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Comparative phenology of *Acacia berlandieri*, *A. minuata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano* in the lower Rio Grande Valley of Texas

Melissa R. Eddy

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COMPARATIVE PHENOLOGY OF ACACIA BERLANDIERI,
A. MINUATA, A. RIGIDULA, A. SCHIAFFNERI, AND
CHLOROLEUCON EBANO IN THE
LOWER RIO GRANDE VALLEY
OF TEXAS

A Thesis

by

MELISSA R EDDY

Submitted to the Graduate School of the
University of Texas-Pan American
in partial fulfillment of the requirements for the degree of
MASTER OF SCIENCE

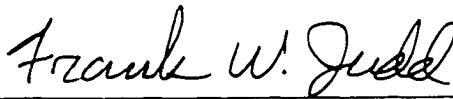
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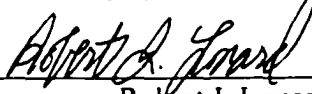
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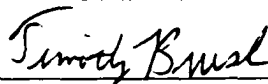
Approved as to style and content by:



Frank W. Judd
Chair of Committee



Robert I. Lonard
Committee Member



Timothy Brush
Committee Member



Mohammed Farooqui
Department Chair



George Avellano
Associate Vice-President for Graduate Studies

December 2000

ABSTRACT

Eddy, Melissa R., Comparative Phenology of *Acacia berlandieri*, *A. minuata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano* in the Lower Rio Grande Valley of Texas. Master of Science (MS), December, 2000, 131 pp., 48 tables, 39 figures, references, 44 titles.

A phenological study of *Acacia berlandieri*, *A. minuata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano* was conducted at three sites in the lower Rio Grande Valley of Texas from July 1998 to August 1999. Flowering in *Acacia* species occurred between January and April 1999, and was influenced by precipitation only in *A. minuata*. The timing of flowering appears to be influenced by the amount of time needed for fruit maturation. Precipitation, photoperiod, and temperature influenced the timing of fruiting in all species except *A. berlandieri*. Shoot elongation and leaf maturation in *Acacia* species were positively correlated with temperature and photoperiod

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INTRODUCTION

Description and Importance of Phenology

Phenology is concerned with the timing of periodic and recurrent biological events in plants and animals, with special emphasis on the influences of abiotic and biotic factors on these events (Lieth, 1974; Bowers and Dimmitt, 1994). Phenology has been important for thousands of years in agriculture (Lieth, 1974; Podolsky, 1984; Primack, 1985). Farmers have used information derived from such studies to determine the timing of planting, harvesting, and control measures for crop pests (Lieth, 1974; Primack, 1985). Phenology is a relatively young field in botany, when compared to agriculture. The Swedish botanist Carolus Linnaeus is considered the father of modern plant phenology, although the Belgian botanist Charles Morren is credited with proposing this field as an area of science (Lieth, 1974). Specific studies conducted on the phenophases of plants (in general) are uncommon (Lieth, 1974) despite human dependence on these producers. Few studies on *Acacia* phenology and growth have been conducted in natural situations (New, 1984), but a major effort by biologists is currently underway to describe phenological patterns in a very specific manner and to determine the causes for these recurring patterns (Primack, 1985).

The Southwestern Naturalist is used in this thesis as a model for style and format.

Phenological studies are important because they provide biologists with baseline descriptive information that is essential to the recognition of reproductive and growth patterns. This information is a crucial prelude to the formulation of hypotheses in experimental research (Bookhout, 1996). Abiotic factors such as temperature, precipitation, and photoperiod can be examined during a phenological study to determine their effects on the reproductive and vegetative responses of the plants involved. For example, research shows that flowering, shoot growth, and breaking of bud dormancy in certain plants is more likely to be controlled by temperature than by length of photoperiod (Lieth, 1974). The effects of biotic factors, such as pollinators and intraspecific competition for these pollinators, may also be examined in the course of a phenology study. Cold temperatures, for example, can interfere with the flights and activities of pollinators. Such adverse conditions might influence phenology in that there may be fewer pollination events, and thus fewer flowers and fruits in an individual plant (Primack, 1985). Results gained from phenological studies may clarify the workings of a particular ecosystem and enhance the knowledge of the reproductive systems of angiosperms (Leonard and Judd, 1989).

The Influence of Abiotic and Biotic Factors on Plant Phenology

Plants that inhabit arid and semi-arid regions have characteristically short periods of growth and seasonal flowering. Typically, precipitation and temperature are the most significant abiotic factors that influence phenological events in such areas. Day length and soil moisture availability are additional abiotic factors that may affect the phenology of a species (Ghazanfar, 1997). Indeed, particular combinations of rainfall, temperature,

and photoperiod may be necessary for successful growth in some plant species (New, 1984; Primack, 1985).

Lieth (1974) reports that flowering and the breaking of bud dormancy are most likely controlled by temperature. *Acacia farnesiana* experiences height increases two to three times greater at warmer temperatures than at cooler temperatures with a similar photoperiod (New, 1984). The timing of leaf production in tropical trees is most influenced by photoperiod and water availability (Barone, 1998). High temperatures and a lack of precipitation, however, can result in the abscission of leaves (New, 1984; Gill and Mahall, 1986; Ghazanfar, 1997)

Yearly variation in climatic patterns may induce changes in plant phenophases (Primack, 1985). Ghazanfar (1997) found that longer than normal periods of rain in the hyperarid deserts of Oman extended the length of flowering, while shorter than normal periods of rainfall decreased the length of flowering. Indeed, all phenological events were delayed by late rain (Ghazanfar, 1997). A drought year occurred during the study, which resulted in a marked decrease in the number of plant species flowering that year. Only three of 54 species flowered during the drought year, and those that did flower did so at much later dates than in earlier years (Ghazanfar, 1997). Similarly, New (1984) reports that some species of *Acacia*, which inhabit areas of Australia where rainfall is highly unpredictable, do not reproduce each year.

Biotic factors also may influence the timing of various phenological events. Closely associated species within a community often exhibit staggered flowering periods. This may improve pollinator success by decreasing competition between flowering individuals.

(Heinrich, 1976; Primack, 1985; Ghazanfar, 1997). The timing of fruit maturation may be influenced by biotic factors, such as the avoidance of mammalian and bird seed predators and attack by pathogenic microbes (Primack, 1985)

Phenology Studies in the Lower Rio Grande Valley of Texas

There have been few studies of the phenology of woody plants of the lower Rio Grande Valley of Texas (LRGV). Native vegetation in this region continues to be threatened as clearing for agricultural and urban development persists and intensifies. Over 90 percent of the native vegetation in the region has been removed (U.S. Fish and Wildlife Service, 1983) without study of the phenology of the species comprising the plant communities. Plant restoration activities are currently underway in the LRGV in an effort to replace lost native vegetation and to create a wildlife corridor along the Rio Grande. It is important to understand the phenology of the plants that are being replanted for habitat restoration purposes. Understanding the phenophases and the abiotic factors that affect them prior to restoration efforts allows for higher success rates in establishment, increased time efficiency, and effective use of funds.

Vora (1990) reported on the phenology of 19 species of native plants (with emphasis on woody species) in the LRGV. He examined plants at Santa Ana National Wildlife Refuge, 12.1 km south of Alamo, Texas. Data from this investigation were supplemented by data collected by USFWS employees and visitors to the area. Their observations were conducted in the area surrounding the wildlife refuge parking lot, the C trail, and on tracts of native vegetation in areas throughout the LRGV during the same time period. Plants in the study were examined weekly for evidence of flowering,

fruiting, leaf growth, and leaf drop. Results indicated that there are three active growth and reproductive periods during a year for native vegetation in the LRGV. The growing periods occur during February, late May to June, and late September through November.

Rainfall varied during the years in which Vora's study was conducted, resulting in differences in plant growth and reproduction. Drought conditions occurred during 1986, resulting in minimal plant growth during that year. Some plants were partially or completely drought-deciduous during hot, dry periods which retarded water loss through transpiration. Vora (1990) concluded that rainfall and soil moisture significantly influenced plant growth and reproduction in the LRGV.

Acacia mimuata, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano* were among the woody plants studied by Vora (1990). He found that *A. mimuata* began flowering in late January and ceased flowering in March. Signs of new growth were evident in *A. mimuata* by early February. Vora observed green fruits in *A. mimuata* by early April, which became more numerous and more visible by May. These legumes ripened by late June. Drought conditions (from January through May of 1986) during Vora's study influenced reproductive productivity of *A. mimuata*, resulting in fewer fruits during that year, as compared to the previous year (Vora, 1990). *Acacia rigidula* began flowering in March and its legumes ripened during July and August. *Acacia schaffneri* retained its pods containing mature seeds through the autumn months and into the early winter months. Vora reported that *Chloroleucon ebano* began flowering in May and continued to flower during June. Flowering continued episodically during the summer months when sufficient soil moisture was present. The legumes of *C. ebano* ripened during July and

August and pods containing mature seeds were retained through the autumn months and into the early winter months (Vora, 1990). Phenological information on timing and duration of flowering and fruiting provided by Vines (1960), Correll and Johnston (1979), Everitt and Drawe (1993), and Taylor *et al.* (1997) differs from the data collected by Vora.

I studied the phenology of four *Acacia* species in the LRGV over a thirteen month period at three sites. *Chloroleucon ebano* was studied to assess the significance of interspecific variation of the congeneric species. A description of these species is provided below.

Species Studied and Objectives

Nine *Acacia* species play an important and specialized ecological role in the lower Rio Grande Valley of Texas (Lonard *et al.*, 1991). The genus *Acacia* (subfamily Mimosoideae) is quite large, with approximately 900 species (New, 1984) found in various regions with warm climates around the world (Turner, 1959, Correll and Johnston, 1979). Members of the genus *Acacia* are trees, shrubs, or suffrutescent herbs with straight spines or recurved prickles. The leaves are bipinnately compound, and a petiolar gland is often present. Flowers are yellow or white in color and occur in globose or spicate heads. They are often fragrant and have numerous stamens (twenty or more per flower). A characteristic feature of the genus *Acacia* is the presence of stamens which are free to the top of the floral cup (Robert Lonard, personal communication). Fruits produced by *Acacia* species are usually linear legumes (Turner, 1959).

The *Acacia* species included in this study are *A. berlandieri* G. Bentham, *A. minnata*

(M.E. Jones) *P. de Beauchamp* subsp. *minuata*, *A. rigidula* G. Bentham, and *A. schaffneri* (S. Watson) Hermann var. *bravoensis* D. Isely. Another member of the family Fabaceae, *Chloroleucon ebano* (J. Berlandier) L. Rico, is included to determine if the differences between species of the same genus are as great as the differences between species of different genera.

The objectives of the study were to 1) describe and quantify the phenology of the four *Acacia* species and one *Chloroleucon* species. 2) examine the relationships between climatic factors and the reproductive and vegetative responses of the species studied. 3) determine if significant differences in phenology exist among species of the genus *Acacia*. 4) determine if the magnitude of phenological differences between members of the genus *Acacia* are as great as that between any of the species and *Chloroleucon ebano*.

The first null hypothesis is that there are no significant differences in the phenologies of *Acacia* species included in the study. The second null hypothesis is that variation in the phenology among *Acacia* species in the study is less than variation between any of the *Acacia* species included in the study and *C. ebano*.

Description of Acacia Species

***Acacia berlandieri* (guajillo)**

Acacia berlandieri is a semi-evergreen (Jones, 1982), spreading shrub that ranges in height from one to four m (Correll and Johnston, 1979; Jones, 1982; Richardson, 1990; Lonard *et al.*, 1991; Everitt and Drawe, 1993). It may occasionally exhibit a tree-like appearance, growing to a height of three m (Vines, 1960; Jones, 1982). It is a drought-tolerant shrub (Taylor *et al.*, 1997) whose range includes southern Texas (especially

along drainages of the Rio Grande in western Hidalgo and Starr counties) (Vines, 1960; Lonard *et al.*, 1991) to northeastern Mexico (Turner, 1959). It is found on many types of soil, but is especially abundant on dry limestone or caliche ridges (Turner, 1959; Vines, 1960; Correll and Johnston, 1979; Scifres, 1980; Jones, 1982; Lonard *et al.*, 1991; Everitt and Drawe, 1993). *Acacia berlandieri* is occasionally found in brushy pastures (Jones, 1982) or on sandy loam or clay soils (Vines, 1960; Scifres, 1980; Jones, 1982). It provides a protective shelter for many species of birds and mammals and it is an important source of pollen for honey bees (Lonard *et al.*, 1991). The leaves of *A. berlandieri* contain approximately 20% crude protein (Lonard *et al.*, 1991) and are eaten by cattle, deer, sheep, and goats (Everitt and Drawe, 1993; Taylor *et al.*, 1997). The seeds are eaten by feral hogs and scaled quail (Taylor *et al.*, 1997).

***Acacia minnata* (huisache, sweet acacia)**

Acacia minnata is a drought-deciduous (Taylor *et al.*, 1997), spiny shrub or small tree that usually grows to a height of two to four m (Correll and Johnston, 1979; Lonard *et al.*, 1991). It grows in tropical and semitropical areas of both hemispheres (Vines, 1960) and is abundant in South Texas (Correll and Johnston, 1979). *Acacia minnata* grows on a variety of soil types (Lonard *et al.*, 1991) and is common in areas with deep, poorly drained sandy soils or low-lying areas with clay soil (Taylor *et al.*, 1997). It may be found in disturbed areas (Vora and Messerly, 1990). *Acacia minnata* provides a protective shelter for nesting white-winged doves (*Zenaidura asiatica*) (Lonard *et al.*, 1991) and mourning doves (*Zenaidura macroura*) (Everitt and Drawe, 1993; Taylor *et al.*, 1997). Altamira orioles (*Icterus gularis*) sometimes nest on taller individuals (Brush, 1998).

The leaves and branches of *A. minima* are often eaten by cattle during the winter (Turner, 1959; Everitt and Drawe, 1993; Taylor *et al.*, 1997). Rodents also consume portions of the stems of *A. minima* in aquatic areas (Taylor *et al.*, 1997). Javelina may sometimes eat the fruits of *A. minima* (Everitt and Drawe, 1993; Taylor *et al.*, 1997). Furthermore, the flowers of *A. minima* provide pollen and nectar for bees and butterflies (Lonard *et al.*, 1991; Taylor *et al.*, 1997).

***Acacia rigidula* (black-brush acacia)**

Acacia rigidula is a spiny, semi-evergreen (Jones, 1982), deciduous (Taylor *et al.*, 1997) shrub or tree (Turner, 1959) that grows to a height of one to three m (Correll and Johnston, 1979; Jones, 1982; Richardson, 1990; Lonard *et al.*, 1991). It grows on a variety of soils (Jones, 1982; Scifres, 1980; Taylor *et al.*, 1997), but is usually found on sandy or gravelly soils (Taylor *et al.*, 1997) or on limestone caliche ridges (Turner, 1959; Taylor *et al.*, 1997). *Acacia rigidula* often grows in association with *A. berlandieri* (Taylor *et al.*, 1997) and other species that make up the South Texas mixed-brush communities (Scifres, 1980; Taylor *et al.*, 1997). It is mainly found in South Texas and covers approximately 3.6 million hectares of rangeland (Scifres, 1980). *Acacia rigidula* is especially abundant in the western portion of the Rio Grande Plains (Lonard *et al.*, 1991). It forms dense thickets which are almost impenetrable in some cases (Vines, 1960; Scifres, 1980; Lonard *et al.*, 1991). *Acacia rigidula* provides a natural cover for birds and small mammals (Taylor *et al.*, 1997) and is an effective erosion-control plant (Vines, 1960). Its leaves (which are approximately 15% crude protein) are sometimes eaten by cattle (Lonard *et al.*, 1991). Northern bobwhite (*Colinus virginianus*)

consume the seeds of this species (Everitt and Drawe, 1993, Taylor *et al.*, 1997). Birds such as cactus wrens (*Campylorhynchus brunneicapillus*) and scissor-tailed flycatchers (*Tyrannus forficatus*) use *A. rigidula* as a nesting site, while bees use the plant for making honey (Taylor *et al.*, 1997).

***Acacia schaffneri* (huisachillo)**

Acacia schaffneri is a rounded spiny, deciduous shrub (Jones, 1982; Lonard *et al.*, 1991; Taylor *et al.*, 1997) that usually grows to a height of two m (Richardson, 1990; Lonard *et al.*, 1991). It closely resembles *A. miniata* (Vines, 1960) and is distinguished by the presence of a sessile petiolar gland between the lowest pair of pinnae (Richardson, 1990). *Acacia schaffneri* is found on a variety of soils (Jones, 1982; Lonard *et al.*, 1991; Taylor *et al.*, 1997) in thickets or open areas (Jones, 1982). It is found in the Rio Grande Plains area (Correll and Johnston, 1979; Lonard *et al.*, 1991; Taylor *et al.*, 1997). *Acacia schaffneri* is used by birds and small mammals as a protective cover. Many birds use the plant as a nesting site (Taylor *et al.*, 1997). The leaves (Lonard *et al.*, 1991, Everitt and Drawe, 1993) and stems (Everitt and Drawe, 1993) of *A. schaffneri* are eaten by deer, goats, and sheep. Feral hogs and javelinas eat the legumes of *A. schaffneri*, while northern bobwhite (*Colinus virginianus*) eat the seeds (Taylor *et al.*, 1997).

Description of *Chloroleucon ebano* (Texas ebony)

Chloroleucon ebano is an evergreen shrub or tree (Turner, 1959; Vines, 1960; Jones, 1982; Everitt and Drawe, 1993) that grows to a height of 10 to 15 m (Lonard *et al.*, 1991; Everitt and Drawe, 1993). It is known also by the synonym *Pithecellobium ebano*. *Chloroleucon ebano* grows in southern Texas and Mexico, often in brushy pastures or in

sandy loam or clay soil (Turner, 1959; Jones, 1982). It often grows in association with blackbrush acacia (*A. rigidula*) (Taylor *et al.*, 1997) and the two species can be difficult to distinguish (Timothy Brush, personal communication). The similarities in appearance and inflorescences are so great that *C. ebano* was once classified as an *Acacia* species (Robert Lonard, personal communication). The seeds of *C. ebano* are eaten by white-tailed deer, javelina (Lonard *et al.*, 1991; Everitt and Drawe, 1993; Taylor *et al.*, 1997), rodents (Everitt and Drawe, 1993; Taylor *et al.*, 1997), and feral hogs (Taylor *et al.*, 1997). The leaves of *C. ebano* are eaten by white-tailed deer (Lonard *et al.*, 1991; Everitt and Drawe, 1993; Taylor *et al.*, 1997). *Chloroleucon ebano* is a valuable nesting and roosting site for many birds (Lonard *et al.*, 1991, Taylor *et al.*, 1997) including mourning doves and white-winged doves (Taylor *et al.*, 1997).

Description of the Lower Rio Grande Valley of Texas

The study was conducted in Starr and Hidalgo counties of the lower Rio Grande Valley of Texas (Fig. 1). This area of Texas corresponds to the Matamorán Biotic District of the Tamaulipan Biotic Province, reported by Blair (1950). The climate of the region is semi-arid and subtropical, with most of the rainfall occurring between May and October. Similar vegetation is found northward in Texas to the Balcones Escarpment and southward in Mexico to the Rio Tamesi (Lonard *et al.*, 1991). Lonard *et al.* (1991) classified the natural vegetation of the lower Rio Grande Valley of Texas into four habitats: river floodplain, coastal prairies and marshes, barrier islands, and brush-grasslands. The brush-grasslands habitat--the focus of this study--is the most widespread native vegetation of the region (Lonard *et al.*, 1991). It is also known as chaparral or

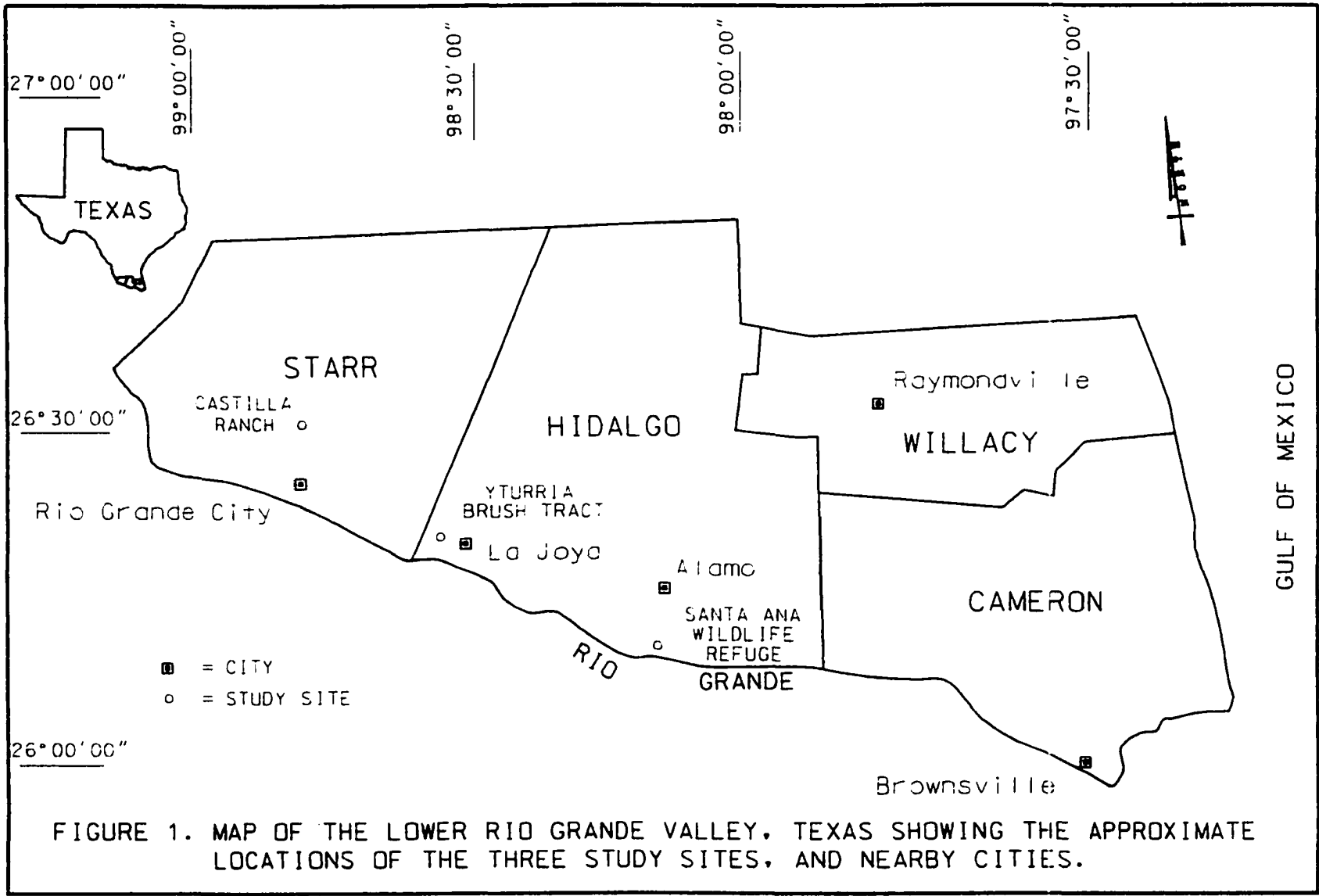


FIGURE 1. MAP OF THE LOWER RIO GRANDE VALLEY, TEXAS SHOWING THE APPROXIMATE LOCATIONS OF THE THREE STUDY SITES, AND NEARBY CITIES.

thorn-scrub (Timothy Brush, personal communication). The overstory of this habitat is usually formed by mesquite (*Prosopis glandulosa*), Texas huisache (*Acacia mimata*), or Texas ebony (*Chloroleucon ebanum*). The understory may be almost impenetrable and is composed of blackbrush acacia (*Acacia rigidula*), cenizo (*Leucophyllum frutescens*), colima (*Xanthoxylum fagara*), coyotillo (*Karwinskia humboldtiana*), granjeno (*Celtis pallida*), and guajillo (*Acacia berlandieri*). Other plants included in the understory are guayacan (*Guaiacum angustifolium*), lantana (*Lantana horrida*), leatherstem (*Jatropha dioica*), lotebush (*Ziziphus obtusifolia*), border paloverde (*Parkinsonia texana* var. *macrum*), Texas prickly pear (*Opuntia engelmannii*), and Texas wild olive (*Cordia boissieri*) (Lonard *et al.*, 1991). Over 90 percent of the native vegetation in the lower Rio Grande Valley of Texas has been cleared for agricultural purposes (U.S. Fish and Wildlife Service, 1983) and urban development (Vora, 1990; Vora and Messerly, 1990). The remaining native vegetation is mainly in the form of islands surrounded by farms, pastures, and urban areas (Vora, 1990; Vora and Messerly, 1990). Many members of the Fabaceae, including members of the genus *Acacia* provide crucial shelter and food for wildlife that inhabit the native brushland vegetation that remains in the lower Rio Grande Valley

MATERIALS AND METHODS

Study Sites

The study sites (Fig. 1) were 1) the Castilla Ranch (CR), an informal name for a privately owned 24.2 ha tract of dense brushland in Starr County, located 11.9 km north of Rio Grande City, Texas; 2) the Yturria brush tract (YBT), a 767.6 ha tract of dense brushland located approximately 7.1 km west of La Joya, Texas (located in Hidalgo County, part of the Lower Rio Grande Valley National Wildlife Refuge); and 3) the Jaguarundi trail, Cattail Lake trail, and Ebony forest area (along the wildlife drive) of the Santa Ana National Wildlife Refuge (SANWR, located 12.1 km south of Alamo, in Hidalgo County, Texas) (Fleetwood, 1973).

At no study site did all five species occur. Individuals were censused on all sites at which they were available in adequate numbers (Table 1). I use nomenclature given by Jones *et al.* (1997). Data were collected biweekly for the duration of the study (July 1998 through August 1999).

Research Design

Ten individuals from each of the plant species present at a site were chosen using the following criteria: 1a) All shrubs selected (*A. berlandieri*, *A. rigidula*, and *A. schaffneri*) were at least 1.5 m tall. Variation in size was observed from site to site with shrubs being low-growing at one site, and more arborescent at another. 1b) All *A. minima* and *C. ebano* selected exhibited typical arborescent growth and were at least three m tall.

Table 1. Sites at which individuals were censused during the phenology study.

Species	Castilla Ranch	Santa Ana NWR	Yturria Tract
<i>Acacia berlandieri</i>		X	X
<i>Acacia rigidula</i>	X	X	X
<i>Acacia schaffneri</i>	X		X
<i>Acacia minnata</i>	X	X	
<i>Chloroleucon ebanum</i>		X	X

2) Individuals did not have overlapping canopies. The distance between individuals of a species ranged from 8 m to 2,320 m, with a mean of 181 m. 3) All individuals chosen were in good condition. Some individuals were drought deciduous as a result of hot dry summer conditions, but living foliage was present on at least 50 percent of the branches of individuals selected for the study. Individuals selected were devoid of discolored foliage (which might indicate stress or poor environmental conditions). These criteria were established to ensure that the individuals studied were healthy.

Approximate measurements of distances between individuals were made using a Garmin GPS 45 Personal Navigator. A marking and mapping method was used since this allows for the determination of individual plant performance in flower, fruit, seed, and leaf production (Sutherland, 1996). Mapping of individuals was accomplished by using landmarks and the GPS and distances between individuals. All individuals in the study were marked with colored flagging, and two removable Jim-Gem aluminum tags were placed on each of the plants. These tags bore a unique identification number for each plant and were tacked onto an individual using a staple gun. One of the tags on each individual was easily visible, and another was in an inconspicuous location. A small dot

of paint and strips of colored flagging were placed on three randomly selected branches on each individual to ensure uniformity when collecting data and to aid in the measurement of shoot elongation. The flagging, tags, and rings were removed at the completion of the study. A special use permit to conduct the study at SANWR and the Yturria Brush tract was obtained from the USFWS

Data Collection

No samples or specimens were removed from any site during the study. Photographs were taken to document the phenological stages of the specimens. Data were recorded on: 1a) flowering and fruiting events. The numbers of inflorescences and fruits were calculated using a subsampling technique. This was accomplished by counting the number of flowers and/or fruits on three marked branches, obtaining the mean of these values, and then multiplying this value by the total number of branches on the tree. 1b) the state of inflorescences. This was evaluated using a method similar to one described by Gill and Mahall (1986). Buds were counted and evaluated as new, growing, or static. Flowering events were documented when the buds on an individual were in anthesis. Fruiting events were documented when the flowers on an individual exhibited the formation of a legume. Fruits were categorized as mature and open, mature and not open, and immature. Dehiscent fruits were categorized as mature and open as long as there were visible seeds adhering to the pods (Friedel *et al.*, 1994). 2a) periods of vegetative growth. This was documented using a method similar to one described by Gill and Mahall (1986). Newly formed leaves were evaluated as young or mature. Leaves on sample branches were categorized (when applicable) as yellow (50 percent or more of

branches), brown (50 percent or more of branches), or abscised (50 percent of more of branches). 2b) Shoot elongation was monitored by applying a small amount of paint on three randomly selected branches to mark the initial length of the shoot. The paint was applied just below the terminal bud or a suitable lateral bud. I initially chose green buds that were uniform in size (approximately 0.5 cm x 0.5 cm) to maintain consistency. Shoot elongation of each individual was measured monthly. 4) climatic data. Official daily air temperatures and precipitation for the duration of the study were obtained from the National Climatic Data Center for McAllen, Texas. Official photoperiod data also were obtained for the duration of the study. Local cooperative observer reports for Rio Grande City and La Joya were obtained from the National Weather Service in Brownsville, Texas.

Statistical Analysis

Analysis of variance (ANOVA) was used to test for significant differences in flowering and fruiting events between months and seasons. Correlation was used to examine the relationship between climatic factors and phenological events. Goodness of fit tests (chi-square and G-tests) and *t*-tests were used to test the significance of differences between pairs of species. Expected values for chi-square and G-tests were determined by dividing the total number of individuals in a particular phenophase by the number of species in that phase at each location. The null hypothesis was that there were an equal number of individuals in a phenophase in each species. Thus, one assumes that the total is evenly distributed among sites. A probability of < 0.05 was considered significant in all statistical analyses.

RESULTS

Official Climatic Data

Official NOAA data for McAllen, Texas showed that mean daily photoperiod ranged from 10 hours and 32 minutes in December 1998 to 13 hours and 45 minutes in June 1999 (Fig. 2)

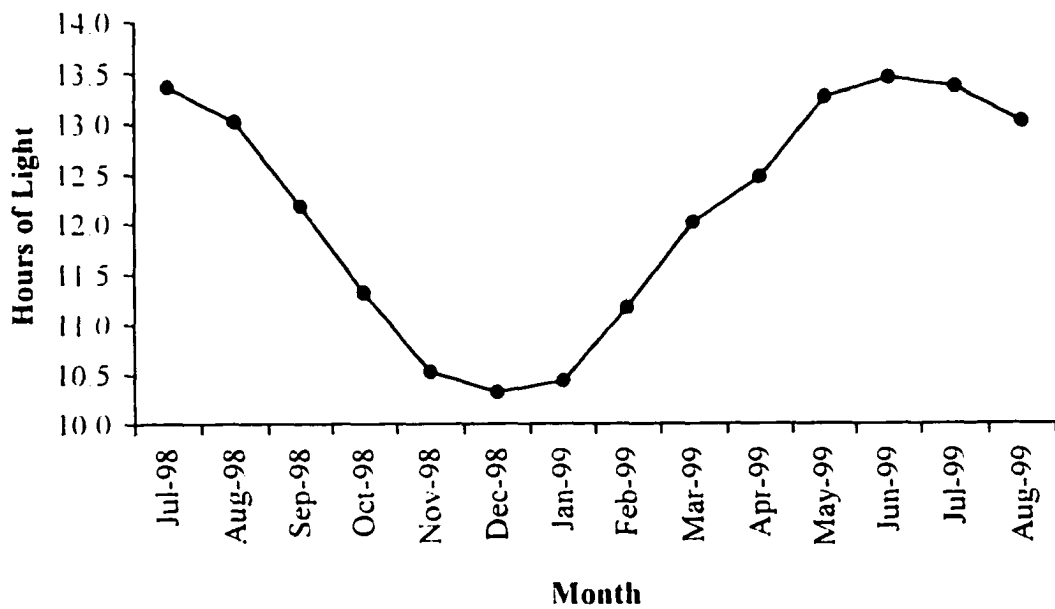


Figure 2. Mean daily photoperiod for McAllen, Texas.

