Section 6 Report Review

Attachment to letter dated ____ August 07, 2002 ____

Project: The Effects of Disturbance on the Ashy Dogweed (*Thymophylla tephroleuca* and the Prostrate Milkweed (*Asclepsias prostrata*)

Final or interim report? Final (half of a final report). We received the final report for work done on Ashy Dogweed but not the portion dealing with the milkweed. TPWD has promised to submit the milkweed final within 60 days of July 12, 2002, so that report will be reviewed later.

Job #: Project 66

Reviewer's Station: Corpus Christi Ecological Services Field Office

Lead station was contacted and concurs with the following comments:
____ Yes ____ No _X_ Not applicable (reviewer is from lead station)

Report: _X_ is acceptable as is (***the Ashy Dogweed portion is acceptable as is - have not received the Prostrate Milkweed portion of the final report yet)**

____ is acceptable as is for an interim report, but the following comments are made for future reference

____ needs revision (listed below)

Comments: (Note to commenter: If you make comments directly on a copy of the report, write legibly and dark so comments will reproduce well when photocopied.)

FINAL REPORT

As Required by

THE ENDANGERED SPECIES PROGRAM

TEXAS

Grant No. E-1-13

Endangered and Threatened Species Conservation

**Project 66: The Effects of Disturbance on the Ashy Dogweed (*Thymophylla tephroleuca*)
And the Prostrate Mildweed (*Asclepias prostrata*)**

K

Prepared by: Paula S. Williamson

TEXAS PARKS & WILDLIFE

John Herron
Program Director, Wildlife Diversity

Robert Cook
Executive Director

July 1st, 2002

FINAL REPORT

STATE: Texas **GRANT NO:** E – 1 – 13

PROGRAM TITLE: Endangered and Threatened Species Conservation

PERIOD COVERED: September 1, 1999 – August 31, 2001

PROJECT NUMBER: 66

PROJECT TITLE: The Effects of Disturbance on the Ashy Dogweed (*Thymophylla tephroleuca*) And the Prostrate Milkweed (*Asclepias prostrata*)

PROJECT OBJECTIVE:

To design a series of controlled experiments testing the effects of various disturbance techniques that landowners regularly practice on their property including: root-plowing and seeding to buffelgrass, and bulldozing on grazed and nongrazed plots on the ashy dogweed and the prostrate milkweed. To determine the importance of the existing seed bank and the re-establishment potential of these species.

PREPARED BY: Paula S. Williamson August 31st, 2001

APPROVED BY: Neil E. Carter 7/12/02
Date

Federal Aid Coordinator
Texas Parks & Wildlife Department

Significant Deviations

The enclosed final report addresses monitoring and disturbance of Ashy Dogweed (*Thymophylla tephroleuca*). Results and discussion of monitoring and disturbance of prostrate milkweed (*Asclepias prostrata*) are available but were not included here due to an oversight by TPWD staff. The prostrate milkweed study results will be forwarded directly to the US Fish and Wildlife Service Ecological Services State Office in Austin and the Federal Aid Office in Albuquerque within the next 60 days.

FINAL REPORT

Ashy Dogweed Monitoring and Disturbance Study
September, 1999 – July, 2001

prepared for
Texas Parks and Wildlife Department

submitted by

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and
Paula S. Williamson

Department of Biology
Southwest Texas State University
San Marcos, Texas 78666

August 31, 2001

ABSTRACT

Thymophylla tephroleuca, a federal and state endangered plant species was monitored from September, 1999 to July, 2001. The study was conducted on three populations in Webb and Zapata Counties, Texas. Life history traits including breeding system, pollination agents, growth and reproductive capacity, phenology, pollen viability, seed viability, recruitment and population density have been examined. Climatic data, including precipitation and temperature, have been obtained. Plant species associated with *T. tephroleuca* habitat have been collected. GPS mapping has been performed to determine population area of two study sites. Seeds have been collected for a genetic reserve of *T. tephroleuca*. A controlled, replicated experiment was also conducted documenting the effects of anthropogenic disturbances on *T. tephroleuca* recruitment. The disturbances included root-plow, blade, root-plow seeded with buffelgrass (to document competitive effects) and controls.

Autogamous, geitonogamous, and xenogamous crosses were conducted to examine the breeding system. Members of the insect families Buprestidae, Bombyliidae and Megachilidae were determined to be effective pollinators. Fruit set only occurred in the xenogamous experiment, with 88.8% seed set. Peak flowering months for field plants are from May to November. However, flowering appears to be initiated by rainfall events as individuals will flower all year long with sufficient watering. Pollen viability averaged 82.1% in 2000 and 86% in 2001. Seed viability averaged 32.3% in 1999, 9.1% in 2000 and 22% in 2001. Density varied significantly between population 1 and population 2. In population 1 (previously disturbed) density increased from 3.4 plants per m^2 in September, 1999 to 4.7 plants per m^2 in August, 2000. Population 2 (not previously disturbed) maintained a density of 0.6 plants per m^2 throughout the study period. The hypothesis that disturbance increases density of *T. tephroleuca* individuals was substantiated by the controlled field experiment. A significantly higher number of individuals were recruited into the root-plow plots than in blade, root-plow seeded with buffelgrass and the control plots.

INTRODUCTION

Ashy dogweed, *Thymophylla tephroleuca* (S. F. Blake) Strother was first collected in 1932 and described in 1935 (Poole, 1987). It was listed as a federally endangered species on July 19, 1984 (USFWS, 1984). It was soon thereafter listed as endangered by the State of Texas. The U.S. Fish and Wildlife Service (1984) has designated the recovery of *T. tephroleuca* priority number 5, indicating it is a full species with a high degree of threat. Currently, there are no other members of the genus listed as threatened or endangered.

The plant is an herbaceous perennial in the family Asteraceae. It has a semi-woody taproot, densely pubescent leaves and a capitula composed of ray and disk florets in a campanulate cup (Adapted from Turner, 1980). The species is endemic to the ceniza-blackbrush-creosotobush brush community (McMahan, Frye, and Brown, 1984) within the South Texas Plains vegetation area (Gould, 1975). Historically, however, this region was thought to have been a grassland. Grazing from introduced livestock and fire suppression are thought to have been the driving force behind the historic changes in vegetation (Archer, 1995). The plants grow in open areas on fine sandy-loam soils of the Hebbronville and Aguilares series with little or no slope (Turner, 1980; Poole, 1987). The species was first discovered in Starr County, although this population has never been relocated. Currently, six populations are known to exist in Webb and Zapata Counties. While all populations exist on privately owned land, one extends onto the highway right-of-way. This population occupies about 10 hectares (25 acres) and has been estimated at 1300 plants (USFWS, 1984). The Texas Department of Transportation, however, has planned to widen the highway, further fragmenting this population (personal comm.)

The *T. tephroleuca* recovery plan (Poole, 1987) indicates that in addition to the Texas Highway Department, practices by the ranching industry are undoubtedly the greatest present threat and have had the most impact on the ashy dogweed. Habitats have been modified by the introduction of buffelgrass (*Cenchrus ciliaris*), an invasive species used for cattle forage. Overgrazing, which forces livestock to eat less desirable species and compacts the soil surface, also threatens dogweed. Oil and gas exploration also potentially contribute to habitat decline. By installing pipelines and constructing roads, populations become fragmented, potentially leading to reduced gene flow and ultimately less genetic variability within the population.

Previous to the current study, little has been documented on this endangered species. Turner (1980) described morphology, systematics, and habitat requirements. Strother (1967) conducted a chromosome count and paper chromatography work on the species. Strother (1986) also resurrected the genus *Dyssodia* and replaced the older name, *Dyssodia tephroleuca*, with the current name. Poole (1992) reported on seed viability and germination criteria. Otherwise, nothing had been documented about the population biology or population ecology (Poole, 1987). The 1999-2000 study examined the life history traits of *T. tephroleuca* in an attempt to understand the factors that are limiting its abundance. Several aspects of the 1999-2000 monitoring as well as personal observation suggest that *T. tephroleuca* benefits from soil disturbances created by landowners. Ranchers root-plow land to remove woody vegetation, creating opportunities for herbaceous growth. Another form of disturbance is blading, which essentially removes all biomass at soil level. This technique is performed to create roads or sites for oil and gas operations. The effect of soil disturbance on seedling emergence has been demonstrated in various species and ecosystems (Armesto and Pickett 1985, Chambers et al. 1990, Miao and Bazzaz 1990, Parker et al. 1993). The 2000-2001 study examined the role of various anthropogenic disturbance techniques on *T. tephroleuca* seedling emergence.

MATERIALS AND METHODS

Fieldwork was conducted on three populations (Figure 1) in Webb and Zapata Counties during September, 1999 to August, 2001. Population 1 is located in Webb County. This population represents the northern extent of the known range of *T. tephroleuca*. Population 2 is located in Zapata County. This population represents the

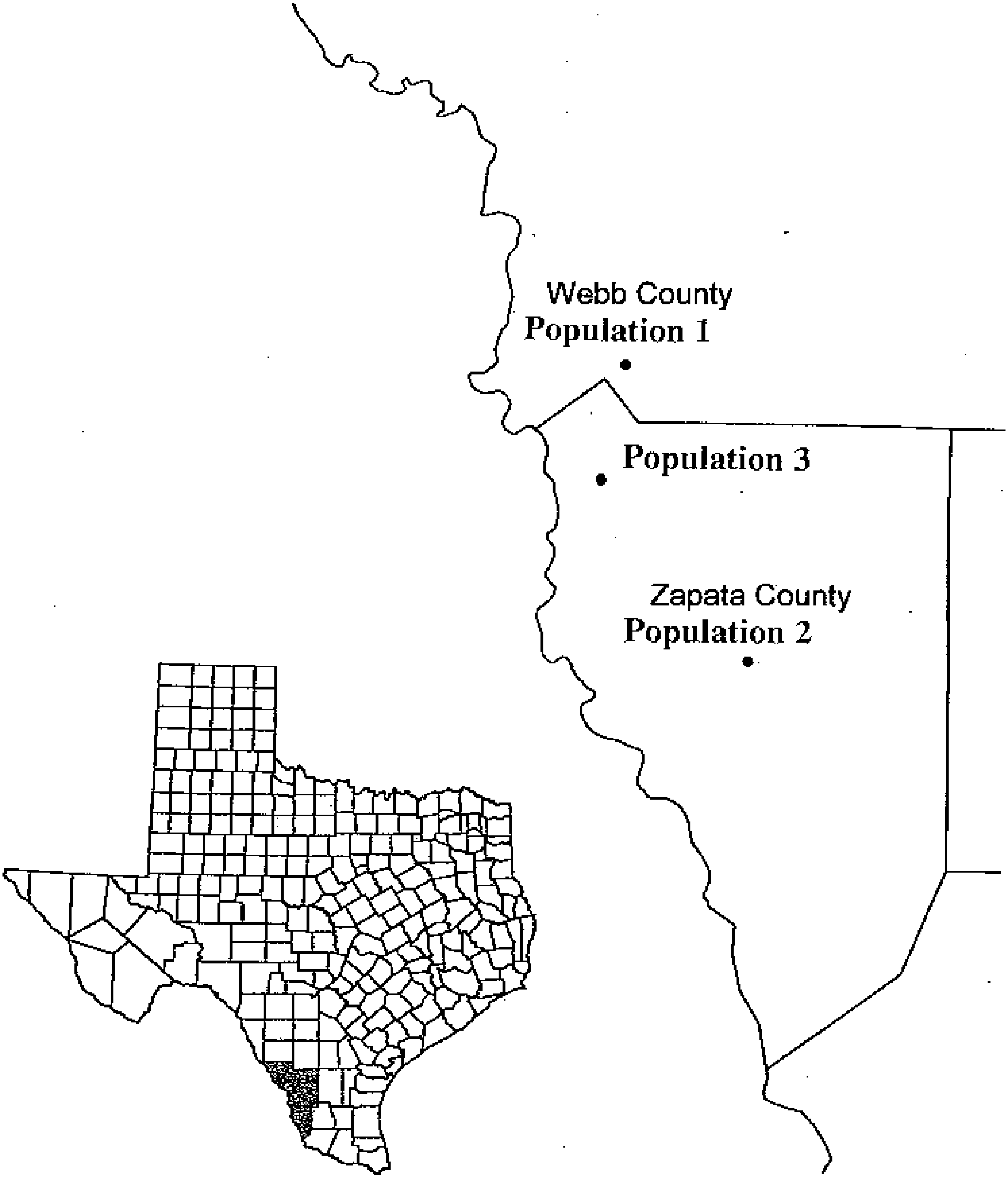

Figure 1. Map of Texas showing distribution of *T. tephroleuca*. The two points indicate the northern and southern extent of its known range.

southern extent of the known range. Population 3 is located near the Webb and Zapata County. This is part of the highway population previously mentioned.

