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The Effect of Climate and Spittlebug (aeneolamia albofasciata) on Buffelgrass (cenchrus cilaris L.) Productivity in the Sonoran Desert

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Utah State University

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THE EFFECT OF CLIMATE AND SPITTLEBUG (AENEOLAMIA ALBOFASCIATA) ON BUFFELGRASS (CENCHRUS CILIARIS L.) PRODUCTIVITY IN THE SONORAN DESERT

by

Martha H. Martin-Rivera

A dissertation submitted in partial fulfillment of the requirements for the degree of

DOCTOR OF PHILOSOPHY

in

Range Science

UTAH STATE UNIVERSITY
Logan, Utah
1994
DEDICATION

I dedicate my dissertation in memory
of my beloved father, Agustin Martin.
I dedicate my dissertation to my husband,
Fernando, and my son Fernando, Jr.,
for their love and encouragement.
Different institutions and individuals contributed to this project. I appreciate the financial support from Consejo Nacional de Ciencia y Tecnologia (CONACYT), Instituto Nacional de Investigaciones Forestales Agricolas y Pecuarias (INIFAP), and the Board of Directors of Centro de Investigaciones Pecuarias del Estado de Sonora (CIPES).

I gratefully acknowledge the financial support provided by Drs. R. D. Plowman, Administrator, USDA-Agricultural Research Service (ARS). I especially wish to thank Dr. N. J. Chatterton, USDA-ARS, Logan, Utah, for his support and use of laboratory facilities.

Sincere appreciation is expressed to Dr. Jerry R. Cox, thesis director, for his help and guidance during the course of this study. Sincere acknowledgment is expressed to the other members of my committee, Drs. Diana G. Alston, Roger E. Banner, G. Allen Rasmusssen, and Christopher A. Call, for their guidance, suggestions and contributions regarding my research and education. Special thanks is extended to Dr. John C. Malechek for his advice, support, and guidance during my program. I also appreciate the statistical advice of Drs. Gary Richardson, Donald V. Sisson, and Susan Durham.

Many others contributed to the completion of my research. These include: Drs. Howard L. Morton, Wayne T. Hamilton, Mark A. Hussey, Bruce Roundy, and Douglas A.
Johnson, who reviewed the manuscript and made suggestions for its improvement. Raymundo Rojas and Katy Young assisted me in the use of the computer. Charmine Verdugo and Mark Burr assisted me with my lab work. I also would like to express my thanks to Ing. Martin Silva, and Biol. Hector Miranda, Oscar Cazares, and Luis Cordero for their assistance in the lab; to Silvano Villa, Hector Campillo, and Miguel Ortiz for their assistance in the field work, and to Debbie Brunson for assistance in typing and organizing this dissertation.

Finally, I thank all of my family. I especially thank my mother, Columba, and my sisters, Esperanza, Teresa, and Lourdes, for always being there with patience, guidance, love, and support. I express my deep gratitude to my husband, Fernando, and to my son Fernando, Jr., for their love, patience, and encouragement during the course of my studies.

Martha H. Martin-Rivera
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ABSTRACT

The Effect of Climate and Spittlebug (Aeneolamia albofasciata) on Buffelgrass (Cenchrus ciliaris L. (Link)) Productivity in the Sonoran Desert

by

Martha H. Martin-Rivera, Doctor of Philosophy
Utah State University

Major Professor: Dr. Jerry R. Cox
Department: Range Science

I conducted field studies during 1984-1988 to determine how (1) precipitation amount and distribution affect buffelgrass (Cenchrus ciliaris L. (Link)) productivity, (2) summer rainfall amount and distribution and temperature influenced the spittlebug (Aeneolamia albofasciata Lalleman) life cycle, and (3) summer burning affects spittlebug densities and buffelgrass productivity.

Experiment I was conducted from 1985 through 1988. Forage samples collected at 15-day intervals were separated into live, recent-dead standing, old-dead standing, and litter. There was a positive relationship between the summer precipitation and the live biomass. Recent-dead standing and old-dead standing decomposed during the summer, fall, or spring.
Experiment II was conducted during summers of 1984, 1985, and 1986. I studied climatic effects on spittlebug life cycle and monitored nymph and adult populations. Egg hatch occurred after accumulative summer precipitation exceeded 50 mm. Five nymphal stages were completed in an average of 27 days and the life cycle averaged 43 days.

Experiment III was conducted during the summer of 1985 and 1986. Four burning treatments were applied at different stages within the spittlebug life cycle. Burning should be conducted as buffelgrass initiates summer growth, and between the second and third nymphal stages. Burns conducted before plant growth and during rapid growth damaged the plant, and insect control was inconsistent.

My studies will help ranchers in northwestern Mexico, south Texas, and northeast Mexico effectively manage buffelgrass pastures. Forage accumulation and decomposition cycles can be used to adjust stocking rates, and knowledge of the insect life cycle and plant productivity can be used to maximize insect control and minimize adverse effect on plant productivity.

(91 pages)
CHAPTER I
INTRODUCTION

Cattle were introduced to the Sonoran Desert of northwestern Mexico in the late 1600’s, but numbers remained low until Indian raids declined in the 1880’s (Hasting and Turner 1972). Since 1890, wet periods with abundant forage were followed by overstocking and drought periods were followed by livestock reductions (Wagoner 1952). With each successive cycle, perennial grass productivity declined and northwestern Mexico rangelands supported fewer livestock (Bryan 1925). Excessive and continuous grazing slowed grass recovery and favored shrub establishment. This overutilization changed the semidesert Sonoran grasslands into shrublands (Cooke and Reeves 1976).

Attempts to restore grassland productivity with native perennial grasses began in the 1950’s (Cota and Johnson 1975), but plantings failed because native grass seedlings could not compete with shrubs and introduced annual weeds for water and nutrients (Cox et al. 1982). In the mid 1950’s African perennial grasses were introduced into northwestern Mexico. One of these grasses, T-4464 buffelgrass [Cenchrus ciliaris L. (Link)], has since been successfully seeded throughout Sonora, Mexico.

Buffelgrass seed from the Turkana Desert in north central Kenya arrived in the United States in 1946 (Holt 1985). Plants were successfully established and persisted
in south Texas, and the U.S. Department of Agriculture, Soil Conservation Service, informally released T-4464 buffelgrass in 1949. Between 1949 and 1985, Texas seed producers sold 7 millions kg of T-4464 seed, and ranchers established the grass on more than 4 million ha. Seed was transported into Mexico and successfully established on more than 400,000 ha in northwestern Mexico (Cota and Johnson 1975, Cox et al. 1988).

The animal-carrying capacity of seeded buffelgrass range is dependent on the amount of plant biomass available for conversion to animal biomass. Many believe that the carrying capacity of rangelands in northwestern Mexico increased after the introduction of T-4464, but production potential in wet and dry years should be measured to verify this assertion. This verification should quantify the annual accumulation and decomposition characteristics of live biomass, dead standing biomass, and litter across years.

Although buffelgrass apparently improves rangeland productivity, it is susceptible to spittlebug (Aeneolamia albofasciata Lalleman) damage. Because improved pastures have a low crop value per hectare compared to grain or vegetable crops, greater insect damage is tolerated before insect control measures are initiated. However, if the cost of land preparation and risks of seeding failures are
high, insect control practices are justified (Contreras 1964, Cazares et al. 1985).

The spittlebug was reported in Mexico in 1858, but was not considered a pest until it began to feed on sugarcane (Saccharum officinarum L.) in 1876 (Coronado 1978). The spittlebug has continued to feed on cultivated grass crops in eastern and southern Mexico, and in the 1980's it invaded buffelgrass pastures in northwestern Mexico (Cazares et al. 1985).

Adult and nymph spittlebug stages have sucking mouth parts (Hagley and Blackman 1966). Nymphs congregate in a bubbly liquid mass to prevent dehydration and feed on young leaves and shoots near the crown. Adults feed on all above-ground plant parts, and they are active early in the morning and late in the afternoon. Where spittlebug infestations occur, foliage is often chlorotic. While plant juices are extracted, diastatic oxidase is released by the insect. This chemical acts as a systematic toxin and disrupts nutrient transport and respiration.