The annual precipitation during the study (National Climatic Data Center) was compared to annual precipitation for McAllen, Texas from 1958-1998 using climatic data obtained from the Texas Office of the State Climatologist (OSC). Monthly precipitation

at McAllen, Texas showed peaks in September and October 1998, March 1999, and August 1999 (Fig. 3). Values ranged from 0.03 cm in February 1999 to 24.09 cm in September 1998, with an average of 4.0 cm per month, and an annual total of 47.78 cm for the period of July 1998 through June 1999. Annual precipitation during the study was approximately 21.3% lower than the 40-year precipitation mean (OSC). The precipitation totals for most months of the study were either at or lower than the 40-year monthly precipitation means (Fig. 3). Table 2 compares the monthly precipitation at McAllen, Texas for six months preceding the beginning of the study (January 1998 through June 1998) with the 40 year monthly precipitation means for McAllen, Texas (Office of State Climatologist). Five of the six months had precipitation totals lower than the 40 year monthly precipitation means for those months. Most importantly, in the four months preceding the onset of the study, there was only 1.35 cm of rainfall, whereas, there is, on average, 19.43 cm. Thus, prior to the beginning the study, rainfall was 93% below average, i.e., drought conditions prevailed. Rainfall during the study was at or below the monthly average in 10 of the 12 months.

Figure 4 shows that air temperatures ranged from 16.7°C in December 1998 to 32.3°C in July 1998, with an average of 26.2°C per month. The absolute low during the study period was 0.56°C (December 1998 and February 1999) and the absolute high during the study period was 43.3°C (May 1999). Mean monthly temperatures from September 1998 through December 1998 were similar to the 40-year mean monthly temperatures (Fig. 4). Slightly higher temperatures were observed in July and August 1998, but distinctly higher temperatures are apparent beginning in January 1999 (Fig. 4). This trend of higher

temperatures continued through June 1999 (Fig. 4). Table 3 compares the mean monthly temperatures at McAllen, Texas for six months preceding the beginning of the study (January 1998 through June 1998) with the 40-year monthly temperature means (Office of State Climatologist). Mean air temperatures in 1999 were markedly higher in January and June than the long term averages for those months (Table 3)

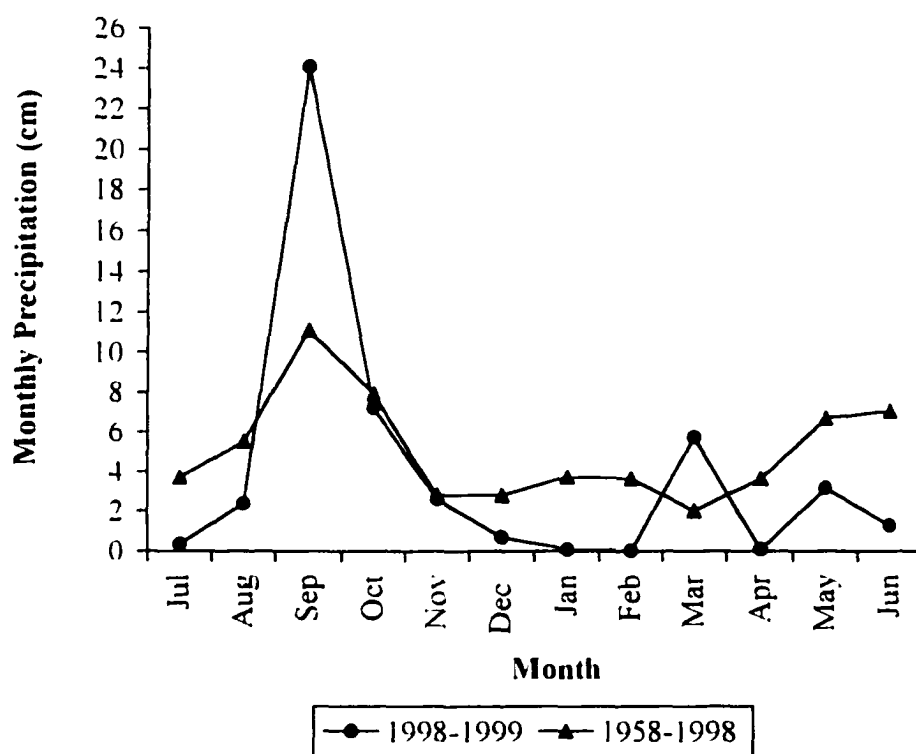


Figure 3. Monthly precipitation for McAllen, Texas for 1998-1999 compared with 40-year monthly precipitation means.

Table 2. Monthly precipitation at McAllen, Texas for six months preceding the beginning of the study compared with the 40-year monthly precipitation means.

	January	February	March	April	May	June
1998	1.32	6.89	1.27	0	0	0.08
1958-1998	3.74	3.63	2.02	3.65	6.70	7.06

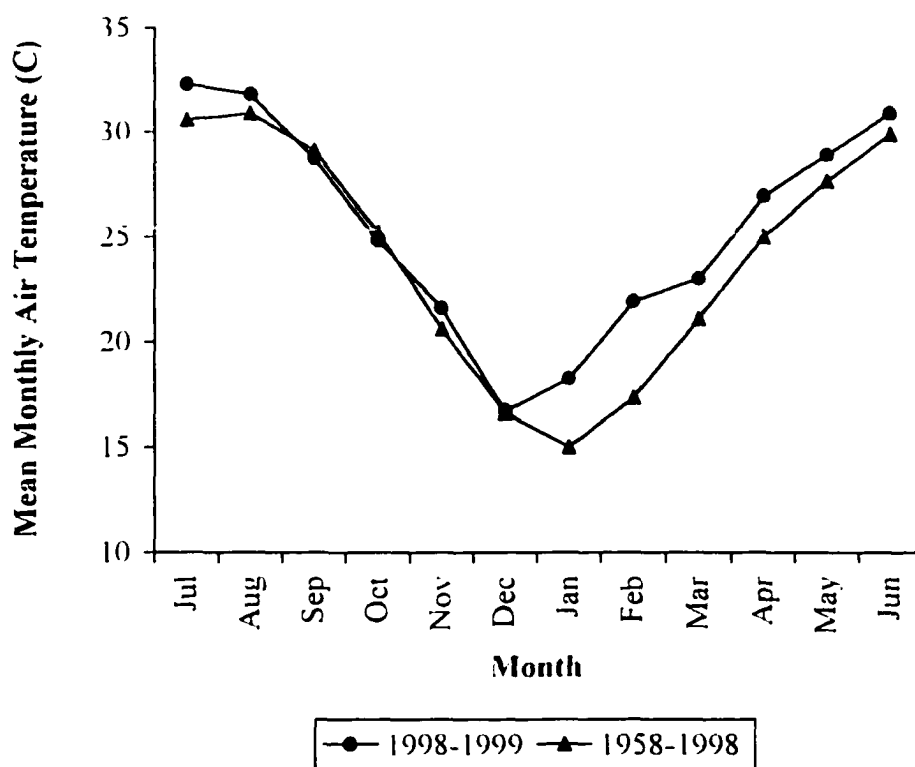


Figure 4. Mean monthly air temperatures at McAllen, Texas for 1998-1999 compared to 40-year mean monthly temperatures.

Table 3. Mean monthly temperature at McAllen, Texas for six months preceding the beginning of the study compared with the 40-year monthly temperature means.

	January	February	March	April	May	June
1998	18.3	17.2	19.7	23.3	27.8	31.4
1958-1998	15.0	17.3	21.1	25.0	27.6	29.9

Local Climatic Data

Local climatic data for the study sites were obtained from the National Weather Service in Brownsville, Texas for the cities nearest Castilla Ranch (Rio Grande City, Texas) and Yturria Brush Tract (La Joya, Texas). The Rio Grande City fire department

submitted the data for Rio Grande City, and Dale Thurber submitted the data for La Joya. Local climatic data for the Santa Ana NWR site was obtained from the Santa Ana NWR/LRGV National Wildlife Refuge fire management department.

Information on precipitation at the three sites is presented in Figure 5. Precipitation at Rio Grande City ranged from .25 cm (in November 1998) to 12.34 cm (in October 1998), with a monthly mean of 1.9 cm. Precipitation values for Santa Ana NWR ranged from .03 cm (observed in October 1998, November 1998, March 1999, May 1999, and July 1999) to 8.05 cm (in August 1999), with a monthly mean of 1.8 cm. Rainfall at La Joya ranged from .05 cm (in July 1999) to 11.81 cm in (August 1999), with a monthly mean of 1.9 cm. The pattern of rainfall at the three study sites was similar and there was little variation in the totals in most months. Exceptions to the similarity in totals occurred in September and October 1998 and August 1999.

Temperature information for the three sites is presented in Figure 6. Temperatures at Rio Grande City ranged from -1.67°C (observed in December 1998, January 1999, and February 1999) to 43.89°C in July 1998. The mean annual temperature in Rio Grande City was 26.41°C. Temperatures at Santa Ana NWR ranged from 2.39°C (in December 1998) to 42.22°C (in May 1999), with an annual mean of 29.22°C. Temperatures at La Joya ranged from -1.11°C in December 1998 to 41.67°C in August 1998. The mean annual temperature at La Joya was 26.0°C. The pattern of temperature was similar at the three study sites, and especially so for Castilla Ranch and Yturria Brush Tract. Temperatures at Santa Ana NWR were higher than at the other two sites from November 1998 through June 1999.

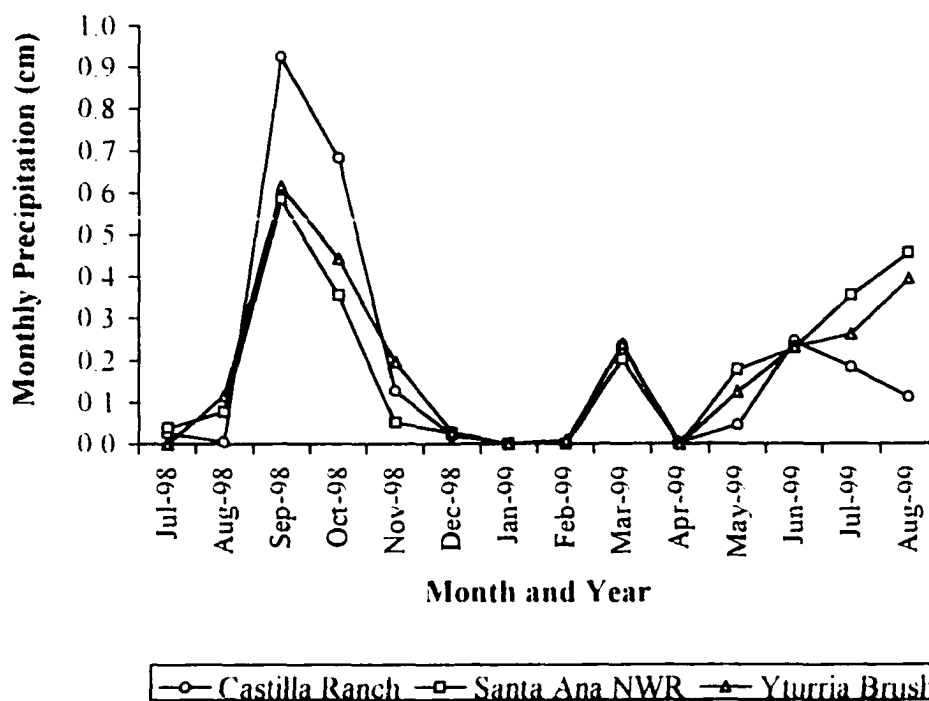


Figure 5 Monthly precipitation values for three study sites. Data were obtained from local cooperative observers

Mean monthly air temperatures at Castilla Ranch and Yturria Brush Tract were similar to the official data obtained from NOAA for the time period (Fig. 4). The mean monthly air temperatures at Santa Ana NWR, however, varied considerably from the official data. These are unexpected results, because Santa Ana NWR is actually closer to the official data station at McAllen, Texas, and closer to the coast than Castilla Ranch and Yturria Brush Tract, and therefore is more likely to be subject to the mediating influence of the Gulf of Mexico. Castilla Ranch and Yturria Brush Tract are located west of Santa Ana NWR and the coast, and therefore are expected to have higher air temperatures in warm months and lower air temperature in cool months. The expected pattern holds from July 1998 through October 1998, but thereafter, the values for Santa Ana NWR are

consistently higher than the NOAA McAllen station until July 1999. This variation from the expected may stem from accuracy of the thermometer at Santa Ana NWR, user error in reading the temperature, or differences in placement of thermometers at the three sites.

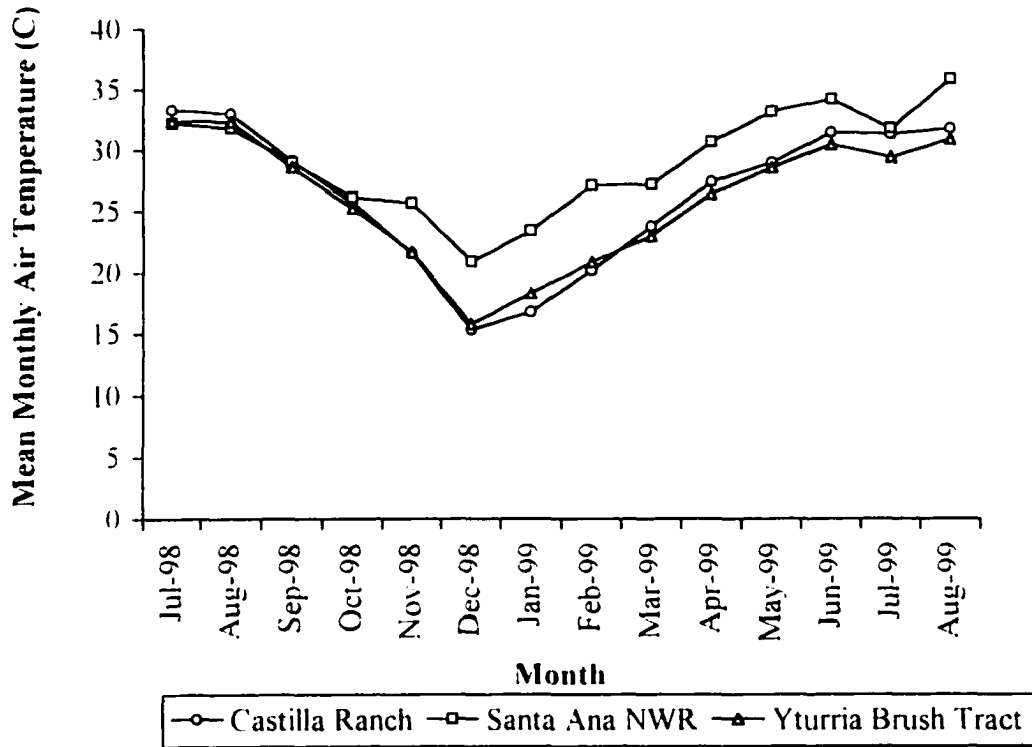


Figure 6 Mean monthly air temperature for three study sites. Data were obtained from local cooperative observers.

Reproductive Phenophases

Flowering Compared

The presence of flowers in anthesis at the study sites was first observed in *Acacia berlandieri* and *A. schaffneri* in January 1999 and in February 1999 for *A. minnata* and *A. rigidula* (Fig. 7). *Acacia minnata* is present within cities in the LRGV, and many

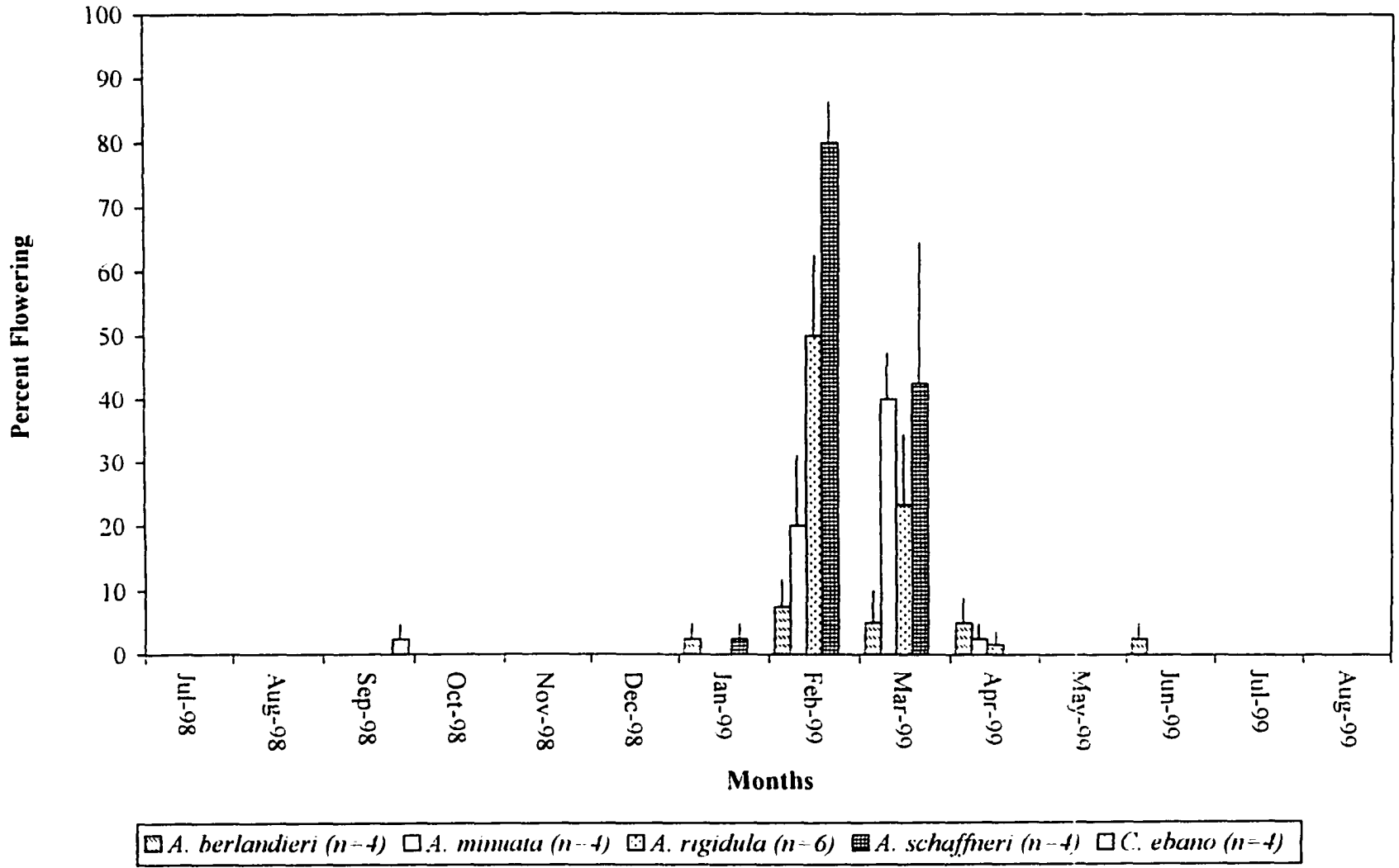


Figure 7. Percentage of individuals flowering at all sites. The average of two censuses taken monthly is shown. Vertical lines from bars show 1 SE.

individuals in cities/towns near the study sites had flowers in anthesis as early as December 31, 1998 (personal observation).

Four of the five species were in flower in February 1999 and March 1999 (Fig. 7). Only *Chloroleucon ebano* was not in flower in these months. Flowering in *A. schaffneri* ceased by the end of March 1999. *Acacia berlandieri*, *A. mimata*, and *A. rigidula* continued to flower in April 1999, but the percentage of individuals flowering was low. The percentage of *A. berlandieri* flowering in March and April was far less than other species (Fig. 7). Flowering in *Chloroleucon ebano* was limited to September 1998, at only one of two sites (Fig. 7), but individuals present in nearby cities and towns flowered copiously during May and June 1999 (personal observation).

G-tests performed on monthly percentage of individuals flowering among species show that significant differences existed in February 1999 ($G = 198.686$), March 1999 ($G = 89.650$), and April 1999 ($G = 11.665$).

G-tests performed on the monthly percentage flowering for each species among months show that significant differences in percentage flowering exist in *Acacia mimata* ($G = 7.988$), *A. rigidula* ($G = 17.068$), and *A. schaffneri* ($G = 18.418$).

Flowering Among Sites

Comparisons of percentage flowering among sites are shown in Figures 8 through 12. Figure 8 compares the flowering of *Acacia berlandieri* at Santa Ana and Yturria Brush Tract. Flowering at Yturria Brush Tract began in January 1999 and continued through April 1999, reaching a peak in February 1999. Flowering at Santa Ana NWR occurred in

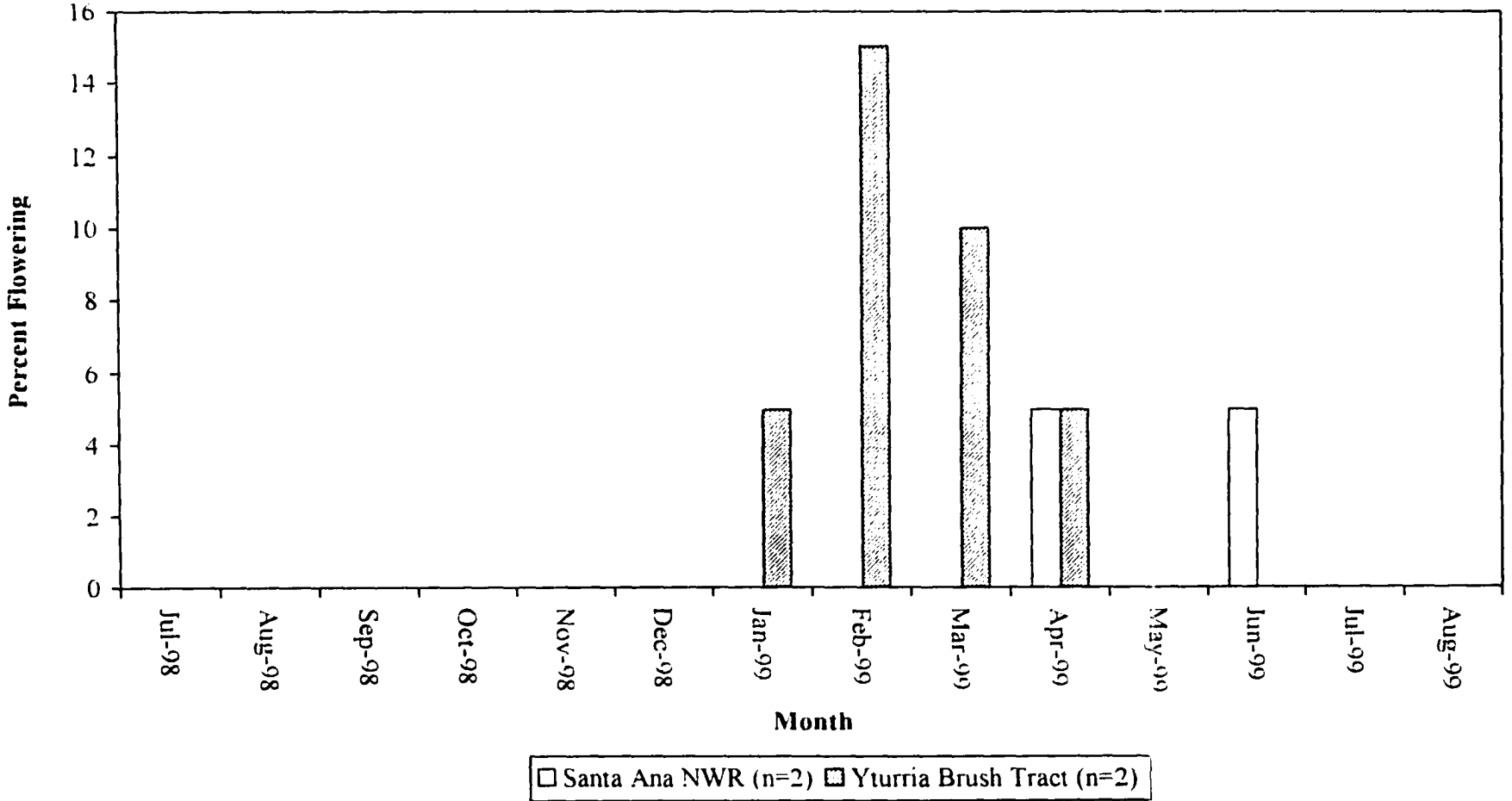


Figure 8. Percentage of individuals of *Acacia berlandieri* flowering at Santa Ana NWR and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site

two short periods, i.e., in April 1999 and during June 1999. A significantly higher percentage of individuals flowered at Yturria Brush Tract than at Santa Ana NWR in January 1999 ($\chi^2 = 5.0$), February 1999 ($\chi^2 = 15.0$), and March 1999 ($\chi^2 = 10.0$). Flowering occurred at one site so the significant difference was not surprising. Flowering in June 1999 was significantly different ($\chi^2 = 5.0$) since flowering only occurred at Santa Ana NWR.

Flowering in *Acacia mimuta* at Castilla Ranch and Santa Ana NWR began in February 1999 (Fig. 9). Flowering continued at Castilla Ranch through April 1999, but ceased in March 1999 at Santa Ana NWR. When flowering occurred at both sites, the mean percentage of individuals with flowers in anthesis at Santa Ana NWR exceeded that of Castilla Ranch. Significant differences in percentage of individuals in flower between sites existed in February 1999 ($\chi^2 = 5.0$) and April 1999 ($\chi^2 = 5.0$).

Flowering in *Acacia rigidula* started in February 1999 at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract (Fig. 10). It ceased in March 1999 at Castilla Ranch and Yturria Brush Tract, but continued through April 1999 at Santa Ana NWR (Fig. 10). Significant differences in flowering of *Acacia rigidula* were observed between sites in February 1999 ($G = 89.731$), March 1999 ($G = 19.867$), and April 1999 ($G = 85.320$).

Acacia schaffneri began flowering in January 1999 at Castilla Ranch, but not until February 1999 at Yturria Brush Tract (Fig. 11). Flowering continued through March 1999 at both sites. Castilla Ranch had a higher percentage of individuals flowering in February and March. Due to the absence of flowering at Yturria Brush Tract in January 1999, there was a significant difference ($\chi^2 = 5.0$) between sites.

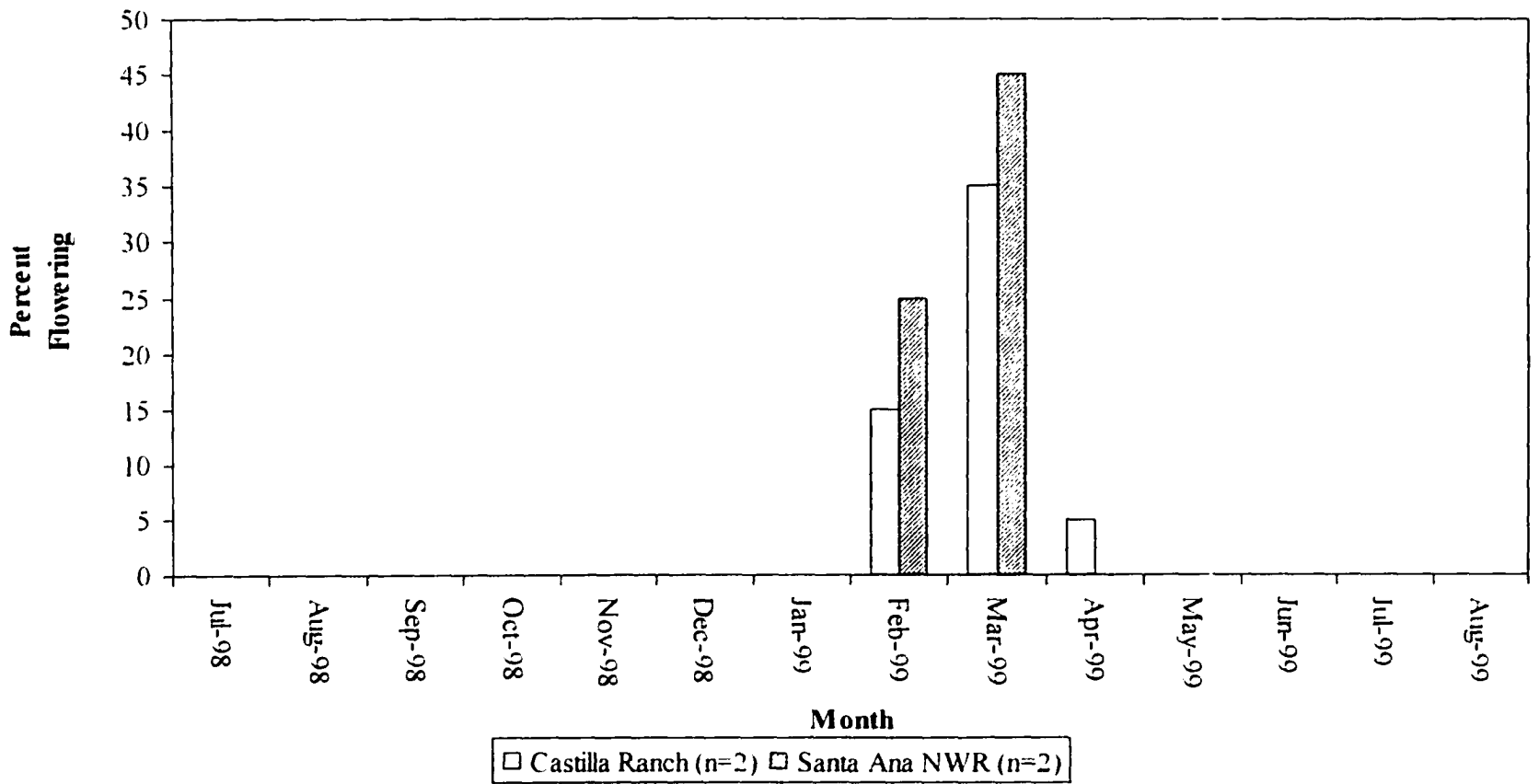


Figure 9. Percentage of individuals of *Acacia mimata* flowering at Castilla Ranch and Santa Ana NWR. The average of two censuses taken monthly is shown for ten individuals at each site

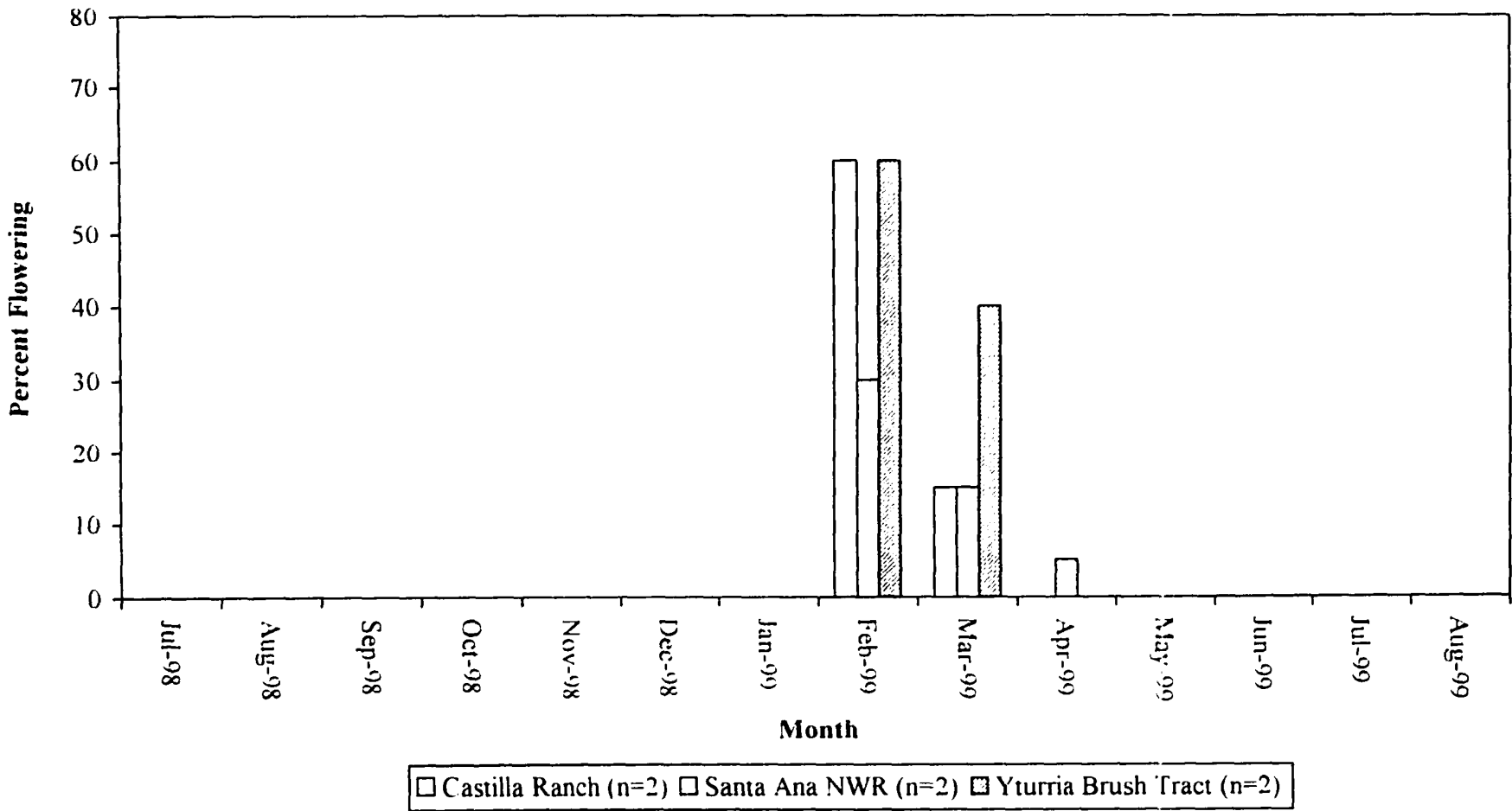


Figure 10. Percentage of individuals of *Acacia rigidula* flowering at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site.

