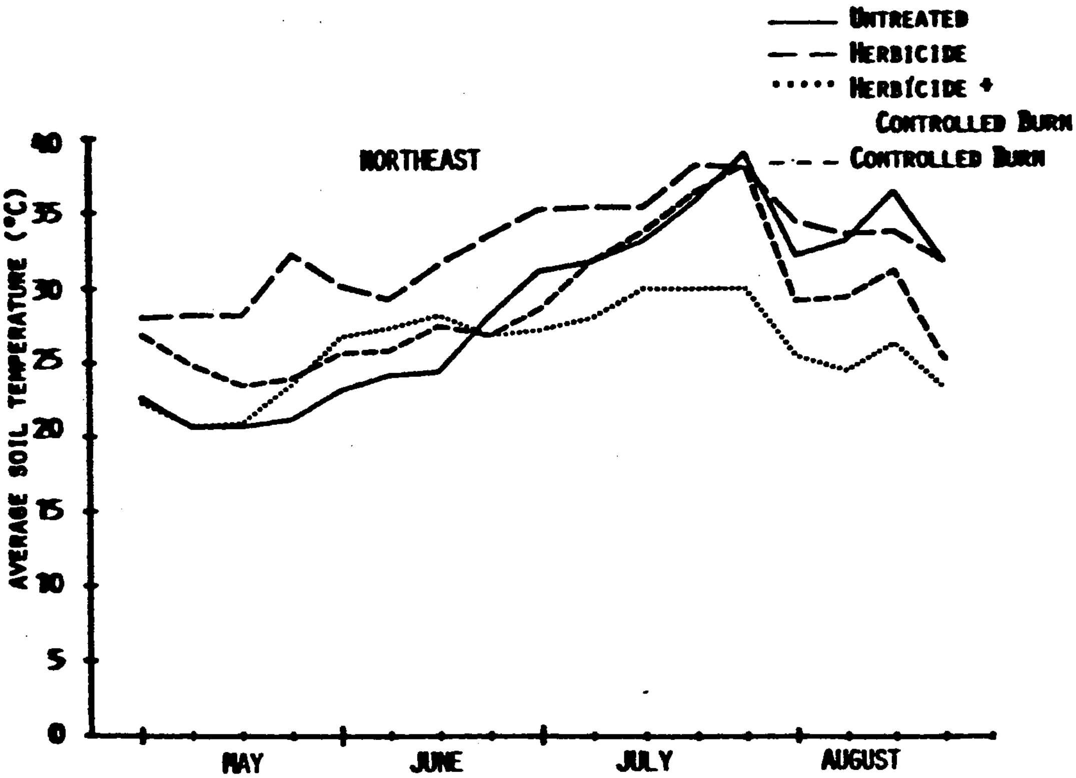
Untreated
Herbicide
Herbicide + Controlled Burn
Controlled Burn
Average % Relative Humidity
0
10
20
30
40
50
60
70
80
90
100
April
May
June
July
Aug
Sept

Figure 17. Weekly Average Ambient Temperature in Edges Managed by Four Different Methods at the Cookson Hills Wildlife Management Unit During the Summer of 1986.



UNTREATED
HERBICIDE
HERBICIDE + CONTROLLED BURN
CONTROLLED BURN
AMBIENT TEMPERATURE (°C)
37.7
32.2
26.6
21.1
15.5
10.0
APRIL
MAY
JUNE
JULY
AUG
SEPT

Figure 18. Weekly Average Soil Temperature in Ecotones Managed by Four Different Methods Located in Contrasting Corners in the Cookson Hills Wildlife Management Unit During the Summer of 1986.