Spittlebugs (20-40/plant) may reduce buffelgrass production by 50% (Martin et al. 1985), but dense populations (100-200/plant) may kill adult plants (Cazares et al. 1985). Above-ground forage removal, prior to peak insect densities in summer, is believed to limit feeding sites and spittlebug populations, but quantitative data are not available.
Several management options have been developed to control spittlebugs in the Gulf of Mexico. These include chemical (Purata 1974), mechanical (Velazco et al. 1969), and spring-burning treatments (Ibarra and Enkerlin 1974). In addition, buffelgrass accessions with limited resistance to the insect can be seeded (Flores and Velazco 1974, Stimman and Taliaferro 1970, Agostini 1980, and Morales 1985). Biological control of spittlebug has been unsuccessful under field conditions. Preliminary information from eastern Mexico indicates that grazing, mowing, and burning reduce spittlebug populations (Coronado 1978). However, these studies have been conducted in humid regions in Mexico. There has been no attempt to evaluate control effects at different stages in the insect’s life cycle in arid areas of Mexico.

I conducted a field study to investigate three research objectives in buffelgrass pastures in northwestern Mexico. First, I determined how precipitation amount and distribution affected accumulation and decomposition of above-ground biomass (Chapter II). Second, I investigated the effect of summer precipitation and temperature on spittlebug nymphal and adult populations (Chapter III). Third, I determined the effect of summer burning at various insect life stages and the subsequent response on buffelgrass (Chapter IV). I synthesized these research
findings and discussed how my results apply to buffelgrass management in Chapter V.

Literature Cited


Bryan, K. 1925. Date of channel trenching (arroyo cutting) in the arid southwest. Science 62: 338-44.


CHAPTER II
CLIMATIC EFFECTS ON Cenchrus ciliaris L.
PRODUCTIVITY IN THE SONORAN DESERT

Abstract

In Sonora, Mexico, buffelgrass [Cenchrus ciliaris L. Link], a perennial bunchgrass from Africa, has been sown on 400,000 ha as a forage for cattle. Hence, there is a need to determine annual changes in above-ground standing biomass and litter in wet and dry years. Summer live biomass peaks averaged 3,025 kg/ha in a wet summer and varied from 465-1,040 kg/ha in two dry summers. Recent-dead biomass approached zero in June or July when maximum daytime temperatures peaked or in April following a wet winter. Old-dead biomass increased with each successive summer thunderstorm and rapidly declined in a wet winter. Litter was highly variable among years and dates but amounts usually peaked in spring and summer, and disappeared in fall. When summer precipitation is above average, buffelgrass annually produces three to four times more green forage than native grasses.

Introduction

In the late 1600's cattle were introduced in the Sonoran Desert of northwestern Mexico, but numbers remained low until Indian raids declined in the 1880's (Hasting and
Turner 1972). Since 1890, wet periods with abundant forage have been followed by overstocking, droughts, and livestock reductions (Wagoner 1952). With each successive cycle, perennial grass productivity declined and northwestern Mexico rangelands supported fewer livestock (Bryan 1925). Excessive and continuous grazing slowed grass recovery and favored shrub establishment. This has resulted in the conversion of semidesert Sonoran grasslands into shrublands (Cooke and Reeves 1976).

Attempts to restore grassland productivity with native perennial grasses began in the 1950’s (Cota and Johnson 1975), but plantings failed because native grass seedlings could not compete with shrubs and introduced annuals for moisture and nutrients (Cox et al. 1982). In the mid-1950’s seed from African perennial grasses were introduced into northwestern Mexico. One of these grasses, T-4464 buffelgrass, has been successfully seeded throughout the Sonoran Desert (Ibarra et al. 1987).

It appears that the carrying capacity of rangelands in northwestern Mexico increased after the introduction of T-4464 (Hanselka and Johnson 1991), but production potential in wet and dry years is variable and needs to be measured to determine if this hypothesis is true. One of the steps in a program to evaluate carrying capacity should be to quantify the annual accumulation and decomposition characteristics of live biomass, dead standing biomass, and
litter in years with different weather patterns (Weaver 1954).

Several studies have evaluated buffelgrass production (Paull and Lee 1978, Gonzales and Dodd 1979, Anning 1982, White 1985, and Ibarra et al. 1987), but none have attempted to evaluate productivity as influenced by climate. The objective of this study was to determine how precipitation amount and distribution affected plant aboveground biomass accumulation and decomposition.

Material and Methods

Study Site

The study site is located 82 km north of Hermosillo in northwestern Sonora, Mexico (29° 41'N Lat., 115° 57'W. Long.) at the Carbo Livestock Research Station. Elevation is 470 m and slope is 1-2%. The soil is an Anthony fine loam (Thermic Typic Torrifluvent), comprised of recent alluvium weathered from granitic rocks, and is moderately basic (pH = 8.5-8.9) and ranges in depth from 2 to 6 m (Hendricks 1985).

Average annual precipitation is 320 mm (Centro de Investigaciones Pecuarias del Estado de Sonora, 1989). Precipitation is bimodally distributed: approximately 60% comes between July and September, and about 40% comes between October and April. May, June, and September are usually dry but exceptions do occur (Fig. 1). Summer
Figure 1. Monthly precipitation (bars), mean daily maximum temperatures (upper solid line), and mean nighttime minimums (lower solid line) during 3 years at Carbo Livestock Research Station in northwestern Mexico.
rainfall comes as thunderstorms, which are frequently localized and of high intensity.

Daytime temperatures averaged 34°C, but frequently exceed 40°C in June through August. Nighttime temperatures average 8°C in winter, and may approach 0°C in January and February.

A 2.5 ha stand of dense, shrub-free buffelgrass was fenced to exclude livestock. Nine 20-by-70 m plots were established with 3 plots in each of 3 blocks. One plot in each block was randomly selected for sampling at 2-week intervals between 15 July 1985 and 1 July 1986. Three additional plots were sampled between 15 July 1986 and 1 July 1987. The remaining 3 plots were sampled between 15 July 1987 and 1 July 1988. The experimental design was a randomized complete block with 3 replications each year.

Field Measurements

On each sampling date, 5 previously unsampled 1-by-1 m quadrats were randomly selected in each plot. Buffelgrass plants were clipped at the soil surface and litter collected from the soil surface.

Forage from 3 of the 5 quadrats in a plot was separated into live (green), recent-dead standing (yellow), and old-dead standing (gray) components. Separated and unseparated forage samples and litter were dried in a forced-draft oven at 40°C for 72 hr and weighed. Forage
component dry weights from the 3 quadrats were pooled and the contribution of each to the total forage dry weight expressed as a percentage. Average component percentages were multiplied by total forage dry weight of unseparated quadrats. The derived dry weight component value for the 2 unseparated and the 3 separated quadrats were averaged to provide an estimate of plot biomass for each forage component at each sampling date.

Precipitation was measured daily at the Carbo Livestock Research Station. Daily precipitation was summed for all dates between harvests.

Statistical Analyses

The year effect was evaluated for each forage component (green, recent-dead, old-dead, and litter) on each sampling date using analysis of variance. When F-values were significant (P≤0.05), Least Significant Difference tests (Steel and Torrie 1960) were used to separate means. Regression and correlation analyses were used to determine relationships between precipitation and forage production in summer and winter.

Results and Discussion

Live Biomass

Live biomass production was bimodally distributed among seasons (Fig. 2-A). Live biomass was different (P≤0.05) among years on 2 summer, 2 fall, and 3 winter
Figure 2. Three year means and standard errors for live biomass (A), recent-dead standing biomass (B), old-dead standing biomass (C), and litter (D) at 24 annual sampling dates for a buffelgrass pasture in Sonora, Mexico. An asterisk (*) above the standard error notation indicates a significant difference (P≤0.05) among years at the same sampling date.
sampling dates and similar at remaining dates over the 3 years. Summer accumulative (July-September) precipitation was above the long-term average (192 mm) in 1986 (358 mm), and below average in both 1985 (186 mm) and 1987 (146 mm). Peak live biomass production was greatest in 1986 (3,025 kg/ha), intermediate in 1985 (1,040 kg/ha), and least in 1987 (465 kg/ha).

Plants began to actively grow 15 days after 20-mm storms on 14 July 1985, 10 July 1986, and 28 July 1987. After initial 20-mm storms, culms elongated in 20 days, leaves elongated in 25 to 27 days, and seedheads were present in 30 days. Most summer leaves became dormant in fall and winter but a few leaves remain green throughout the year. Following fall, winter, and spring moisture, green leaves emerge at the crown base but leaves elongate only when minimum temperatures approach 15°C (Ibarra et al. 1991).