Population Area

Populations 1 and 2 were digitally mapped using a Global Positioning System (GPS) unit. The population perimeter was outlined with the unit, then transposed onto an aerial photo of the site using DOQQ imagery and Global Information Systems (GIS) computer capabilities. From these data, population area in hectares was determined.

Characterization of Climate Associated with the Habitat

Climatic data from Zapata and Laredo, Texas were obtained from the National Climatic Data Center in order to elucidate the relationship between rainfall and phenology of *T. tephroleuca*. Daily temperature and precipitation data were obtained for September, 1999 to July, 2000.

Genetic Reserve

Plants propagated from seeds collected in May, 1999 are currently being grown in an outdoor bed at the biology greenhouse, located on the campus of Southwest Texas State University (SWT) in San Marcos, Texas. These individuals were used for analysis of the breeding system in *T. tephroleuca*. A seed repository was also initiated and is being refrigerated in dry paper bags at SWT. Seeds were collected from each population following the Center for Plant Conservation guidelines (Falk and Holsinger, 1991).

Associated Species

Associated plant species growing in *T. tephroleuca* habitat at the three monitored population sites have been collected and identified (Correll and Johnston, 1979). Herbarium specimens have been prepared and deposited in the Southwest Texas State University Herbarium (SWT).

Pollen Viability

Pollen viability was determined using three plants growing in the outdoor bed at SWT in 1999, two plants from population 3 in 2000, and three plants from population 3 in 2001. Pollen from several inflorescences of the same plant was deposited onto a slide and immersed in a drop of 1% lactophenol-aniline blue stain (Kearns and Inouye, 1993). Pollen grains were allowed to stain for 2.5 hours then examined using a compound light microscope. Pollen that stained dark blue was considered viable, while those that were faintly stained or not stained at all were considered nonviable. All pollen on each slide was observed and scored as either viable or nonviable.

Pollination Agents

Field observations were made to determine pollination agents of *T. tephroleuca*. Potential pollinators were captured, identified and examined for the presence of pollen using scanning electron microscopy (SEM).

Breeding System Experiments

1) Autogamy- 50 inflorescences from five plants growing at SWT were used for this experiment. Stigmas were clipped on all florets except for one disk floret prior to anthesis. Exclosure bags were then used to eliminate crosses other than autogamy from occurring. A total of 50 disk florets were used for the experiment.
2) Geitonogamy- 46 inflorescences from five plants growing at SWT were used for this experiment. Buds were initially bagged to exclude floral visitation. At anthesis, exclosure bags were removed and pollen was transferred from other inflorescences on the same plant to the stigmas of the experimental inflorescences. After hand pollination, bags were put back on the inflorescences. A total of 2188 florets were used for this experiment.
3) Xenogamy- Eight inflorescences from five plants growing at SWT were used for this experiment. At anthesis, florets were cross-pollinated by transferring the pollen from another plant to the stigmas of the experimental inflorescences. A total of 348 florets were used for this experiment.

In all experimental crosses, development of an embryo within an achene signified that fertilization occurred. If fertilization did not occur, no embryo was found within the achene.

Growth and Reproductive Capacity

To monitor growth and reproductive capacity of *T. tephroleuca*, a transect was established along a 50 m portion of populations 1 and 2 following Lesica, 1987. A 1 m^2 quadrat was positioned along one side of the transect and individuals in this quadrat were monitored. A total of 50 quadrats were established for each transect. Aerial diameter, height, number of inflorescences and number of inflorescences with fruit were determined for each plant along the transect every 4-7 weeks from September, 1999 to August, 2000. Seedling recruitment and population density were also determined for each population as represented by the transects. Transects were monitored on the following dates:

September 9-12, 1999	April 14-15, 2000
October 8-10, 1999	May 18-21, 2000
November 20-21, 1999	June 15-19, 2000
December 20-21, 1999	July 28-30, 2000
January 22-23, 2000	August 25-26, 2000
February 18-20, 2000	

Seed Viability

Two hundred seeds collected at population 1 in May 1999, two hundred each from populations 2 and 3 in June 2000, and two hundred from population 3 in May 2001 were tested for viability using a 1% tetrazolium stain (Weber and Wiesner, 1980). Achenes were scarified by agitating them in a one-part bleach to four-parts water solution for ten minutes. Seeds were then placed in an open-faced petri dish, covered with nylon and placed under running tap water overnight. The seeds were then rinsed with deionized (DI) water and allowed to remain in the DI water an additional night. The seeds were prepared for staining by cutting the seed coat longitudinally, exposing the embryo. The stain was prepared by adding 1 gm of tetrazolium to one hundred milliliters of tap water at pH 7.0. The seeds were placed in the stain immediately after cutting the seed coat to prevent dessication. Embryos that stained red after four hours were considered viable.

Disturbance Experiment

To test the effects of anthropogenic disturbance on *T. tephroleuca*, a series of controlled experiments were conducted at population 3. Three treatments plus controls were assigned to a random part of the population. Treatments are as follows:

Root-plow
Root-plow with buffelgrass seed
Blade
Control

Treatments were replicated five times totaling 20 plots, each 5m X 5m in size. A 75 hp Caterpillar tractor with a 4-cylinder engine was used to perform all disturbances. For the root-plow treatment, a root-plow attachment with 1.5-foot deep trenching capabilities was utilized. For the blading treatment, a bulldozing attachment was used to blade the surface. After the treatments were conducted, buffelgrass (*Cenchrus ciliaris*) seed was spread by hand over five of the root-plow replicates to test the competitive effects of this exotic species on *T. tephroleuca*. As a measure to control cattle grazing, a 5-foot high cattle panel fence was constructed around the perimeter of the experiment. Each plot was then divided into four quadrants for monitoring purposes. Plots were monitored for *T. tephroleuca* recruitment monthly between 2000 and 2001 on the following dates:

July 28-30, 2000	January 12, 2001
August 25-26, 2000	February 16, 2001
September 29, 2000	March 16, 2001
October 28, 2000	April 13-14, 2001
November 25, 2000	May 14-15, 2001
December 15, 2000	June 29, 2001

Results

Population Area

The area of the two populations mapped using GPS was determined (Figures 2, 3). The area of population 1 is 1.41 hectares and that of population 2 contained within the study area is 66.21 hectares. Plants were observed on the adjacent property, however, access has not been granted to complete the population delineation.

Characterization of Climate Associated with the Habitat

Monthly mean maximum temperature, mean minimum temperature and precipitation data for September, 1999 through July, 2000 obtained from the National Climatic Data Center for stations located in Laredo and Zapata, Texas are shown in Figures 4, 5, 6 and 7. The annual mean maximum temperature was 87.2 °F for Laredo and 87.8 °F for Zapata. The annual mean minimum temperature was 63.5 °F for Laredo and 63.3 °F for Zapata.

Total precipitation was 11.51 inches in Laredo and 12.71 inches in Zapata. The majority of precipitation in Laredo fell in September, October and February through May (Figure 6). The majority of precipitation in Zapata fell in September, October, February and April through June (Figure 7).

Associated Species

Plants growing in association with *T. tephroleuca* at the three monitored population sites combined are listed in Table 1.

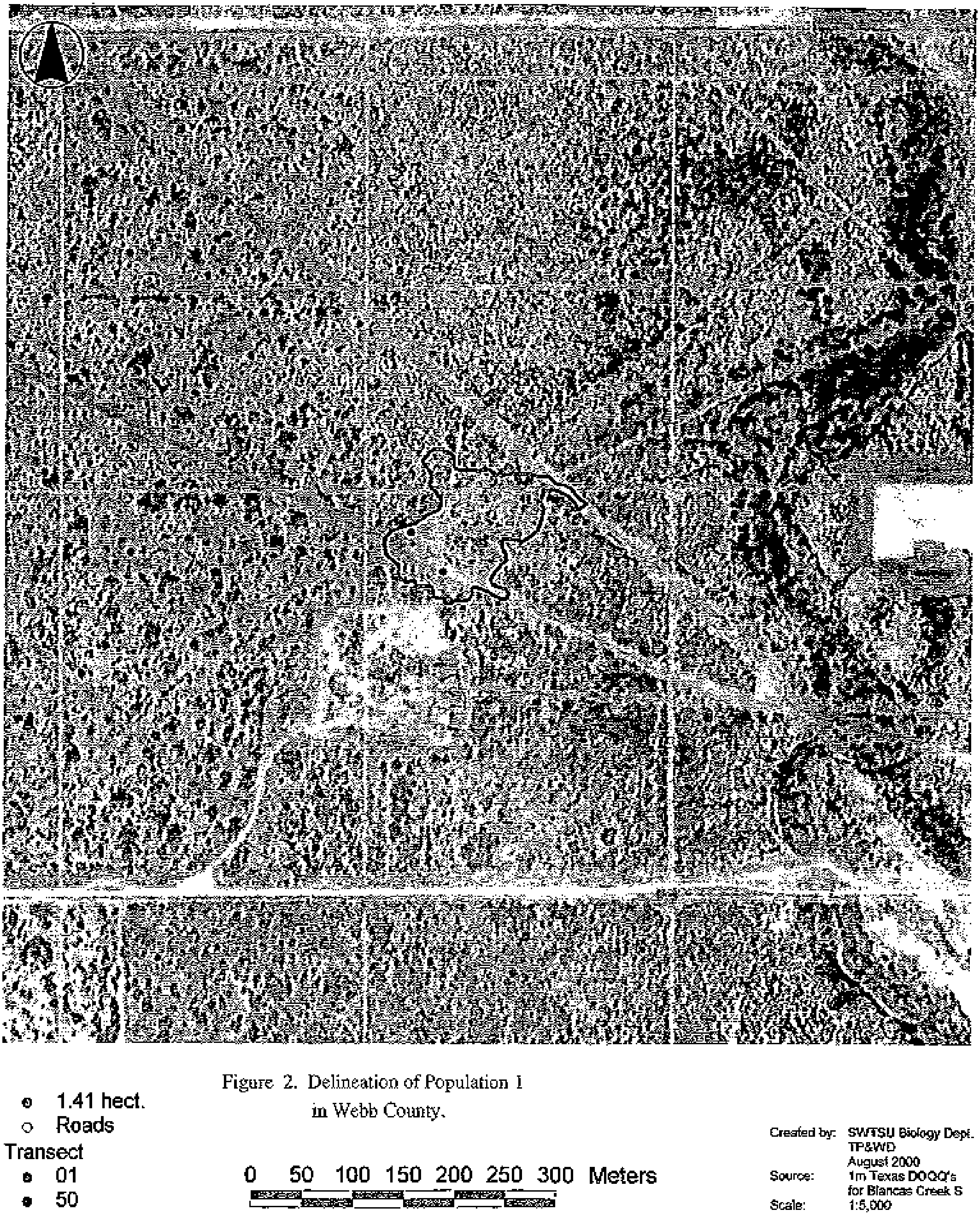

Figure 2. Delineation of Population 1
in Webb County.