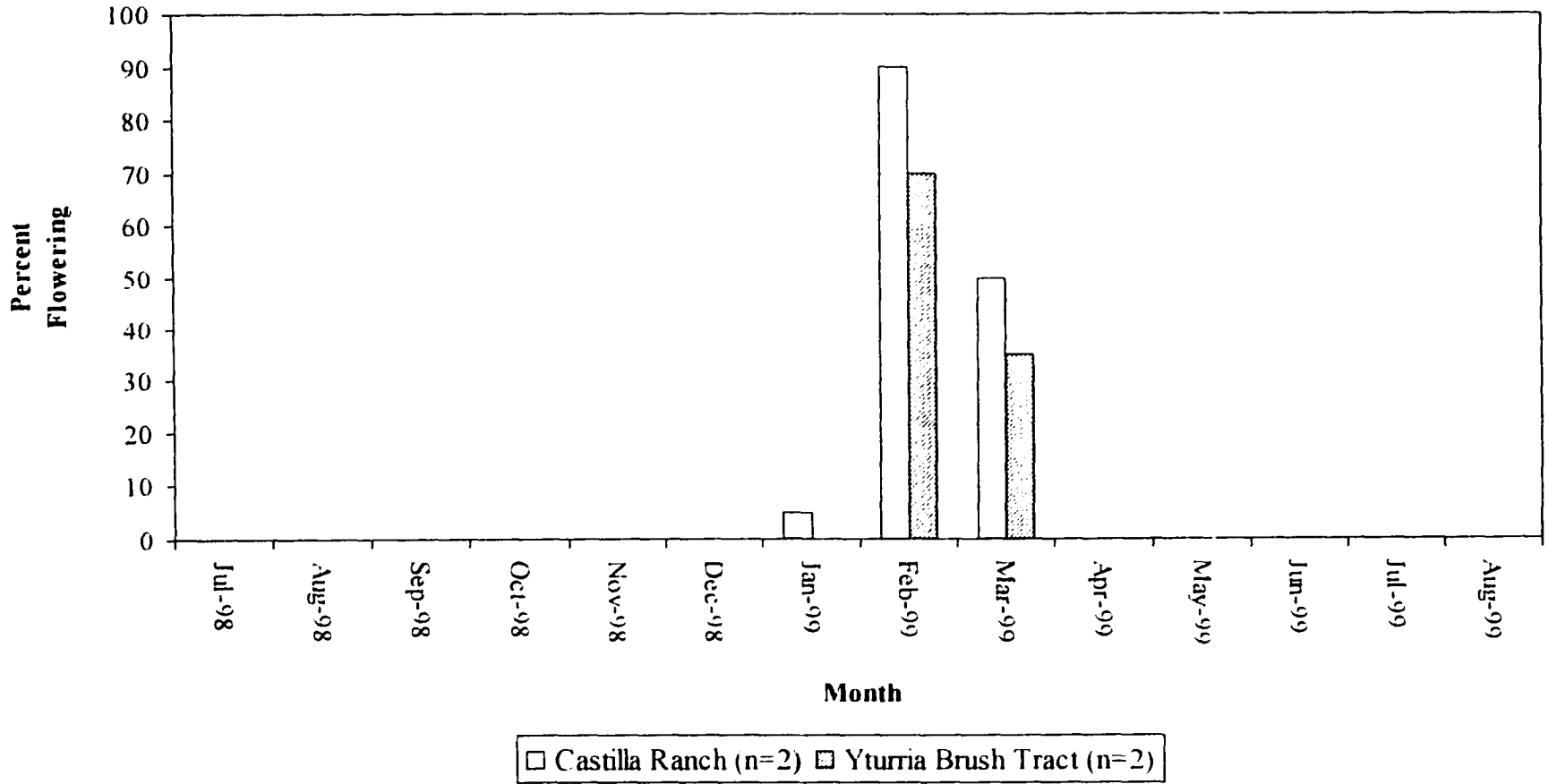


Figure 11 Mean percentage of individuals of *Acacia schaffneri* flowering at Castilla Ranch and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site.

Flowering in *Chloroleucon ebano* was observed only at Yturria Brush Tract in September 1998 (Fig. 12). Green flower buds formed on individuals at Santa Ana NWR, but these buds never matured into open flowers. Because of the absence of flowering at Santa Ana NWR, there was a significant difference between sites ($\chi^2 = 5.0$).

Correlation Between Flowering and Official Climatic Data

All of the *Acacia* species flowered in winter or spring months, i.e., at low temperatures and increasing photoperiod. Correlation coefficients are calculated for January 1999 through April 1999 between percent flowering and mean daily photoperiod, monthly precipitation, and mean monthly temperature. *Acacia berlandieri* and *A. mimata* had positive correlations between percent flowering and mean daily photoperiod and mean monthly temperature (Table 4). *Acacia rigidula* and *A. schaffneri* had negative correlations between percent flowering and mean daily photoperiod and mean monthly temperature (Table 4). *Acacia mimata*, *A. rigidula*, and *A. schaffneri* had positive correlations between percent flowering and monthly precipitation (Table 4). *Acacia berlandieri* had a negative correlation between percent flowering and monthly precipitation (Table 4). *t*-tests showed that only the *r*-value for percent flowering and monthly precipitation in *A. mimata* was significant (Table 4). *Chloroleucon ebano* flowered only during the month of September 1998, and therefore, correlation coefficients between percent flowering and the climatic factors could not be calculated.

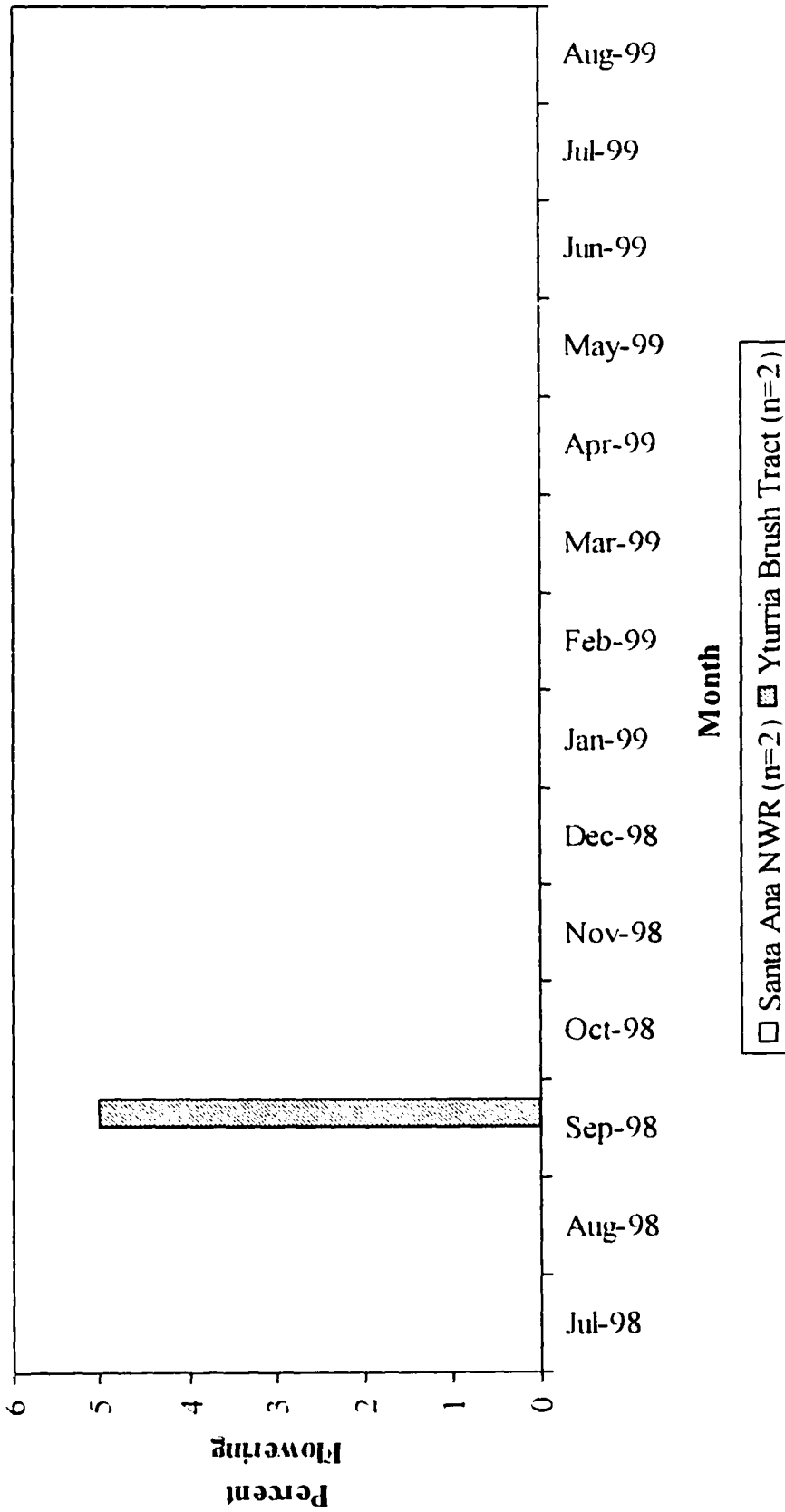


Figure 12. Percentage of individuals of *Chloroleucon ebano* flowering at Santa Ana NWR and Yturria Brush Tract. The average of two censuses taken monthly for ten individuals at each site are shown.

Table 4. Correlation coefficients (r) for meteorological factors versus percent flowering. R values are based on sample sizes of 4, i.e., 4 months of flowering data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.334	0.501	ns	-0.007	0.010	ns	0.422	0.658	ns
<i>A. minnata</i>	0.298	0.441	ns	0.872	2.519	<.05	0.095	0.135	ns
<i>A. rigidula</i>	-0.070	0.099	ns	0.120	0.171	ns	-0.043	0.061	ns
<i>A. schaffneri</i>	-0.096	0.136	ns	0.188	0.271	ns	-0.092	0.131	ns

Correlation Between Flowering and Local Observer Climatic Data

Castilla Ranch

Correlations between monthly percentage of individuals flowering at Castilla Ranch (*Acacia minnata*, *A. rigidula*, and *A. schaffneri*) and the local climatic data from Rio Grande City, Texas (monthly precipitation and mean monthly temperature for January 1999 through April 1999) and the official photoperiod data (for January 1999 through April 1999) showed that *A. minnata* had positive correlations between percent flowering and mean daily photoperiod, monthly precipitation, and mean monthly temperature (Table 5). *Acacia rigidula* and *A. schaffneri* had negative correlations between percent flowering and mean daily photoperiod and mean monthly temperature (Table 5). *Acacia rigidula* had a negative correlation between percent flowering and monthly precipitation, while *A. schaffneri* had a positive correlation with monthly precipitation (Table 5). Only the correlation between percent flowering and monthly precipitation in *A. minnata* was significant (Table 5).

Table 5. Correlation coefficients (r) between meteorological factors and flowering for three species at Castilla Ranch. R values are based on sample sizes of 4, i.e., 4 months of flowering data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. minima</i>	0.397	0.612	ns	0.914	3.186	<05	0.284	0.419	ns
<i>A. rigidula</i>	-0.177	0.254	ns	-0.094	0.134	ns	-0.218	0.316	ns
<i>A. schaffneri</i>	-0.108	0.154	ns	0.210	0.304	ns	-0.181	0.260	ns

Santa Ana NWR

Correlations between the monthly percentage of individuals flowering at Santa Ana NWR (*A. berlandieri*, *A. minima*, and *A. rigidula*) and the local climatic data collected at Santa Ana NWR (from January 1999 through April 1999) showed that all species had nonsignificant positive correlations between percent flowering and mean daily photoperiod and mean monthly temperature (Table 6). *Acacia berlandieri* had a negative correlation between percent flowering and monthly precipitation (Table 6). *Acacia minima* and *A. rigidula* had positive correlations between percent flowering and monthly precipitation (Table 6). None of the correlations between percent flowering and the climatic factors at Santa Ana NWR were significant (Table 6). Correlations could not be performed on *C. ebano* because there was no flowering event at this site (Fig. 12).

Yturria Brush Tract

Correlations between the flowering data collected from the species present at Yturria Brush Tract (*A. berlandieri*, *A. minima*, and *A. schaffneri*) and the climatic data collected

Table 6. Correlation coefficients (r) between meteorological factors and flowering for three species at Santa Ana NWR. R values are based on sample sizes of 4, i.e., 4 months of flowering data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.700	1.386	ns	-0.333	0.499	ns	0.805	1.919	ns
<i>A. miniata</i>	0.225	0.327	ns	0.841	2.198	ns	0.023	0.033	ns
<i>A. rigidula</i>	0.045	0.064	ns	0.126	0.180	ns	0.165	0.237	ns

from La Joya, Texas (from January 1999 through April 1999) showed that all *Acacia* species had nonsignificant negative correlations with mean daily photoperiod and mean monthly temperature (Table 7). All *Acacia* species had nonsignificant positive correlations between percent flowering and monthly precipitation (Table 7).

Chloroleucon ebano flowered only once (during September 1998), so correlations between percent flowering and the climatic factors were not calculated.

Table 7. Correlation coefficients (r) between meteorological factors and flowering for four species at Yturria Brush Tract. R values are based on sample sizes of 4, i.e., 4 months of flowering data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.081	0.115	ns	0.209	0.302	ns	-0.168	0.241	ns
<i>A. rigidula</i>	-0.017	0.024	ns	0.367	0.558	ns	-0.133	0.19	ns
<i>A. schaffneri</i>	-0.081	0.115	ns	0.209	0.302	ns	-0.168	0.241	ns

Fruiting Compared

Dates when fruits were first observed are provided in Table 8. While most species produced numerous fruits, *A. berlandieri* and *C. ebano* did not exhibit lengthy or copious

flowering or fruiting periods during 1999. Flowers in *A. berlandieri* were produced at both sites where the species occurred, yet they did not become mature fruits. Many fruits that were observed on *C. ebano* were remnants from the season prior to the beginning of the study (in July 1998), but some formed after a very short flowering event at Santa Ana NWR. Many of the fruits produced by *C. ebano* also did not reach maturity. However, *C. ebano* was observed flowering within nearby cities and towns and produced numerous fruits that reached maturity during June and July 1999 (personal observation).

Table 8. Dates of flowering, fruiting, and fruit maturation for all three sites. An asterisk indicates that a particular stage was not observed, while "n/a" indicates that these species produce fruits that are indehiscent.

Species	Site	First Flowers	First Immature Fruits	First Mature Fruits	First Dehiscence
<i>A. berlandieri</i>	SANWR	4/24/99	*	*	*
<i>A. berlandieri</i>	YBT	2/14/99	3/27/99	*	*
<i>A. minuta</i>	CR	2/13/99	3/27/99	5/22/99	n/a
<i>A. minuta</i>	SANWR	2/28/99	3/28/99	5/23/99	n/a
<i>A. rigida</i>	CR	2/13/99	3/27/99	5/8/99	5/8/99
<i>A. rigida</i>	SANWR	2/14/99	3/13/99	5/9/99	5/22/99
<i>A. rigida</i>	YBT	2/14/99	3/28/99	5/9/99	5/23/99
<i>A. schaffneri</i>	CR	1/16/99	2/27/99	5/22/99	n/a
<i>A. schaffneri</i>	YBT	2/14/99	2/27/99	6/5/99	n/a
<i>C. ebano</i>	SANWR	*	11/8/98	5/9/99	*
<i>C. ebano</i>	YBT	9/12/99	9/25/99	*	*

Mature indehiscent fruits produced in the spring and summer of 1998 were retained by *A. minuta* through November 1998 and by *A. schaffneri* through February 1999 (Fig. 13). Mature indehiscent fruits produced in 1999 were retained by *A. minuta* and

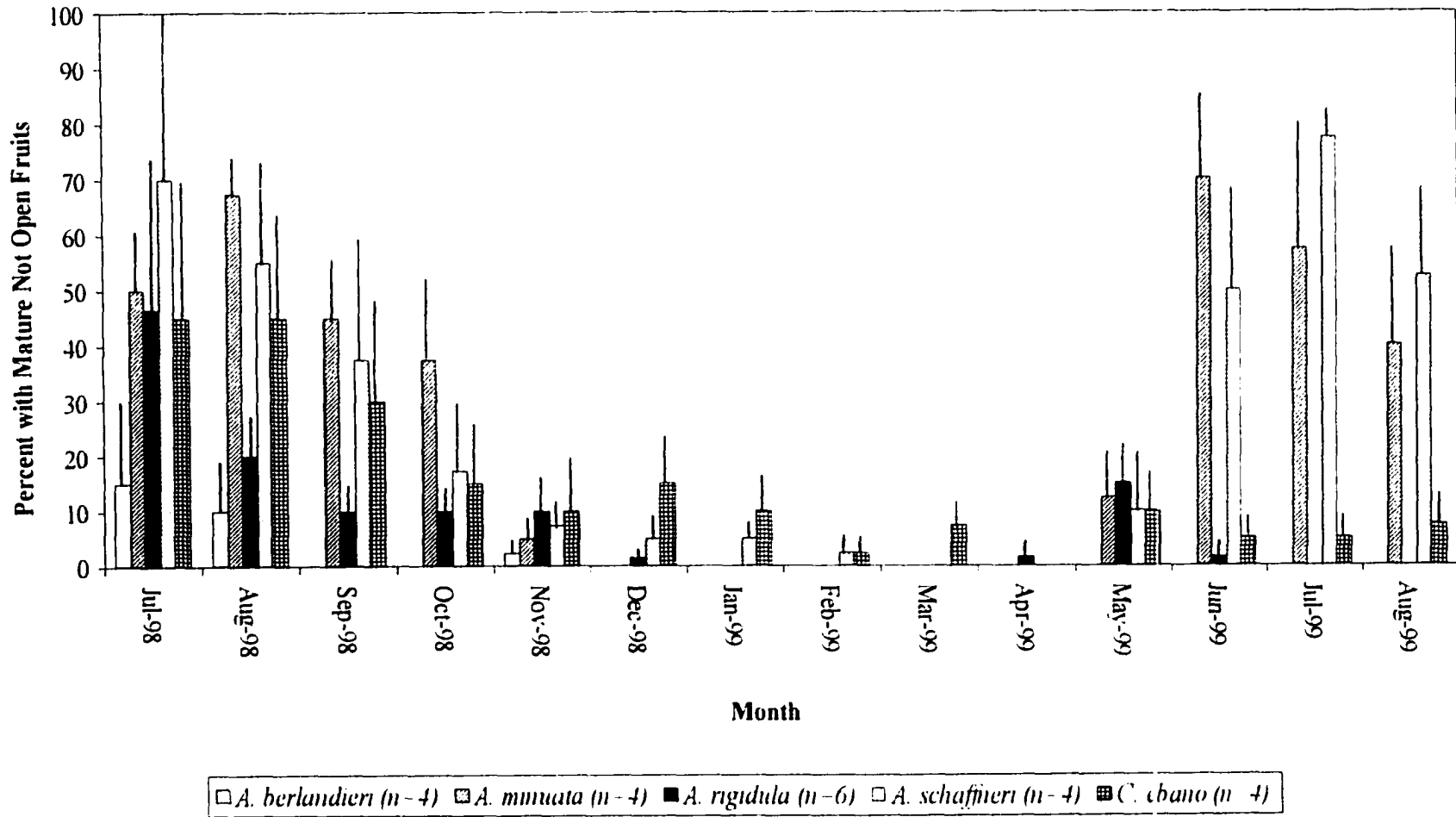


Figure 13. Percentage of individuals with mature not open fruits at all sites. The average of two censuses is shown. Vertical lines from bars show 1 SE.

A. schaffneri through August 1999 (Fig. 13). Mature dehiscent fruits produced in 1998 were retained by *A. berlandieri* through December 1998 and through February 1999 in *A. rigidula* (Fig. 14). *Chloroleucon ebano* had fruits in January 1999, but these fruits resulted from a flowering event in September 1998 (Fig. 14). Mature dehiscent fruits produced in 1999 were retained by *A. rigidula* through July 1999 and through August 1999 by *C. ebano* (Fig. 14). The fruits of *C. ebano* took the longest to reach the mature not open state. Fruits of *C. ebano* took an average of 195 days to develop from flowers into mature not open fruits. The fruits of *A. schaffneri* took an average of 118.5 days to develop from flowers into mature not open fruits. Fruits in *A. minuata* took an average of 91 days to mature, while the fruits of *A. rigidula* took an average of 84 days to reach the mature not open state and an average of 107 days to dehisce.

Mature not open fruits

G-tests on monthly percent of individuals with mature not open fruits for all five species showed that significant differences ($P < 0.01$) existed between species during all months except November 1998, February 1999, and April 1999 (Table 9). G-tests on monthly percent of *Acacia* individuals with mature/not open fruits showed that significant differences existed between *Acacia* species during all months but November 1998, February 1999, and April 1999 (Table 10). G-tests on monthly percent of *A. minuata*, *A. rigidula*, and *A. schaffneri* individuals with mature not open fruits (Table 11) showed that significant differences between species existed during August through October 1998, December 1998, and January 1999, and June 1999 through August 1999. Chi-square tests on monthly percent of *A. minuata* and *A. rigidula* individuals with

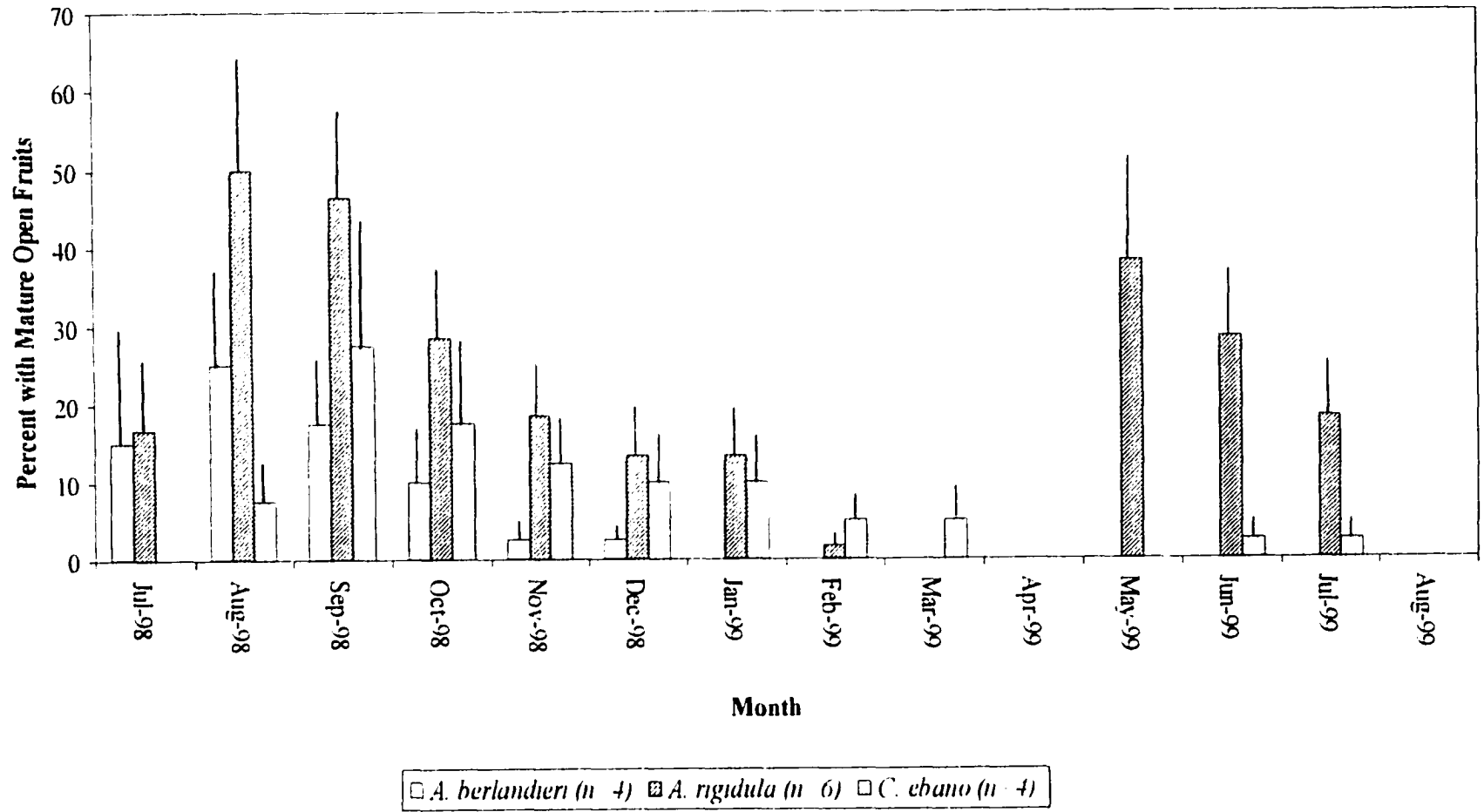


Figure 14. Percentage of individuals with mature open fruits at all sites. The average of two censuses is shown. Vertical lines from bars show 1 SE.

mature not open fruits showed that significant differences between species existed in August 1998, September 1998, October 1998, June 1999, July 1999, and August 1999 (Table 12). Chi-square tests on monthly percent of *A. minuata* and *A. schaffneri* individuals with mature not open fruits revealed significant differences between species only in October 1998, December 1998, and January 1999 (Table 13).

Table 9. G-tests on monthly percent of individuals with mature not open fruits among species. The level of probability is given for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	39.679	<.001
Aug-98	65.786	<.001
Sep-98	80.874	<.001
Oct-98	55.682	<.001
Nov-98	6.789	ns
Dec-98	35.836	<.001
Jan-99	29.188	<.001
Feb-99	9.163	ns
Mar-99	24.142	<.001
Apr-99	5.472	ns
May-99	22.615	<.001
Jun-99	185.204	<.001
Jul-99	223.325	<.001
Aug-99	142.073	<.001

Table 10. G-tests on monthly percent of individuals with mature not open fruits for *Acacia* species only. The level of probability is given for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	39.476	<.001
Aug-98	65.060	<.001
Sep-98	79.608	<.001
Oct-98	55.203	<.001
Nov-98	4.924	ns
Dec-98	10.788	<.05
Jan-99	13.471	<.01
Feb-99	6.892	ns
Apr-99	4.674	ns
May-99	22.383	<.001
Jun-99	156.720	<.001
Jul-99	189.724	<.001
Aug-99	130.127	<.001

Table 11. G-tests on monthly percent of individuals with mature not open fruits for *Acacia minnata*, *A. rigidula*, and *A. schaffneri*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	5.770	ns
Aug-98	28.97	<.001
Sep-98	26.39	<.001
Oct-98	18.00	<.001
Nov-98	1.699	ns
Dec-98	7.333	<.05
Jan-99	10.79	<.01
Feb-99	5.513	ns
Apr-99	3.715	ns
May-99	1.007	ns
Jun-99	86.30	<.001
Jul-99	112.45	<.001
Aug-99	76.91	<.001

Table 12. Chi-square tests on monthly percent of individuals with mature not open fruits for *Acacia mimuata* and *A. rigidula*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	0.120	ns
Aug-98	25.756	< .001
Sep-98	22.273	< .001
Oct-98	15.888	< .001
Nov-98	1.667	ns
Dec-98	1.700	ns
Apr-99	1.700	ns
May-99	0.227	ns
Jun-99	64.971	< .001
Jul-99	57.400	< .001
Aug-99	40.000	< .001

Table 13. Chi-square tests on monthly percent of individuals with mature not open fruits for *Acacia mimuata* and *A. schaffneri*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	3.333	ns
Aug-98	1.275	ns
Sep-98	0.681	ns
Oct-98	7.273	< .05
Nov-98	0.497	ns
Dec-98	5.00	< .05
Jan-99	5.00	< .05
Feb-99	2.408	ns
May-99	0.277	ns
Jun-99	3.333	ns
Jul-99	2.963	ns
Aug-99	1.687	ns

Mature open fruits

G-tests on monthly percent of individuals with mature open fruits for all three species bearing dehiscent fruits showed that *A. rigidula* had higher percentages of individuals with mature open fruits than *Acacia berlandieri* and *Chloroleucon ebano* from July 1998 through January 1999, and from May 1999 through July 1999 (Table 14). *Chloroleucon ebano* had a higher percentage of individuals with mature open fruits than *A. berlandieri* and *A. rigidula* during February 1999 (Table 14). No significant differences existed between species during April 1999 and August 1999 because there were no fruits on any of the three species. Chi-square tests on monthly percent of *Acacia* individuals with mature open fruits showed *A. rigidula* had higher percentages of individuals with mature open fruits than *A. berlandieri* in nine of the 14 months (Table 15). *Acacia berlandieri* and *A. rigidula* did not have any fruits during March, April, and August 1999, so chi-square analysis was not performed for these months (Table 15). Chi-square tests were performed on monthly percent of individuals with mature open fruits in *A. berlandieri* and *C. ebano* (Table 16) and *A. rigidula* and *C. ebano* (Table 17). Both sets of tests showed that significant differences existed between species during seven of the 14 months, but these differences were found during different months (Tables 16 & 17). *Acacia berlandieri* had higher percentages of individuals with mature open fruits than *C. ebano* during July 1998 and August 1999. *Chloroleucon ebano* had higher percentages of individuals with mature open fruits than *A. berlandieri* from November 1998 through March 1999. *Acacia rigidula* had higher percentages of individuals with mature open fruits than *C. ebano* from July 1998 through September 1998, and from May

1999 through July 1999. *Chloroleucon ebano* had a higher percentage of individuals with mature open fruits than *A. rigidula* in March 1999.

Table 14. G-tests on monthly percent of individuals with mature open fruits among species (*Acacia berlandieri*, *A. rigidula*, and *Chloroleucon ebano*). The level of probability is given for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	25.598	<.001
Aug-98	35.529	<.001
Sep-98	14.052	<.001
Oct-98	9.494	<.01
Nov-98	14.115	<.001
Dec-98	8.437	<.05
Jan-99	19.472	<.001
Feb-99	7.333	<.05
Mar-99	10.788	<.01
May-99	84.373	<.001
Jun-99	50.530	<.001
Jul-99	30.623	<.001

Table 15. Chi-square tests on monthly percent of individuals with mature open fruits in *Acacia berlandieri* and *A. rigidula*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	0.091	ns
Aug-98	8.333	<.01
Sep-98	13.281	<.001
Oct-98	8.817	<.01
Nov-98	17.647	<.001
Dec-98	9.134	<.01
Jan-99	13.400	<.001
Feb-99	1.700	ns
May-99	38.400	<.001
Jun-99	28.400	<.001
Jul-99	18.201	<.001

Table 16. Chi-square tests on monthly percent of individuals with mature open fruits in *Acacia berlandieri* and *Chloroleucon ebano*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	15.00	< .001
Aug-98	9.394	< .01
Sep-98	2.222	ns
Oct-98	2.038	ns
Nov-98	6.667	< .01
Dec-98	4.465	< .05
Jan-99	10	< .01
Feb-99	5	< .05
Mar-99	5	< .05
Jun-99	2.408	ns
Jul-99	2.408	ns

Table 17. Chi-square tests on monthly percent of individuals with mature open fruits in *Acacia rigidula* and *Chloroleucon ebano*. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	16.601	< .001
Aug-98	31.359	< .001
Sep-98	4.968	< .05
Oct-98	2.583	ns
Nov-98	1.123	ns
Dec-98	0.466	ns
Jan-99	0.494	ns
Feb-99	1.603	ns
Mar-99	5.000	< .05
May-99	38.400	< .001
Jun-99	21.639	< .001
Jul-99	12.002	< .001

Fruiting Among Sites

Mature not open fruits

Comparisons of percentage of individuals with mature not open fruits among species are shown in Figures 15-19. Figure 15 shows the percentage of *Acacia berlandieri* individuals with mature not open fruits at Santa Ana NWR and YBT. Mature not open fruits were present at Yturria Brush Tract from the flowering period prior to the beginning of the study in July 1998. Immature fruits were observed on individuals at Yturria Brush Tract in January 1999, March 1999, April 1999, and May 1999 (following the flowering period which occurred in January 1999 through April 1999), but these fruits never matured. Mature not open fruits were never observed at Santa Ana NWR during the study, although immature fruits were observed in July 1998 through September 1998 (from the flowering period that occurred prior to the beginning of study). Immature fruits (resulting from flowering periods at Santa Ana NWR in April 1999 and June 1999) were not seen. Chi-square tests showed that significant differences in monthly percent with mature not open fruits at Santa Ana NWR and Yturria Brush Tract existed in July 1998, August 1998, and November 1998 (Table 18). Such results are expected since mature not open fruits were observed only at Yturria Brush Tract during the study.