Observations made during this 3-year study suggest that buffelgrass initiates leaf production whenever soil moisture is available and minimum temperatures are more than 15°C. When more than 150 mm of precipitation was recorded during summer (Fig. 1), live biomass exceeds more than 1,000 kg/ha (Fig. 2-A). When summer precipitation is less than 150 mm, live biomass approaches 500 kg/ha.

In northwest Mexico, precipitation is bimodally distributed and summer precipitation has the greatest
effect on plant growth (Hanselka and Johnson 1991). The coefficient of determination ($r^2$) between accumulative summer precipitation and summer buffelgrass growth was 0.85 (Table 1). This value is 20% greater than that reported for other introduced African grasses (Cox et al. 1990) and native grasses (Cable 1975). Hence about four-fifths of the summer buffelgrass growth can be accounted for by accumulating the July to September precipitation. The $r^2$ between accumulative winter precipitation and winter growth was 0.04. This value is low because winter temperatures of less than 5°C limit growth (Cox et al. 1988).

Recent Dead Biomass

Recent-dead biomass was different ($P<0.05$) among years on 1 summer, 1 winter, and 2 spring sampling dates, and similar on remaining dates over the 3 years (Fig. 2-B). Peak amounts were greatest in 1985, intermediate in 1986, and least in 1987.

During the 3 years, recent-dead biomass approached zero in late June, July or April. With each successive July and August storm, recent-dead transferred to old-dead (a yellow to gray color change). In the summer, the recent- to old-dead transfer occurred in as few as 20 days (1985 and 1986) or as many as 50 days (1987).

In the mild winter of 1985-86 (Fig. 1), green culms from tillers produced in the previous July senesced slowly
Table 1. Simple linear regression equations for buffelgrass live, recent-dead biomass, old-dead biomass and litter, and either total accumulative summer or winter precipitation between 1985-88.

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<th>Season</th>
<th>Biomass</th>
<th>Regression equation</th>
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<td>$Y = \text{[Equation]}$</td>
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<tr>
<td>Summer</td>
<td>Live</td>
<td>$Y = -1527.9 + 19.8X$</td>
<td>0.85</td>
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<tr>
<td></td>
<td>Recent-dead</td>
<td>$Y = -979.0 + 5.5X$</td>
<td>0.22 NS</td>
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<tr>
<td></td>
<td>Old-dead</td>
<td>$Y = -3299.1 + 5.1X$</td>
<td>0.03 NS</td>
<td></td>
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<tr>
<td></td>
<td>Litter</td>
<td>$Y = 716.9 + 0.1X$</td>
<td>0.01 NS</td>
<td></td>
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<tr>
<td>Winter</td>
<td>Live</td>
<td>$Y = 1431.2 + 1.7X$</td>
<td>0.04 NS</td>
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<tr>
<td></td>
<td>Recent-dead</td>
<td>$Y = 197.9 + 39.1X$</td>
<td>0.30 NS</td>
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<td></td>
<td>Old-dead</td>
<td>$Y = -1666.5 + 69.9X$</td>
<td>0.25 NS</td>
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<td></td>
<td>Litter</td>
<td>$Y = 1060.8 + 14.3X$</td>
<td>0.10 NS</td>
<td></td>
</tr>
</tbody>
</table>

$^a$ = Significant at $P \leq 0.05$.
NS = Not significant.
from top to bottom, and recent-dead biomass gradually accumulated. During the winters of 1986-87 and 1987-88, temperatures approached zero in either February and March or December, respectively. Immediately following mean minimum temperatures of 5°C or less we observed a rapid live to recent-dead biomass transfer, and if cold temperatures were followed by precipitation, there was a corresponding recent- to old-dead biomass transfer.

Old-Dead Standing Biomass

Old-dead biomass was different \((P<0.05)\) at 2 summer sampling dates, and similar at all remaining dates over the 3 years (Fig. 2-C). Low quantities in summer 1985 were related to livestock activity prior to fencing and quantities remained low in the wet summer of 1986. Live and recent-dead biomass produced during summer gradually transferred to old-dead during fall, winter, or spring. The rate of transfer depended on moisture and temperature.

Litter

Litter quantities were similar \((P<0.05)\) at all sampling dates over the 3 years (Fig. 2-D). Litter amounts in summer of 1985 exceeded those in other years because old culms dislodged by cattle prior to fencing accumulated on the soil surface after summer thunderstorm activity.

Litter quantities peaked in summer during the thunderstorm season, gradually disappeared in fall,
increased in winter, and dramatically increased during a spring when maximum temperatures exceeded 35°C (Fig. 1 and Fig. 2-D). Anderson and Coleman (1985) reported litter accumulations at end of summer and at the beginning of spring, and decomposition in summer when wind speed increased. In Lehmann lovegrass (*Eragrostis lehmanniana* Ness.) communities, litter is easily moved by wind and water (Cox et al. 1990). Runoff moves culms and leaf fragments, and fragments accumulate in open spaces between plants during summer and winter storms.

Management Implications

Above-ground net primary production of buffelgrass peak standing crop was 7,025 kg/ha in south Texas (Gonzalez and Dodd 1979, Hanselka and Johnson 1991), ranged from 3,000 to 7,000 kg/ha in Queensland, Australia (Paull and Lee 1978), and averaged 3,600 kg/ha in Sonora. Above-ground net primary production of 10 North America ungrazed temperate grasslands averaged 2,350 kg/ha and ranged from 540 to 5,230 kg/ha (Sims and Singh 1978). Mean buffelgrass above-ground net primary production is intermediate between the mid- and tall-grass prairies.

Summer precipitation amounts and distribution in Sonora between 1984 and 1987 are comparable to the years between 1969 and 1983 (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). When summer precipitation is
below, equal to, or above the long-term average, native perennial grass production averaged 300, 450, and 700 kg/ha, respectively (Ibarra 1990), while under similar conditions buffelgrass live biomass production averaged 465, 1,040, and 3,025 kg/ha. Our most important findings are that in dry summers buffelgrass produces as much live biomass as the native grasses, but when precipitation is average or above-average, buffelgrass produces 2 to 3 times more live biomass than native grasses (Ibarra et al. 1991).

In the Sonoran Desert, livestock carrying capacity on native ranges varies from 27 to 40 ha/AU, and on buffelgrass pastures from 3 to 4 ha/AU (Ibarra and Cox 1988, Martin 1989). Animal unit increases on buffelgrass pastures occur when cattle graze shrubs in winter and spring, forbs and buffelgrass leaves in spring, and live buffelgrass in summer and fall. This seasonal pattern of vegetation diversity and animal selectivity may explain why animal productivity increased after the introduction of buffelgrass in northwest Mexico (Ibarra 1990).

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CHAPTER III
SPITTLBUG LIFE CYCLE ON BUFFELGRASS
IN NORTHWESTERN MEXICO

Abstract

Spittlebug (Aeneolamia albofasciata Lalleman) is the most economically important insect pest of buffelgrass pastures in Mexico. In 1984-1986, studies were conducted to determine the effect of climate on the insect’s life cycle in Sonora, Mexico. Spittlebug nymph and adult densities were compared to summer accumulative precipitation events and maximum and minimum temperatures during 3 years. The correlation between accumulative summer rainfall and nymph densities was $r = 0.93$ and for adult densities was $r = 0.92$. Mean maximum and minimum temperatures, however, were not related to adult or nymphal densities in any year. Spittlebug adult densities peaked in 1984 when precipitation was 2 times above normal (320 mm). Insect densities declined ($P \leq 0.05$) when precipitation was below-normal (286 mm) in 1985. Insect life cycle duration was variable among years and averaged $43 \pm 3$ days across the 3 years. The spittlebug was univoltine in 1985 and 1986, but a partial second generation was present in 1984 when precipitation was above average.
Introduction

The productivity of arid and semiarid rangelands around the world has been improved through the introduction of exotic grasses such as buffelgrass (*Cenchrus ciliaris* (L.) Link) (Humphreys 1967, Gonzales and Dodd 1979, Cox et al. 1988, Walker and Weston 1990). This perennial, warm-season bunchgrass, native to Africa, was introduced into Sonora, Mexico, in 1954. Since introduction, the species has been successfully established on over 400,000 ha in Sonora, Mexico (Ibarra and Cox 1990, Martin and Ibarra 1991), and there is potential for establishment on 4 million additional ha (Cazares et al. 1986). Buffelgrass forage production exceeds that of native grasses by 10 times, and stocking rates are frequently 3 to 10 times greater than on native rangelands (Hanselka 1985, Ibarra and Cox 1990).