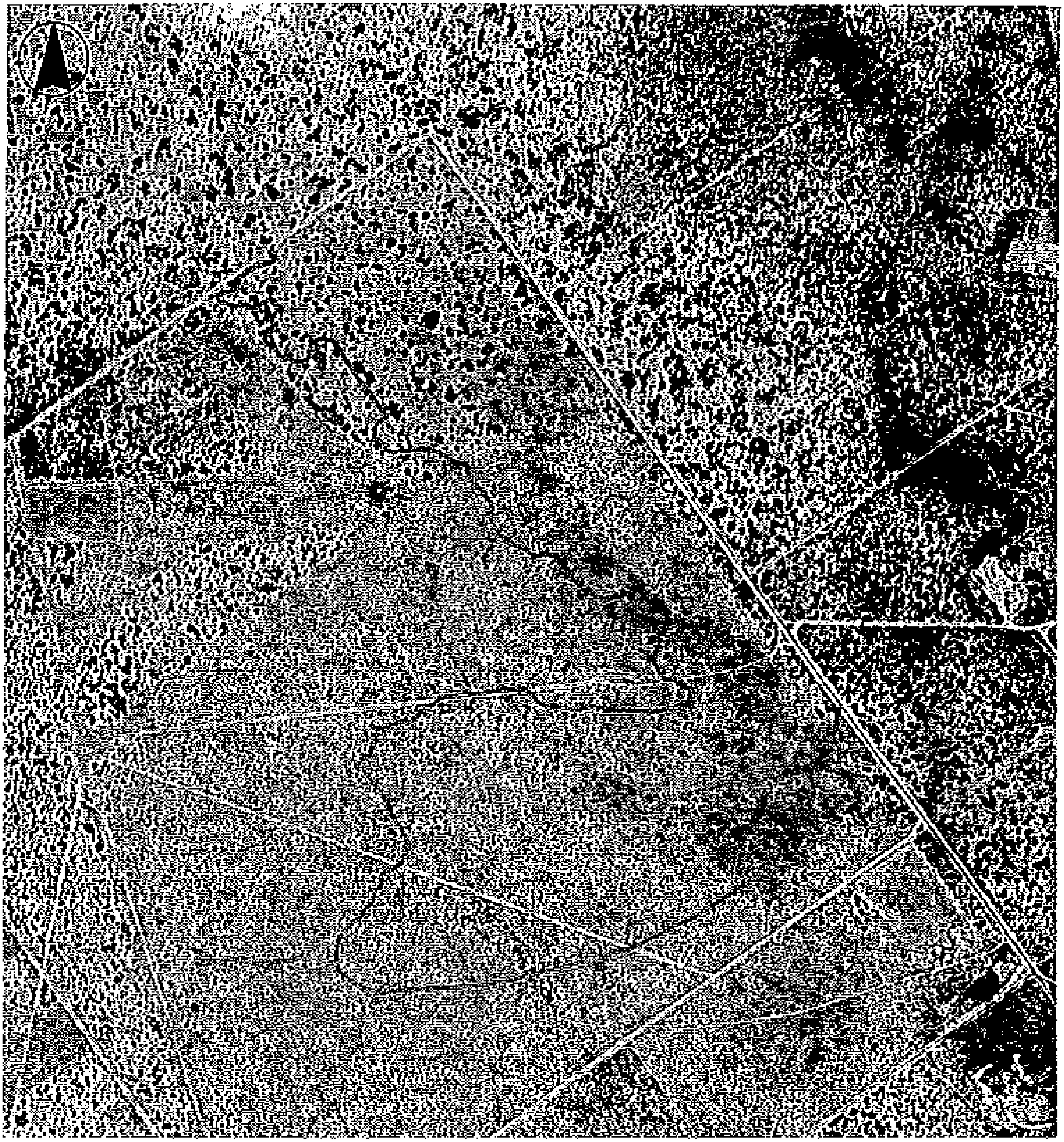

Figure 3. Delineation of Population 2 on ranch in Zapata County.

66.21 hect.
Roads
Transect
01
50

0 100 200 300 400 500 600 Meters

Created by: SWTSU Biology Dept. TP&WD August 2000
Source: 1m Texas DOQQ's for Magotes Hill
Scale: 1:10,000

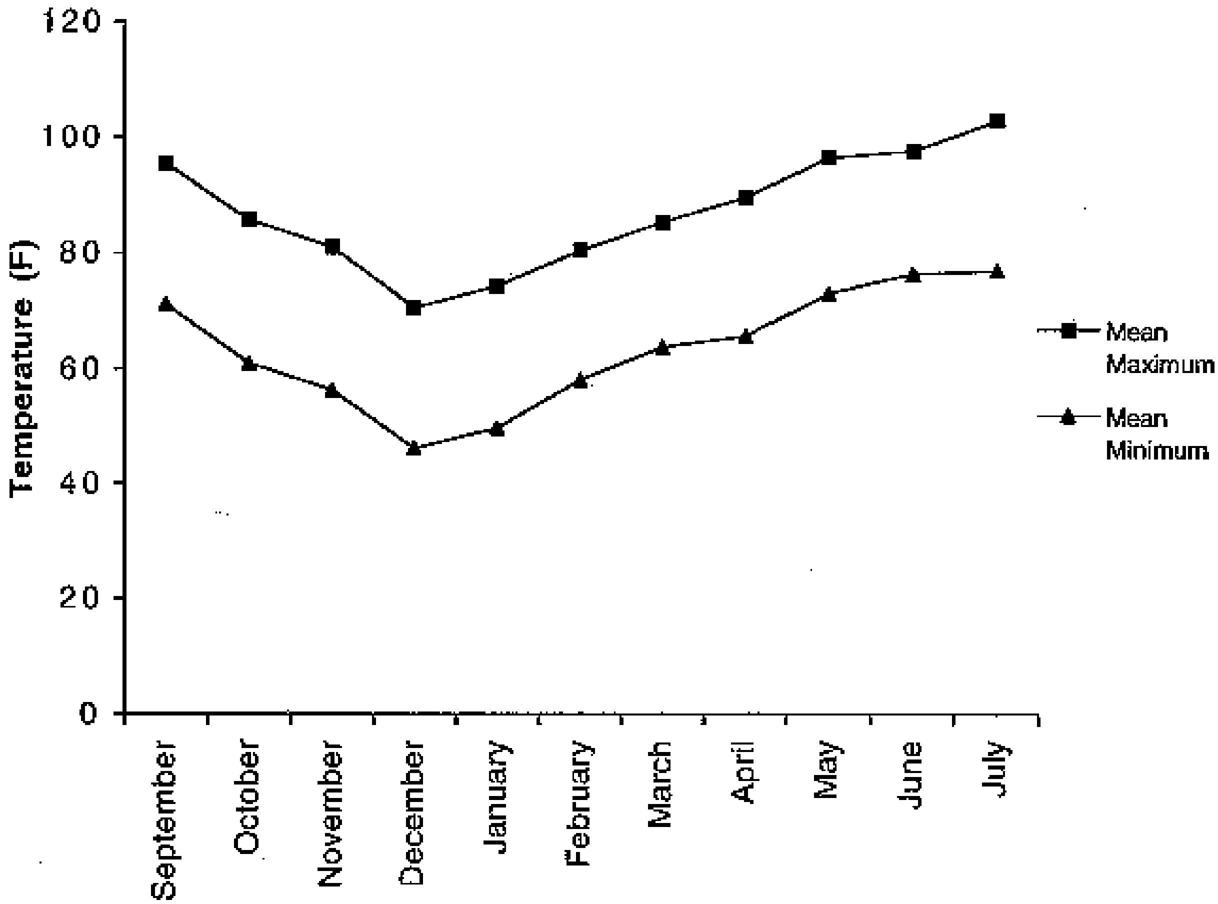

Figure 4. Mean monthly temperatures recorded at Laredo, Texas from September, 1999-July, 2000.

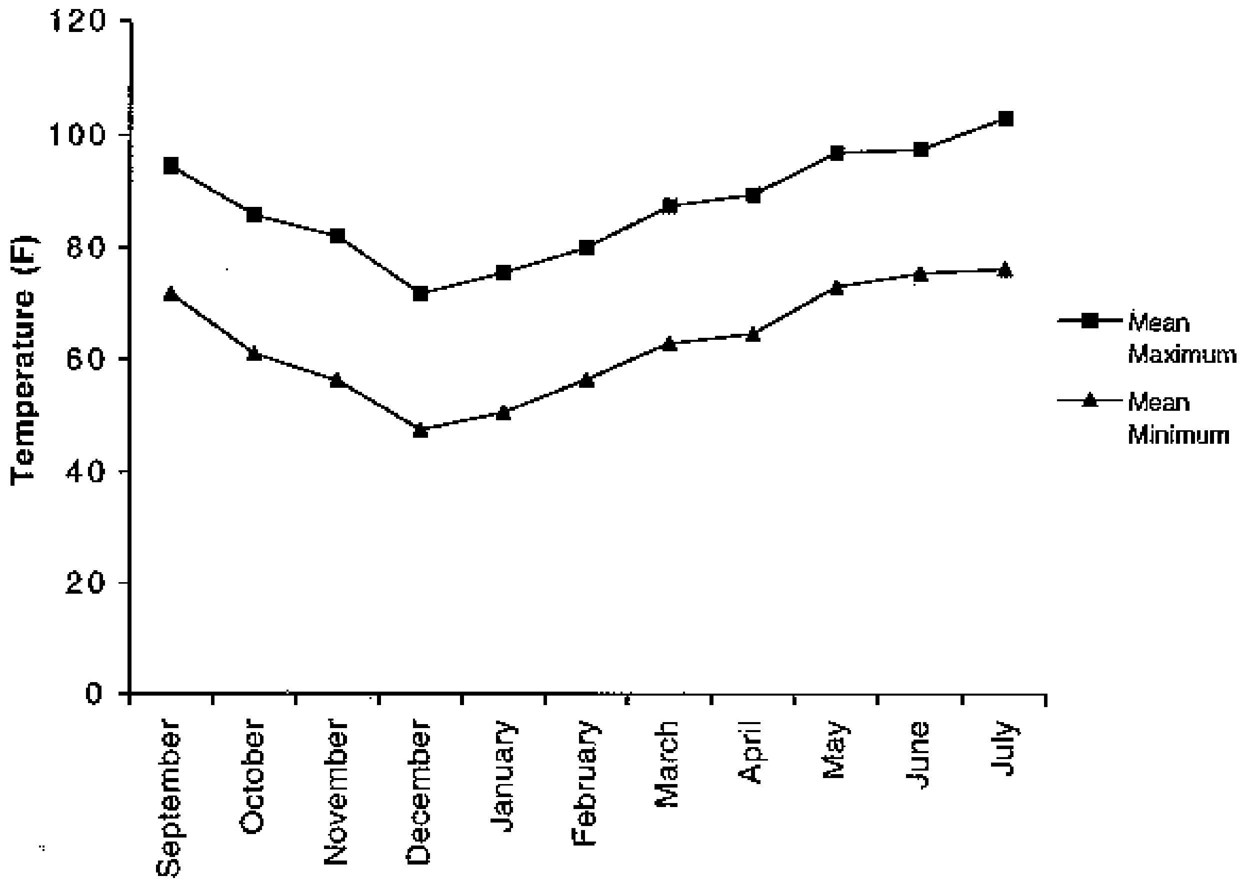

Figure 5. Mean monthly temperatures recorded at Zapata, Texas from September, 1999-July, 2000.