Table 18. Chi-square tests on monthly percent of individuals with mature not open fruits for *Acacia berlandieri* at Santa Ana NWR and Yturria Brush Tract. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	30	<.001
Aug-98	20	<.001
Nov-98	5	<.05

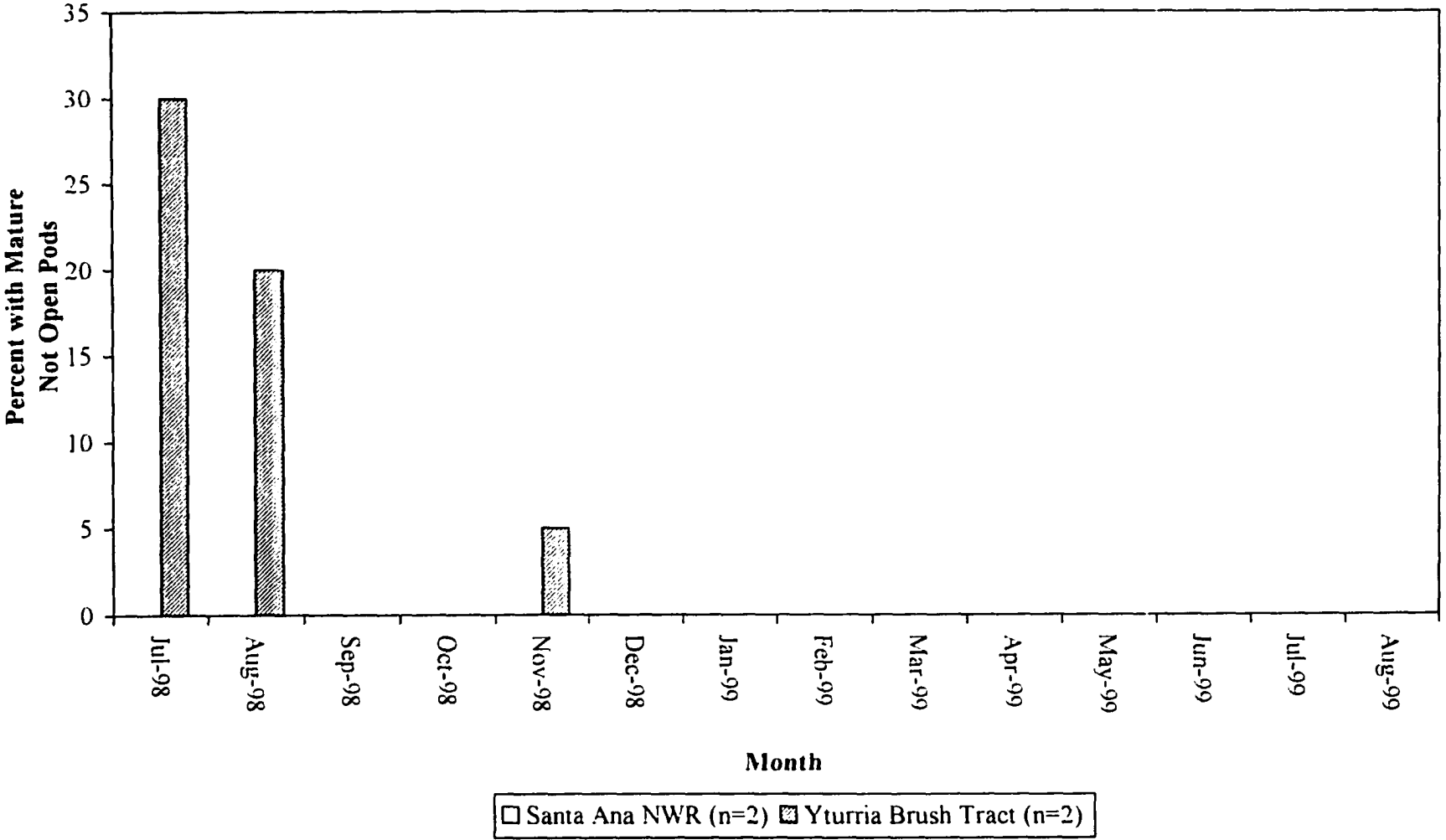


Figure 15. Monthly percentage of *Acacia berlandieri* individuals with mature not open pods at Santa Ana NWR and Yturria Brush Tract.

Mature not open pods in *Acacia mimuta* (from the 1998 flowering period) were observed in July 1998 through November 1998 at Castilla Ranch, and in July 1998 through October 1998 at Santa Ana NWR (Fig. 16). By December 1998, the individuals at both sites had dropped all mature not open fruits (Fig. 16). The flowering period at Castilla Ranch (which occurred from February 1999 through April 1999) resulted in mature not open fruits by May 1999 (Fig. 16). The percentage of individuals with mature not open fruits at Castilla Ranch peaked in June 1999, and then began to decrease as individuals dropped their pods (Fig. 16). Flowering at Santa Ana NWR in February 1999 and March 1999 resulted in the formation of mature open fruits by May 1999 (Fig. 16). Peaks in the percentage of individuals with mature not open fruits at Santa Ana NWR occurred in June 1999 and July 1999. The percentage decreased in August 1999, as individuals dropped their pods (Fig. 16). Significant differences in monthly percent with mature not open fruits existed between Castilla Ranch and Santa Ana NWR in July 1998, October 1998, November 1998, June 1999, July 1999, and August 1999 (Table 19).

Table 19. Chi-square tests on monthly percent of individuals with mature not open fruits for *Acacia mimuta* at Castilla Ranch and Santa Ana NWR. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	4.000	<.05
Aug-98	1.667	ns
Sep-98	1.111	ns
Oct-98	27.00	<.001
Nov-98	10.00	<.01
May-99	1.000	ns
Jun-99	17.86	<.001
Jul-99	48.91	<.001
Aug-99	45.00	<.001

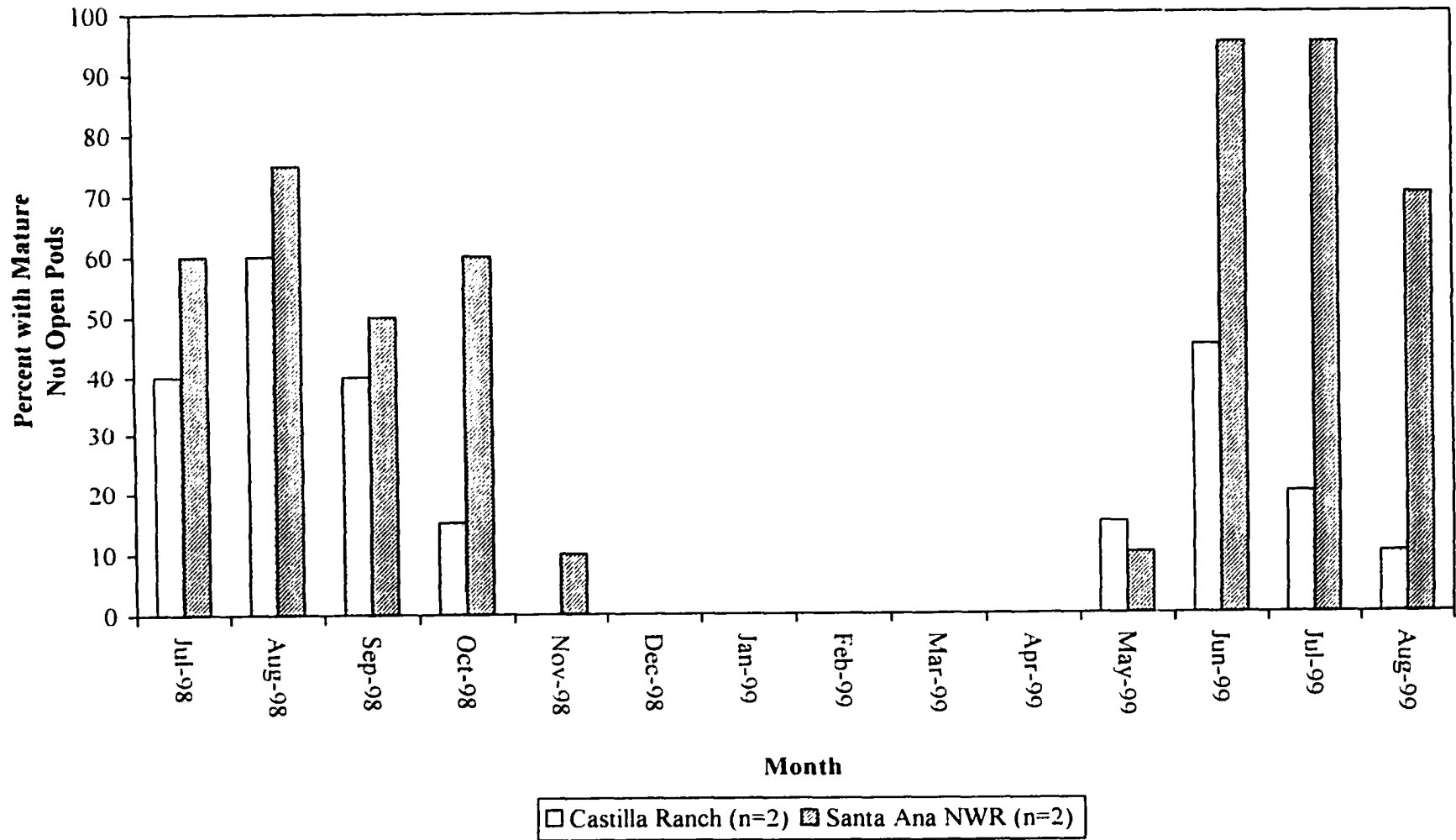


Figure 16. Monthly percentage of *Acacia mimata* individuals with mature not open pods at Castilla Ranch and Santa Ana NWR.

Figure 17 compares the percentages of *Acacia rigidula* individuals with mature not open pods at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. Mature not open fruits (from the 1998 flowering season) were observed from July 1998 through December 1998 at Yturria Brush Tract, from July 1998 through November 1998 at Santa Ana NWR, and from July 1998 through September 1998 at Castilla Ranch. Flowering at Castilla Ranch and Yturria Brush Tract (February 1999 and March 1999) resulted in mature not open fruits at those sites by May 1999. Flowering at Santa Ana NWR (February 1999 through April 1999) resulted in mature not open pods by May 1999. By June 1999, all mature pods at Castilla Ranch and Santa Ana NWR dehisced. Most pods at Yturria Brush Tract also dehisced by June 1999, but there was a small percentage that remained unopened during June 1999. All pods at the three sites dehisced by July 1999. G-tests showed the monthly percentages with mature not open fruits at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract were significantly different in July 1998, August 1998, October 1998, November 1998, December 1998, May 1999, and June 1999 (Table 20).

Table 20. G-tests on monthly percent of individuals with mature not open fruits for *Acacia rigidula* at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. The level of probability is given for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	94.909	<.001
Aug-98	21.622	<.001
Sep-98	5.2320	ns
Oct-98	27.726	<.001
Nov-98	38.883	<.001
Dec-98	10.966	<.01
May-99	14.555	<.001
Jun-99	10.966	<.01

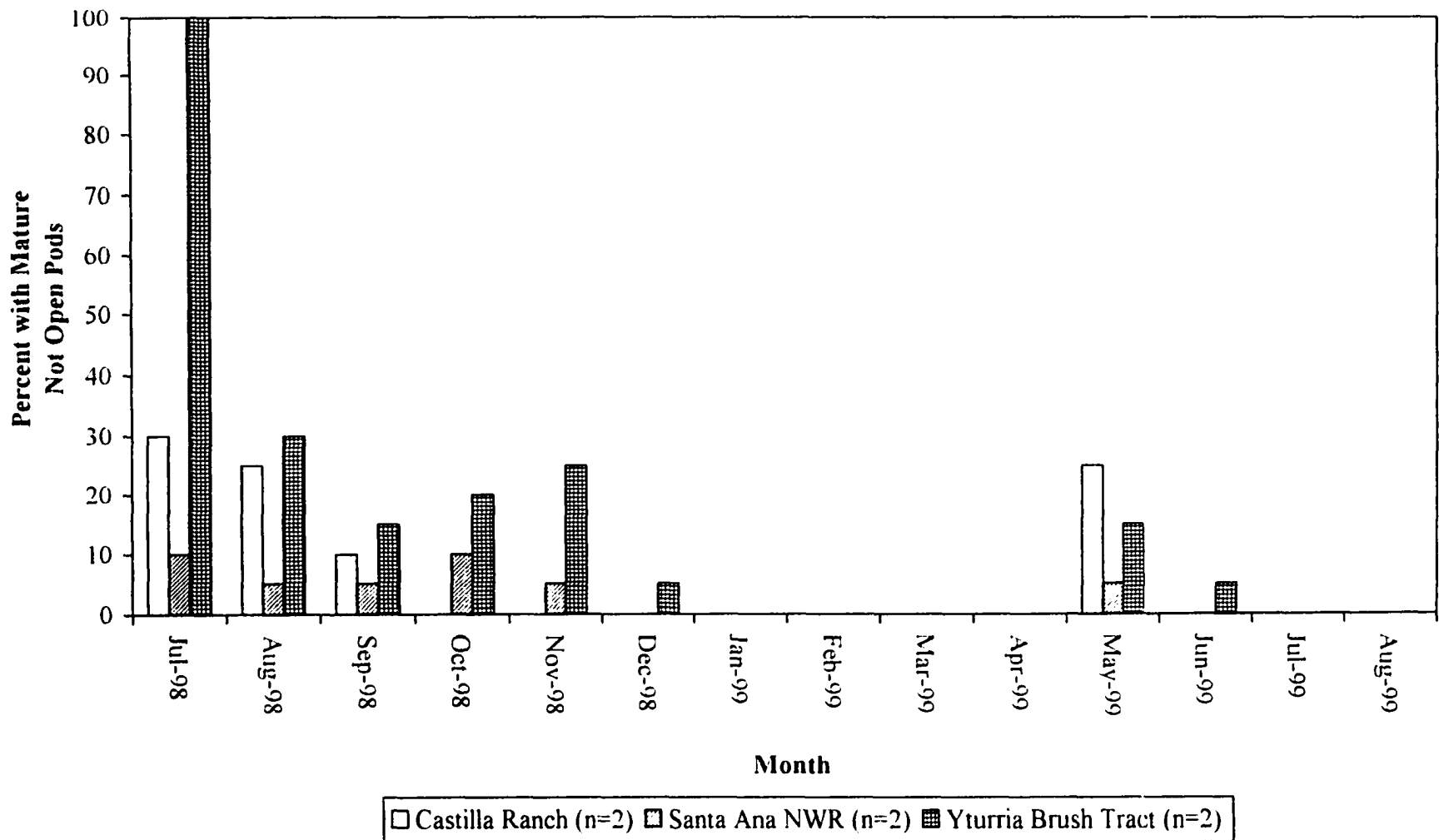


Figure 17. Monthly percentage of *Acacia rigidula* individuals with mature not open pods at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract.

Mature not open pods in *Acacia schaffneri* (from the 1998 flowering period) were observed at Castilla Ranch from July 1998 through September 1998, and from July 1998 through February 1999 at Yturria Brush Tract (Fig. 18). The percentage of individuals with mature not open pods gradually decreased as individuals dropped their pods. Flowering at Castilla Ranch in January 1999 through March 1999 resulted in the formation of mature not open pods by May 1999 (Fig. 18). Flowering at Yturria Brush Tract (February 1999 and March 1999) resulted in mature not open pods by June 1999 (Fig. 18). The percentage of individuals with mature not open fruits at Castilla Ranch peaked in June and July 1999, while the percentage at Yturria Brush Tract peaked during July 1999 and August 1999 (Fig. 18). Significant differences in monthly percent with mature not open fruits at Castilla Ranch and Yturria Brush Tract existed in July 1998, August 1998, September 1998, October 1998, November 1998, and December 1998. Significant differences also existed in January 1999, February 1999, May 1999, June 1999, and August 1999 (Table 21)

Figure 19 shows the percentage of *Chloroleucon ehano* with mature not open fruits at Santa Ana NWR and Yturria Brush Tract. Mature not open fruits resulting from the 1998 flowering period prior to the beginning of the study remained on individuals at Santa Ana NWR through August 1998. Mature not open fruits from the 1998 flowering period remained on individuals at Yturria Brush Tract through March 1999. The pods at both sites were mature, yet they failed to open, and were stunted in length and width. Mature not open pods were observed at Santa Ana NWR by May 1999. These pods were not numerous, and are likely to have come from ephemeral flowering events that were not

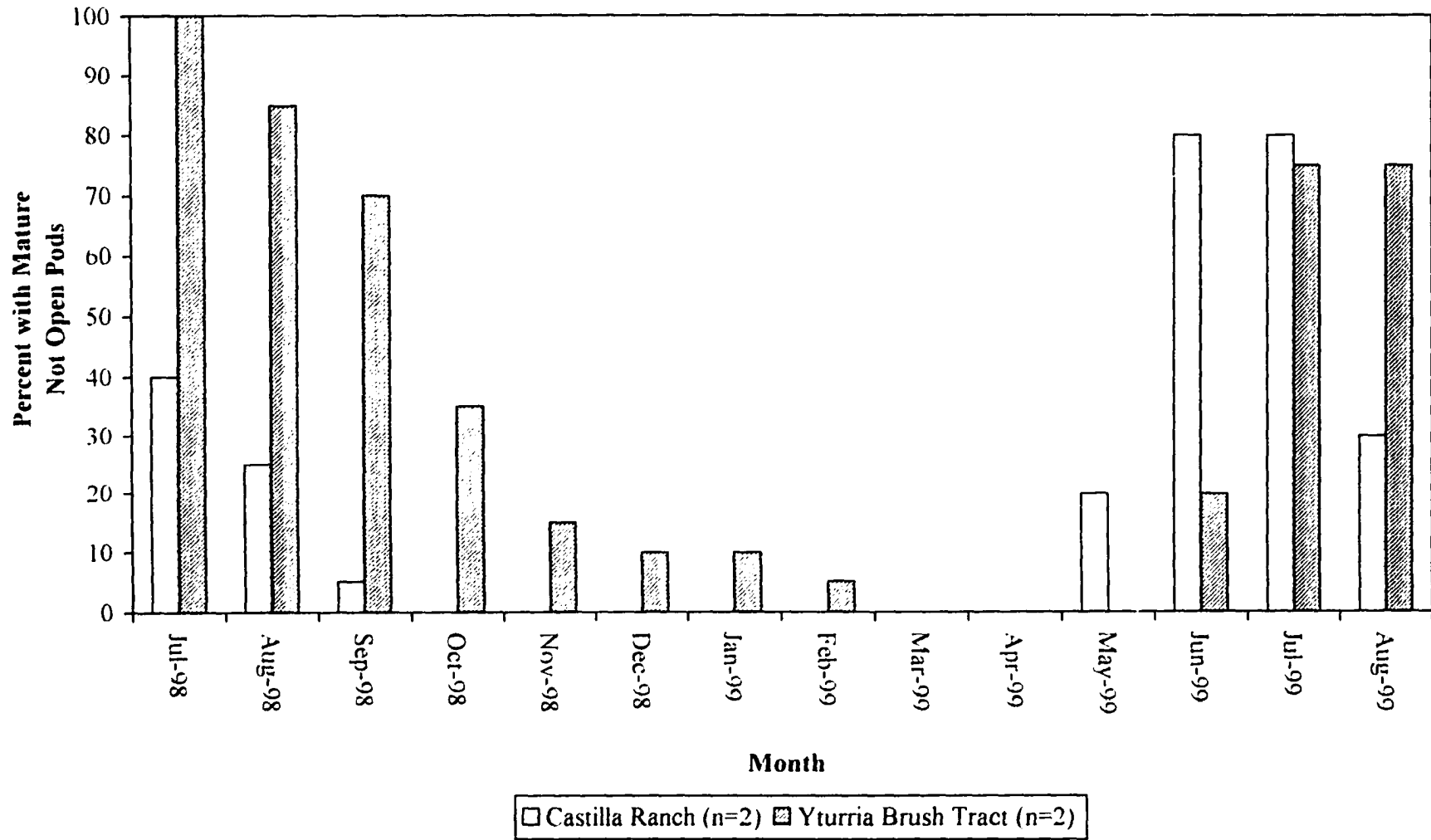


Figure 18. Monthly percentage of *Acacia schaffneri* individuals with mature not open pods at Castilla Ranch and Yturria Brush Tract.

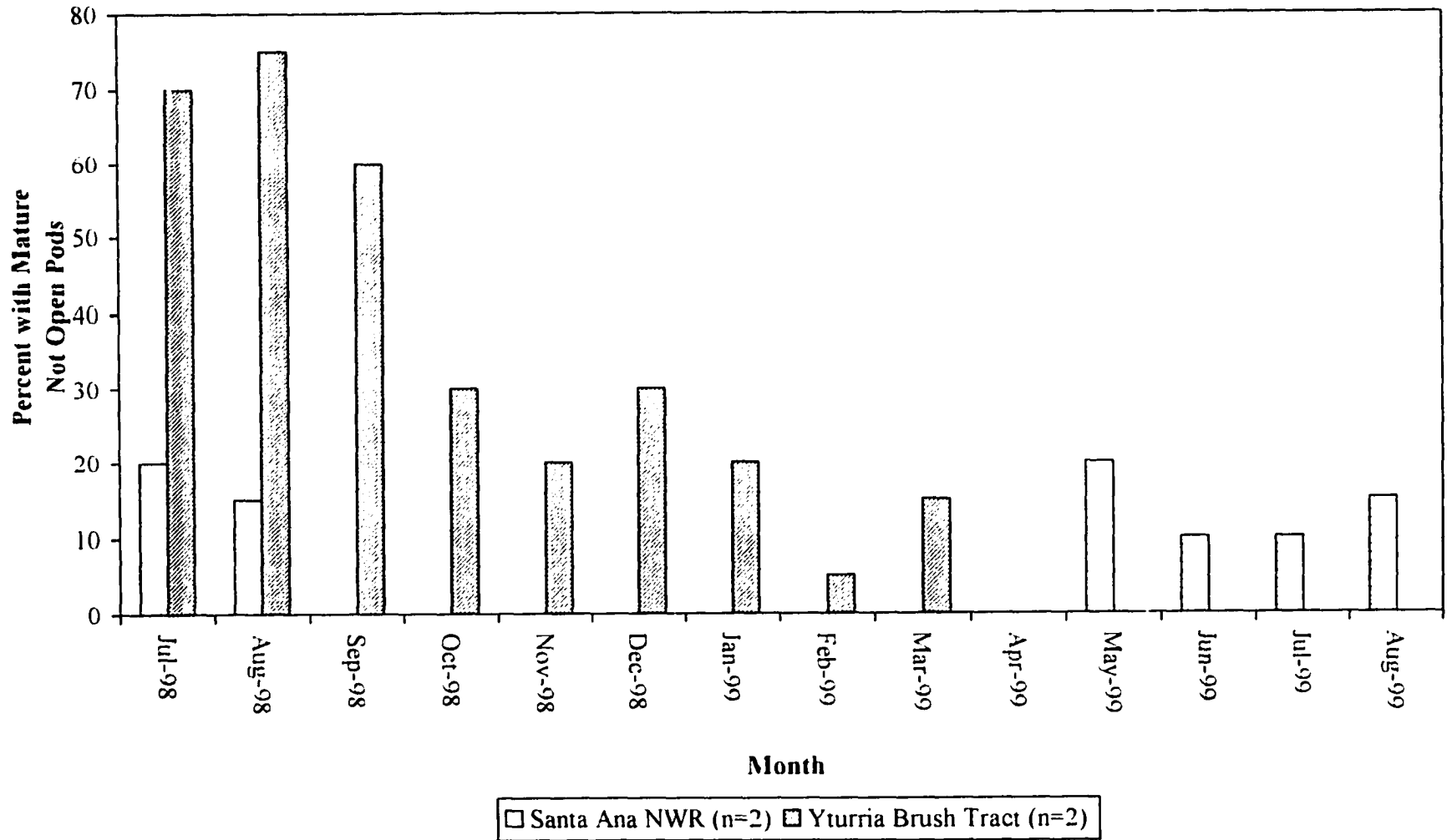


Figure 19 Monthly percentage of *Chlorolencon ebano* individuals with mature not open pods at Santa Ana NWR and Yturria Brush Tract

observed. Significant differences in monthly percent with mature not open fruits at Santa Ana NWR and Yturria Brush Tract existed from July 1998 through March 1999, and also from May 1999 through August 1999 (Table 22).

Table 21. Chi-square tests on monthly percent of individuals with mature not open fruits for *Acacia schaffneri* at Castilla Ranch and Yturria Brush Tract. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	25.71	< .001
Aug-98	32.73	< .001
Sep-98	56.33	< .001
Oct-98	35.00	< .001
Nov-98	15.00	< .001
Dec-98	10.00	< .01
Jan-99	10.00	< .01
Feb-99	5.000	< .05
May-99	20.00	< .001
Jun-99	36.00	< .001
Jul-99	0.161	ns
Aug-99	19.29	< .001

Table 22. Chi-square tests on monthly percent of individuals with mature not open fruits for *Chloroleucon ebano* at Santa Ana NWR and Yturria Brush Tract. The level of probability is given for significant values. "ns" = nonsignificant.

Month	Chi-Square	Probability
Jul-98	27.78	< .001
Aug-98	40.00	< .001
Sep-98	60.00	< .001
Oct-98	30.00	< .001
Nov-98	20.00	< .001
Dec-98	30.00	< .001
Jan-99	20.00	< .001
Feb-99	5.000	< .01
Mar-99	15.00	< .001
May-99	20.00	< .001
Jun-99	10.00	< .01
Jul-99	10.00	< .01
Aug-99	15.00	< .001

Mature open fruits

Comparisons of monthly percentage of individuals with mature open fruits in *Acacia berlandieri*, *A. rigidula*, and *Chloroleucon ebanum* are shown in Figures 20-22. Figure 20 shows the monthly percentage of *A. berlandieri* individuals with mature open fruits at Santa Ana NWR and Yturria Brush Tract. Mature open fruits from the 1998 flowering period were present through December 1998 at Yturria Brush Tract, with August 1998 having the highest percentage of individuals (Fig. 20). Mature open fruits in *A. berlandieri* were not seen at Santa Ana NWR throughout the study (Fig. 20). Chi-square tests showed that significant differences in monthly percentage of individuals with mature open fruits at Santa Ana NWR and Yturria Brush Tract existed from July 1998 through December 1998 (Table 23). These are expected results since mature open fruits were not seen at Santa Ana NWR for the duration of the study (Fig. 20).

Table 23. Chi-square tests on monthly percent of individuals with mature open fruits for *Acacia berlandieri* at Santa Ana NWR and Yturria Brush Tract. The level of probability is shown for significant values. "ns" - nonsignificant

Month	Chi-Square	Probability
Jul-98	15.0	< .001
Aug-98	50.0	< .001
Sep-98	35.0	< .001
Oct-98	20.0	< .001
Nov-98	5.0	< .05
Dec-98	5.0	< .05

Mature open fruits of *Acacia rigidula* individuals from the 1998 flowering event were seen at Castilla Ranch and Santa Ana NWR in July 1998, but were not observed at Yturria Brush Tract until August 1998 (Fig. 21). Mature open fruits from the 1998 flowering period were seen on individuals at Santa Ana NWR through October 1998, at

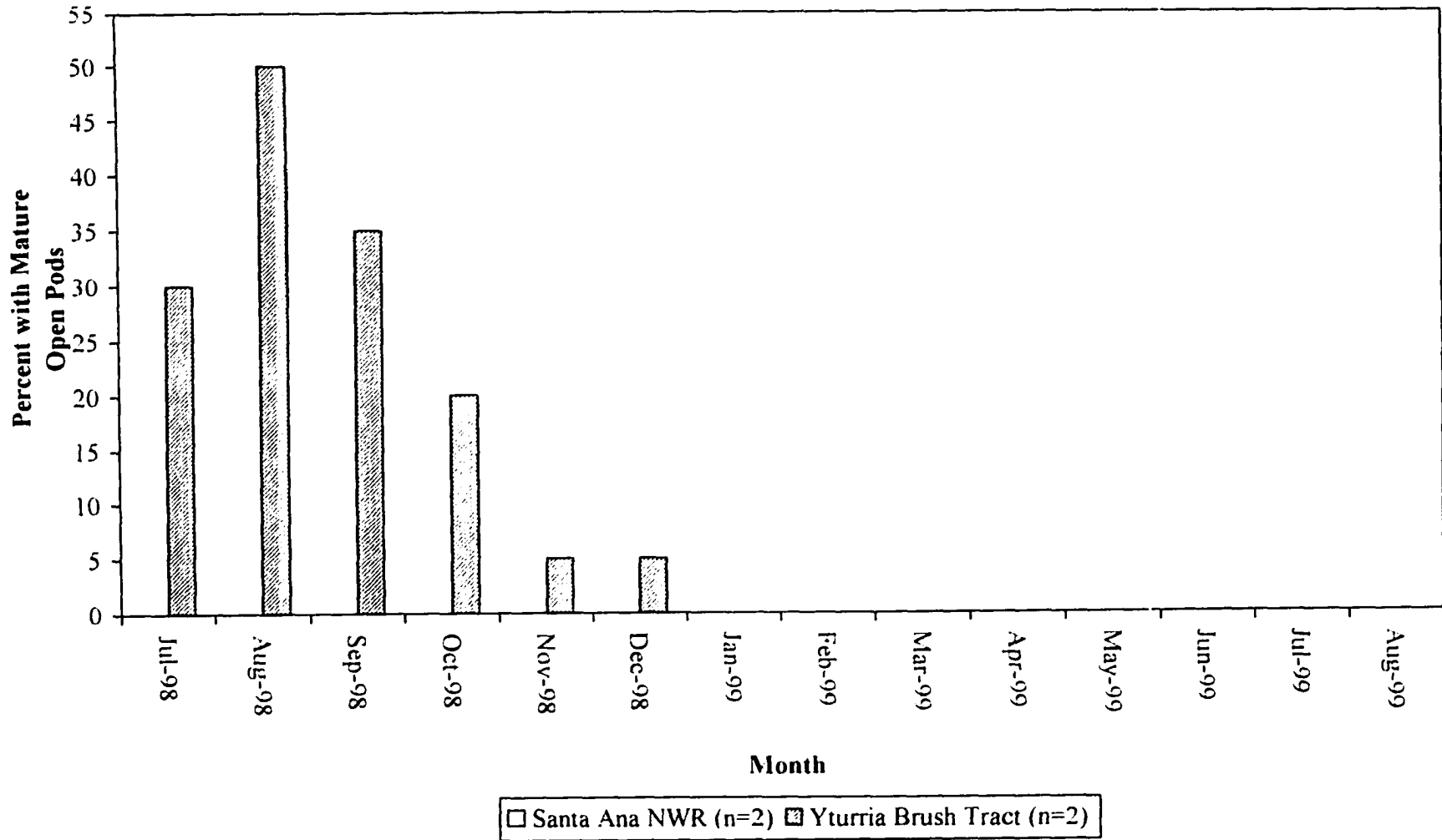


Figure 20. Monthly percentage of *Acacia berlandieri* individuals with mature open pods at Santa Ana NWR and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site.