Although the grass is an ideal agronomic selection (Contreras 1964, Cazares et al. 1985, Martin and Ibarra 1991) to improve rangelands, it is susceptible to spittlebug (*Aeneolamia albofasciata* Lalleman) (Homoptera:Cercopidae) injury. Because forage grasses have low production costs and low crop values per acre compared with cultivated crops, greater insect injury will be tolerated before economic thresholds are reached and control measures initiated. However, if buffelgrass establishment and failure risk are high, and productivity
declines as spittlebug damage increases (Martin et al. 1985), then relatively low cost insect control practices are justified.

The spittlebug is a wide-ranging pest in cultivated and wild plants. Host plants in Sonora, Mexico include corn (Zea mays L.), rice (Oriza sativa L.), sorghum (Sorghum vulgare L.), stargrass [Cynodon plectostachyus (Kschum) Pielger], bermudagrass (Cynodon dactylon L.), rhodesgrass (Chloris gayana L.), Johnsongrass (Sorghum halepense L.), black grama (Bouteloua eriopoda Torr.), bahiagrass (Paspalum notatum Flugge.), and buffelgrass (Coronado 1978, Cazares et al. 1985). In 1858, spittlebug damage was reported on crops in eastern Mexico (Coronado 1978). Since then the insect has spread along the Pacific coast, and now occurs in the states of Chiapas, Oaxaca, Guerrero, Colima, Nayarit, and Sinaloa (Arrieta and Coronado 1968, Flores 1968) (Fig. 3).

Insect attacks on native and exotic grasses were reported in 1947 (Marrufo and Enkerlin 1974). Spittlebug dispersal in northwestern Mexico may be related to buffelgrass seeding on rangeland, but this has not been substantiated. Along the Gulf of Mexico, spittlebug populations dramatically increased by 1955, and in the 1960's, from 40,000 to 60,000 ha of pasture grasses were injured (Velazco et al. 1969). In Sonora, spittlebugs were first reported in buffelgrass pastures in 1981, and by 1984
Figure 3. Spittlebug distribution in Mexico.
plant populations began to decline (Lopez 1984). In 26 Sonoran counties, Cazares et al. (1985) reported spittlebug nymph densities between 45 to 212 per buffelgrass plant.

Spittlebug nymphs and adults have piercing, sucking mouthparts (Coronado 1978). Nymphs feed on juices from lower plant parts (xylem and parenchyma), and from small roots at the soil surface. Injury is followed by a reduction in grass vigor and health (Hagley and Blackman 1966).

To prevent dehydration, nymphs congregate in a bubbly liquid mass (Fewkes 1963). Adults feed on stems, crowns, and young succulent leaves. Injured leaves develop chlorotic areas around the puncture site. Adults suck sap and inject a systemic toxin known as diastatic oxidase. The compound disrupts plant nutrient transport and respiration (Enkerlin and Morales 1980, Willson and Valerio 1989).

In the Gulf of Mexico, spittlebug management options have been developed for guinea (Panicum maximum Jack), pangola (Digitaria decumbens Stnt.), merkeron (Pennisetum purpureum Ashum), para (Bracharia mutica L.), and buffelgrass. Options include chemicals such as carbamates (carbaryl), organochlorines (DDT, Gamma-BHC, Dieldrin), organophosphates (diazinon, malathion, parathion) (Canavati 1974, Purata 1974), shredding and grazing (Velazco et al. 1969), burning (Ibarra and Enkerlin 1974), and planting

The spittlebug life cycle has been documented on agronomic crops and grasses in eastern Mexico. In eastern Mexico, climatic conditions, agriculture, and livestock production systems differ from those in northwestern Mexico. Differences are based on the amount and distribution of precipitation, and relative humidity. Buffelgrass pastures support about 80% of the livestock production industry in northwestern Mexico (Ibarra and Cox 1990). Extrapolation of spittlebug population controls from humid eastern Mexico to arid and semiarid areas is not possible because climatic and edaphic conditions differ between areas. No previous attempt has been made to determine the spittlebug life cycle in arid buffelgrass pastures. To develop an effective spittlebug program for buffelgrass pastures in Sonora, ecological and biological studies are needed to select ideal insect control practices. The study objective was to determine precipitation and temperature effects in northwestern Mexico on the spittlebug life cycle in buffelgrass pastures.
Materials and Methods

Study Site Description

The study site was located 82 km north of Hermosillo in northcentral Sonora, northwestern Mexico (29° 41'N lat., 115° 57'W. long.) at the Carbo Livestock Research Station. Former vegetation was a desert shrubland typical of the Sonoran Desert. The study site was mechanically cleared and seeded to buffelgrass during 1970. Elevation at the site is 470 m with gentle slopes that vary from 1-3%. The soil is an Anthony fine loam (Thermic Typic Torrifluvent) of recent alluvium, weathered from granitic rocks, moderately basic (pH = 8.5-8.9), and soil depth ranges from 2 to 6 m (Hendricks 1985).

Average annual precipitation for a 25-year period is 320 mm (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). Precipitation is bimodally distributed; approximately 60% occurs between July and September, and about 40% occurs between October and April. May, June, and September are usually dry but exceptions do occur. Daytime temperatures average 34°C in summer, but may frequently exceed 40°C in June and July. Nighttime temperatures average 5°C in winter, and may approach 0°C in January and February (Climatography of Mexico 1982).
Experimental Design

Nine 1-ha, dense, shrub-free buffelgrass stands naturally infested with spittlebugs were randomly selected and fenced to exclude livestock. Three stands were randomly selected for daily sampling between 1 July and 15 September 1984, 3 were sampled between 1 July and 15 September 1985, and 3 were sampled between 1 July and 15 September 1986. The experimental design was a completely randomized design.

Egg Sampling Procedure

To obtain egg densities, soil samples were randomly collected at 0 to 5 cm with a 12.9 cm soil auger. The 5 samples were combined, washed, and passed through a 0.5-mm diameter sieve. Remaining material was soaked overnight and placed in a 50% solution of NaCl. Eggs were counted in 5 microscopy fields (Fewkes 1967). Egg populations were reported in m².

Nymphal Sampling Procedure

Nymph developmental stages were identified by differences in size, appearance, and wing pad size after the first instar (Bodegas 1973). While sampling, nymphs were removed from the spittle mass. After counting nymphs were returned to the spittle mass.

On each sampling date, 5 previously unsampled 1-by-1 m quadrats were selected in each stand. Spittlebug
nymphs in each development stage were recorded on plants within each quadrat ($\bar{x} = 5$ plants/m²). Sampling was conducted every other day in summers 1984, 1985, and 1986.

Adult Sampling Procedure

Adult insects were sampled with light traps between August 15 to September 15. One light trap was installed in the center of each buffelgrass stand. The trap consisted of a kerosene lantern hung at 1.5 m above a 1.0 x 1.0 x 0.1 m metallic pan filled with kerosene. When the nymphal population approached 4th and 5th instars, light traps were ignited during 20 consecutive days from sundown to sunrise during summers of 1984, 1985, and 1986. Captured adult insects were counted and sexed daily. Kerosene was replenished as needed. Nymph and adult population densities were used to quantify the spittlebug life cycle.

Daily precipitation and mean maximum and minimum temperatures were recorded at the Carbo Livestock Research Station.

Statistical Analyses

Adults densities were averaged over all collection days and nymphal stage densities were averaged among the 5 quadrats. Adult and nymph mean densities were log-transformed ($\log (x+1)$) and a one-way ANOVA was used to determine differences between years ($P \leq 0.05$). A Tukey's test was used to separate means (Steel and Torrie 1980).
Spittlebug nymph and adult population densities were correlated with cumulative summer rainfall and daily maximum and minimum temperatures.