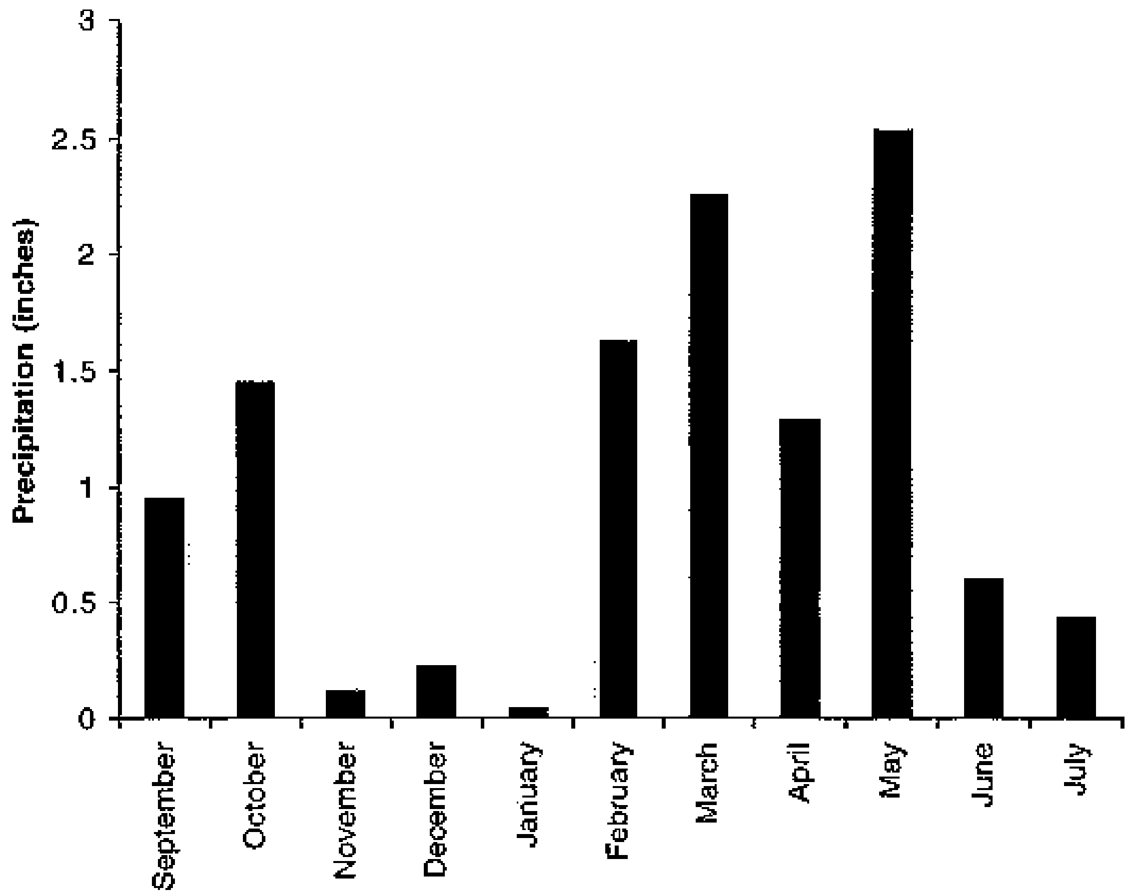

Figure 6. Monthly precipitation recorded at Laredo, Texas from September, 1999-July, 2000.

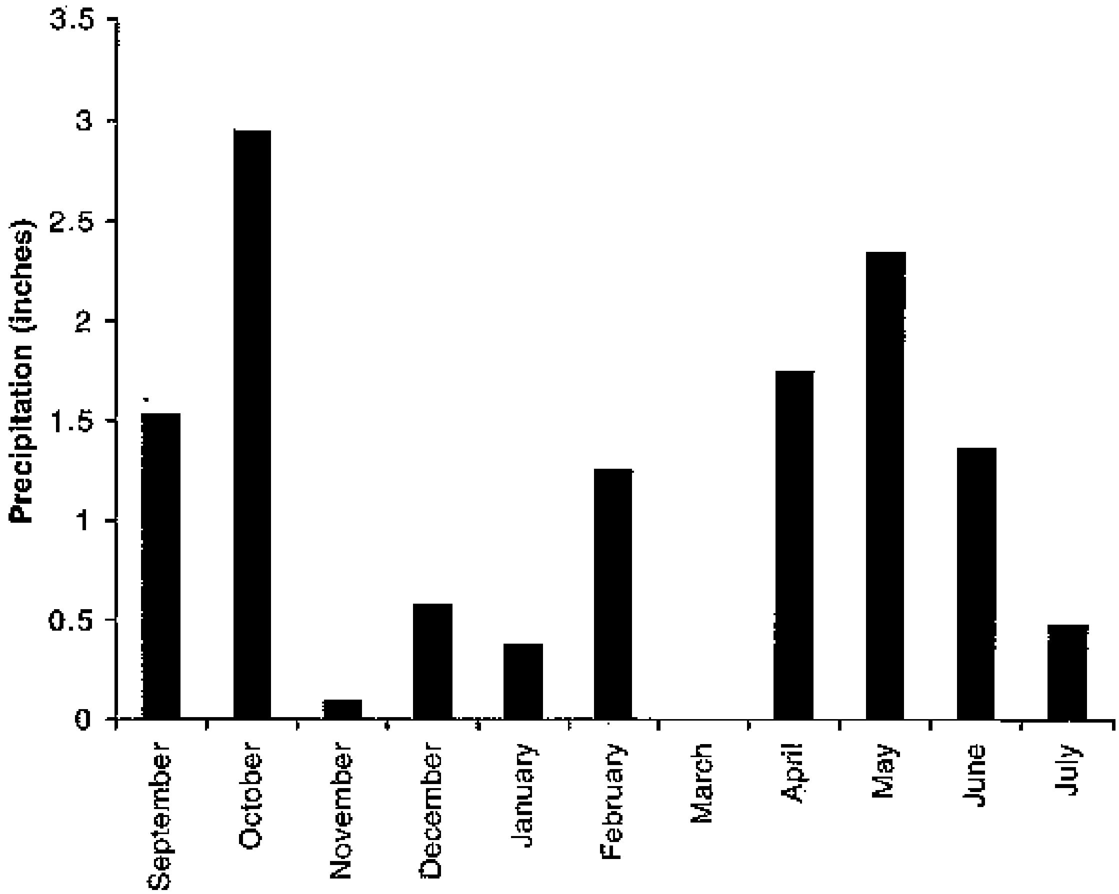

Figure 7. Monthly precipitation recorded at Zapata, Texas from September, 1999-July, 2000.

Table 1. List of associated species collected at populations 1, 2 and 3.

Scientific Name	Common Name	Family Name
Froelichia floridana	Snake-cotton	Amaranthaceae
Cynanchum barbigerum var. *breviflorum*		Asclepiadaceae
Gaillardia pulchella	Firewheel	Asteraceae
Hymenoxys scaposa	Bitterweed	Asteraceae
Thymophylla pentachaeta var. *pentachaeta*	Parralena	Asteraceae
Tiquilia canescens	Oreja de Perro	Boraginaceae
Evolvolus sericeus		Convolvulaceae
Cassia pumilio	Dwarf Senna	Fabaceae
Caesalpinia caudata		Fabaceae
Sida helleri	Copper Sida	Malvaceae
Sida filicaulis		Malvaceae
Acalypha radians	Three-seeded Mercury	Euphorbiaceae
Schrankia latidens	Sensitive Brier	Fabaceae
Desmanthus velutinus		Fabaceae
Indigofera miniata var. *miniata*	Scarlet Pea	Fabaceae
Parkinsonia texana	Paloverde	Fabaceae
Prosopis glandulosa	Honey Mesquite	Fabaceae
Nama hispidum		Hydrophyllaceae
Krameria ramosissima	Calderona	Krameriaceae
Linum imbricatum	Tufted Flax	Linaceae
Allionia incarnata	Umbrella-wort	Nyctaginaceae
Portulaca mundula	Chisme	Portulacaceae
Castela texana	Allthorn Goatbush	Simaroubaceae
Hermannia texana		Sterculiaceae
Lantana horrida	Texas Lantana	Verbenaceae

Pollen Viability

Pollen viability of the greenhouse plants (n=389 pollen grains examined) averaged 73% (Table 2). Viability of pollen taken from two plants in the field in 2000 (n=1422 pollen grains examined) averaged 82.5% (Table 3). Viability of pollen taken from three plants in the field in 2001 (n=1012 pollen grains examined) averaged 86% (Table 4).

Table 2. Pollen viability in *T. tephroleuca* grown in the greenhouse. Results are for winter of 1999.

Plant	Viable	Nonviable	Percent Viable
GH 1	54	22	71.0
GH 2	78	42	65.0
GH 3	161	32	83.0

Table 3. Pollen viability in *T. tephroleuca* from field. Results are for summer of 2000.

Plant	Viable	Nonviable	Percent Viable
H1	840	166	84.0
H2	336	80	81.0

Table 4. Pollen viability in *T. tephroleuca* from field. Results are for summer of 2001.

Plant	Viable	Nonviable	Percent Viable
H1	353	48	88.0
H2	217	34	86.5
H3	301	59	83.6

Pollination Agents

Members of the insect families Buprestidae, Bombyliidae and Megachilidae were observed and captured on *T. tephroleuca* inflorescences. *T. tephroleuca* pollen was identified and observed on insect bodies using SEM.

Pollination Experiments

Results of the crossing experiments are shown in Table 5. No fruit set occurred in the autogamous crossing. Seven embryos were formed in the geitonogamous crossing. The statistically insignificant amount is possibly the result of a flaw in experimental design on just those two inflorescences. 88.8% seed set occurred in the xenogamous crossing.

Table 5. Experimental crosses to determine breeding system in *T. tephroleuca.*

Cross	No. Flowers	No. Embryos	% Seed Set
Autogamous	50	0	0
Geitonogamous	2188	7	.3
Xenogamous	348	309	88.8

Growth and Reproductive Capacity

In the greenhouse, aerial diameter increased linearly (Figure 8). Height also increased over the year. However, due to the plants' irregular growth form, height appears to yield to aerial diameter as a plant gets taller and eventually becomes more prostrate (Figure 9). The number of flowers increased steadily as plants aged with a decline in January and February (Figure 10). Given a constant watering regime, such as in the greenhouse, *T. tephroleuca* exhibits normal linear growth and constant flowering. In the field, however, with drought conditions, water becomes a limiting factor in growth and reproduction. To illustrate trends observed in the field, five random plants along each transect were chosen. Of the five plants analyzed from each population site, only one from the population 2 transect and two from the population 1 transect grew in aerial diameter over the year (Figures 11, 12). None of the ten plants grew in height, with a noticeable decrease occurring in some individuals (Figures 13, 14). The number of flowers from each population peaked in the fall and spring months, with a decline in January-April (Figures 15, 16). Unlike growth and reproduction, seedling recruitment and population density were not similar between the two populations. At population 2, recruitment within the transect was nonexistent, with no new seedlings or plant mortality over the year. Plant density in the population transect remained unchanged throughout the year at 0.6 plants/m^2. The population 2 site had never been previously disturbed according to the landowner. The population 1 site, however, had been disturbed within the past five years by a pipeline that had been installed by a gas company (personal observation). Germination of individuals within the population 1 transect was prevalent, and was highest coinciding with increased rainfall in the fall and spring months (Figure 17). Mortality, on the other hand, was temporally sporadic. Hoof prints were often visible in spots that were once occupied by plants, suggesting trampling or herbivory may have been the cause of death. Lack of precipitation is also correlated with the death of individuals, with a high mortality occurring in the dry months of January and July (Figure 18). Plant density in population 1 increased from 3.4 plants per m^2 in September, 1999 to 4.7 plants per m^2 in August, 2000.