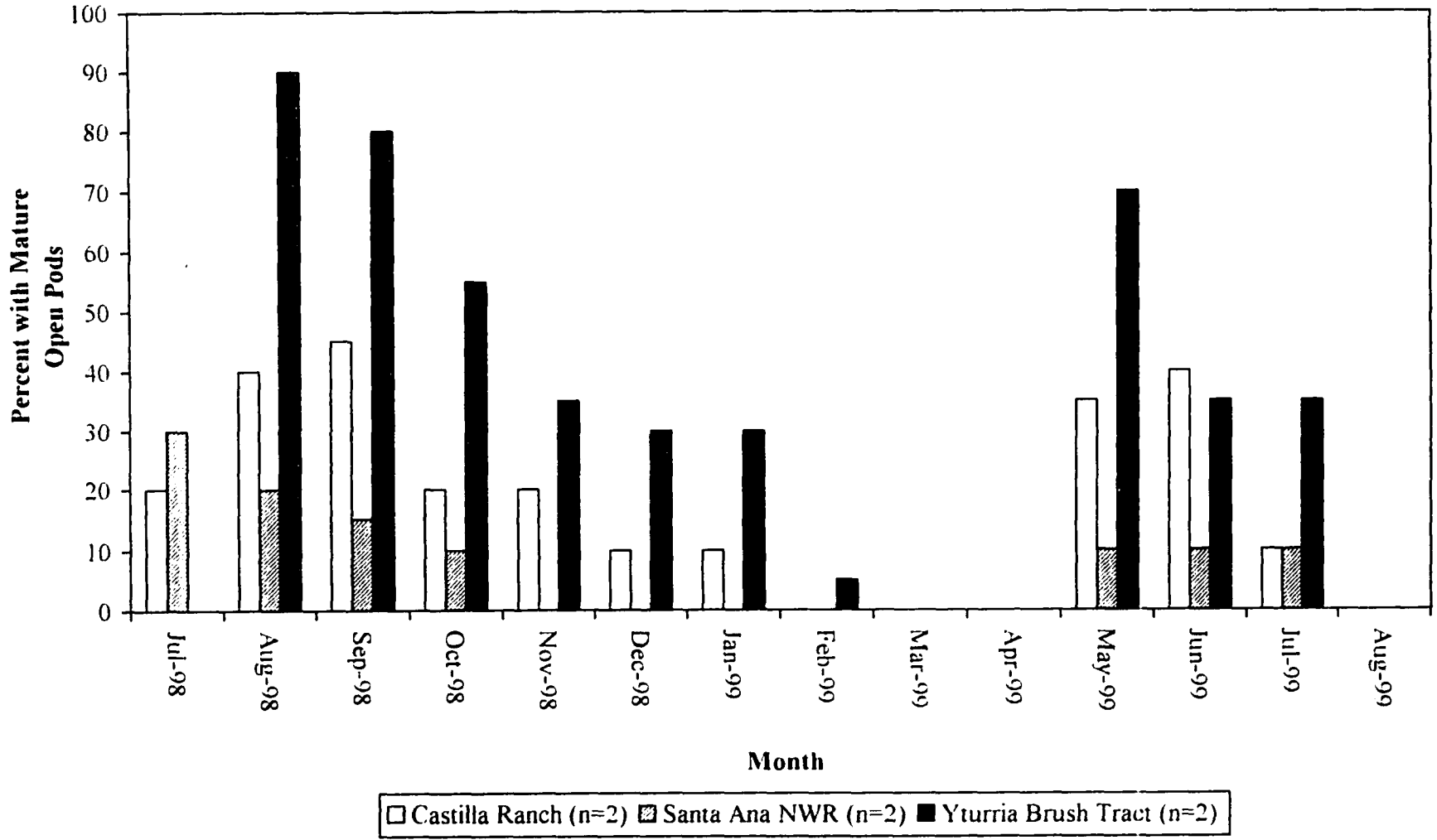


Figure 21. Monthly percentage of *Acacia rigidula* individuals with mature open pods at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site.

Castilla Ranch through January 1999, and at Yturria Brush Tract through February 1999 (Fig. 21). Mature open fruits resulting from the 1999 flowering event were first seen at all three sites in May 1999, and they were retained on individuals through July 1999 (Fig. 21). G-tests on monthly percent of *A. rigidula* individuals with mature open fruits showed that significant differences existed between Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract from July 1998 through February 1999 and from May 1999 through July 1999 (Table 24).

Mature open pods in *Chloroleucon ebano* were observed only at Yturria Brush Tract during the study (Fig. 22). *Chloroleucon ebano* individuals at Santa Ana NWR had mature not open fruit present on individuals, but these did not open during the study (Figs. 19 & 22). Chi-square tests showed that significant differences in monthly percent of individuals with mature open fruits existed between sites from August 1998 through March 1999 and June and July 1999 (Table 25). Such results are expected since mature open fruits were never seen at Santa Ana NWR during the study (Fig. 22).

Table 24. G-tests on monthly percent of individuals with mature open fruits for *Acacia rigidula* at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. The level of probability is shown for significant values. "ns" = nonsignificant.

Month	G	Probability
Jul-98	42.36	< .001
Aug-98	51.298	< .001
Sep-98	48.717	< .001
Oct-98	38.401	< .01
Nov-98	48.945	< .001
Dec-98	43.102	< .001
Jan-99	43.102	< .001
Feb-99	10.788	< .01
May-99	51.262	< .001
Jun-99	21.750	< .001
Jul-99	21.219	< .001

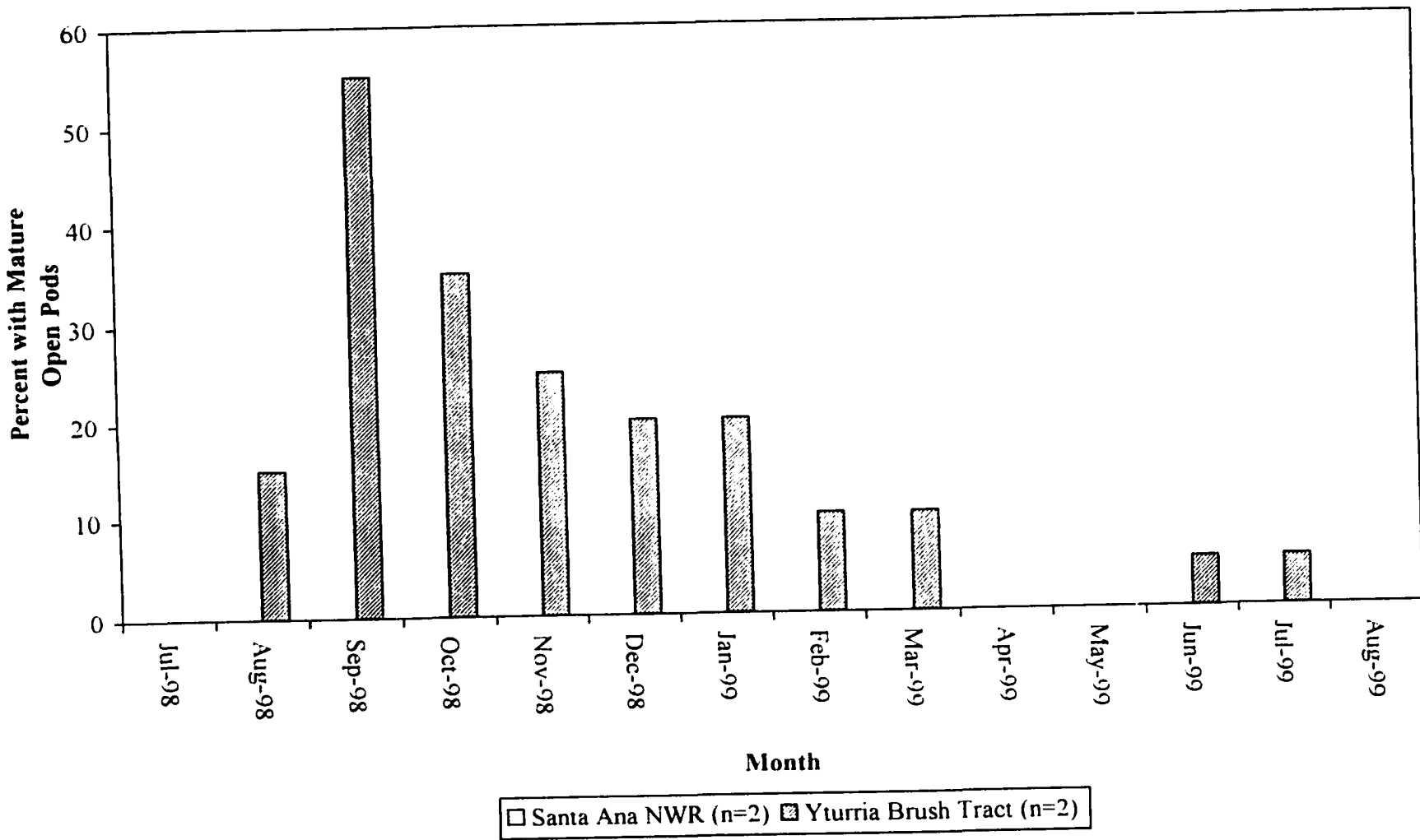


Figure 22. Monthly percentage of *Chloroleucon ebano* individuals with mature open pods at Santa Ana NWR and Yturria Brush Tract. The averages of two censuses taken monthly are shown for ten individuals at each site.

Table 25. Chi-square tests on monthly percent of individuals with mature open fruits for *Chloroleucon ebano* at Santa Ana NWR and Yturria Brush Tract. The level of probability is shown for significant values. "ns" = nonsignificant

Month	Chi-Square	Probability
Aug-98	15	<.001
Sep-98	55	<.001
Oct-98	35	<.001
Nov-98	25	<.001
Dec-98	20	<.001
Jan-99	20	<.001
Feb-99	10	<.001
Mar-99	10	<.001
Jun-99	5	<.05
Jul-99	5	<.05

Correlation Between Official Climatic Data and Fruiting

Mature not open fruit

Correlations using official climatic data for all fourteen months in the study showed that all species had positive correlations between monthly percent of individuals with mature not open fruits and mean daily photoperiod (Table 26). The correlations between monthly percent of individuals with mature not open fruits and mean daily photoperiod were significant in *A. minuta* and *A. schaffneri* only (Table 26). Positive correlations between monthly percent of individuals with mature not open fruits and monthly precipitation existed in *Acacia minuta*, *A. schaffneri*, and *Chloroleucon ebano*, while *A. berlandieri*, and *A. rigidula* had negative correlations (Table 26). None of the correlations with monthly precipitation were significant. All species had positive correlations between monthly percent with mature not open fruits and mean monthly

temperature, but only the correlations in *A. minnata* and *A. schaffneri* were significant (Table 26).

Table 26. Correlation coefficients (r) for meteorological factors versus percent with mature not open fruits. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.327	1.199	ns	-0.194	0.685	ns	0.438	1.688	ns
<i>A. minnata</i>	0.701	3.405	< .05	0.207	0.733	ns	0.804	4.684	< .05
<i>A. rigidula</i>	0.344	1.269	ns	-0.011	0.038	ns	0.459	1.790	ns
<i>A. schaffneri</i>	0.715	3.543	< .05	0.081	0.282	ns	0.782	4.346	< .05
<i>C. ebano</i>	0.226	0.803	ns	0.251	0.898	ns	0.390	1.467	ns

Mature open fruit

Correlations using official climatic data for all fourteen months in the study and the fruiting data for *Acacia berlandieri*, *A. rigidula*, and *Chloroleucon ebano* showed that *A. berlandieri* and *A. rigidula* had positive correlations between monthly percent with mature open fruits and mean daily photoperiod (Table 27). *Chloroleucon ebano* had a negative correlation between monthly percent with mature open fruits and mean daily photoperiod (Table 27). None of the correlations with mean daily photoperiod were significant. All three species had positive correlations between monthly percent with mature open fruit and monthly precipitation, but only the correlation in *C. ebano* was significant (Table 27). *Acacia berlandieri* and *A. rigidula* had nonsignificant positive correlations between monthly percent with mature open fruits and mean monthly temperature, and *C. ebano* had a nonsignificant negative correlation between monthly percent with mature open fruits and mean monthly temperature (Table 27).

Table 27. Correlation coefficients (r) for meteorological factors versus percent with mature open fruits. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.193	0.681	ns	0.404	1.530	ns	0.406	1.530	ns
<i>A. rigidula</i>	0.263	0.944	ns	0.417	1.589	ns	0.384	1.441	ns
<i>C. ehano</i>	-0.499	1.995	ns	0.729	3.689	<.05	-0.303	1.101	ns

Correlation Between Local Observer Data and Fruiting

Mature not open fruit

Castilla Ranch

Correlations using local observer climatic data for Rio Grande City for all fourteen months in the study showed that *Acacia minima*, *A. rigidula*, and *A. schaffneri* had positive correlations between monthly percent with mature not open fruit and mean daily photoperiod (Table 28). The correlations between monthly percent with mature not open fruit and mean daily photoperiod were significant in *A. minima* and *A. schaffneri* (Table 28). *Acacia minima* had a nonsignificant positive correlation between monthly percent with mature not open fruit and monthly precipitation, and *A. rigidula* and *A. schaffneri* had nonsignificant negative correlations (Table 28). All species had significant positive correlations between monthly percent with mature not open fruits and mean monthly temperature (Table 28).

Table 28. Correlation coefficients (r) for meteorological factors versus percent with mature not open fruits at Castilla Ranch. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.638	2.870	<.05	0.259	0.929	ns	0.739	3.800	<.05
<i>A. rigidula</i>	0.503	2.016	ns	-0.075	0.261	ns	0.522	2.120	<.05
<i>A. schaffneri</i>	0.734	3.744	<.05	-0.135	0.472	ns	0.652	2.979	<.05

Santa Ana NWR

Correlations using local observer climatic data for Santa Ana NWR for all fourteen months in the study showed that *Acacia minnata*, *A. rigidula*, and *Chloroleucon ebano* had positive correlations between monthly percent with mature not open fruit and mean daily photoperiod, monthly precipitation, and mean monthly temperature (Table 29). The correlations between monthly percent with mature not open fruit and mean daily photoperiod were significant in *A. minnata* and *C. ebano*. Only the correlation between monthly percent with mature not open fruit and monthly precipitation in *A. minnata* was significant. The correlations between monthly percent with mature not open fruit and mean monthly temperature were significant in *A. minnata* and *C. ebano*. *Acacia berlandieri* did not have mature not open fruits during the study, so correlations were not calculated.

Yturria Brush Tract

Correlations using the local observer climatic data for La Joya for all fourteen months of the study and the fruiting data for *Acacia berlandieri*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano* showed that all species had positive correlations between monthly

Table 29. Correlation coefficients (r) for meteorological factors versus percent with mature not open fruits at Santa Ana NWR. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. mimata</i>	0.672	3.143	<.05	0.559	2.335	<.05	0.636	2.855	<.05
<i>A. rigidula</i>	0.109	0.380	ns	0.117	0.408	ns	0.058	0.201	ns
<i>C. ebano</i>	0.728	3.678	<.05	0.116	0.405	ns	0.673	3.152	<.05

percent with mature not open fruit and mean daily photoperiod (Table 30). The correlations were significant in *A. schaffneri* and *C. ebano* only. *Acacia berlandieri* and *A. rigidula* had nonsignificant negative correlations between monthly percent with mature not open fruit and monthly precipitation while *A. schaffneri* and *C. ebano* had nonsignificant positive correlations between monthly percent with mature not open fruit and monthly precipitation (Table 30). All species had positive correlations between monthly percent with mature not open fruit and mean monthly temperature (Table 30). The correlations between monthly percent with mature not open fruit and mean monthly temperature were significant in *A. schaffneri* and *C. ebano* only.

Table 30. Correlation coefficients (r) for meteorological factors versus percent with mature not open fruits at Yturria Brush Tract. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.327	1.199	ns	-0.312	1.138	ns	0.457	1.780	ns
<i>A. mimata</i>	0.264	0.948	ns	-0.170	0.598	ns	0.409	1.553	ns
<i>A. schaffneri</i>	0.519	2.103	<.05	0.336	1.236	ns	0.703	3.424	<.05
<i>C. ebano</i>	0.683	3.239	<.05	0.440	1.697	ns	0.778	4.290	<.05

Mature open fruits

Castilla Ranch

Correlations using all fourteen months of local observer climatic data for Rio Grande City showed that *Acacia rigidula* had nonsignificant positive correlations between monthly percent with mature open fruit and mean daily photoperiod, monthly precipitation, and mean monthly temperature (Table 31).

Table 31. Correlation coefficients (r) for meteorological factors versus percent with mature open fruits at Castilla Ranch. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. rigidula</i>	0.328	1.203	ns	0.426	1.631	ns	0.428	1.640	ns

Santa Ana NWR

Correlations using all fourteen months of local observer climatic data for Santa Ana NWR showed that *Acacia rigidula* had positive correlations between monthly percent with mature open fruit and mean daily photoperiod, monthly precipitation, and mean monthly temperature (Table 32). Only the correlation between monthly percent with mature open fruit and mean monthly temperature was significant. Correlations were not calculated for *A. berlandieri* and *Chloroleucon ebano* because they did not have mature open fruit at this site.

Table 32. Correlation coefficients (r) for meteorological factors versus percent with mature open fruits at Santa Ana NWR. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. rigidula</i>	0.583	2.486	<.05	0.150	0.526	ns	0.420	1.603	ns

Yturria Brush Tract

Correlations using all fourteen months of local observer climatic data for La Joya showed that *Acacia berlandieri* and *A. rigidula* had nonsignificant positive correlations between monthly percent with mature open fruit and mean daily photoperiod and mean monthly temperature (Table 33). *Chloroleucon ebano* had nonsignificant negative correlations between monthly percent with mature open fruit and mean daily photoperiod and mean monthly temperature (Table 33). All species had positive correlations between monthly percent with mature open fruit and monthly precipitation (Table 33). Only the correlation between monthly percent with mature open fruit and monthly precipitation in *C. ebano* was significant.

Table 33. Correlation coefficients (r) for meteorological factors versus percent with mature open fruits at Yturria Brush Tract. R values are based on sample sizes of 14, i.e., 14 months of fruiting data and the corresponding mean daily photoperiod, monthly precipitation, and mean monthly temperature values. $t = t$ value. The level of probability (P) is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.193	0.681	ns	0.238	0.849	ns	0.459	1.790	ns
<i>A. rigidula</i>	0.082	0.285	ns	0.383	1.436	ns	0.238	0.849	ns
<i>C. ebano</i>	-0.499	1.99	ns	0.595	2.564	<.05	-0.239	0.852	ns

Vegetative Growth

Shoot Elongation Among Species

Monthly shoot elongation is shown for each species in Figure 23. *Acacia minnata* consistently exhibited the greatest values, with an annual mean (11 month) of 9.9 cm (n = 200, SD = 4.061). *Acacia schaffneri* exhibited the smallest shoot elongation values in the early months of the study, but had steadily increasing values, resulting in an annual mean of 7.7 cm (n = 200, SD = 6.222). *Acacia schaffneri* reached a peak in shoot elongation in August 1999, where its shoot elongation (15 cm) was the greatest of all five species. *Acacia berlandieri* (n = 200, SD = 2.498) and *A. rigidula* (n = 200, SD = 3.427) had similar annual mean values of 6.6 cm and 6.8 cm, respectively. *Chloroleucon ebanum* exhibited the least shoot elongation during the study, with an annual mean of 4.0 cm (n = 200, SD = 2.544). ANOVA of the shoot elongation data for all five species showed that significant differences in monthly shoot elongation existed between the species (F = 3.09, 4, 50 df, P<0.05). T-tests between pairs of species showed that monthly shoot elongation was greater in *A. minnata* than in *A. berlandieri* (t = 3.59, 16 df, P<0.05) and greater in *A. minnata* than in *A. rigidula* (t = 2.69, 16 df, P<0.05). Monthly shoot elongation was greater in *A. berlandieri* than in *C. ebanum* (t = 3.15, 16 df, P<0.05) and greater in *A. minnata* than in *C. ebanum* (t = 5.58, 16 df, P<0.05). Monthly shoot elongation in *A. rigidula* was greater than in *C. ebanum* (t = 2.57, 16 df, P<0.05).

Comparison of Shoot Elongation Among Sites

Table 34 shows shoot elongation values for all species and sites. Monthly shoot elongation values for each site are shown in Figures 24-28. The shoot elongation values

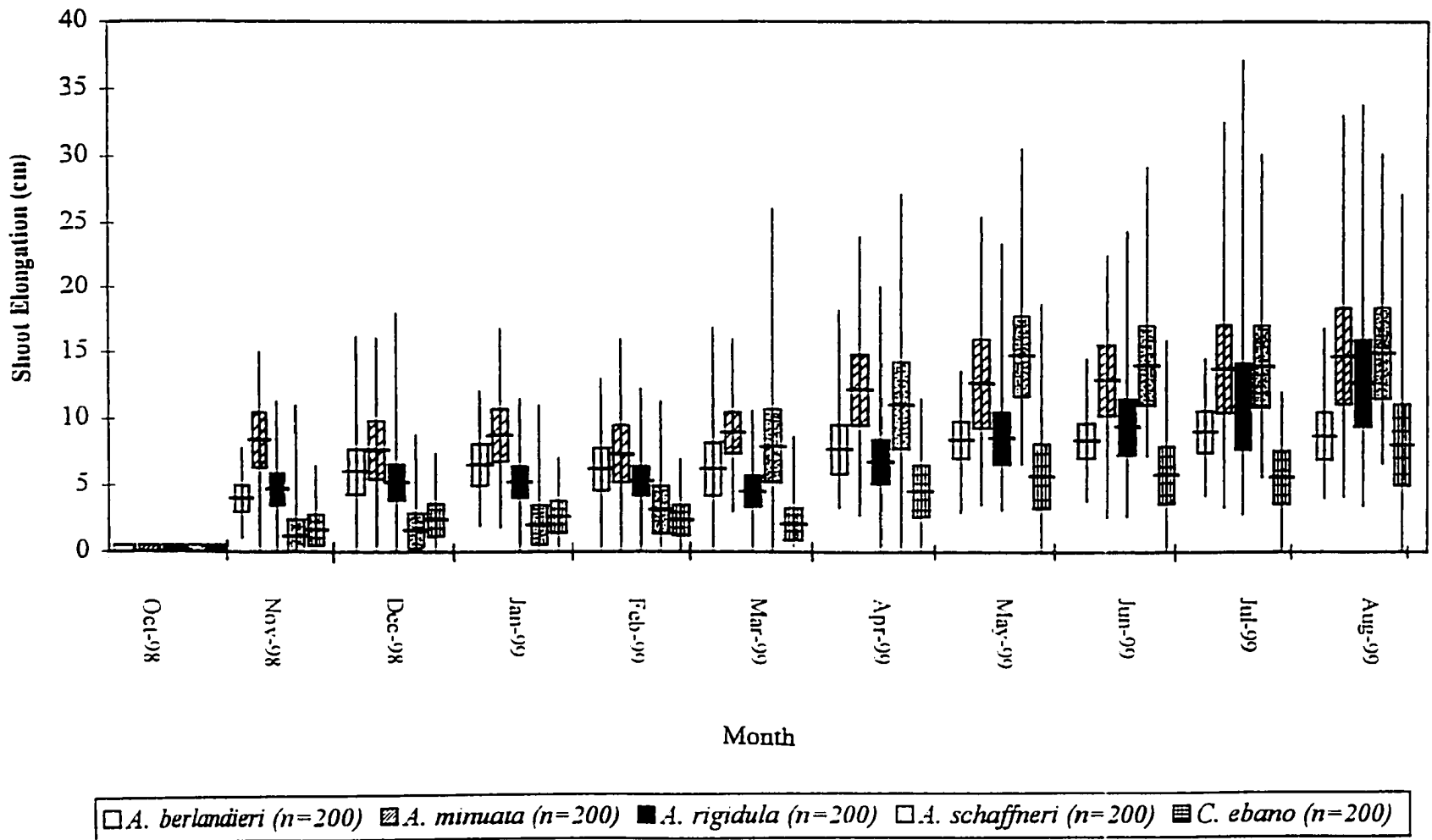


Figure 23. Monthly shoot elongation for all species. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

of *Acacia berlandieri* at Santa Ana NWR and Yturria Brush Tract are shown in Figure 24. There is overlap of the 95% confidence intervals of the two sites in each month, which suggests that there were no significant differences between sites in any month. Subsequent *t*-tests confirmed this was so. *P* exceeded .05 in each month.

Table 34. Shoot elongation data for species and sites. CR = Castilla Ranch, SANWR = Santa Ana NWR, YBT = Yturria Brush Tract. *n* = sample size, SE = standard error of the mean.

Species	Site	<i>n</i>	Range (cm)	Annual Mean (cm)	SE
<i>A. berlandieri</i>	SANWR	110	0.5-18.2	6.8	0.353
<i>A. berlandieri</i>	YBT	110	0.5-16.8	6.4	0.395
<i>A. minuata</i>	CR	110	0.0-24.1	8.5	0.541
<i>A. minuata</i>	SANWR	110	0.0-33.0	11.1	0.667
<i>A. rigidula</i>	CR	110	0.0-37.1	8.5	0.810
<i>A. rigidula</i>	SANWR	110	0.0-20.1	6.6	0.440
<i>A. rigidula</i>	YBT	110	0.5-13.2	5.1	0.248
<i>A. schaffneri</i>	CR	110	0.0-27.2	7.7	0.624
<i>A. schaffneri</i>	YBT	110	0.0-30.6	7.8	0.847
<i>C. ebano</i>	SANWR	110	1.0-13.9	2.7	0.320
<i>C. ebano</i>	YBT	110	0.0-27.2	4.8	0.464

Figure 25 shows the shoot elongation data for *A. minuata* at Castilla Ranch and Santa Ana NWR. Overlap of the 95% confidence intervals of the two sites is observed during all months, suggesting that no significant differences exist between sites in any months, but *t*-tests showed shoot elongation in *A. minuata* was greater at Santa Ana NWR than at Castilla Ranch in June 1999 ($t = 2.14$, 18 df, $P < .05$). There were no significant differences in monthly shoot elongation in *A. schaffneri* at Castilla Ranch and Yturria Brush Tract (Fig. 26). Monthly shoot elongation in *Chloroleucon ebano* was greater at Yturria Brush Tract than at Santa Ana NWR (Fig. 27) in November 1998 ($t = 2.519$, 18

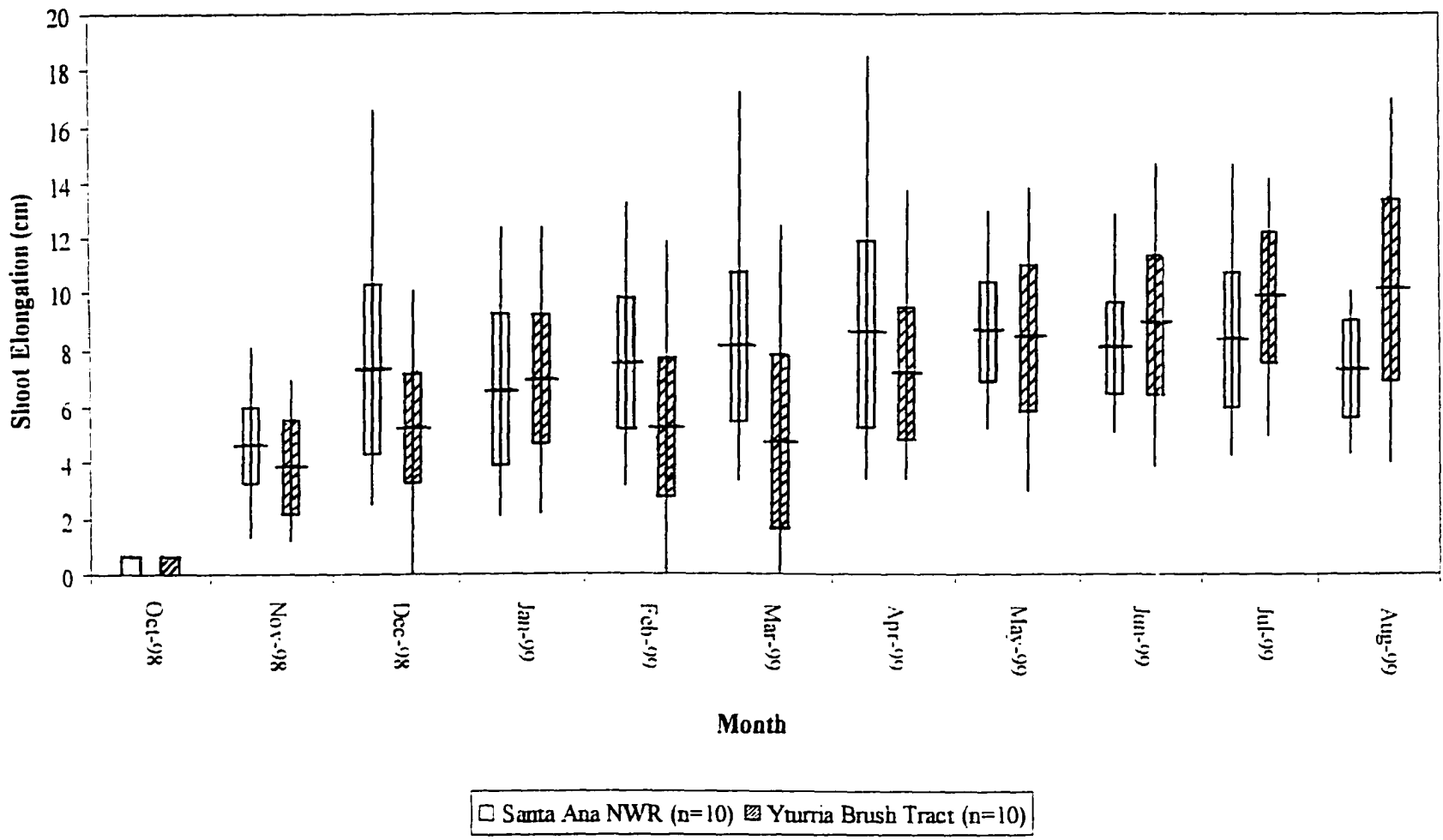


Figure 24. Monthly shoot elongation values of *Acacia berlandieri* for Santa Ana NWR and Yturria Brush Tract. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

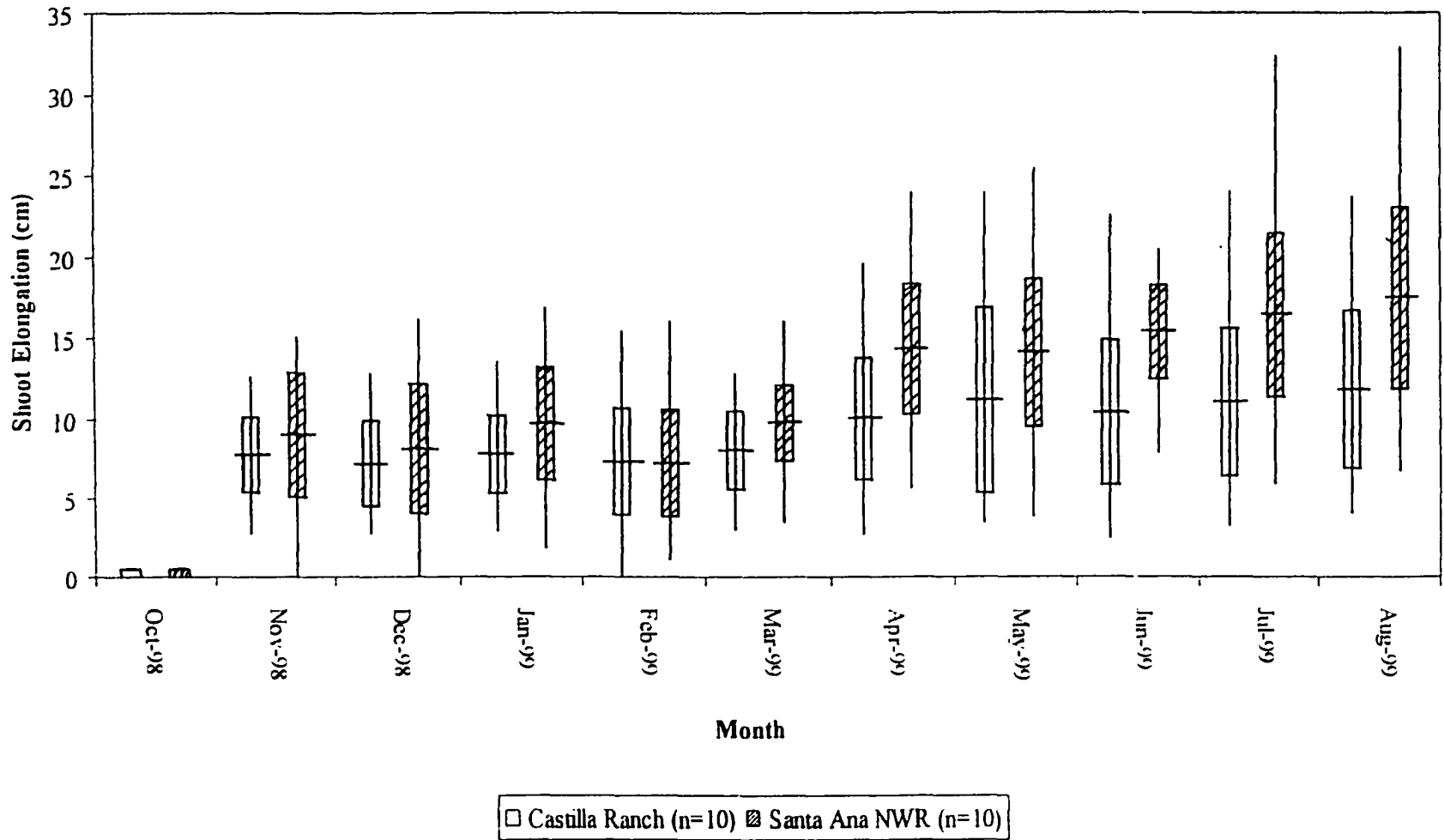


Figure 25. Monthly shoot elongation values of *Acacia mimuta* for Castilla Ranch and Santa Ana NWR. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