Results and Discussion

Eggs

During the 3 years, over-wintering eggs began to hatch early in summer after the accumulation of approximately 50 mm of rainfall. Most eggs were near buffelgrass crowns and densities ranged from 150 to 200 eggs/m².

In 1984, egg hatch began on July 7, after accumulative rainfall of 60 mm. In 1985, egg hatch began on July 21 after an accumulative rainfall of 46 mm. In summer 1986, egg hatch began on July 14 after accumulative rainfall approached 45 mm. The earlier hatching time in 1984 was due to a greater amount and distribution of rainfall during the months of May and June in 1984 versus 1985 and 1986. These results differ from those in the Gulf of Mexico where eggs hatched after 80 mm of accumulative precipitation (Ibarra and Enkerlin 1974).

In the Gulf of Mexico, egg hatch began when ambient temperatures were between 24°C and 26°C in July and August (Ibarra and Enkerlin 1974). In western Mexico eggs hatched when daily temperatures averaged between 28°C and 37°C during July (Lopez 1984).
Observations during this 3-year study indicate that spittlebug females preferentially select egg-laying sites under buffelgrass litter. During field sampling we commonly measured 3 to 5 1st instar nymphs/m² in areas partially covered with litter between buffelgrass plants. Densities were 5 to 10 times greater under dense litter accumulations at the plant base.

Nymph Populations

We identified 5 instars (Fig. 4), the same number found by other researchers in eastern Mexico (Ibarra and Enkerlin 1974, Coronado 1978). In summer 1985, we did not find 1st instar nymphs after small storms on 4, 9, 10, 11, and 12 July, but nymphs were present after heavy dew between 15 and 20 July. The 1st and 2nd instar nymphs are small and difficult to locate in dense buffelgrass crown litter. First and 2nd instar nymphs were most frequently observed feeding on fresh crown tissue and fine roots at the soil surface. As air temperatures increased during the day, nymphs congregated in groups (3 to 5 nymphs/group) and secreted a bubbly (spittle) liquid. When nymph populations were high in summer 1984 and surface soil was moist, the spittle mass was frequently found beneath the soil surface near buffelgrass crowns. Willson and Valerio (1989) reported that spittlebug nymph population densities increased under litter accumulations in Brachiaria
The first instar appears approximately 15 days after the initiation of summer rains.

1st INSTAR DURATION 4-5 DAYS

2nd INSTAR DURATION 5-6 DAYS

3rd INSTAR DURATION 4-6 DAYS

The average life cycle is 43 days.

EGGS
Size 0.8 mm wide by 0.3 mm long.

Adult size is 5 to 6 mm wide and 7 to 9 mm long. Average adult longevity is 12 to 18 days. One or more generations per year.

Females may oviposit from 40 to 100 eggs/cycle.

Adults die in mid-September.

4th INSTAR DURATION 5-6 DAYS

5th INSTAR DURATION 6-7 DAYS

Figure 4. The spittlebug life cycle in Sonora, Mexico.
decumbens pastures. Duration of the 1st and 2nd nymphal stages ranged from 4.1-5.2, and 4.8-5.6 days, respectively (Table 2).

The 3rd and 4th instars congregated on culms and leaves 10 cm above the soil surface and fed during morning and late afternoon hours. In the wet summer of 1984, nymphs migrated to a zone 10 to 30 cm above the soil surface, but in the dry summers of 1985 and 1986, nymphs migrated to the dense canopy litter at the plant base. Duration of the 3rd and 4th instars ranged from 4.3-6.5, and 5.0-6.2 days, respectively (Table 2).

The 5th instar nymphs fed on leaves near the canopy. Duration of the 5th instar ranged from 5.3-7.4 days (Table 2). Final metamorphosis to adult occurred in the individual spittlemass (Fig. 4). Correlation (r) between accumulative precipitation and nymph density was 0.93 in 1984, 0.83 in 1985, and 0.92 in 1986. There were no correlations (P<0.05) found between either maximum or minimum temperatures and any nymphal stages (r= 0.06-0.35).

Adult Populations

Adult population densities differed (P<0.05) among years. Seasonal total populations were greatest in 1984, intermediate in 1986, and least in 1985 (Figs. 3, 4, and 5). Mean adult densities within years were related to the amount and distribution of summer precipitation.
Table 2. Mean duration and standard deviation of adult and nymphal developmental stages (instars 1-5) in buffelgrass pastures in Sonora Mexico, in 1984-1986.

<table>
<thead>
<tr>
<th>Year</th>
<th>Adults(^a)</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1984</td>
<td>17.5a ± 8.9</td>
<td>5.2a ± 2.5</td>
<td>5.1a ± 2.5</td>
<td>6.5a ± 2.2</td>
<td>6.2a ± 3.0</td>
<td>7.4a ± 3.0</td>
</tr>
<tr>
<td>1985</td>
<td>12.4c ± 6.3</td>
<td>4.1b ± 2.3</td>
<td>4.8b ± 1.6</td>
<td>4.3c ± 2.4</td>
<td>5.0b ± 2.6</td>
<td>5.3b ± 2.7</td>
</tr>
<tr>
<td>1986</td>
<td>16.1b ± 8.3</td>
<td>4.9a ± 2.6</td>
<td>5.6a ± 2.7</td>
<td>5.6b ± 2.8</td>
<td>5.6b ± 2.8</td>
<td>6.3a ± 3.2</td>
</tr>
</tbody>
</table>

\(\text{Means for length of adult and nymphal developmental stages within a column with the same letter are not significantly different (P≤0.05).}\)
Figure 5. Spittlebug nymphal instars (1st-5th) and adult populations (A), precipitation amounts and distribution, and mean maximum (upper line) and minimum (lower line) temperatures (B) at Carbo, Mexico, in summer 1984.
Correlation (r) between accumulative precipitation and adult population density was 0.91, 0.80, and 0.90 in 1984, 1985, and 1986, respectively. The correlation for all years was $r = 0.91$. Precipitation in summers of 1984 through 1986 is similar to that of the past 25 years (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). Comparisons indicated that 1 year out of 25 was similar to 1984, 5 years were similar to 1986, and 19 years were similar to 1985. There were no significant ($P \leq 0.05$) correlations between either maximum and minimum temperature and adult densities in any year ($r = 0.01-0.35$).

The temporal pattern of adult populations was somewhat variable among years, but peak densities occurred between 15 to 20 August in all years (Figs. 5, 6, and 7). The magnitude of the initial adult population peak in 1984 (58 adults/trap) was about one-fifth of the second peak (250 adults/trap).

Summer (July-September) accumulative precipitation was above the long-term average (192 mm) in 1984 (419 mm) and 1986 (358 mm) and below average in 1985 (186 mm). In the driest year (1985), the adult population occurred during 12 days (Fig. 6). Adult populations peaked on August 23 (158 adults/trap), and disappeared in early September. In both 1984 and 1986, adult populations peaked in early August (Fig. 7). In 1984 a second peak occurred on August 28. In
Figure 6. Spittlebug nymphal instars (1st-5th) and adult populations (A), precipitation amounts and distribution, and mean maximum (upper line) and minimum (lower line) temperatures (B) at Carbo, Mexico, in summer 1985.
Figure 7. Spittlebug nymphal instars (1st-5th) and adult populations (A), precipitation amounts and distribution, and mean maximum (upper line) and minimum (lower line) temperatures (B) at Carbo, Mexico, in summer 1986.
1986, the second peak did not occur because an intense rain storm (75 mm in 30 minutes) apparently killed all adults.

Adults actively fed in buffelgrass pastures during morning (7 to 10 a.m.) and late afternoon (5 to 9 p.m.). Adults rested at flag leaf bases in the upper plant canopy during mid day and night, and mated on the soil surface in the shade of buffelgrass canopies. The average life span of adults varied between 12 and 18 days (Table 2). A female can produce up to 142 eggs/cycle (Fewkes 1967). Laboratory studies (Oomen 1976) have indicated that spittlebug females produce up to 160 eggs between 12-18 days when relative humidity is 70%. Under natural conditions, the female egg-laying capacity may be less.

I observed sexual activity throughout the day at buffelgrass plant bases. Sex ratio from 300 adult insects indicated 3 males available for 1 female in early August, 1 male for 1 female in late August, and 1 male for 3 females in September.