Seed Viability

Results of tetrazolium staining shows much variance in seed viability from 1999 to 2001. Seeds collected in 1999 had an average viability of 36.5% (Table 6). Seeds collected in 2000 had an average viability of 7.5% (Table 7). Seeds collected in 2001 had 22% viability (Table 8).

Table 6. Analysis of seed viability in two populations of *T. tephroleuca*. Results are for summer of 1999.

Population	Viable	Nonviable	Percent Viable
1	78	122	39.0
2	67	133	34.0

Table 7. Analysis of seed viability in three populations of *T. tephroleuca*. Results are for summer of 2000.

Population	Viable	Nonviable	Percent Viable
1	25	175	12.5
2	8	192	4.0
3	32	168	16.0

Table 8. Analysis of seed viability in one population of *T. tephroleuca*. Results are for summer of 2001.

Population	Viable	Nonviable	Percent Viable
3	44	156	22.0

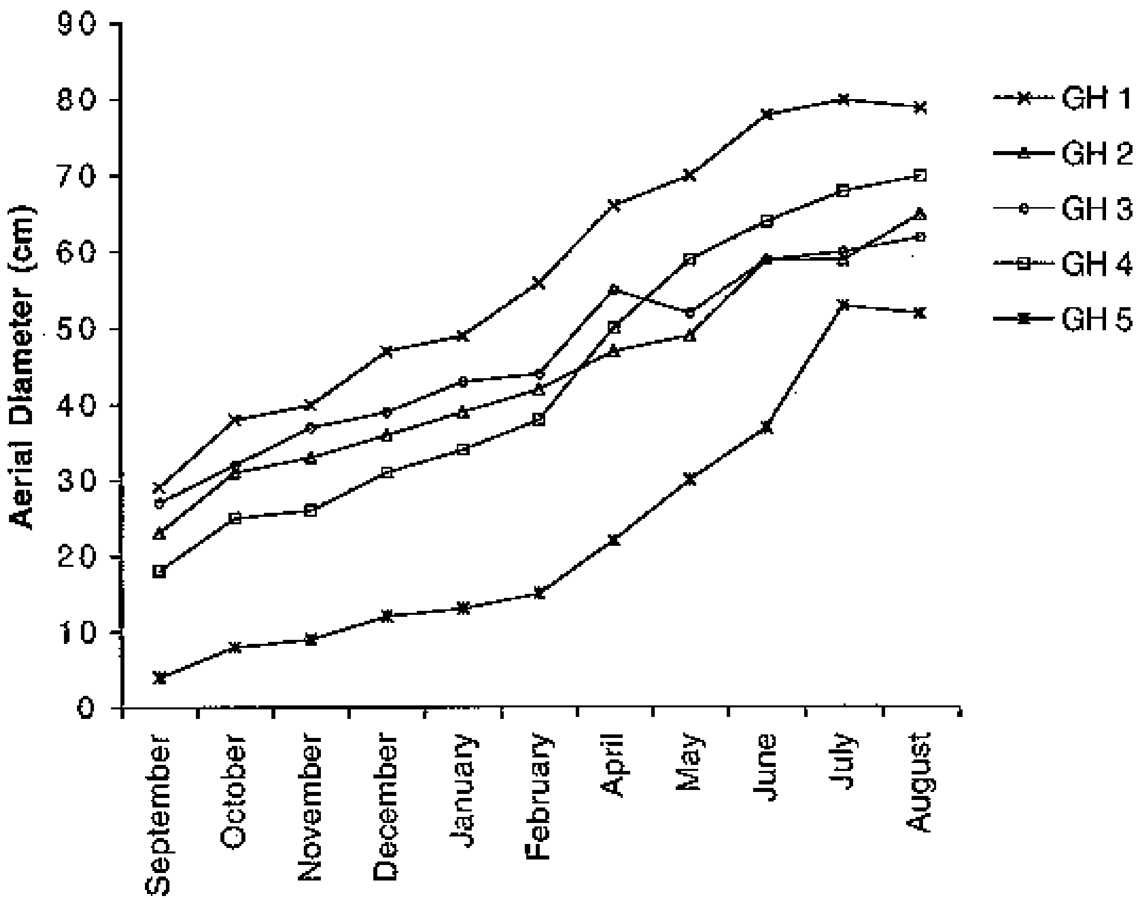

Figure 8. Aerial diameter of plants located at SWT during 1999-2000 study period.

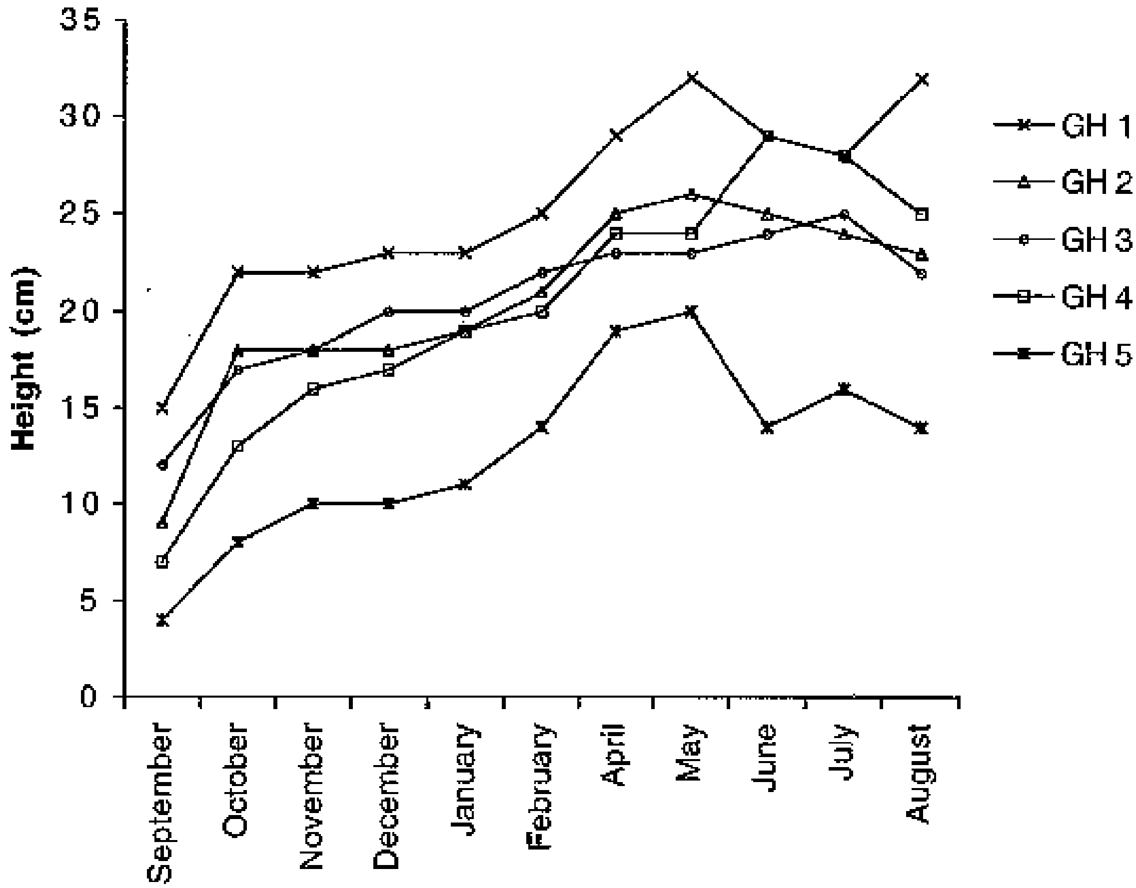

Figure 9. Height of plants located at SWT during the 1999-2000 study period.

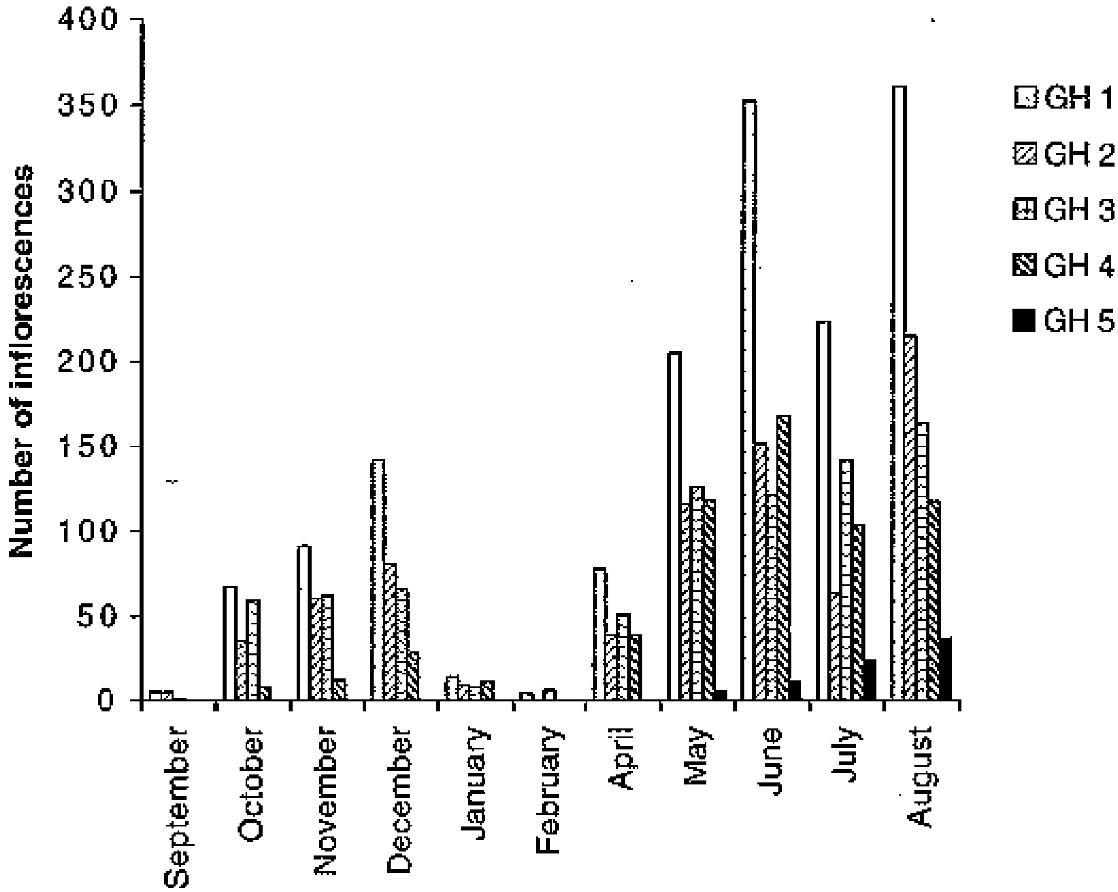

Figure 10. Number of inflorescences produced by the plants located at SWT during the 1999-2000 study period.