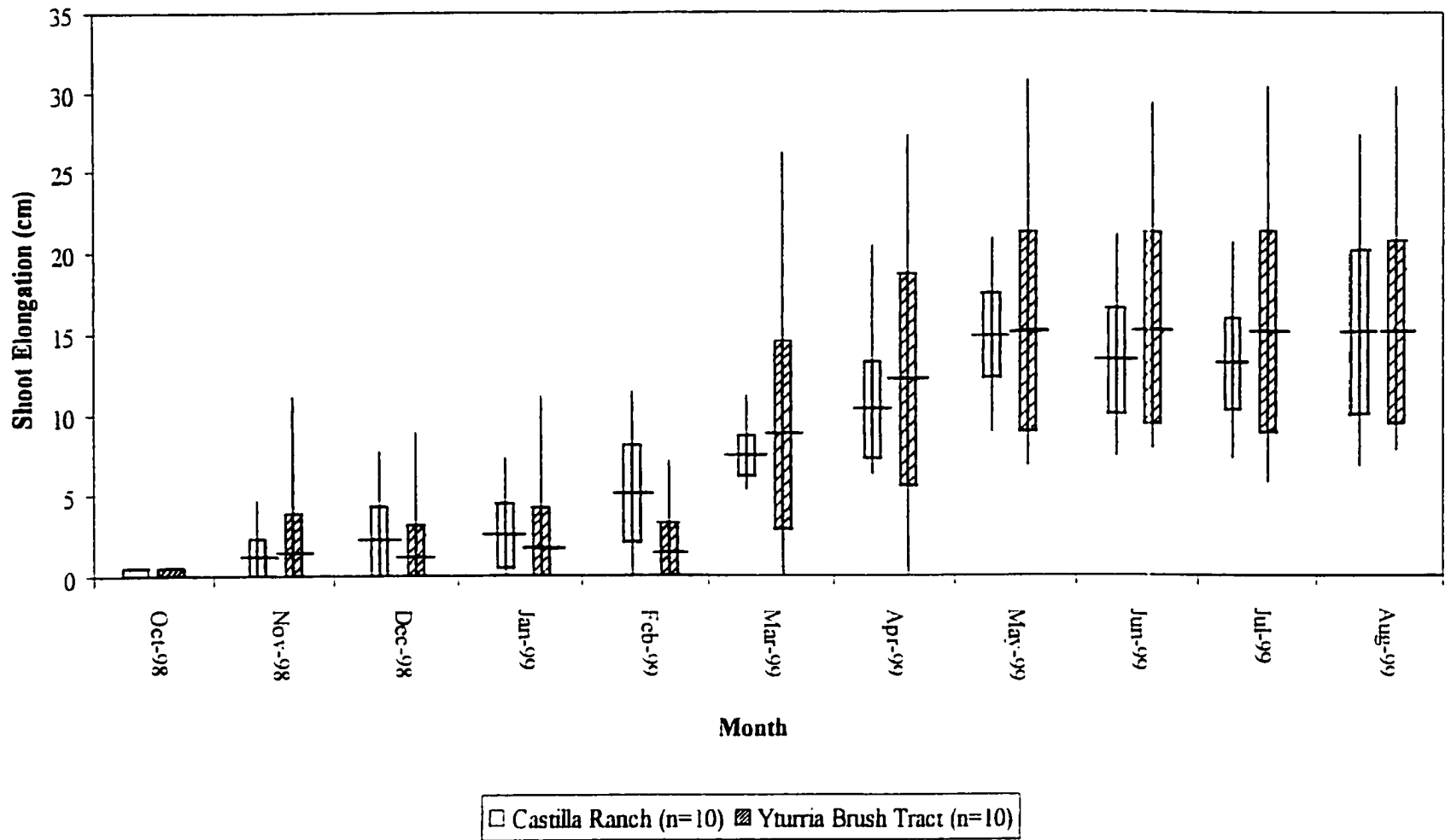


Figure 26. Monthly shoot elongation values of *Acacia schaffneri* for Castilla Ranch and Yturria Brush Tract. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

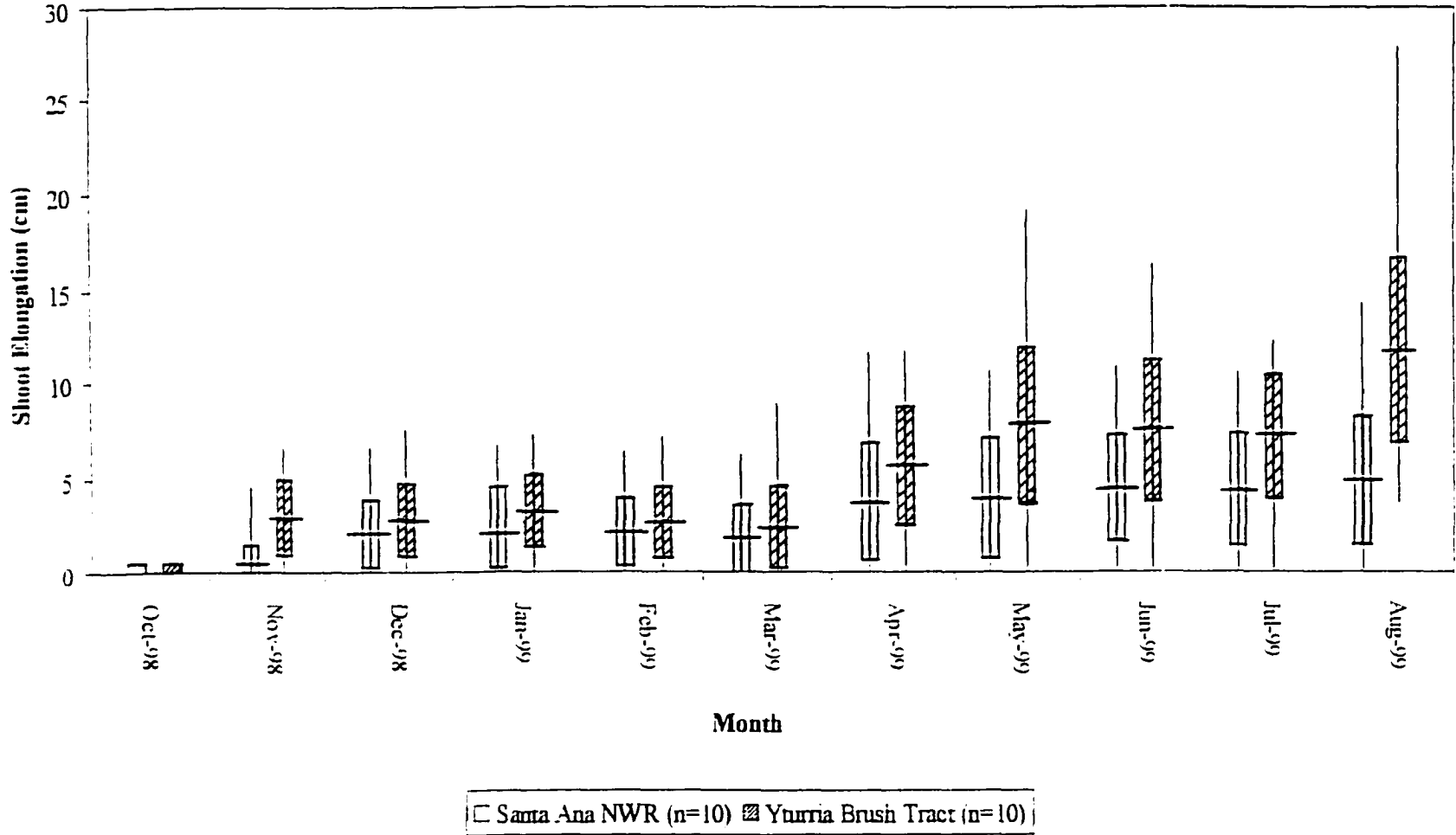


Figure 27 Monthly shoot elongation values of *Chloroleucon ebano* for Santa Ana NWR and Yturria Brush Tract. Vertical lines show the range, horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

df, $P < .05$) and August 1999 ($t = 2.627$, 18 df, $P < .05$). ANOVA showed that significant differences existed in *A. rigidula* between the three sites ($F = 9.253$, 2 and 327 df, $P < .05$). *T*-tests showed that significant differences in monthly shoot elongation in *A. rigidula* was greater at Castilla Ranch than at Yturria Brush Tract (Fig. 28) in May 1999 ($t = 2.81$, 18 df, $P < .05$), June 1999 ($t = 3.51$, 18 df, $P < .05$), July 1999 ($t = 3.28$, 18 df, $P < .05$), and August 1999 ($t = 4.12$, 18 df, $P < .05$). Monthly shoot elongation in *A. rigidula* was greater at Santa Ana NWR than at Yturria Brush Tract (Fig. 28) in June 1999 ($t = 3.32$, 18 df, $P < .05$), July 1999 ($t = 2.79$, 18 df, $P < .05$), and August 1999 ($t = 2.44$, 18 df, $P < .05$). *Acacia rigidula* individuals at Castilla Ranch had greater monthly shoot elongation than individuals at Santa Ana NWR (Fig. 28) in August 1999 ($t = 2.85$, 18 df, $P < .05$)

Correlation Between Shoot Elongation and Climatic Factors (Official Climatic Data)

Correlation coefficients between monthly shoot elongation values (for each species) and the official climatic data are shown in Table 35. All *Acacia* species and *Chloroleucon ebano* had significant positive correlations with mean daily photoperiod. None of the correlations between shoot elongation and monthly precipitation were significant. All species had positive correlations between mean monthly shoot elongation and mean monthly air temperature and except for *A. berlandieri*, the correlations were significant. (Table 35).

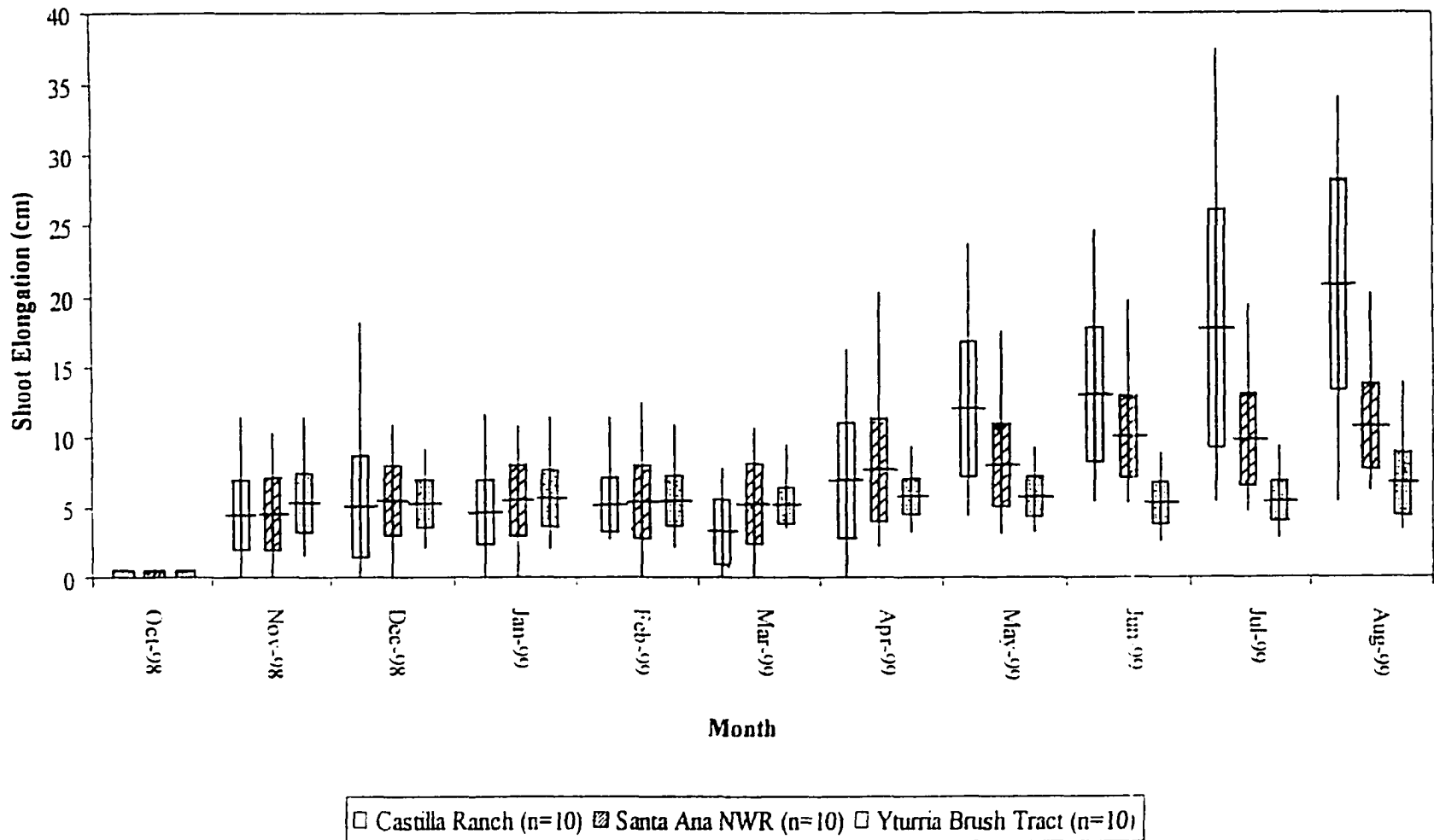


Figure 28. Monthly shoot elongation values of *Acacia rigidula* for Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean

Table 35. Correlation coefficients and *t*-tests of meteorological factors and shoot elongation. R values are based on sample sizes of 11, i.e., 11 months of shoot elongation data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.642	2.512	<.05	-0.351	1.125	ns	0.476	1.624	ns
<i>A. mimata</i>	0.700	2.941	<.05	-0.209	0.641	ns	0.603	2.268	<.05
<i>A. rigidula</i>	0.729	3.195	<.05	-0.066	0.198	ns	0.684	2.813	<.05
<i>A. schaffneri</i>	0.962	10.57	<.05	0.094	0.283	ns	0.885	5.702	<.05
<i>C. ebano</i>	0.816	4.235	<.05	0.047	0.141	ns	0.767	3.586	<.05

Correlation Between Shoot Elongation and Local Observer Climatic Data

Castilla Ranch

Acacia mimata, *A. rigidula*, and *A. schaffneri* at Castilla Ranch had significant positive correlations between mean monthly shoot elongation values and mean daily photoperiod (Table 36). These species had negative correlations with monthly precipitation at Rio Grande City (Table 36), but only that of *A. mimata* was significant. There were significant positive correlations found between mean shoot elongation and mean monthly air temperature in *A. rigidula* and *A. schaffneri* (Table 36). *Acacia mimata* exhibited a positive but nonsignificant correlation with mean monthly air temperature (Table 36) at Castilla Ranch.

Table 36. Correlation coefficients and *t*-tests of meteorological factors and shoot elongation for three species at Castilla Ranch. R values are based on sample sizes of 11, i.e., 11 months of shoot elongation data and the mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. mimata</i>	0.626	2.408	<.05	-0.669	2.700	<.05	0.468	1.589	ns
<i>A. rigidula</i>	0.766	3.575	<.05	-0.233	0.719	ns	0.726	3.53	<.05
<i>A. schaffneri</i>	0.945	8.668	<.05	-0.214	0.657	ns	0.830	4.464	<.05

Santa Ana NWR

Correlation between mean shoot elongation of *A. berlandieri*, *A. minnata*, *A. rigidula*, and *C. ebano* and the local climatic data from Santa Ana NWR and the shoot elongation data showed that all species had positive correlations with mean daily photoperiod. All correlations were significant except for that of *A. berlandieri* (Table 37). *Acacia berlandieri* had a negative correlation with monthly precipitation, and *A. minnata*, *A. rigidula*, and *C. ebano* exhibited positive correlations (Table 37), but none of these values were significant. All species had positive correlations with mean monthly temperature at Santa Ana NWR (Table 37) and the correlations were significant except for that of *A. berlandieri*.

Table 37. Correlation coefficients and *t*-tests of meteorological factors and shoot elongation for four species at Santa Ana NWR. R values are based on sample sizes of 11, i.e., 11 months of shoot elongation data and the mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.495	1.079	ns	-0.177	0.540	ns	0.410	1.349	ns
<i>A. minnata</i>	0.737	3.271	<.05	0.249	0.771	ns	0.747	3.371	<.05
<i>A. rigidula</i>	0.745	3.351	<.05	0.286	0.895	ns	0.756	3.465	<.05
<i>C. ebano</i>	0.834	4.535	<.05	0.357	1.147	ns	0.806	4.085	<.05

Yturria Brush Tract

Correlation between the shoot elongation data of *A. berlandieri*, *A. rigidula*, *A. schaffneri*, and *C. ebano* and the local climatic data for La Joya, Texas showed that all species had significant positive correlations with mean daily photoperiod, except for *A. berlandieri* (Table 38). *Acacia berlandieri*, *A. rigidula*, and *C. ebano* had negative

correlations with monthly precipitation, and *A. schaffneri* had a positive correlation with monthly amount of precipitation (Table 38). None of these values were significant. All species had positive correlations with mean monthly temperature (Table 38). The correlations of *A. berlandieri*, *A. schaffneri*, and *C. ebano* were significant.

Table 38. Correlation coefficients and *t*-tests of meteorological factors and shoot elongation for four species at Yturria Brush Tract. R values are based on sample sizes of 11, i.e., 11 months of shoot elongation data and the mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	0.703	2.965	<.05	-0.084	0.253	ns	0.567	2.065	ns
<i>A. rigidula</i>	0.257	0.798	ns	-0.464	1.571	ns	0.091	0.274	ns
<i>A. schaffneri</i>	0.961	10.425	<.05	0.249	0.771	ns	0.866	5.196	<.05
<i>C. ebano</i>	0.772	3.644	<.05	-0.084	0.253	ns	0.749	3.391	<.05

Leaf Viability Among Species

The conditions of leaves were evaluated at each census as green, yellow, brown, or abscised (Table 39). All five species had green leaves for most of the study, despite the hot and dry environmental conditions during much of the year. *Acacia berlandieri*, *A. rigidula*, and *Chloroleucon ebano* had 100% of individuals with green leaves for five months of the study (Table 39). *Acacia minuta* had 100% of individuals with green leaves for seven months of the study and *A. schaffneri* had 100% of individuals with green leaves for eight months of the study (Table 39). In *A. berlandieri*, *A. minuta*, *A. rigidula*, and *C. ebano*, the minimum mean percentage of individuals with green leaves occurred in August 1998 (Table 39). The minimum mean percentage of individuals with green leaves in *A. schaffneri* occurred in February 1999.

Table 39. Monthly percentages of individuals with green leaves.

	<i>A. berlandieri</i>	<i>A. minuata</i>	<i>A. rigidula</i>	<i>A. schaffneri</i>	<i>C. ebano</i>
Jul-98	45	85	83.3	95	50
Aug-98	22.5	85	70	87.5	45
Sep-98	27.5	92.5	81.7	95	87.5
Oct-98	35	100	75	100	85
Nov-98	82.5	97.5	91.7	100	95
Dec-98	92.5	100	100	100	100
Jan-99	95	97.5	100	90	100
Feb-99	100	92.5	86.7	72.5	97.5
Mar-99	95	100	76.7	95	95
Apr-99	100	100	96.7	100	100
May-99	97.5	100	96.7	100	100
Jun-99	100	100	100	100	100
Jul-99	100	100	100	100	80
Aug-99	100	100	100	100	92.5

The presence of yellow leaves in all species was uncommon. *Acacia minuata* and *Chloroleucon ebano* did not have any individuals with yellow leaves during the study. *Acacia schaffneri* (2.5% of the individuals) and *A. rigidula* (11.7% of the individuals) exhibited yellow leaves only during August 1998. Twenty percent of the *A. berlandieri* individuals exhibited yellow foliage in July 1998, 22.5% of the individuals exhibited yellow leaves in August 1998, and 2.5% of the individuals exhibited yellow foliage in May 1999.

Acacia minuata and *Chloroleucon ebano* did not have any individuals with brown leaves during the study. Two and a half percent of the *A. schaffneri* individuals had brown leaves only during January 1999. *Acacia rigidula* had the highest mean monthly percentages of individuals with brown foliage (February 1999 and March 1999), in

which 3.4% and 5.9% of the individuals (respectively) had brown foliage. *Acacia berlandieri* exhibited brown foliage in 20% of the individuals in July 1998, and 22.5% with brown foliage in August 1998.

Abscised leaves were common in July through September 1998 (Table 40), when most of the high air temperatures were recorded (Fig. 4). *Acacia berlandieri* had individuals with abscised leaves for seven consecutive months of the study (Table 40), with percentages ranging from 5% (January 1999) to 65% (October 1998). *Chloroleucon ehano* had individuals with abscised leaves for five consecutive months and sporadically during other times during the study (Table 40). *Acacia rigidula* had individuals with abscised foliage for five consecutive months and also four consecutive months during the study (Table 40). *Acacia schaffneri* exhibited two three-month periods (July 1998 through September 1998 and January 1999 through March 1999) in which individuals possessed abscised leaves (Table 40). *Acacia minima* had a three month period in which individuals lacked foliage, followed by a two month period four months afterward (Table 40).

Leaf Viability Among Sites

Chi-square tests showed that significant differences in monthly percentage of individuals with green leaves at Santa Ana NWR and Yturria Brush Tract existed in *A. berlandieri* (Fig. 29) in July 1998 ($\chi^2 = 10.0$), August 1998 ($\chi^2 = 33.75$), and September 1998 ($\chi^2 = 36.818$). *Acacia berlandieri* had significant differences in monthly percentage of individuals with abscised leaves at Santa Ana NWR and Yturria Brush Tract (Fig. 30) in December 1998 ($\chi^2 = 15.0$), January 1999 ($\chi^2 = 10.0$), and March 1999 ($\chi^2 = 10.0$).

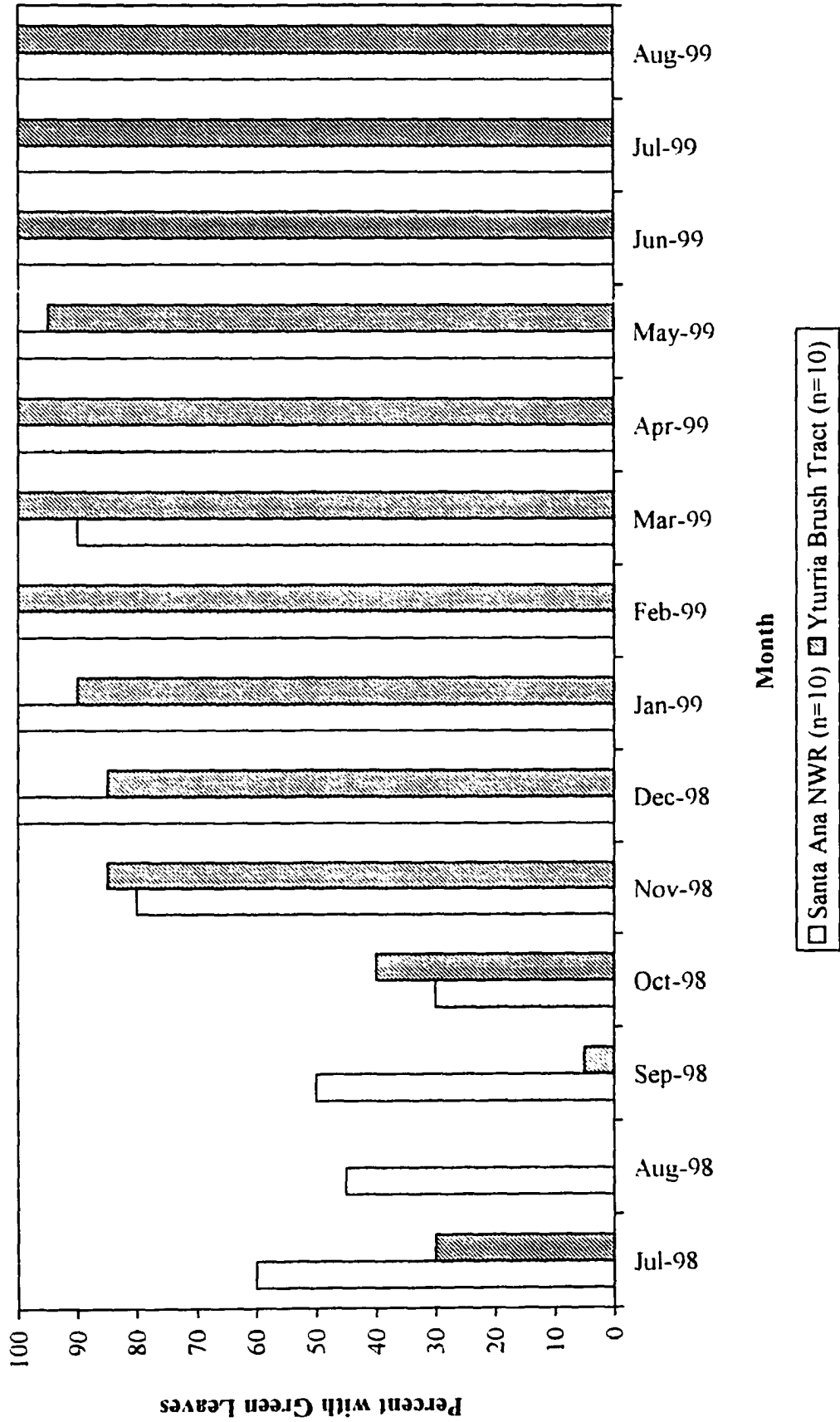


Figure 29. Monthly percentage of *Acacia berlandieri* individuals with green leaves at Santa Ana NWR and Yturria Brush Tract.

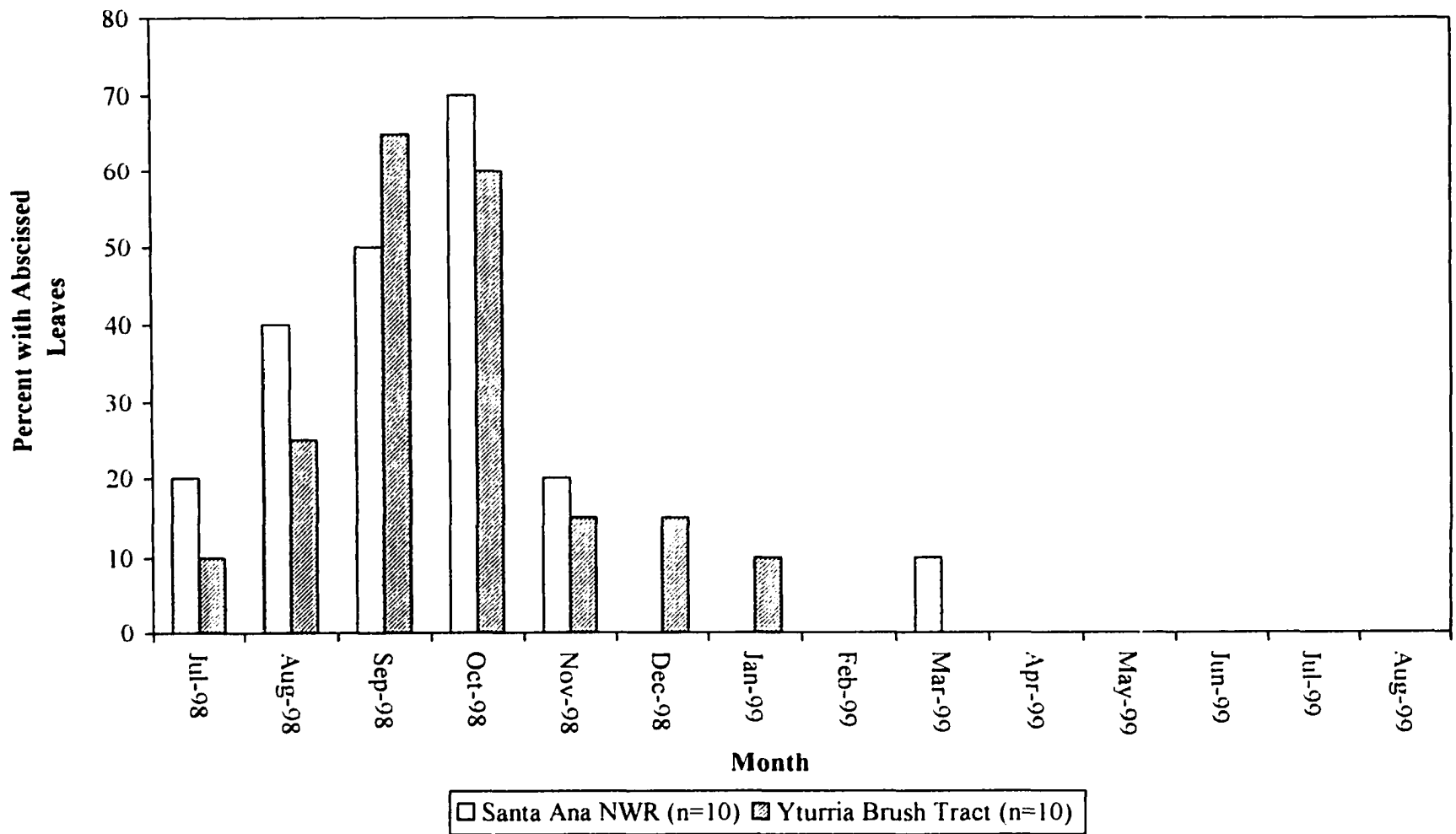


Figure 30. Monthly percentage of *Acacia berlandieri* individuals with abscised leaves at Santa Ana NWR and Yturria Brush Tract.

Table 40. Monthly percentages of individuals with abscised leaves.

	<i>A. berlandieri</i>	<i>A. minuata</i>	<i>A. rigidula</i>	<i>A. schaffneri</i>	<i>C. ebano</i>
Jul-98	15	15	16.7	5	50
Aug-98	32.5	15	18.4	10	55
Sep-98	57.5	7.5	18.4	5	35
Oct-98	65	0	10	0	15
Nov-98	17.5	2.5	8.4	0	5
Dec-98	7.5	0	0	0	0
Jan-99	5	2.5	0	7.5	0
Feb-99	0	7.5	10	27.5	2.5
Mar-99	5	0	18.3	5	5
Apr-99	0	0	3.3	0	0
May-99	0	0	3.3	0	0
Jun-99	0	0	0	0	0
Jul-99	0	0	0	0	20
Aug-99	0	0	0	0	7.5

Acacia minuata exhibited significant differences in monthly percentage of individuals with green leaves at Castilla Ranch and Santa Ana NWR (Fig. 31) in July 1998 ($\chi^2 = 5.294$) and August 1998 ($\chi^2 = 5.294$). Significant differences were found in the monthly percentage of *A. minuata* individuals with abscised leaves at Castilla Ranch and Santa Ana NWR (Fig. 32) in July 1998 ($\chi^2 = 30.0$), August 1998 ($\chi^2 = 30.0$), September 1998 ($\chi^2 = 15.0$), November 1998 ($\chi^2 = 5.0$), January 1999 ($\chi^2 = 5.0$), and February 1999 ($\chi^2 = 15.0$).