Forage was chlorotic where adults fed (Coronado 1978). Chlorosis spreads from the feeding puncture, and tissue color changes from green to yellow. Similar injuries were observed in sugar cane (Fewkes 1967). Adult spittlebug damage is due to salivary secretions. Diastatic oxidase in the saliva increases plant respiration and inhibits translocation (Stimman and Taliaferro 1970).
Management Implications

A relationship was found between summer precipitation spittlebug nymph and adult densities. Spittlebug populations were greatest in buffelgrass pastures when summer precipitation was above the long-term average; insect densities declined 46% when summer rainfall was below average.

In central Sonora, Mexico, spittlebugs completed one generation in years of average and below-average precipitation. In wet summers (419 mm), a second incomplete generation may be initiated (1984).

It is necessary to understand spittlebug population dynamics before developing a management plan. The result of this study would suggest that any treatment which interrupts the single spittlebug life cycle in the Sonoran Desert will limit adult populations in following summers.

Land managers in northwestern Mexico currently recommend chemicals, intensive grazing, and burning to control spittlebug populations. On large pastures, chemicals are not economical and following above-average summer rainfall, it is not possible to remove above-ground forage production with grazing animals. The best management alternative may be burning but there are no studies which correlated season of burning and impact on spittlebug populations and buffelgrass densities.
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CHAPTER IV
SUMMER BURNING EFFECTS ON SPITTLEBUG NYMPHS AND ADULTS IN BUFFELGRASS PRODUCTIVITY IN THE SONORAN DESERT

Abstract

The objectives of this study were to determine prescribed fire effects on (1) spittlebug (Aeneolamia albofasciata Lall.) populations at different life stages and (2) subsequent buffelgrass [Cenchrus ciliaris (L) Link] productivity. Summer burning treatments were replicated in 1985 and 1986. Insect populations and forage production were monitored for 4 consecutive summer growing seasons at the Carbo Livestock Research Station in northwestern Mexico. Prescribed burns during summer removed dead forage and litter, and disrupted the insect life cycle. Total green biomass production was greater when fire was applied immediately after the initiation at the summer rainy season. An early summer burn when the insect is between the second and the third nymphal stages reduced the nymph and adult populations by 95% and 100%, respectively. Buffelgrass density increased when burns were applied before egg hatch, immediately after egg hatch, and between the 2nd small and 3rd small nymphal instars. Plant densities decreased when burns were applied after buffelgrass green up and when buffelgrass was unburned.
Introduction

Many plant communities are maintained by periodic fires, and without fire the community diversity declines, excessive fuel accumulates, and disease and insect populations increase (Vogl 1971a). When fire is controlled, grasslands are invaded by shrubs and trees. When shrubs and trees dominate, grasslands become decadent, impenetrable thickets (Wright 1974, Dodge 1972).


Prescribed fire has been used to control spittlebug (Aeneolamia albofasciata Lalleman) populations in sugar cane (Saccharum officinarum L.), pangola grass (Digitaria decumbens Stnt), and stargrass [Cynodon plectostachyus
(Kschum) Pielger] on the Gulf of Mexico (Coronado 1978). Velazco et al. (1969), Ibarra and Enkerlin (1974), and Enkerlin and Morales (1979) reported that burning kills spittlebug nymphs and eggs located at or near the soil surface. These studies were not designed to evaluate grass after fire.

Morphological characteristics generally determine a plant's response to fire. In general, perennial grasses are better adapted to survive fire than forbs or woody plants. During dormancy, grasses and forbs escape fire damage because meristematic tissue is below the soil surface. Differences in growth patterns between warm- and cool-season grasses and forbs can be exploited with seasonal burning to promote one group over another (Box and White 1969, Johnson 1970, White 1980, White and Hanselka 1991). Cool-season grasses, such as threeawn (*Aristida* spp.), are damaged when burned during active spring growth. Warm-season grasses burned at the same time may not be damaged because they are inactive.

In northeastern Mexico, prescribed fire during the spittlebug life cycle may limit spittlebug populations and enhance buffelgrass growth. The study objectives were to determine if summer burning during the spittlebug life cycle would reduce insect populations and stimulate forage production.
Material and Methods

The study site is located 82 km north of Hermosillo in northwestern Sonora, Mexico (29° 41' N lat., 115° W. long.) on the Carbo Livestock Research Station. Elevation is 470 m, slope is 1-2%, and soil is an Anthony fine loam (Thermic Typic Torrifluvent). Soils are recent alluvium, weathered from granitic rocks, moderately basic (pH = 8.5-8.9), and range from 2 to 6 m in depth (Hendricks 1985).

Average annual precipitation is 320 mm (Centro de Investigaciones Pecuarias del Estado de Sonora 1989). Precipitation is bimodally distributed: approximately 60% occurs as rain between July and September and the remaining 40% as rain between October and April. May, June, and September are usually dry months but exceptions do occur. Daytime temperatures average 34°C in summer, but frequently exceed 40°C in June and July. Nighttime temperatures average 8°C in winter, but they fall to 0°C in January and February.

A 10-ha stand of shrub-free, dense buffelgrass naturally infested with spittlebug was fenced to exclude livestock. Twenty 50-by-50 m plots were established in a randomized complete block design with 5 treatments and 4 replications. The study was repeated in summers of 1985 and 1986. The treatments corresponded to 5 different spittlebug stages within the life cycle. Treatments were
burning before egg hatch ($T_1$); burning 7 to 14 days before the summer rains (late June); burning during or after egg hatch or the accumulation of 50 mm of summer precipitation ($T_2$) (Chapter III); burning between the second and third nymphal instar ($T_3$); and burning between the fifth nymphal instar and adult stage ($T_4$). The fifth treatment was an unburned control ($T_5$).

Firelines were dozed around each plot, and a backfire was initiated. After the backfire removed 3 to 5 m, the remaining area was burned with a headfire. The time from ignition to total consumption of all above-ground fuel was recorded by plot. Burns were conducted between 9 and 10 a.m. (Table 3). Wind speeds varied from 8-12 km/h, air temperatures ranged from 29-32°C, and relative humidity fluctuated from 38-70%.

Forage Sampling

Prior to burning, plants were sampled in five 1-by-1-m randomly selected quadrats and after fire, at the peak of the summer growing season (mid-August) during 4 consecutive years. Buffelgrass plants were clipped at 5 cm above the soil surface. Forage was separated into live (green), recent-dead standing (yellow), and old-dead standing (gray) biomass components. Forage samples were dried in a forced-draft oven at 40°C for 72 hr. All yields are reported on a dry weight basis.
Table 3. Fuel characteristics and environmental conditions at burn time during 1985 and 1986 in northwestern Mexico.

<table>
<thead>
<tr>
<th>Season</th>
<th>Fuel Load (Kg/ha)</th>
<th>Fuel Water Content (%)</th>
<th>Wind Speed (km/hr)</th>
<th>Air Temperature (°C)</th>
<th>R.H. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summer 1985</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prehatching (T₁)</td>
<td>3587</td>
<td>25</td>
<td>8.0</td>
<td>29.5</td>
<td>46</td>
</tr>
<tr>
<td>Hatching (T₂)</td>
<td>3247</td>
<td>38</td>
<td>8.1</td>
<td>32.0</td>
<td>43</td>
</tr>
<tr>
<td>2⁰ &amp; 3⁰ nymphal instar (T₃)</td>
<td>3378</td>
<td>39</td>
<td>12.1</td>
<td>35.0</td>
<td>38</td>
</tr>
<tr>
<td>5⁰ nymphal instar and Adults (T₄)</td>
<td>3287</td>
<td>45</td>
<td>12.5</td>
<td>29.0</td>
<td>66</td>
</tr>
<tr>
<td><strong>Summer 1986</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prehatching (T₁)</td>
<td>4973</td>
<td>35</td>
<td>7.9</td>
<td>30.0</td>
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</tr>
<tr>
<td>Hatching (T₂)</td>
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<td>8.0</td>
<td>31.2</td>
<td>48</td>
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<tr>
<td>2⁰ &amp; 3⁰ nymphal instar (T₃)</td>
<td>4305</td>
<td>42</td>
<td>9.6</td>
<td>33.8</td>
<td>52</td>
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<tr>
<td>5⁰ nymphal instar and Adults (T₄)</td>
<td>4689</td>
<td>50</td>
<td>9.5</td>
<td>32.2</td>
<td>70</td>
</tr>
</tbody>
</table>
Insect Sampling

Spittlebug populations were sampled before fire was applied (1984 and 1985) and during 4 consecutive summers. In each plot nymphs were counted in 5 previously unsampled 1-by-1-m quadrats between mid-June and August. Spittlebugs were separated in 5 nymphal stages (Bodegas 1973). To reduce variability within a plot, 2 points were randomly selected. From each point, while walking in a zig-zag fashion, insects were netted in 25 strokes. Adult insects from the 50 nets were averaged for a plot and the mean was considered a plot replication. While adult insects were present, I netted every other day.