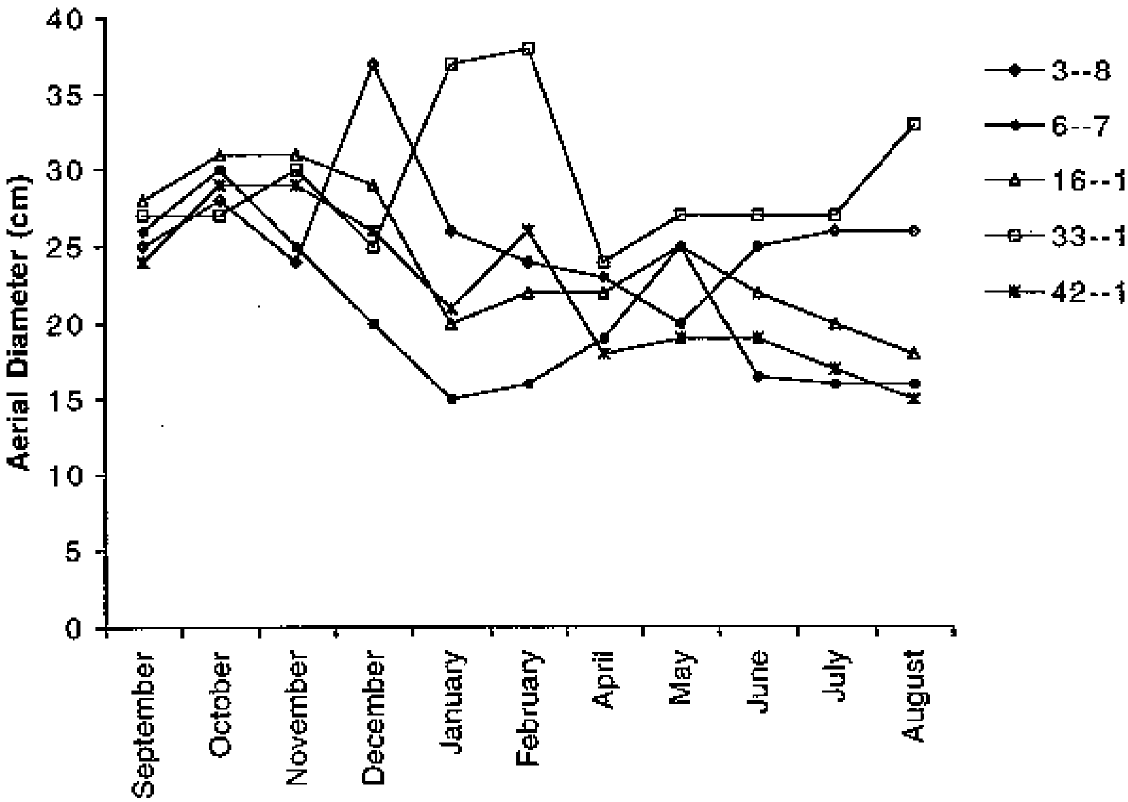

Figure 11. Aerial diameter of five plants from Population 1 transect measured during 1999-2000 study period.

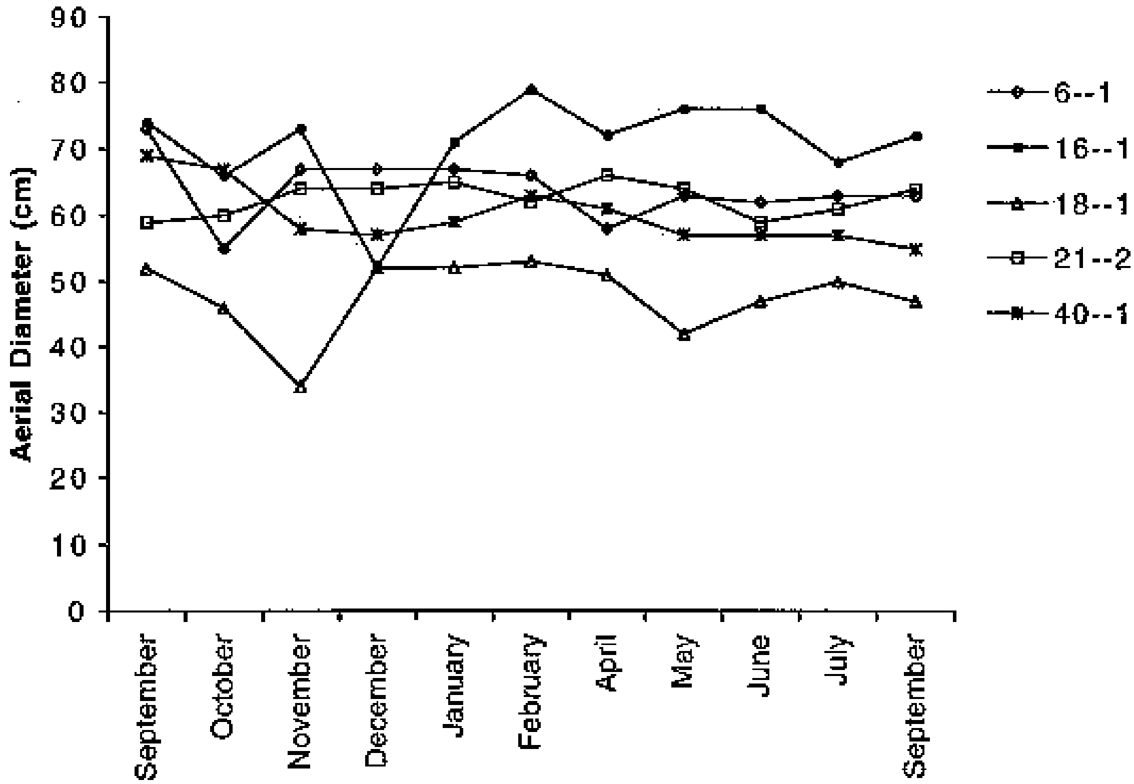

Figure 12. Aerial diameter of five plants from Population 2 transect measured during 1999-2000 study period.

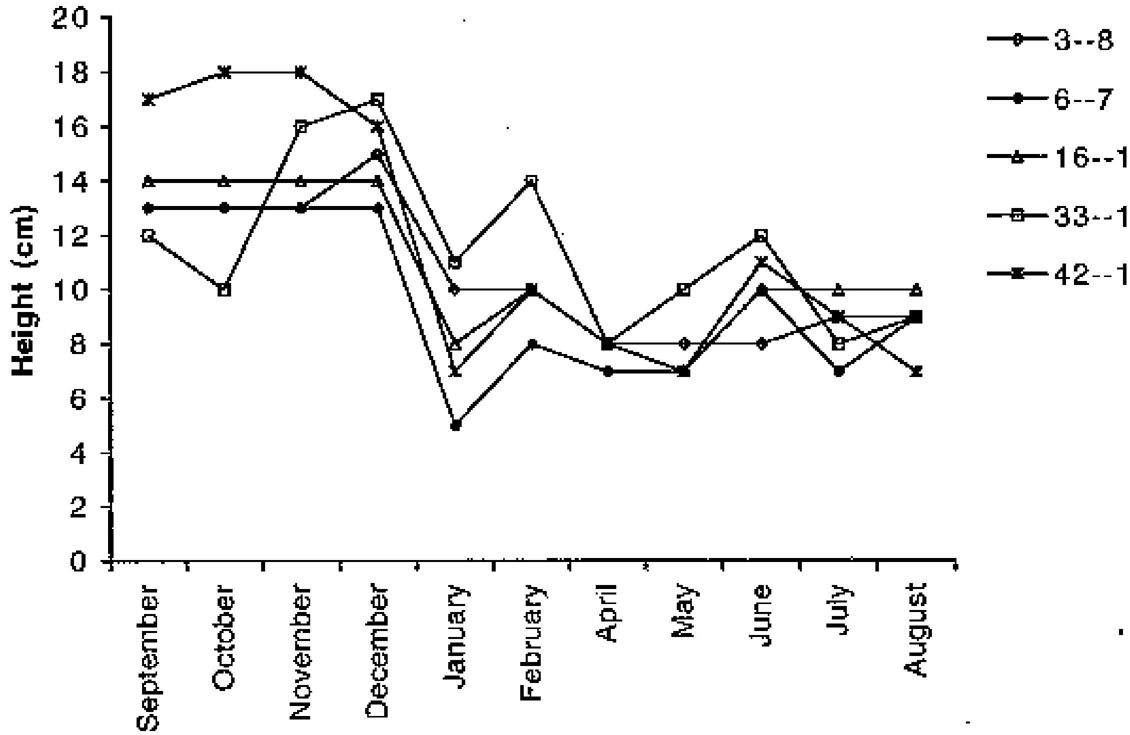

Figure 13. Height of five plants from Population 1 transect measured during 1999-2000 study period.

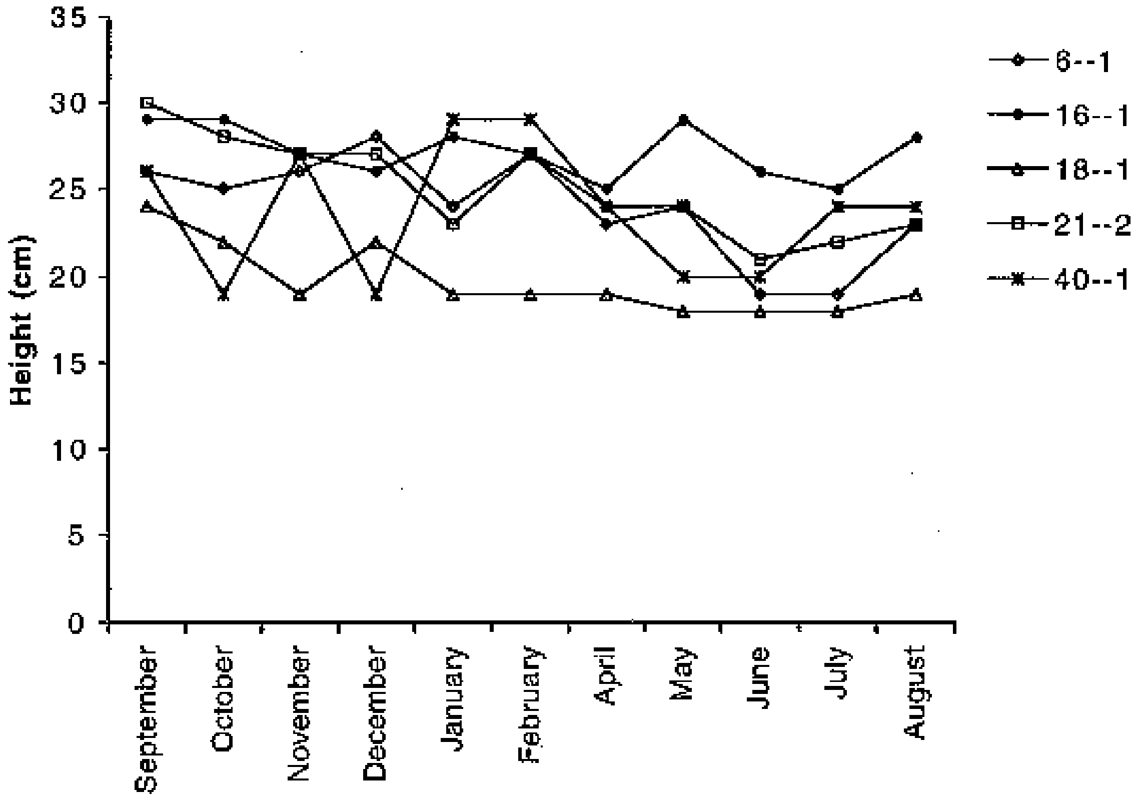

Figure 14. Height of five plants from Population 2 transect measured during 1999-2000 study period.