No significant differences were found between monthly percentage of individuals with green foliage in *A. schaffneri* at Castilla Ranch and Yturria Brush Tract (Fig. 33). Significant differences existed in monthly percentage of individuals with abscised foliage in *A. schaffneri* at Castilla Ranch and Yturria Brush Tract (Fig. 34) in July 1998

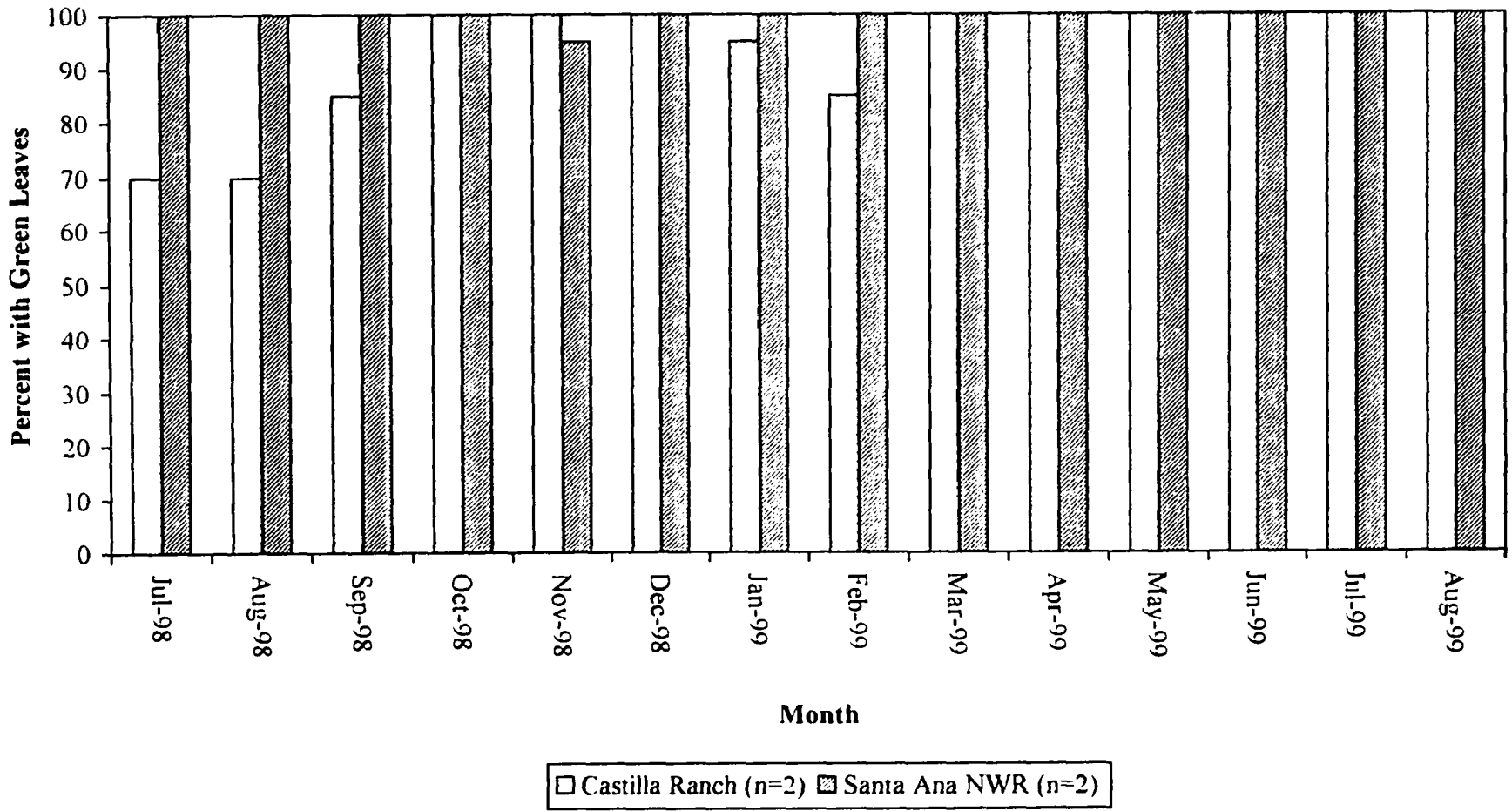


Figure 31. Monthly percentage of *Acacia mimuta* individuals with green leaves at Castilla Ranch and Santa Ana NWR.

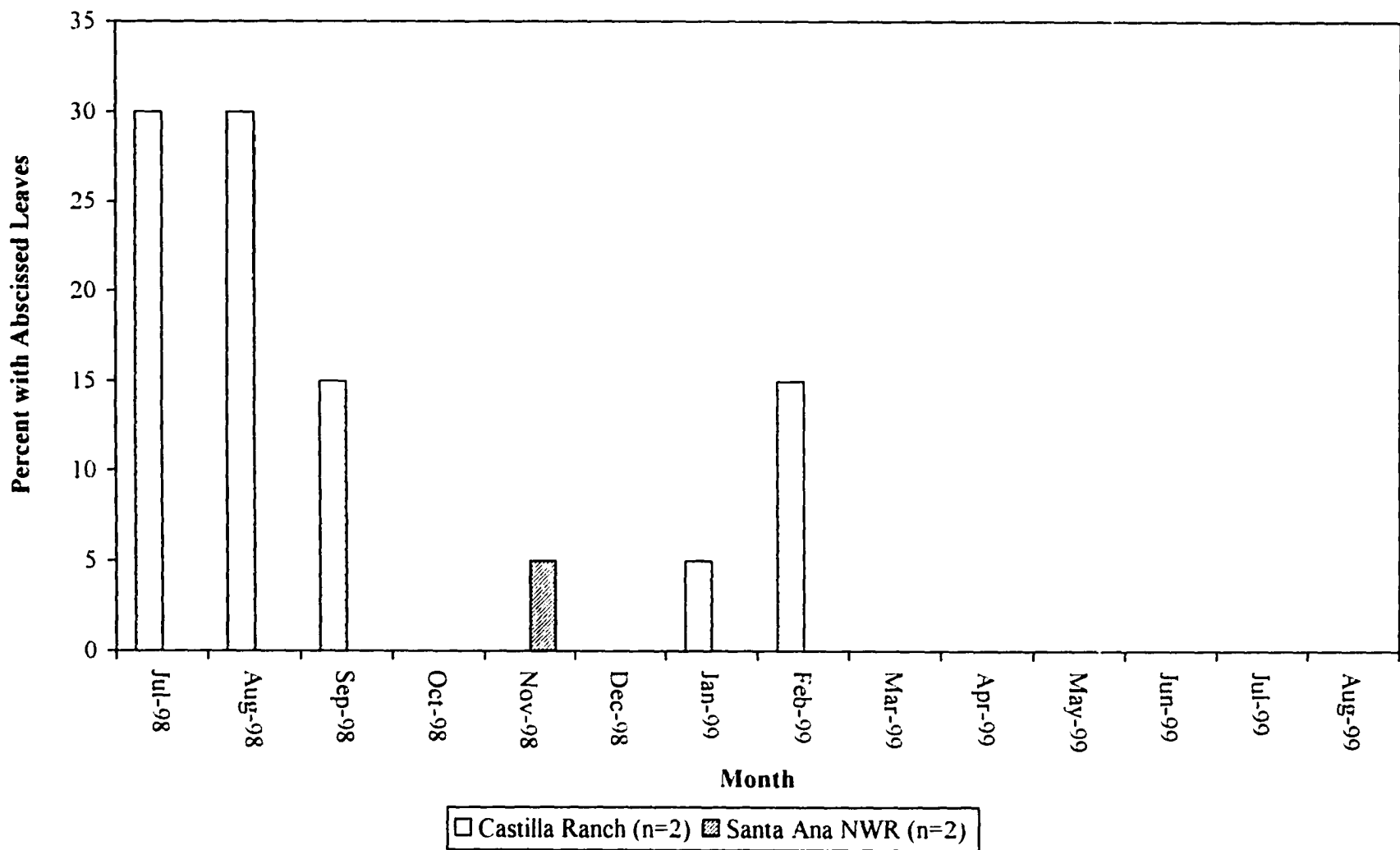


Figure 32. Monthly percentage of *Acacia mimuta* individuals with abscised leaves at Castilla Ranch and Santa Ana NWR.

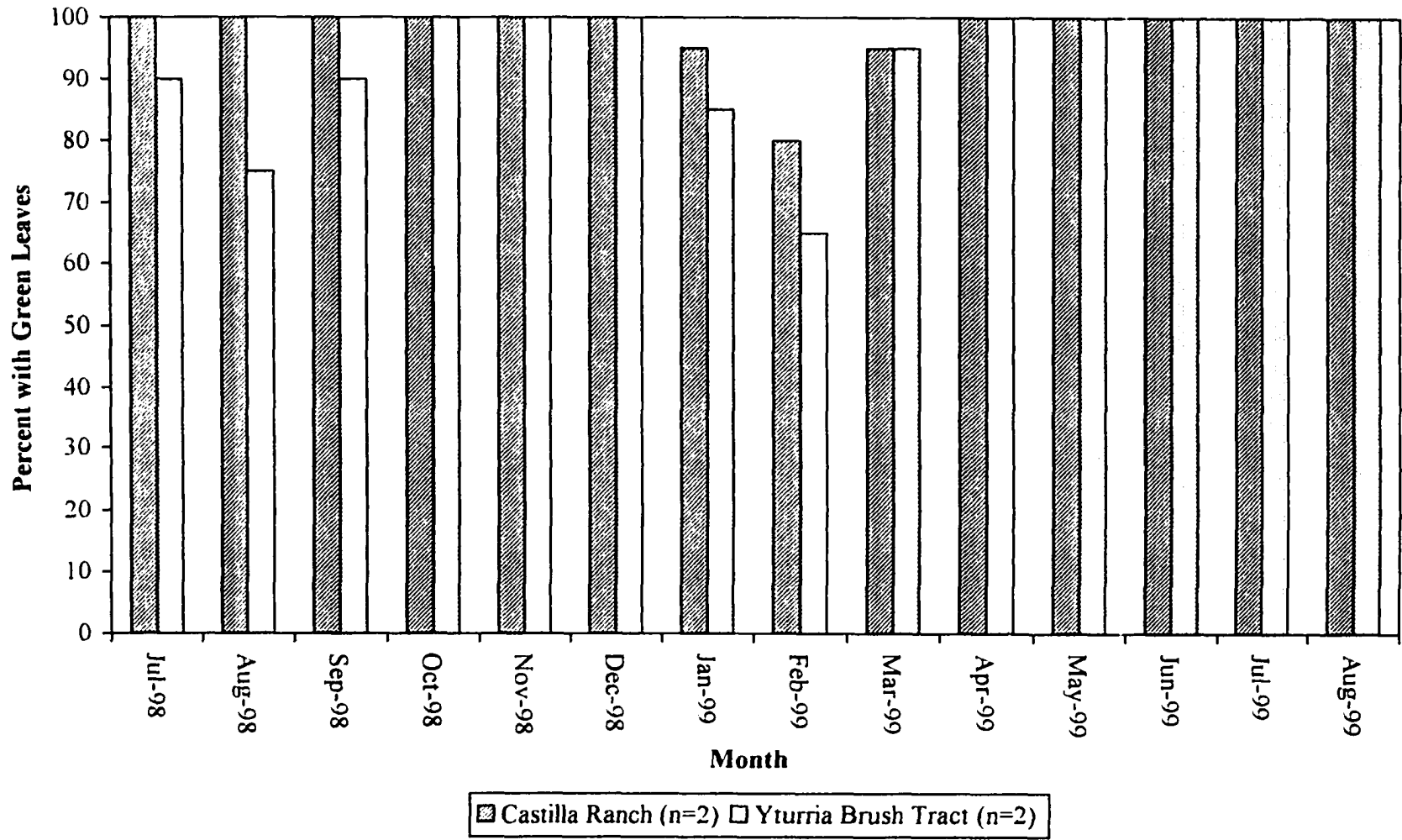


Figure 33. Monthly percentage of *Acacia schaffneri* individuals with green leaves at Castilla Ranch and Yturria Brush Tract.

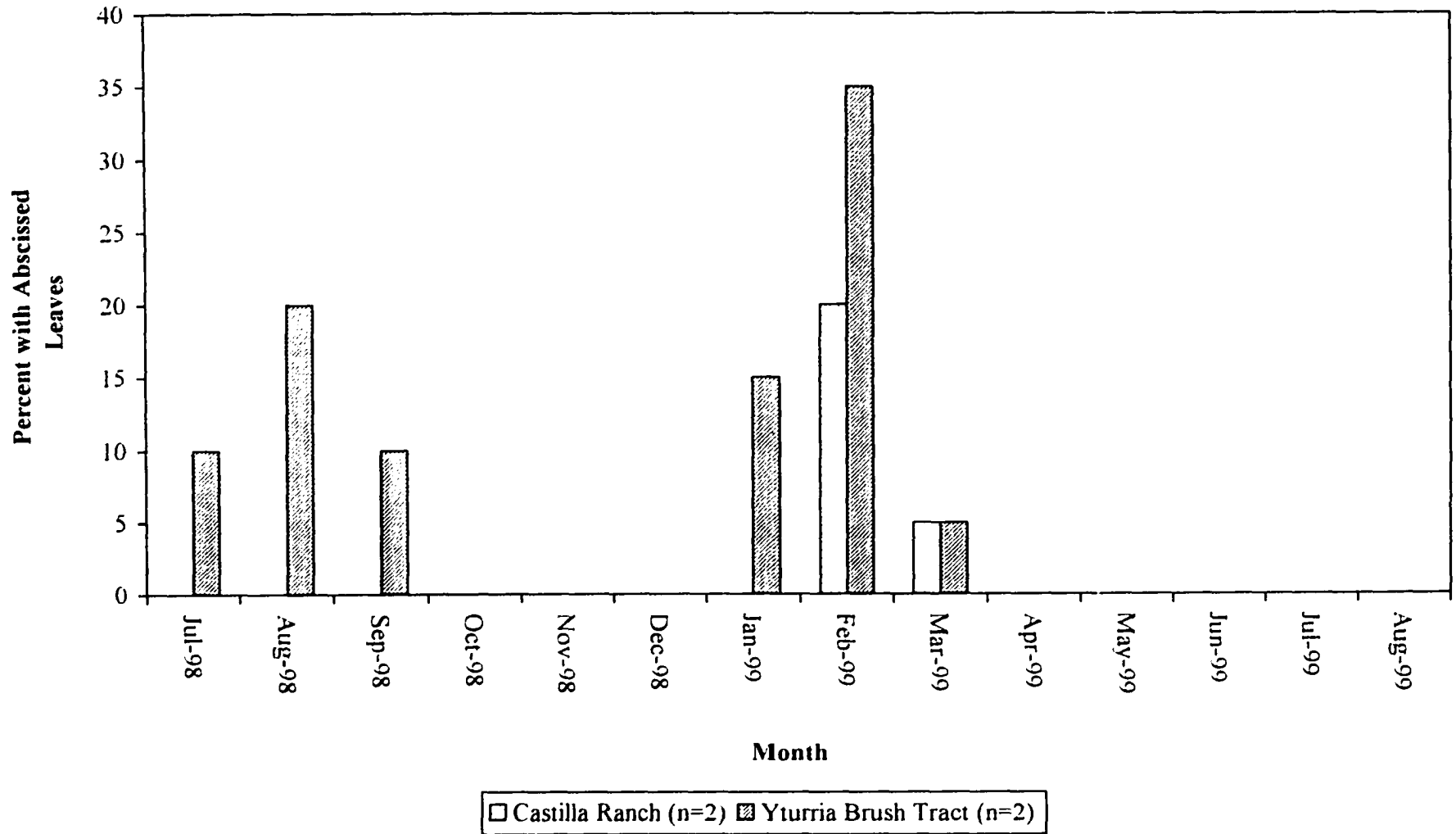


Figure 34. Monthly percentage of *Acacia schaffneri* individuals with abscised leaves at Castilla Ranch and Yturria Brush Tract.

($\chi^2 = 10.0$), August 1998 ($\chi^2 = 20.0$), September 1998 ($\chi^2 = 10.0$), January 1999 ($\chi^2 = 15.0$), and February 1999 ($\chi^2 = 4.091$).

Chi-square tests showed that significant differences in monthly percentage of individuals with green foliage in *C. ebano* at Santa Ana NWR and Yturria Brush Tract (Fig. 35) existed in July 1998 ($\chi^2 = 4.0$), August 1998 ($\chi^2 = 27.778$), September 1998 ($\chi^2 = 27.692$), and July 1999 ($\chi^2 = 10.0$). Significant differences in monthly percentage of individuals with abscised foliage in *C. ebano* at Santa Ana NWR and Yturria Brush Tract (Fig. 36) were found in July 1998 ($\chi^2 = 4.0$), August 1998 ($\chi^2 = 22.727$), and September 1998 ($\chi^2 = 51.429$). Monthly percentages of individuals with abscised foliage in *C. ebano* at Santa Ana NWR and Yturria Brush Tract were significantly different during February 1999 ($\chi^2 = 5.0$), July 1999 ($\chi^2 = 40.0$), and August 1999 ($\chi^2 = 15.0$).

G-tests were performed on the leaf viability data for *A. rigidula* because it was present at all three study sites. Significant differences in monthly percentage of individuals with green leaves in *A. rigidula* (Fig. 37) existed in July 1998 ($\chi^2 = 11.097$) and August 1998 ($\chi^2 = 19.190$). *Acacia rigidula* exhibited significant differences between sites in monthly percentage of individuals with abscised foliage (Fig. 38) during July 1998 ($\chi^2 = 59.621$), August 1998 ($\chi^2 = 48.945$), September 1998 ($\chi^2 = 45.257$), October 1998 ($\chi^2 = 38.883$), November 1998 ($\chi^2 = 27.566$), February 1999 ($\chi^2 = 27.726$), March 1999 ($\chi^2 = 20.236$), April 1999 ($\chi^2 = 22.173$), and May 1999 ($\chi^2 = 22.173$).

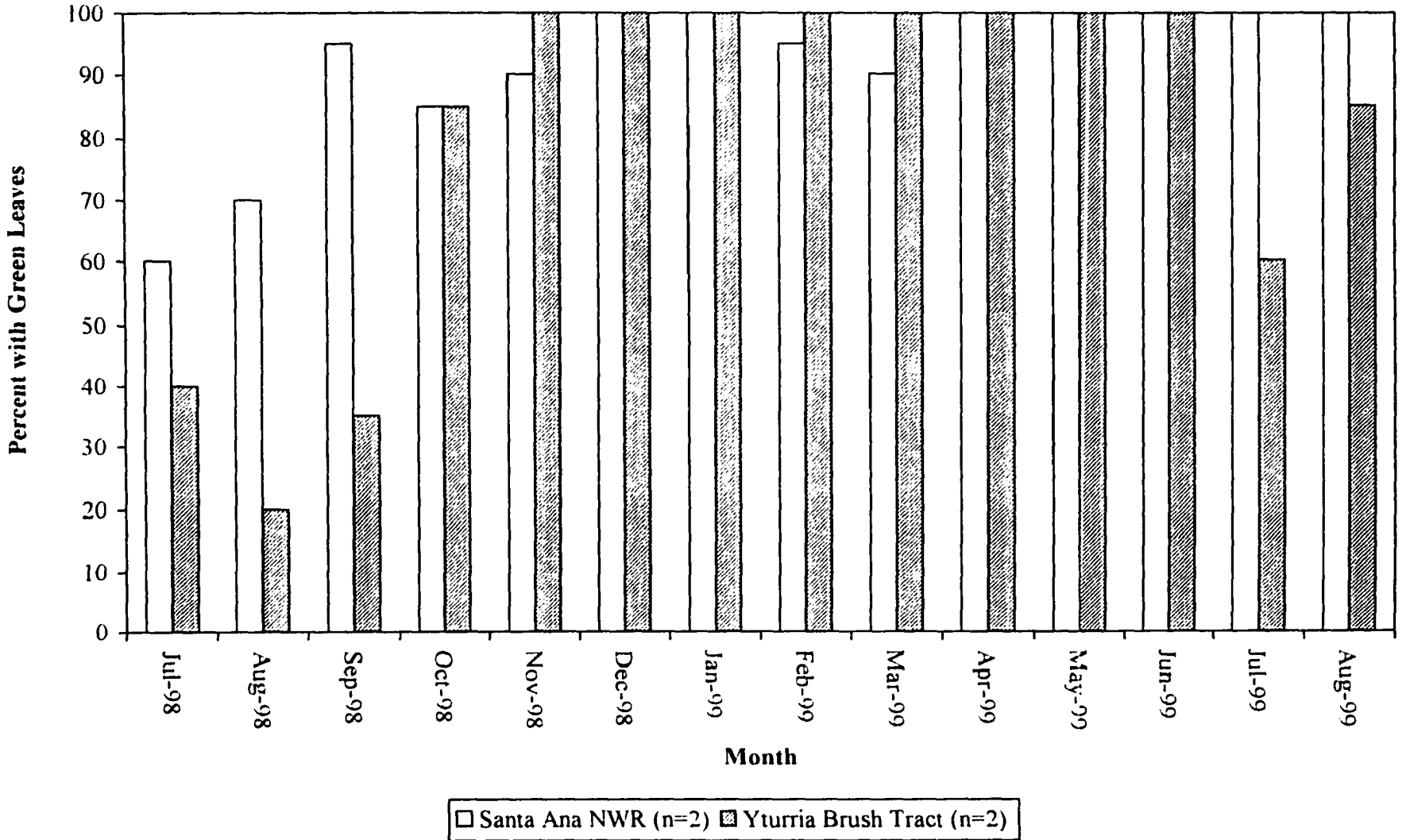


Figure 35. Monthly percentage of *Chloroleucon ebano* individuals with green leaves at Santa Ana NWR and Yturria Brush Tract.

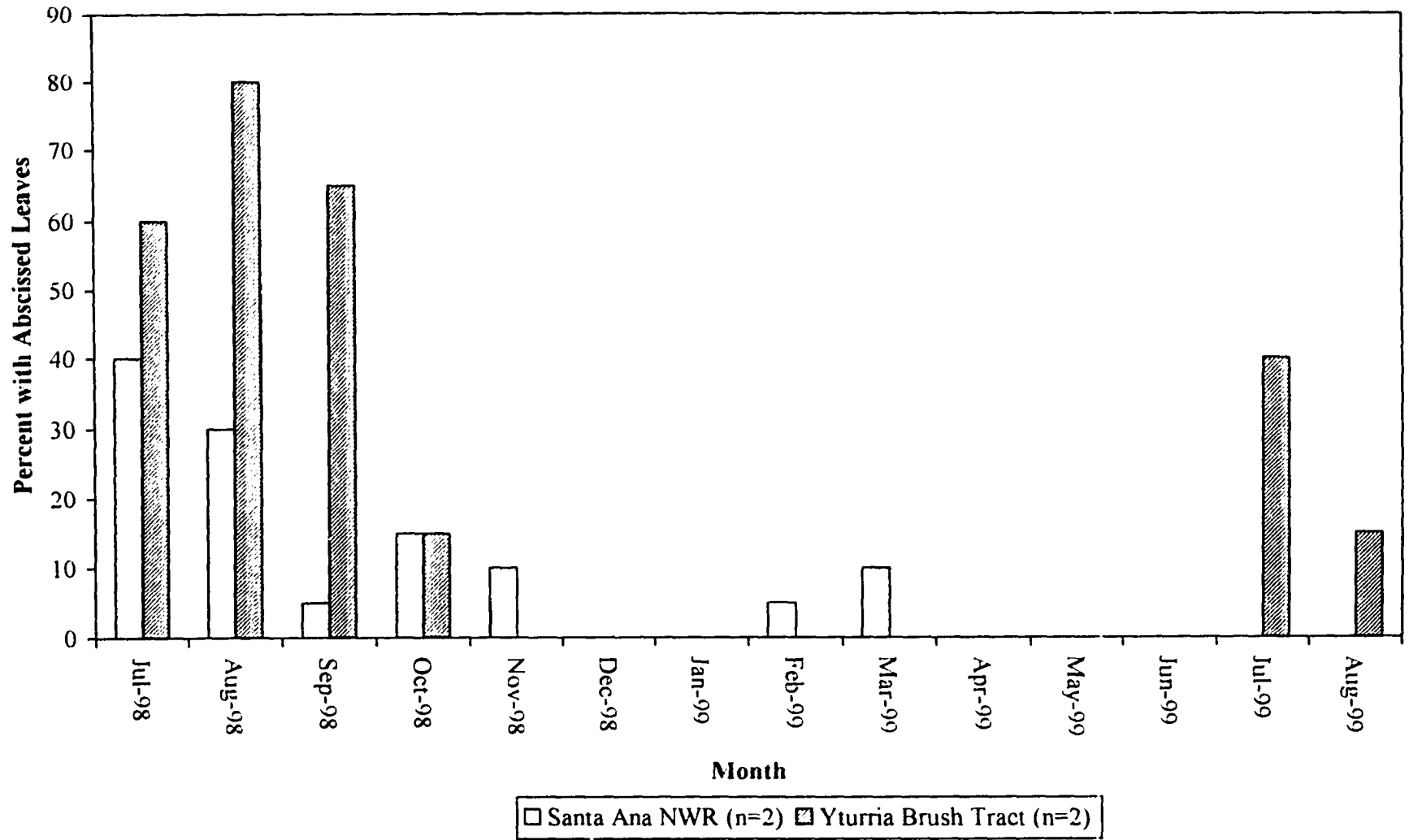


Figure 36. Monthly percentage of *Chloroleucon ebano* individuals with abscised leaves at Santa Ana NWR and Yturria Brush Tract.

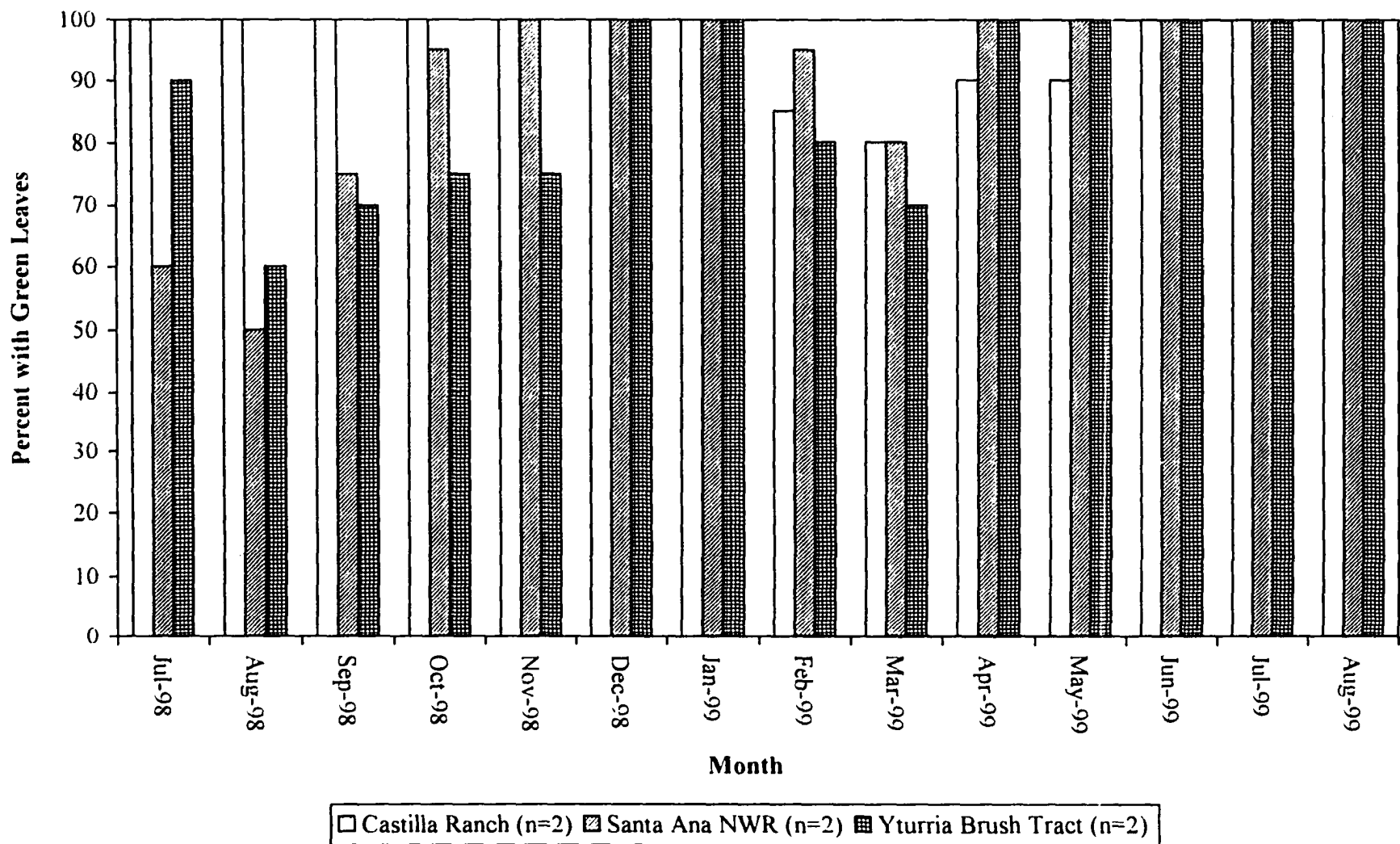


Figure 37. Monthly percentage of *Acacia rigidula* individuals with green leaves at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract.

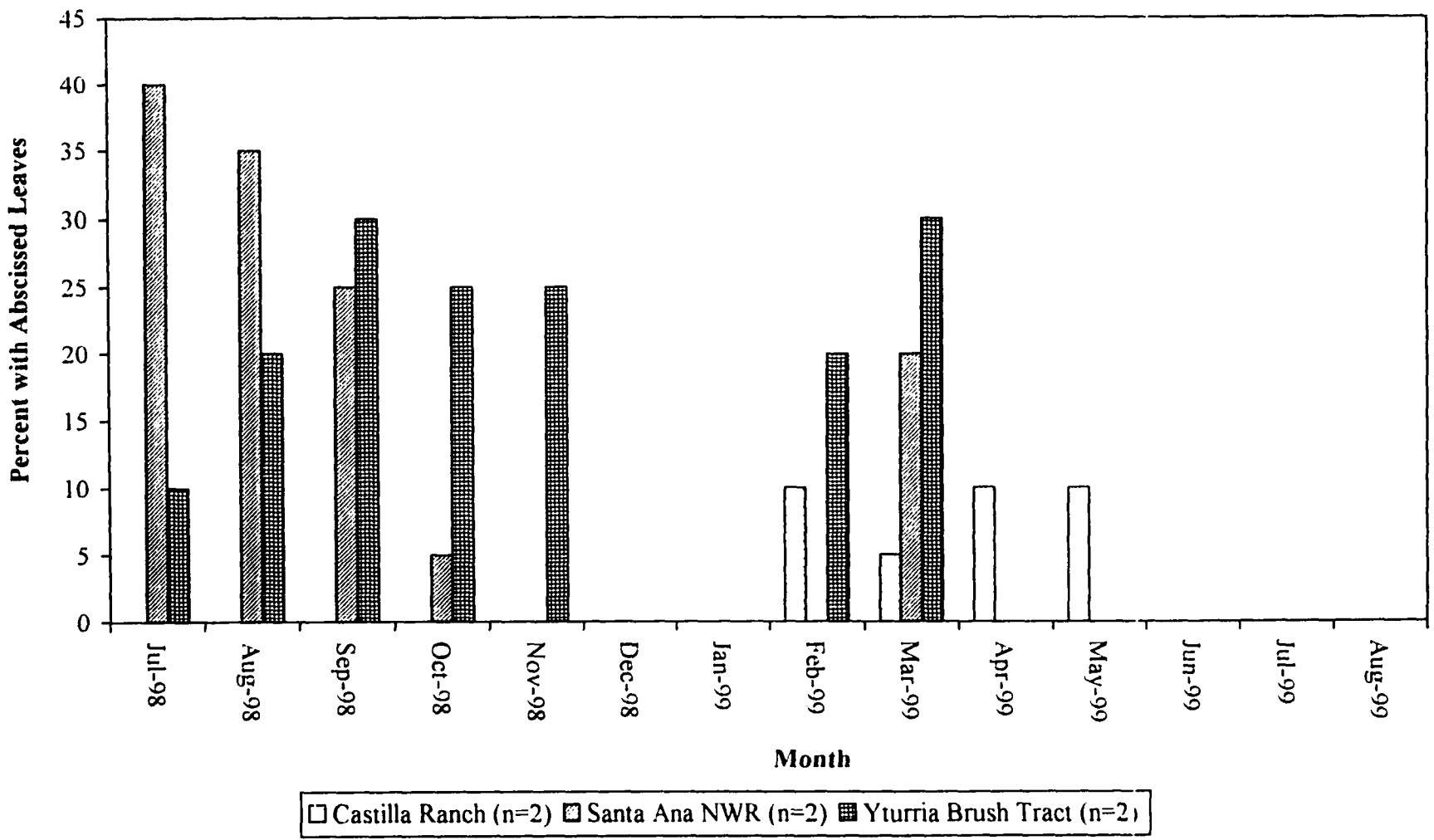


Figure 38. Monthly percentage of *Acacia rigidula* individuals with abscised leaves at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract.