Precipitation and maximum and minimum temperature were recorded daily at the Carbo Livestock Research Station. The station is approximately 2 km from the study site.

Statistical Analyses

Experimental design was a randomized complete block with 4 replications for burns applied at strategic times within the life cycle. Burns were applied on new plots in 1985 and 1986. The accumulation of herbage within a component was highly variable among years. For example, old-dead standing biomass did not accumulate for 4 years after burning. When these conditions existed, the population variances were tested for homogeneity. When populations had common variances, the data were pooled and subjected to analysis; when population variances differed
(P≤0.05), unburned plots were analyzed separately from burned plots. When F-values were significant (P≤0.05), Least Significant Difference tests (Steel and Torrie 1960) were used to separate means.

Adult and nymph densities were averaged over all collection days for each plot, and data subjected to log transformation (x+1). However, insect densities are presented in an untransformed format. Analysis was by split-plot ANOVA. There were no differences in the responses of buffelgrass and spittlebug population by year (1985 and 1986); therefore, data from the 2 years were pooled.

Results and Discussion

The prescribed burns coincided with spittlebug development and buffelgrass phenological stages (Tables 3 and 4). Burning prior to grass growth removed old above-ground biomass. Prescribed burns during plant growth (T₂ and T₃) were less uniform because new growth was high in moisture. Approximately 20 and 35% of the total fuel load was green in T₂ and T₃, and only 70 to 80% of the standing biomass and litter was consumed in these treatments. T₄ was applied when most foliage was green (60%) and 50% of the plant mass remained after the burn.
Table 4. Phenological stages of buffelgrass at the time of burning treatments (1985-1986).

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Date</th>
<th>Spittlebug Development Stage</th>
<th>Buffelgrass Phenological Stage</th>
</tr>
</thead>
<tbody>
<tr>
<td>T₁</td>
<td>July 27</td>
<td>Eggs</td>
<td>No growth</td>
</tr>
<tr>
<td>T₂</td>
<td>August 7</td>
<td>Hatching</td>
<td>2 leaf stage (5 cm)</td>
</tr>
<tr>
<td>T₃</td>
<td>August 23</td>
<td>2nd and 3rd instar</td>
<td>Early culm elongation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(10 to 15 cm)</td>
</tr>
<tr>
<td>T₄</td>
<td>August 29</td>
<td>5th nymphal instar and Adult</td>
<td>Active growth</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>(leaves &gt; 20 cm)</td>
</tr>
<tr>
<td>T₅</td>
<td>Unburned</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Density

Plant density increased about 50% in T₁ and T₃, 38% in T₂, and 8% in T₄, 1 year after burning (Table 5). Plant density increased 32% in T₁ and T₃, and 43% in T₄ 4 years after burning.

Forage Production

The total annual precipitation was 285 mm in 1985, 479 mm in 1986, 232 mm in 1987, 324 mm in 1988, and 406 mm in 1989. Preburn fuel loads (total grass biomass) were different (P<0.05) between 1985 and 1986 (Table 3). This difference is attributed to precipitation in 1986. Total green standing biomass at the end of the 1986 growing season increased 77% in T₁, 83% in T₂, and 78% in T₃. Green declined 42% in T₄ (Table 6). In contrast, current year green growth in the unburned plots was 30% of the total biomass (Table 6).

Two years after burning, in both 1985 and 1986, live biomass production declined 48% (Table 6). The live biomass decline is attributed to precipitation accumulation and spittlebug damage (nymph and adults). Precipitation effects are important because rainfall was above the long-term average (320 mm) for the 2 years following treatments (1985 and 1986).

Burning in summer before rapid plant growth had less impact on buffelgrass density and forage production than
Table 5. Mean average (1985-1986) plant density/m² in buffelgrass pastures after burning in northwestern Mexico.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Years After Burn</th>
<th>Total Mean&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Prehatching (T&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>7.3</td>
<td>5.0</td>
</tr>
<tr>
<td>Hatching (T&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>9.3</td>
<td>6.3</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; &amp; 3&lt;sup&gt;rd&lt;/sup&gt; nymphal instar (T&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>6.0</td>
<td>6.0</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; nymphal instar and Adults (T&lt;sub&gt;4&lt;/sub&gt;)</td>
<td>5.8</td>
<td>5.9</td>
</tr>
<tr>
<td>Control (T&lt;sub&gt;5&lt;/sub&gt;)</td>
<td>3.4</td>
<td>3.0</td>
</tr>
<tr>
<td>Total Mean&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.4&lt;sup&gt;a&lt;/sup&gt;</td>
<td>5.2&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a</sup>, <sup>b</sup> Means within a column or a row followed by the same letter are not significantly different (P<0.05).
Table 6. Mean average (1985-1986) total buffelgrass live biomass (kg DM/ha) after burning in northwestern Mexico.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Years After Burn</th>
<th>Total Mean^b</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Prehatching (T₁)</td>
<td>1669</td>
<td>1627</td>
</tr>
<tr>
<td>Hatching (T₂)</td>
<td>1662</td>
<td>2896</td>
</tr>
<tr>
<td>2nd &amp; 3rd nymphal instar (T₃)</td>
<td>1364</td>
<td>1664</td>
</tr>
<tr>
<td>5th nymphal instar and Adults (T₄)</td>
<td>657</td>
<td>683</td>
</tr>
<tr>
<td>Control (T₅)</td>
<td>1558</td>
<td>1201</td>
</tr>
<tr>
<td>Total Mean^a</td>
<td>1382b</td>
<td>1614a</td>
</tr>
</tbody>
</table>

^a, ^b Means within a column or a row followed by the same letter are not significantly different (P≤0.05).
burning before plant growth or after rapid plant growth (Table 6). In both 1985 and 1986, there was a slight delay in the onset of summer precipitation. Crowns exposed to intense summer temperatures before summer rains may have been damaged. Late summer burning after 60% plant growth reduced both density and productivity. I attribute this to lack of soil moisture after the burn.

Recent-dead biomass accumulated in the next 4 summers (Table 7). Accumulations were greatest in $T_2$ and $T_3$, intermediate in $T_1$, and least in $T_4$. A comparison of burning treatments suggested that spittlebug damage in the unburned control was 38% less than in burned areas.

Following summer fire, old-dead biomass gradually accumulated in the next 4 summers (Table 8). The gradual accumulation after fire indicates that this component accumulates only in summers when rainfall is above the long-term average.

For 4 consecutive years following burning, nymph and adult spittlebug populations were significantly (P<0.05) reduced by burning prior to the 5th instar stage (Tables 9 and 10). Adults found on burn plots were attributed to migration from untreated areas.