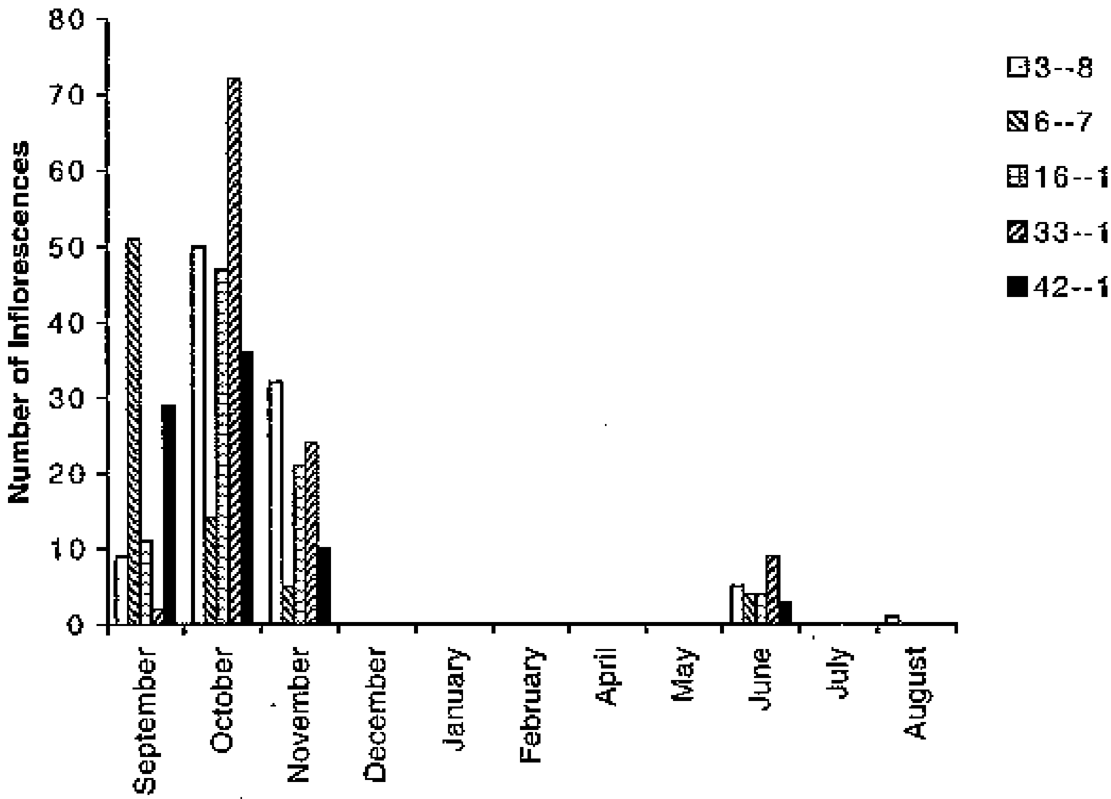

Figure 15. Number of inflorescences produced by five plants at Population 1 transect during 1999-2000 study period.

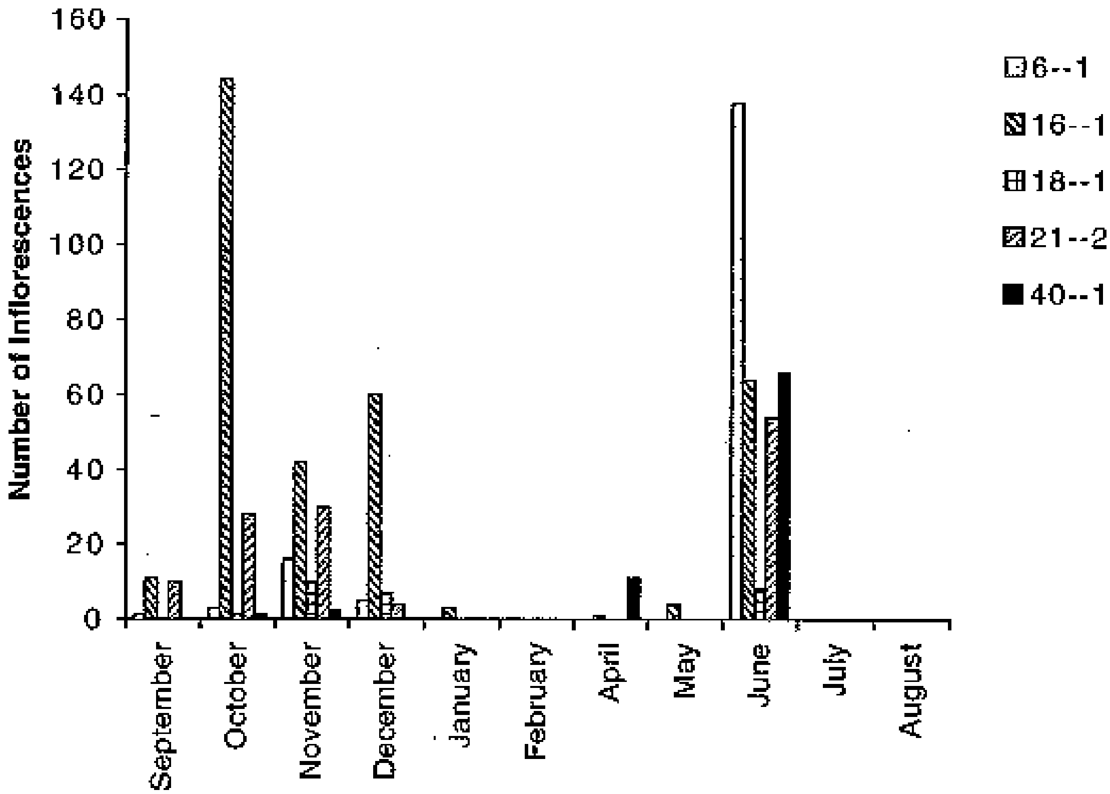

Figure 16. Number of inflorescences produced by five plants at the Population 2 transect during 1999-2000 study period.

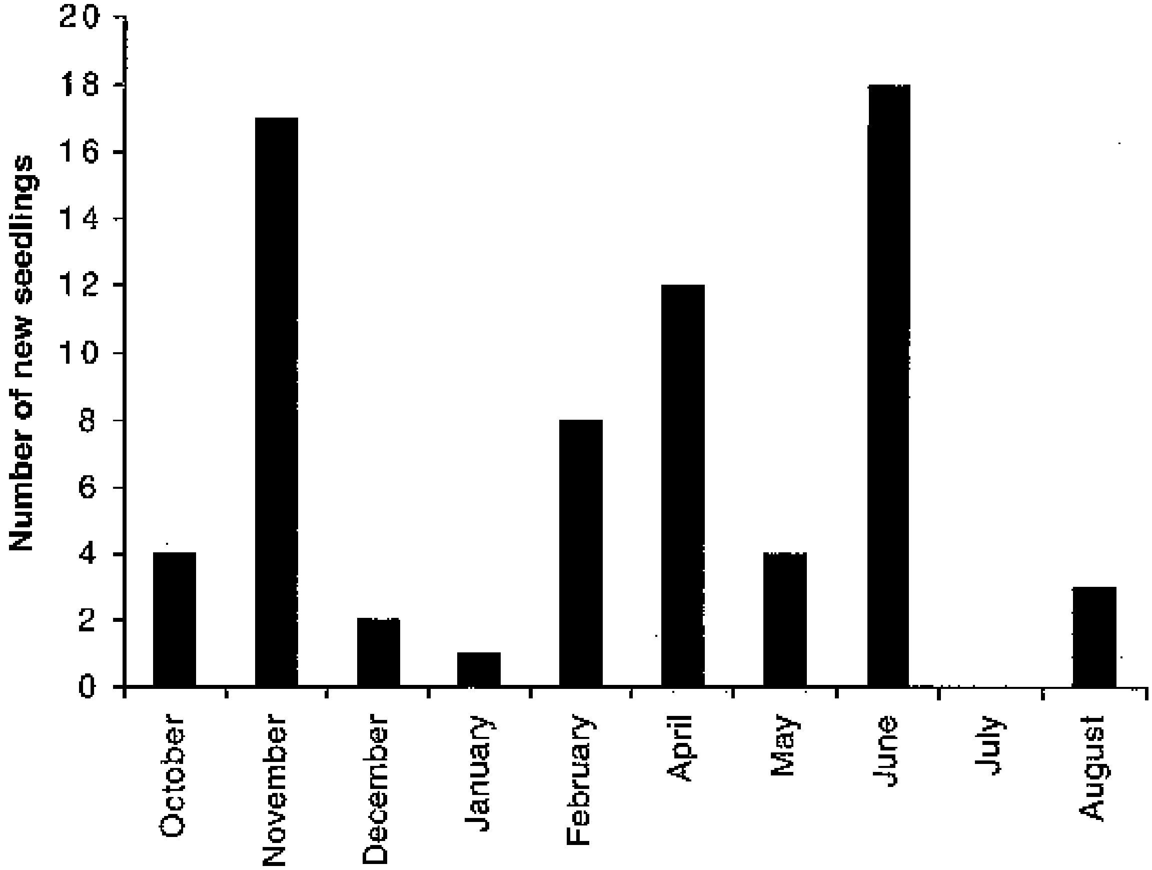

Figure 17. Number of new seedlings monitored each month at Population 1 during 1999-2000 study period.

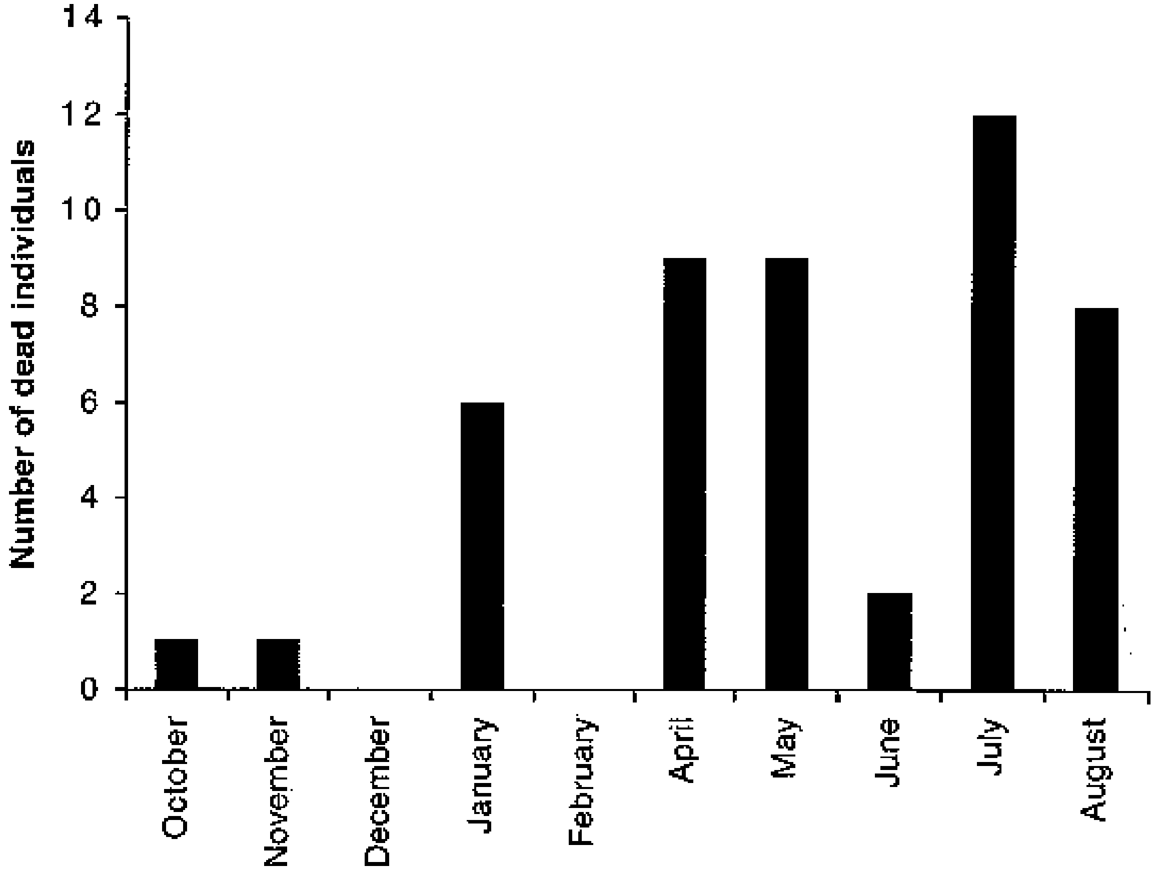

Figure 18. Number of dead individuals monitored each month at Population 1 during 1999-2000 study period.