UNTREATED
HERBICIDE
HERBICIDE + CONTROLLED BURN
CONTROLLED BURN
NORTHEAST
AVERAGE SOIL TEMPERATURE (°C)
0
5
10
15
20
25
30
35
40
MAY
JUNE
JULY
AUGUST

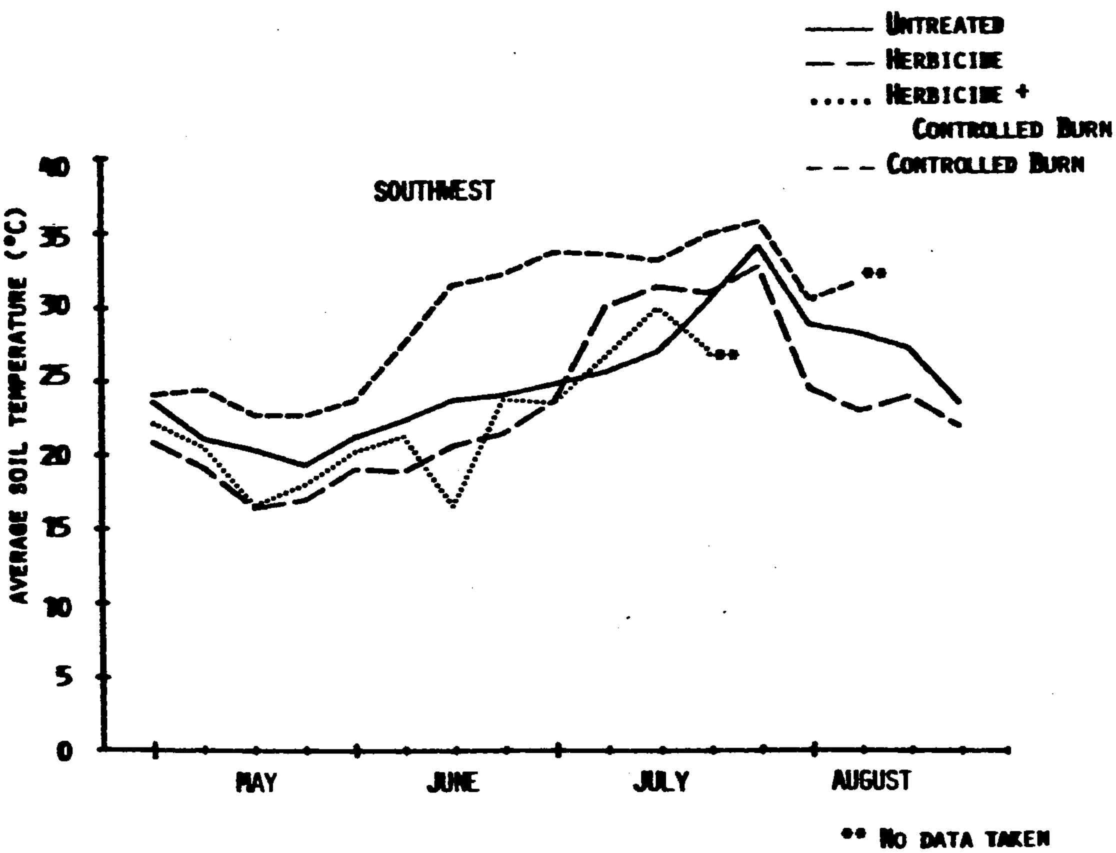

UNTREATED
HERBICIDE
HERBICIDE + CONTROLLED BURN
CONTROLLED BURN
SOUTHWEST
AVERAGE SOIL TEMPERATURE (°C)
0
5
10
15
20
25
30
35
40
**
MAY
JUNE
JULY
AUGUST
** NO DATA TAKEN

TABLE XI

$\bar{X}$ SOIL MOISTURE IN TREATMENTS BY CORNER AT THE COOKSON HILLS WILDLIFE MANAGEMENT UNIT DURING THE SUMMER OF 1986.

Corner	Treatment	$\bar{X}$ % soil moisture[a]
Southwest	Herbicide	14.4_{a}
	Herbicide + Controlled Burn	13.3_{b}
	Unmanaged	12.5_{bc}
	Controlled Burn	12.0_{c}
Northeast	Unmanaged	18.1_{a}
	Herbicide	16.3_{bc}
	Herbicide + Controlled Burn	15.7_{bc}
	Controlled Burn	15.0_{c}

$\bar{X}$ with the same letter within corners are not significantly different at $P < 0.05$.

[a] $\bar{X}$ % soil moisture represents 3 replicates.

VITA

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