Management Implications

Prescribed fire disrupted the spittlebug's life cycle by removing standing dead biomass and litter on the soil
Table 7. Mean average (1985-1986) total buffelgrass recent-dead standing biomass (kg DM/ha) after burning in northwestern Mexico.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Years After Burn</th>
<th>Total Mean&lt;sup&gt;a&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Prehatching (T&lt;sub&gt;1&lt;/sub&gt;)</td>
<td>0</td>
<td>488</td>
</tr>
<tr>
<td>Hatching (T&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0</td>
<td>627</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt; &amp; 3&lt;sup&gt;rd&lt;/sup&gt; nymphal instar (T&lt;sub&gt;3&lt;/sub&gt;)</td>
<td>0</td>
<td>466</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt; nymphal instar and Adults (T&lt;sub&gt;4&lt;/sub&gt;)</td>
<td>0</td>
<td>341</td>
</tr>
<tr>
<td>Control (T&lt;sub&gt;5&lt;/sub&gt;)</td>
<td>909</td>
<td>755</td>
</tr>
<tr>
<td>Total Mean&lt;sup&gt;a&lt;/sup&gt;</td>
<td>181&lt;sup&gt;b&lt;/sup&gt;</td>
<td>535&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

<sup>a, b</sup> Means within a column or a row followed by the same letter are not significantly different (P≤0.05).
Table 8. Mean average (1985-1986) total buffelgrass old-dead standing biomass (kg DM/ha) after burning in northwestern Mexico.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Years after burn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Prehatching (T₁)</td>
<td>0</td>
</tr>
<tr>
<td>Hatching (T₂)</td>
<td>0</td>
</tr>
<tr>
<td>2ⁿᵈ &amp; 3ⁿᵈ nymphal instar (T₃)</td>
<td>0</td>
</tr>
<tr>
<td>5ᵗʰ nymphal instar and Adults (T₄)</td>
<td>0</td>
</tr>
<tr>
<td>Control (T₅)ᵃ</td>
<td>1168a</td>
</tr>
</tbody>
</table>

ᵃ Means within a row followed by the same letter are not significantly different (P≤0.05).
ᵇ Old material was less than 20 to 40 g/plots (T= trace).
Table 9. Mean average (1985-1986) spittlebug nymph densities/m² as influenced by summer burning on buffelgrass pastures in northwestern Mexico.

<table>
<thead>
<tr>
<th>Treatments</th>
<th>One Year Before Burning</th>
<th>Years After Burn</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1 2 3 4</td>
</tr>
<tr>
<td>Prehatching ($T_1$)</td>
<td>42</td>
<td>0    0    0    0</td>
</tr>
<tr>
<td>Hatching ($T_2$)</td>
<td>45</td>
<td>0    0    0    0</td>
</tr>
<tr>
<td>2nd &amp; 3rd nymphal instar ($T_3$)</td>
<td>35</td>
<td>0    0    0    0</td>
</tr>
<tr>
<td>5th nymphal instar and Adults ($T_4$)</td>
<td>55</td>
<td>0    0    0    0</td>
</tr>
<tr>
<td>Control ($T_5$)*</td>
<td>43</td>
<td>25b  18c  15c  20b</td>
</tr>
</tbody>
</table>

*Means within a row followed by the same letter are not significantly different ($P \leq 0.05$).
### Table 10. Mean average (1985-1986) spittlebug adult densities/m² as influenced by summer burning of buffelgrass pastures in northwestern Mexico.

<table>
<thead>
<tr>
<th>Burning Treatment</th>
<th>One Year Before Burning</th>
<th>Years After Burning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Prehatching (T₁)</td>
<td>20</td>
<td>1</td>
</tr>
<tr>
<td>Hatching (T₂)</td>
<td>35</td>
<td>1</td>
</tr>
<tr>
<td>2nd &amp; 3rd nymphal instar (T₃)</td>
<td>30</td>
<td>0</td>
</tr>
<tr>
<td>5th nymphal instar and Adults (T₄)</td>
<td>36</td>
<td>15</td>
</tr>
<tr>
<td>Control (T₅)</td>
<td>30</td>
<td>29b</td>
</tr>
</tbody>
</table>

Means within rows followed by the same letter are not significantly different (P<0.05).
surface (Tables 8, 9, and 10). Fire destroyed eggs at the soil surface and removed protective cover for nymphal stages.

The prescribed burn which had the least impact on buffelgrass production and the greatest impact on spittlebug populations should be recommended. Based on the results (Tables 6, 7, 8, 9, and 10), I recommend burning after the accumulation of 50 mm and before active plant growth (T2 and T3).

Literature Cited


Centro de Investigaciones Pecuarias del Estado de Sonora. 1989. 20 Años de Investigacion Pecuaria en el CIPES. Centro de Investigaciones Pecuarias del Estado de Sonora. INIFAP-SARH., GOB. EDO. SON., UGRS. 142 PP.


CHAPTER V
SYNTHESIS

This study was designed to: 1) determine how precipitation amount and distribution affect the accumulation and decomposition of buffelgrass above-ground biomass, 2) evaluate how summer precipitation and maximum and minimum temperatures influence the spittlebug life cycle in buffelgrass pastures, and 3) evaluate how summer burning affects spittlebug populations and buffelgrass productivity.

Chapter II

The results indicate that buffelgrass initiates leaf growth whenever soil moisture is available and minimum temperatures are more than 15°C. When more than 150 mm of precipitation was received during July and August, live biomass exceeded 1,000 kg/ha. When summer precipitation was less than 150 mm, live biomass approached 500 kg/ha. In dry summers, buffelgrass produced as much live biomass as the native grasses, but when precipitation was average or above-average, buffelgrass produced 2 to 3 times more live biomass than native grasses. Similar results have been reported in Australia, Pakistan, and United States (Khan 1971, Paull and Lee 1978, Gonzalez and Dodd 1979, Hanselka and Johnson 1991).
Chapter III

The spittlebug life cycle averaged 43 days during 3 summers (1984-1986). After accumulative summer rainfall events exceeded 50 mm, diapausing eggs hatched and nymphs fed on small buffelgrass roots at the soil surface. The 1st instar averaged 3 days, and the remaining 4 instars ranged from 4 to 6 days. Total nymphal development varied from 25 to 27 days, and adults survived from 12 to 18 days. In the Sonoran Desert, spittlebug populations were univoltine in summer when precipitation was average (320 mm) or below average. In years with above average rainfall, there were two generations but the second generation was incomplete.

My results differ from those from the Gulf of Mexico (Contreras 1964, Velazco et al. 1969, Coronado 1978, and Enkerlin and Morales 1979). In the Gulf area, the spittlebug life cycle is 9 days longer than in the Sonoran Desert. Greater amounts and extended distribution of rainfall in the Gulf support 2 to 3 complete spittlebug generations per year, while in the northwest insect populations are limited by summer precipitation. Egg hatch in humid areas begins after 80 mm of spring and summer rainfall (Coronado and Sosa 1966, Enkerlin and Morales 1979, Morales 1985). In northwestern Mexico, egg hatch began after 50 mm of summer rainfall. In humid areas, nymphs fed on forage grasses from early spring to late fall
(Ibarra and Enkerlin 1974), but in arid areas nymph populations were measured in July and August.

Chapter IV

Burning as buffelgrass initiates summer growth and before rapid growth, minimizes plant injury, and significantly reduced spittlebug populations for 4 years. Summer burning destroys eggs near the soil surface and removes dead plant material which provides a humid environment for nymphal development. Burning during the second and third nymphal stages (T₂ and T₃) reduces nymphal populations by 100% and adult populations by 95% for 4 consecutive years after treatment.

Summer burning is a practical way to control spittlebug populations in buffelgrass pastures. Knowledge of the insect life cycle and when the insect can be controlled without damaging buffelgrass productivity is a researchable hypothesis with practical application for ranchers. Summer burning has a negative effect on insect populations and a positive effect on plant productivity, when summer rainfall is average (320 mm) or above average.

Suggestions for Future Research

Even though the studies investigated the effects of climate on productivity, appearance of the spittlebug, and
summer burning control on buffelgrass in arid areas, several questions remain unanswered:

1. Although buffelgrass has been established for 40 years in Sonora, information is lacking about long-term productivity of this grass. Ranchers speculate that productivity has declined in buffelgrass pastures through time, but quantitative information is not available.

2. Monitoring should be continued for the presence of the spittlebug in buffelgrass pastures in Sonora. The effect of other factors such as evapotranspiration and humidity should be studied to evaluate their influence on the spittlebug life cycle.

3. Although burning can be used to control spittlebug populations in some areas, burning may not be effective in areas with low precipitation and low forage production (Wright and Bailey 1980). Other control measures such as grazing may be necessary to control spittlebug populations in these areas. Additional research is needed to determine the effect of a combination of burning and grazing on buffelgrass productivity and spittlebug populations in various climates.
Literature Cited


Gonzales, C.L., and J.D. Dodd. 1979. Production response of native and introduced grasses to mechanical brush manipulation, seeding and fertilization. J. Range Manage. 32: 305-309.


VITA

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Candidate for the Degree of

Doctor of Philosophy

Dissertation: The Effect of Climate and Spittlebug (Aeneolamia albofasciata) on Buffelgrass (Cenchrus ciliaris L.) Productivity in the Sonoran Desert.

Major Field: Range Science

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