Disturbance Experiment

Treatment comparisons indicate that mean density was significantly greater in root-plow plots than in control plots ($P<.05$, *t* –test). No significant difference occurred, however, between the control plots and either the blade or the root-plow with buffelgrass plots (Figure 19). In the root-plow treatment, mean density declined from 270 plants/plot in February to 137 plants/plot in June. In the same time period the root-plow with buffelgrass seeded treatment declined from 156 plants/plot to 64 plants/plot and the blade treatment from 116 plants/plot to 63 plants/plot. Buffelgrass was found growing within the seeded plots. The competitive effects of the grass on germination and subsequent establishment of *T. tephroleuca* seedlings likely caused the convergence of densities between the root-plow with buffelgrass treatment and the blade treatment. The control plots also declined in density from 92 plants/plot in February to 19 plants/plot in June. Germination within all plots was episodic in February, correlating to a rainy winter in the region. The decline in individuals per plot from February to June can be attributed to the unusually dry spring and competition from annuals. Prior to February, no germination was reported.

DISCUSSION

Precipitation in an arid environment is undoubtly one of the most limiting factors determining success in plants. This is evident in several aspects of this study on *T. tephroleuca*. Seed viability varied considerably for achenes collected throughout the study period. Mean viability values declined from 36.5% in 1999 to 7.5% in 2000. Achenes exhibited an increase in viability to 22% for 2001. The differences in seed viability is likely to be caused by precipitation differences between the three summers. Wood, et. al (1997) obtained similar results when comparing achene development in Broom snakeweed (*Gutierrezia sarothrae*) over a two year time period. Their results indicate that climatic conditions contributed to the higher rate of achene deterioration in the second year as compared to the first year's data. Wood, et al. (1997) also indicate in

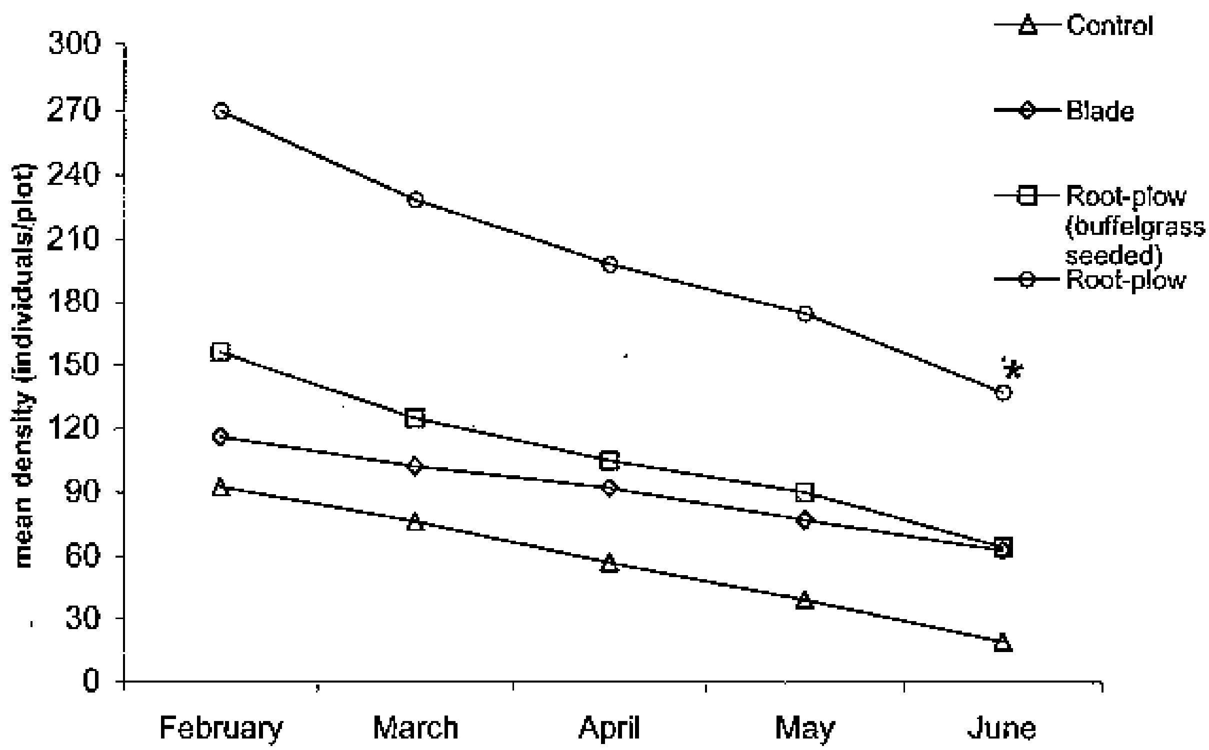

Figure 19. Mean number of *Thymophylla tephroleuca* seedlings per plot following different disturbance treatments. (*P<0.05, *t* -test)

their study that during both years, achenes exhibited a pronounced periodicity of viability, as seeds were always most viable when recovered during fall and winter (October to April) but declined sharply late in spring (May to July). Collecting *T. tephroleuca* achenes during the summer months might have had a pronounced influence on viability.

Another potential result of the aridity is an apparent lack of growth, both aerial and vertical, of individuals from both monitored populations. Only two of the ten plants analyzed increased in aerial diameter and height. Two other possible scenarios accounting for the lack of growth are herbivory and senescence of ramets. Cattle and deer hoof prints are often visible in the transects. Cattle and deer might be utilizing the plants as a primary food source because of its relative height to most grasses. Drought conditions could increase this effect with a lack of annual grasses to fill the ungulates' diet. Another effect of decreased precipitation that has been observed is that entire ramets have died and broken off, only to be replaced by new growth with a rainfall event. This continual change in plant canopy structure likewise makes measurements of an individual change.

Plants experimentally crossed autogamously did not set fruit. Self-pollination appears to be inhibited by protandry, in that the stamens mature before the stigmas. Plants crossed geitonogamously produced a statistically insignificant amount of embryos, indicating that *T. tephroleuca* is self-incompatible. The mechanism of self-incompatibility (pre- or post-zygotic inhibition) needs to be investigated further. Plants crossed xenogamously had 88.8% seed set, signifying that *T. tephroleuca* is an obligate outcrossing species. Outcrossing does seem to be limited by pollination agents. The fact that multiple pollinators were captured and determined to be carrying *T. tephroleuca* pollen suggests that no exclusive mutualistic relationship exists between the plant and any one insect.

Plant density and recruitment varied significantly between population 1 and 2. Population 2 is dominated by large, mature individuals in an undisturbed site. Recruitment was nonexistent in this population and density remained unchanged at 0.6 plants per m^2. The lack of bare ground inhibited germination and competition from forbs and grasses likely inhibited establishment. Mortality was also nonexistent. The large size structure of individuals within the population kept trampling, herbivory and drought from killing whole plants. Population 1, however, is situated in a previously disturbed site and is dominated by juvenile individuals. Density increased from 3.4 plants per m^2 in September, 1999 to 4.7 plants per m^2 in August, 2000. Characteristics of the site include loose soils and limited competition from grasses and increased irradiance from the lack of plant cover. These conditions are conducive to germination and establishment of plants needing heat and moisture to break dormancy, such as *T. tephroleuca* (Poole 1992). Mortality occurred often due to the small size of individuals and their inability to survive drought conditions and trampling. Over the year 69 new plants were mapped and 48 died, totaling 21 new individuals recruited into the transect. Comparisons of density, recruitment, size structure and physical characteristics of the population 1 and 2 sites indicated that the soil disturbance possibly had a positive effect on *T. tephroleuca* germination and establishment. Physical disturbances generate conditions favorable for recruitment and growth by reducing competition for nutrients, light and moisture (Sousa, 1984). Species responses to disturbance are typically associated with their life history and physiological traits, as well as the type and magnitude of the disturbance (Chambers 1995, McIntyre et al. 1995). *Thymophylla tephroleuca* has shown to increase germination from 23.8% without heat-stratification to 48.9% with heat-stratification (Poole 1992). A disturbance that reduces canopy cover will increase the amount of red light incident on the soil surface, as well as moisture and nutrient availability. If the resident vegetation is incorporated into the soil as a result of the disturbance (as in root-plowing), soil nutrients will further increase as the organic matter decomposes. Peterson and Bazzaz (1978) showed increased germination in *Aster pilosus*, a perennial common in early successional fields, under high levels of irradiance, red light, and moderately high concentrations of nitrate. The root-plow with buffelgrass plots had moderately high germination in February, but declined rapidly due to the competitive effects of buffelgrass. Density values of these plots merged with those in the bladed plots at the end of the study period, suggesting that both of these land practices equally influence *T. tephroleuca* establishment. When blading, the bulldozer attachment had the effect of removing the top 1-2 in. of soil in addition to the resident vegetation. This possibly resulted in the removal of much of the seed bank, which is necessary for germination following a disturbance. The fact that germination did occur but densities declined throughout the year further suggest that plants need the increased nutrient levels and loose soils to become established.

Results of this study suggest that a disturbance that tills the soil under gives *T. tephroleuca* conditions necessary for germination. Landowners now can be informed that root-plowing through a population of *T. tephroleuca* can be beneficial to the existence of the species, as long as the resident seed bank only is allowed to revegetate the area.

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APPENDIX I.

The following deviations from the proposed methodology have been made:

6) Document presence or absence of persistent soil seed bank

A soil seed bank study was conducted at one population. However, no seedlings germinated in the study. This may have been due to insufficient light in the SWT greenhouse rather than being an indication of the absence of a seed bank. Because the results are nebulous, this component of the study was omitted from the report.

7) Survey potential habitat for undiscovered populations

Surveys for additional populations were conducted on the ranches we had access to. No additional populations were found. Therefore, we did not include survey data in the final report.

8) Document effects of various disturbance techniques regularly employed by landowners

All plots are fenced. It was determined that we would not be able to separate landowner disturbance effects from grazing effects in our statistical analysis. We consider the information gathered in a study of disturbance effects more important in providing technical assistance to the landowners in developing plans for Ashy dogweed conservation. Therefore, unfenced treatments were eliminated from the experimental design because it was deemed that they would confound results. To gage a more complete understanding of recruitment, density and cover for Ashy dogweed colonizing the plots, data was recorded monthly rather than every three months as originally proposed.