Correlation Between Leaf Condition and Climatic Factors (Official Data)

Correlation coefficients are shown in Table 41 for the monthly percentage of individuals with green leaves and mean daily photoperiod, monthly precipitation, and mean monthly air temperature. The only significant correlation was between *C. ebano* and mean monthly temperature. *Acacia berlandieri*, *A. minuata*, and *A. rigidula* had negative correlations with mean daily photoperiod, monthly precipitation, and mean monthly temperature, while *Acacia schaffneri* had positive correlations with mean daily photoperiod, monthly precipitation, and mean monthly temperature. *Chloroleucon ebano* had negative correlations with mean daily photoperiod and mean monthly temperature, and a positive correlation with monthly precipitation.

Table 41. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with green foliage. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.081	0.282	ns	-0.505	2.027	ns	-0.321	1.174	ns
<i>A. minuata</i>	-0.194	0.685	ns	-0.063	0.219	ns	-0.352	1.303	ns
<i>A. rigidula</i>	-0.019	0.066	ns	-0.335	1.232	ns	-0.169	0.594	ns
<i>A. schaffneri</i>	0.225	0.800	ns	0.121	0.422	ns	0.193	0.681	ns
<i>C. ebano</i>	-0.424	1.622	ns	0.015	0.052	ns	-0.559	2.335	<.05

None of the correlations with mean daily photoperiod were significant. Positive correlations were found between monthly percentage of individuals with abscised foliage and mean daily photoperiod in *A. minuata*, *A. rigidula*, and *C. ebano* (Table 42). *Acacia berlandieri* and *A. schaffneri* exhibited negative correlations between monthly percentage with abscised leaves and mean daily photoperiod (Table 42).

Acacia berlandieri, *A. minnata*, *A. rigidula*, and *C. ebano* had positive correlations between monthly percentage of individuals with abscised foliage and monthly precipitation (Table 42). *Acacia schaffneri* exhibited a negative correlation between monthly percentage of individuals with abscised leaves and monthly amount of precipitation (Table 42). The only correlation that was significant was that between *A. berlandieri* and monthly precipitation (Table 42).

Acacia berlandieri, *A. minnata*, *A. rigidula*, and *Chloroleucon ebano* had positive correlations between monthly percentage of individuals with abscised foliage and mean monthly temperature (Table 42). *Acacia schaffneri* exhibited a negative correlation between monthly percentage of individuals with abscised leaves and mean monthly temperature (Table 42). Only the correlation in *C. ebano* between monthly percentage with abscised foliage and mean monthly temperature was significant (Table 42).

Table 42. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with abscised foliage. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.162	0.569	ns	0.661	3.051	<.05	0.081	0.282	ns
<i>A. minnata</i>	0.194	0.685	ns	0.063	0.219	ns	0.352	1.303	ns
<i>A. rigidula</i>	0.074	0.257	ns	0.434	1.669	ns	0.210	0.744	ns
<i>A. schaffneri</i>	-0.215	0.763	ns	-0.103	0.359	ns	-0.188	0.663	ns
<i>C. ebano</i>	0.406	1.539	ns	0.271	0.975	ns	0.574	2.428	<.05

Correlations Between Leaf Condition and Local Observer Data

Castilla Ranch

Correlations between the monthly percentage of individuals with green leaves and mean daily photoperiod, monthly precipitation, and mean monthly temperature for Rio Grande City, Texas (Castilla Ranch) showed that *Acacia mimata* had negative correlations with mean daily photoperiod and mean monthly temperature, and *A. rigidula* and *A. schaffneri* had positive correlations with mean daily photoperiod and mean monthly temperature (Table 43). None of these coefficients were significant. All three species had positive, but nonsignificant correlations with monthly precipitation (Table 43).

Table 43. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with green foliage at Castilla Ranch. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. mimata</i>	-0.239	0.853	ns	0.073	0.254	ns	-0.346	1.277	ns
<i>A. rigidula</i>	0.023	0.080	ns	0.203	0.718	ns	0.205	0.726	ns
<i>A. schaffneri</i>	0.341	1.257	ns	0.223	0.792	ns	0.436	1.678	ns

None of the correlations between monthly percentage of individuals with abscised foliage and the climatic factors were significant. *Acacia schaffneri* had negative correlations between monthly percentage with abscised foliage and mean daily photoperiod, monthly precipitation, and mean monthly temperature (Table 44). *Acacia rigidula* had a positive correlation between monthly percentage with abscised leaves and mean daily photoperiod, and negative correlations with monthly precipitation and

mean monthly air temperature (Table 44). *Acacia mimuta* had positive correlations between monthly percentage with abscised foliage and mean daily photoperiod and mean monthly temperature (Table 44). A negative correlation existed in *A. mimuta* between mean monthly percentage with abscised foliage and monthly precipitation (Table 44).

Table 44. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with abscised foliage at Castilla Ranch. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. mimuta</i>	0.239	0.853	ns	-0.073	0.254	ns	0.346	1.277	ns
<i>A. rigidula</i>	0.066	0.229	ns	-0.313	1.142	ns	-0.118	0.412	ns
<i>A. schaffneri</i>	-0.240	0.856	ns	-0.177	0.623	ns	-0.325	1.190	ns

Santa Ana NWR

Correlation coefficients between the leaf viability data of the species found at Santa Ana NWR (*A. berlandieri*, *A. mimuta*, *A. rigidula*, and *C. ebano*) and the local observer climatic data for SANWR showed that *Acacia berlandieri*, *A. rigidula*, and *Chloroleucon ebano* had negative but nonsignificant correlations between monthly percentage of individuals with green foliage and mean daily photoperiod (Table 45). None of the correlations with mean monthly air temperature were significant. *Acacia mimuta* had a positive correlation between monthly percentage of individuals with green leaves and mean daily photoperiod (Table 45). *Acacia mimuta*, *A. rigidula*, and *C. ebano* had positive correlations between monthly percentage of individuals with green foliage and monthly precipitation (Table 45). *Acacia berlandieri* had a negative correlation between

monthly percentage of individuals with green foliage and monthly precipitation (Table 45). Positive correlations between monthly percentage of individuals with green leaves and mean monthly temperature were found in *A. berlandieri* and *A. minnata* (Table 45). *Acacia rigidula* and *C. ebano* had negative correlations between mean monthly percentage with green foliage and mean monthly temperature (Table 45).

Table 45. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with green foliage at Santa Ana NWR. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.024	0.083	ns	-0.292	1.058	ns	0.043	0.149	ns
<i>A. minnata</i>	0.394	1.485	ns	0.198	0.700	ns	0.235	0.838	ns
<i>A. rigidula</i>	-0.322	1.178	ns	0.016	0.055	ns	-0.185	0.652	ns
<i>C. ebano</i>	-0.216	0.766	ns	0.204	0.722	ns	-0.116	0.405	ns

None of the correlations between monthly percentage of individuals with abscised foliage and mean daily photoperiod were significant. Positive correlations between monthly percentage of individuals with abscised foliage and mean daily photoperiod were found in *Acacia rigidula* and *Chloroleucon ebano* (Table 46). *Acacia berlandieri* and *A. minnata* had negative correlations between monthly percentage of individuals with abscised foliage and mean daily photoperiod (Table 46). *Acacia berlandieri*, *A. rigidula*, and *C. ebano* had positive correlations between monthly percentage of individuals with abscised foliage and monthly precipitation (Table 46). *Acacia minnata* had a negative correlation between monthly percentage of individuals with abscised foliage and monthly precipitation (Table 46). Positive correlations between monthly

percentage of individuals with abscised foliage and mean monthly temperature existed in *A. rigidula* and *C. ebano* (Table 46). *Acacia berlandieri* and *A. minucata* had negative correlations between monthly percentage with abscised foliage and mean monthly temperature (Table 46).

Table 46. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with abscised foliage at Santa Ana NWR. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.081	0.282	ns	0.401	1.516	ns	-0.124	0.433	ns
<i>A. minucata</i>	-0.394	1.485	ns	-0.198	0.700	ns	-0.235	0.838	ns
<i>A. rigidula</i>	0.334	1.228	ns	0.051	0.177	ns	0.179	0.630	ns
<i>C. ebano</i>	0.216	0.766	ns	-0.204	0.722	ns	0.116	0.405	ns

Yturria Brush Tract

Correlation coefficients for the leaf viability data collected at Yturria Brush Tract and the local observer data for La Joya, Texas showed that *Acacia rigidula* and *A. schaffneri* had positive correlations between monthly percentage of individuals with green leaves and mean daily photoperiod (Table 47). Negative correlations between monthly percentage of individuals with green foliage and mean daily photoperiod were found in *A. berlandieri*, and *Chloroleucon ebano* (Table 47). None of the correlations with mean daily photoperiod were significant. *Acacia berlandieri*, *A. rigidula*, and *C. ebano* had negative but nonsignificant correlations between monthly percentage of individuals with green foliage and monthly precipitation (Table 47). *Acacia schaffneri*

had a positive but nonsignificant correlation between monthly percentage of individuals with green leaves and monthly precipitation (Table 47). Negative correlations between monthly percentage with green foliage and mean monthly temperature were found in *A. berlandieri*, *A. rigidula*, and *C. ebano* (Table 47). *Acacia schaffneri* had a positive correlation between monthly percentage of individuals with green leaves and mean monthly temperature (Table 47). The correlation between monthly percentage of individuals with green foliage and mean monthly temperature in *C. ebano* was the only one that was significant.

Table 47. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with green foliage at Yturria Brush Tract. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.116	0.405	ns	-0.326	1.195	ns	-0.402	1.521	ns
<i>A. rigidula</i>	0.154	0.540	ns	-0.334	1.228	ns	-0.086	0.299	ns
<i>A. schaffneri</i>	0.148	0.518	ns	0.308	1.121	ns	0.077	0.268	ns
<i>C. ebano</i>	-0.445	1.721	ns	-0.280	1.010	ns	-0.641	2.893	<.05

None of the correlations with mean daily photoperiod were significant. Inverse correlations between monthly percentage of individuals with abscised foliage and mean daily photoperiod existed in *Acacia berlandieri*, *A. rigidula*, and *A. schaffneri* (Table 48). *Chloroleucon ebano* had a positive correlation between monthly percentage of individuals with abscised leaves and mean daily photoperiod (Table 48). *Acacia berlandieri*, *A. rigidula*, and *C. ebano* had positive correlations between monthly percentage with abscised leaves and monthly precipitation (Table 48). *Acacia schaffneri*

had a negative correlation between monthly percentage of individuals with abscised leaves and monthly precipitation (Table 48). Only the correlation between *A. berlandieri* and monthly precipitation was significant. *Acacia berlandieri* and *C. ebano* had positive correlations between monthly percentage of individuals with abscised foliage and mean monthly temperature (Table 48). *Acacia rigidula* and *A. schaffneri* had negative correlations between monthly percentage with abscised foliage and mean monthly temperature (Table 48). Only the positive correlation between monthly percentage of individuals with abscised leaves and mean monthly temperature in *C. ebano* was significant.

Table 48. Correlation coefficients and *t*-tests of meteorological factors and percentage of individuals with abscised foliage at Yturria Brush Tract. R values are based on sample sizes of 14, i.e., 14 months of leaf viability data and mean daily photoperiod, monthly precipitation, and mean monthly temperature. The level of probability is given for significant values. "ns" = nonsignificant.

Species	PHOTOPERIOD			PRECIPITATION			TEMPERATURE		
	r	t	P	r	t	P	r	t	P
<i>A. berlandieri</i>	-0.238	0.849	ns	0.641	2.893	< .05	0.058	0.201	ns
<i>A. rigidula</i>	-0.268	0.964	ns	0.433	1.664	ns	-0.041	0.142	ns
<i>A. schaffneri</i>	-0.184	0.648	ns	-0.310	1.130	ns	-0.124	0.433	ns
<i>C. ebano</i>	0.445	1.721	ns	0.280	1.010	ns	0.641	2.893	<.05

Mean Leaf Measurements and Time Needed For Maturation

Mature leaf length measurements in *Acacia berlandieri* ranged from 11.0 mm to 155.0 mm (n = 344), with a mean of 95.6 mm (SE = 1.06). Leaflet lengths ranged from 19.0 mm to 150.0 mm (n = 344), with a mean of 51.6 mm (SE = .796). Leaflet widths ranged from one mm to 15.0 mm (n = 344), with a mean of 4.4 mm (SE = .117). Figure 39 shows the time needed for leaves to reach the mature size range. The leaves of

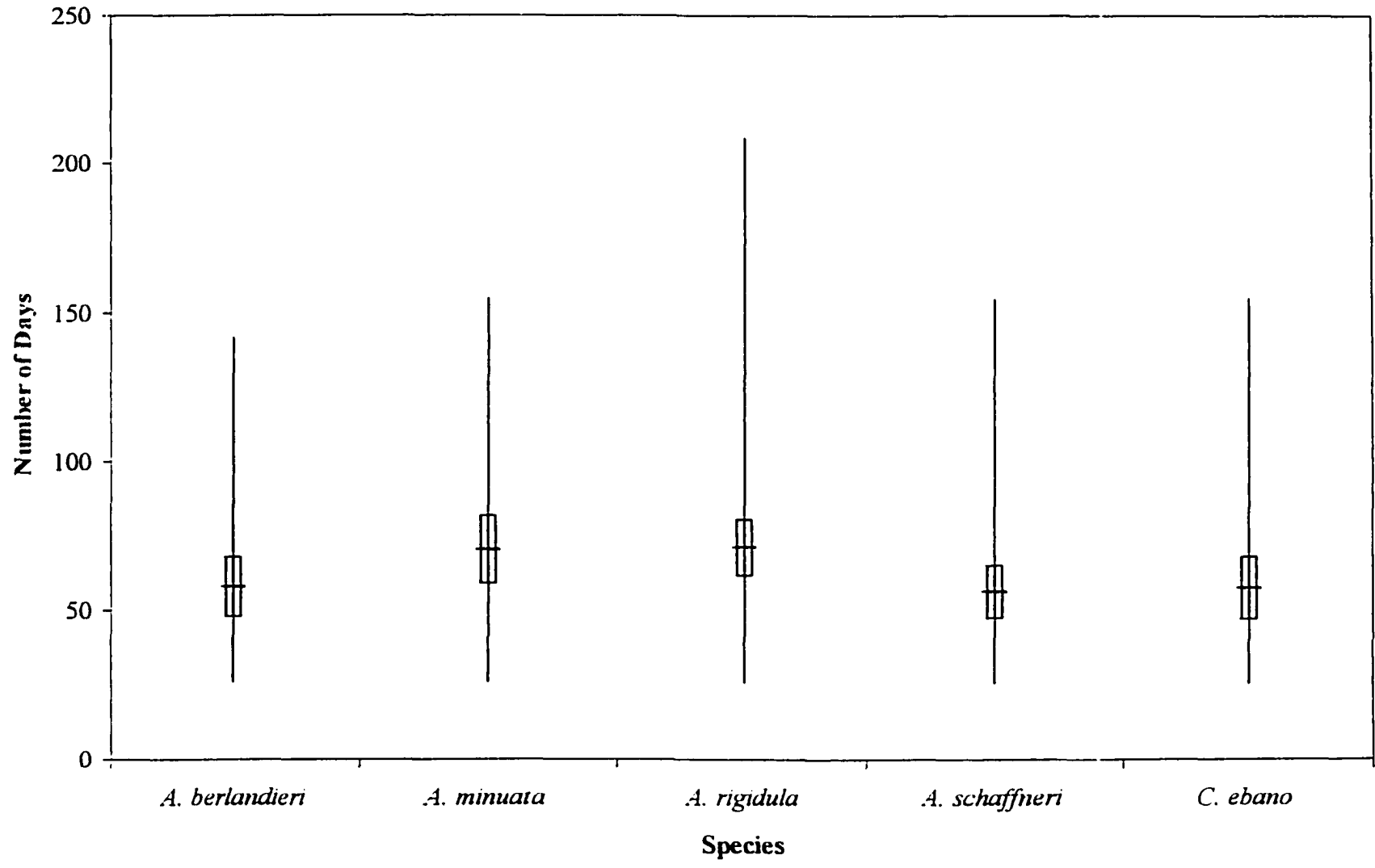


Figure 39. The number of days needed for leaf maturation for all species. Vertical lines show the range; horizontal lines denote the mean. Vertical bars represent 95% confidence intervals about the mean.

individuals at Santa Ana NWR and Yturria Brush Tract took an average of 57.5 days ($n = 54$, $SE = 4.91$) to reach the mature size range.

Mature leaf length measurements in *Acacia mimuata* ranged from 7.0 mm to 35.0 mm ($n = 323$), with a mean of 17.8 mm ($SE = .321$). Leaflet lengths ranged from 4.0 mm to 30.0 mm ($n = 323$), with a mean of 14.1 mm ($SE = .265$). Leaflet widths ranged from one mm to 6.0 mm ($n = 323$), with a mean of 2.6 mm ($SE = .055$). The mean number of days that leaves took to reach the mature size range at Castilla Ranch and Santa Ana NWR (Fig. 39) was 69.9 ($n = 54$, $SE = 5.54$).

Mature leaf length measurements in *Acacia rigidula* ranged from 3.0 mm to 32.0 mm ($n=315$), with a mean of 7.4 mm ($SE = .355$). Leaflet lengths ranged from 2.0 mm to 32.0 mm ($n=315$), with a mean of 10.4 mm ($SE = .230$). Leaflet widths ranged from one mm to 17.0 mm ($n=315$), with a mean of 6.4 mm ($SE = .172$). The mean number of days needed for *A. rigidula* leaves to reach the mature size range at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract (Fig. 39) was 70.9 ($n = 102$, $SE = 4.61$).

Mature leaf length measurements in *Acacia schaffneri* ranged from 3.0 mm to 33.0 mm ($n = 379$), with a mean of 15.3 mm ($SE = .268$). Leaflet lengths ranged from 3.0 mm to 38.0 mm ($n = 379$), with a mean of 13.6 mm ($SE = .248$). Leaflet widths ranged from .5 mm to 7.0 mm ($n = 379$), with a mean of 2.3 mm ($SE = .050$). The leaves of individuals at Castilla Ranch and Yturria Brush Tract took an average of 56.1 days ($n = 71$, $SE = 4.24$) to reach the mature size range (Fig. 39).

Mature leaf length measurements in *Chloroleucon ebano* ranged from 3.0 mm to 56.0 mm ($n = 327$), with a mean of 16.0 mm ($SE = .478$). Leaflet lengths ranged from

2.0 mm to 30.0 mm ($n = 327$), with a mean of 13.0 mm ($SE = .270$). Leaflet widths ranged from 2.5 mm to 13.0 mm ($n = 327$), with a mean of 6.4 mm ($SE = .121$). The leaves of individuals at Santa Ana NWR and Yturria Brush Tract took an average of 57.5 days ($n = 59$, $SE = 5.15$) to reach the mature size range (Fig. 39).

ANOVA performed on the number of days needed to reach mature size range for all species showed that significant differences existed between species ($F = 2.38$, 4 and 340 df, $P < .05$). *T*-tests performed on pairs of species using the number of days need to reach mature size range showed that the leaves of *Acacia rigidula* took longer to reach maturity than the leaves of *A. schaffneri* ($t = 2.25$, 171 df, $P < .05$) and that the leaves of *A. minima* took longer to reach maturity than the leaves of *A. schaffneri* ($t = 2.01$, 128 df, $P < .05$).

DISCUSSION

Reproductive Phenophases

Flowering Among Species

The flowering periods for the species generally were similar to information provided by Vines (1960), Correll and Johnston (1979), Jones (1982), Vora (1990) Everitt and Drawe (1993), and Taylor *et al.* (1997). *Acacia berlandieri* had the longest period of flowering (four consecutive months) and *Chloroleucon ebanum* had the shortest period (one month). *Acacia minuta*, *A. rigidula*, and *A. schaffneri* each flowered for three consecutive months. Broad overlap in flowering among *Acacia* species was expected because taxonomically related species usually exhibit similar flowering patterns (Ollerton and Lack, 1982; Johnson, 1992). For example, *Acacia longifolia*, *A. melanozylon*, and *A. saligna* in South Africa produced flowers during winter and early spring (Milton and Moll, 1982), supporting the idea of genetically determined flowering times in related species (Schmitt, 1983; Smith-Ramirez, *et al.*, 1998). Timing of flowering was more similar between *Acacia* species than between any of the *Acacia* species and *C. ebanum*. Flowering in *Acacia* species did not occur after the photoperiod reached 13.4 hours sunlight. *Acacia berlandieri* flowered after mean monthly temperature was 30°C or above, and it ceased when the mean reached about 32°C. High temperatures may cause a cessation of flowering in this species. Threshold values for photoperiod and temperature may have to be achieved before flowering begins in *Acacia* species. Likewise, upper

limits of temperature and photoperiod may determine the cessation of flowering.

Primack (1985) reported that flowering of a species may be restricted to certain times during a year as a result of daylight, temperature, and water constraints. Vora (1990) reported that the most active periods for growth and reproduction for many plant species in the LRGV are in February, late May to June, and late September to November. I observed flowering during these periods in one or more of the species at one or more sites.

Significant differences in monthly percent flowering existed between species from February 1999 to April 1999. Such variations in percentage of individuals flowering between species were expected since differences in flowering exist in the majority of species and populations (Ollerton and Lack, 1982).

Acacia berlandieri flowered at Santa Ana NWR and Yturria Brush Tract from January to April 1999. This is generally consistent with information provided by Taylor et al. (1997) who reported that flowering in this species occurs from November through April. Everitt and Drawe (1993) provide similar information, stating that flowering in *A. berlandieri* occurs from November through March.

Vines (1960) and Taylor et al. (1997) report that *A. rigidula* produces flowers between February and May, while Correll and Johnston (1979) and Everitt and Drawe (1993) state that flowering in *A. rigidula* occurs between February and July. Vora (1990) reported that flowering in *A. rigidula* began by March. Individuals at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract flowered from February through April 1999, i.e., for a shorter period than previously reported. Lower than normal precipitation for

the five months preceding the study may have influenced the length of the flowering period. Flowering of *A. schaffneri* at Castilla Ranch and Santa Ana NWR began in January 1999 and ceased in March 1999, i.e., flowering occurred for about 60 days. Jones (1982) reports that flowering in *A. schaffneri* occurs between February and April, i.e., for a similar total period, but with flowering beginning about one month later. Richardson (1990) reported that *Chloroleucon ebano* flowers during the spring, summer, and fall months, often following rains. Vora (1990) found that production of flowers in *C. ebano* begins in May and continues through June. Correll and Johnston (1979) and Everitt and Drawe (1993) stated that *C. ebano* produces flowers from April to July, and rarely through November. I observed flowering only during September 1998 at Yturria Brush Tract. Although correlations could not be calculated for *C. ebano* and the climatic factors, the amount of rain received in September 1998 greatly exceeded the 40-year mean for that month (Fig 4), and may have influenced individuals to flower out of normal phenophase. Many species are able to respond rapidly to changing environmental conditions that are suitable for the production of flowers because they have dormant flower buds (Primack, 1985).

Vora (1990) reported that *C. ebano* flowered in response to autumn rains in September 1985. Richardson (1995) states that *C. ebano* produces flowers shortly after rains. It is possible that *C. ebano* may flower at any time of the year if rainfall is above a threshold value. Evidence supporting this is that *C. ebano* individuals in residential areas are usually watered regularly, yet they do not flower continuously. Thus, a threshold value may be involved because the residential individuals do not respond continuously to

regular watering. While there are not sufficient data to establish a specific threshold value, it is likely that this value falls between the 3.17 cm of precipitation received in May 1999 (when *C. ebano* is usually observed to flower) and the 24.09 cm received in September 1998.

Acacia minima at Castilla Ranch and Santa Ana NWR began flowering in February 1999 and continued through April 1999. These observations vary slightly from what other authors have reported. Vora (1990) reported that flowering in *A. minima* was observed in late January and continued through March. Everitt and Drawe (1993) stated that flowering in *Acacia minima* occurs from February to March. Correll and Johnston (1979) reported that flowering occurs during spring months, but may occur again after rains during drought conditions. A significant correlation between monthly percent flowering and official climatic data showed that flowering in *A. minima* increased as precipitation increased. Perhaps precipitation was the cause for *A. minima* flowering for an additional month.

Flowering Among Sites

Variation in percent flowering between sites was common. It is unlikely that photoperiod caused these differences because variation is less than one minute between sites. Similarly, due to the geographic proximity of the sites (less than 84 km) there was little difference in temperature between sites. It is unlikely that temperature was responsible for differences in percent flowering between sites. Correlation coefficients show that the climatic factors did not significantly influence flowering in most species. However, it is important to note that the precipitation data were recorded at only one of

the sites, i.e., Santa Ana NWR. The official precipitation data were recorded at McAllen, Texas, and the local observer data for Castilla Ranch and Yturria Brush Tract were recorded at nearby towns, not the sites where data were collected. It is possible that precipitation occurred in localized areas, that may or may not have included the study sites. Furthermore, precipitation may occur in some areas of a study site, and not others. Without this precise information, it is difficult to assess the influence of precipitation. Thus, differences in flowering (and other phenophases) among species between sites may be due to variation in precipitation between sites.

Significant differences in the flowering of *Acacia berlandieri* existed among sites in January through March 1999, and in June 1999. These differences result from the production of flowers at only one site (Yturria Brush Tract) from January to March 1999. The variation between sites in June 1999 is attributed to flowering only at Santa Ana NWR. Neither of the flowering periods produced many flowers, and the flowers produced did not result in the formation of mature fruit. The lack of flowers and fruits in *A. berlandieri* individuals may be related to low soil moisture. Lieth (1974) reported that amount of soil moisture at the beginning of a reproductive period influences flowering response in plants. A lack of moisture during this crucial period may affect some species, resulting in few or no flowers (Lieth, 1974). Nonetheless, the flowering at Yturria Brush Tract corresponded to the periods of flowering that were reported by Everitt and Drawe (1993) and Taylor et al. (1997).

Significant differences in the flowering of *Acacia rigidula* existed among sites from February through April 1999. Variation in February 1999 is the result of Santa Ana

NWR having a lower percentage of flowering individuals than Castilla Ranch or Yturria Brush Tract. Variation in March 1999 is explained similarly. Castilla Ranch and Santa Ana NWR had equivalent percentages of flowering individuals, but they were each less than the percentage flowering at Yturria Brush Tract. Variation in April 1999 is due to flower production only at Santa Ana NWR.

Correll and Johnston (1979) and Everitt and Drawe (1993) reported that flowering normally occurs in *A. schaffneri* during the spring months, but may occur after rains during drought conditions. This was not observed at either of the sites despite higher than normal precipitation in September 1998. Significant differences between sites existed in January 1999 because flowering occurred at Castilla Ranch only during that month.

Flowering in *Acacia mimuta* began at Castilla Ranch and Santa Ana NWR in February 1999. It ceased in March 1999 at Santa Ana NWR, and thus supported the observations of Everitt and Drawe (1993) who reported that flowering in this species ends in March. Flowering at Castilla Ranch continued through April 1999, and may have been related to an increase in precipitation. A significant positive correlation between flowering in *A. mimuta* and monthly precipitation at Castilla Ranch indicated that flowering increased as precipitation increased. Rainfall may have influenced *A. mimuta* to produce flowers for a longer time. It has been documented that a longer than normal rainy period prolongs the flowering period in some species (Ghazanfar, 1997).

Significant differences in the flowering of *Acacia mimuta* existed among sites in February 1999 and April 1999. The variation in February 1999 is due to a higher

percentage of individuals at Santa Ana NWR flowering. The variation in April 1999 is a result of the flower production only at Castilla Ranch.

Genetic differences within populations may have a slight influence on the differences in percent flowering between sites. Many species of the genus *Acacia* have well-defined, predictable phenological patterns, yet diversity does occur (New, 1984). Ollerton and Lack (1982) stated that variation in flowering is one phenophase in which differences are often observed. Because of the proximity of the study sites, it is unlikely that genetic variations between individuals greatly influenced flowering among sites.

Correlations Between Flowering and Meteorological Factors

Although most of the correlations between percent flowering and the climatic factors were not significant, the climatic factors are clearly important. Ghazanfar (1997) reported that precipitation, temperature, and photoperiod are three of the most important abiotic factors affecting plant phenophases. Most phenophases have been closely linked to water relations, with the exception of flowering (Nilsen and Muller, 1981). Thus, the results obtained are not unexpected. The species I studied are xeric-adapted plants, which may be genetically programmed to respond out of phenophase only when a substantial amount of precipitation occurs. This may be an evolutionary adaptation designed to ensure that flowers produced out of phenophase will, indeed, produce viable fruits. Lonard and Judd (1989) reported that precipitation on nearby South Padre Island might not be a limiting factor for flower production, unless an extended drought has occurred and has lowered the water table. Examination of official climatic data show that although my study sites received less than the 40 year mean monthly precipitation,

precipitation during the study was not within drought range. However, precipitation values for the five months preceding the study were 93% lower than the normal values, and therefore soil moisture could have been quite low as the study began.

Petanidou et al. (1995) studied the phenology of a Mediterranean plant community and reported that temperature triggered flowering. Milton and Moll (1982) found that photoperiod or temperature in climates where rainfall is not a limiting factor may stimulate anthesis. Lonard and Judd (1989) did not have clear results on the effects of photoperiod on the phenology on native angiosperms on South Padre Island. They suggested that temperature and photoperiod may act together to influence phenology, while they do not significantly influence it separately (especially in a subtropical area with mild winters). Primack (1985) stated that it is often difficult to distinguish the influence of a particular physical factor on flowering patterns, since the meteorological factors often vary together. Lieth (1974) reported that temperature most likely controls the flowering in most tree species. My data show that *Acacia* species flower when photoperiod is increasing (rather than decreasing), thus they may be categorized as long-day plants.

It is possible that the abiotic factors I examined may influence biotic factors, such as pollinators. Schemske et al. (1978), reported that flowering in seven species of woodland herbs began when temperatures became suitable for pollinator activity. The ability of pollinators to visit flowers may be limited during cooler times of the year (Primack, 1985). Temperatures began to increase in February 1999 in the LRGV, and this is the time when three of the four *Acacia* species had their peak percentages of flowering.

Fruiting Among Species

Mature not open fruit between species

Milton and Moll (1982) found that the productivity of most *Acacia* species is highest when temperatures are elevated and soil moisture is sufficient. High percentages of individuals with mature but not open fruits in all *Acacia* species were found in July and August 1998. Their percentages decreased steadily from September 1998 to February 1999. As winter ended, and temperatures began to increase in spring, the numbers of individuals with mature not open fruits in the *Acacia* species also increased, with the highest percentages of individuals occurring from June to August 1999. Vora (1990) reported that mature fruits were observed in *A. rigidula* and *Chloroleucon ebano* in July and August. Milton's and Moll's (1982) findings are supported by significant positive correlations in *A. minima* and *A. schaffneri* between monthly percent of individuals with mature not open fruits and mean monthly temperature. Significant positive correlations between monthly percent of individuals with mature not open fruits and mean daily photoperiod also existed in *A. minima* and *A. schaffneri*. It is often difficult to isolate a single climatic factor (i.e., temperature) that influences phenology, because temperature and photoperiod vary together.

Frankie et al. (1974) reported that in 75 species of plants studied in Costa Rica, fruits matured during the dry season. Milton and Moll (1982) stated that a characteristic feature of the genus *Acacia* is that the pods of most species ripen during a dry season, regardless of when flowers are produced. Ripening of *Acacia* fruits during a dry season may aid the hardening and drying of the seed testas. Such hardening prolongs the life of

seeds, and protects them from germinating prematurely (Milton and Moll, 1982; Bowers and Dimmitt, 1994). Although correlations between monthly percentage of individuals with mature not open fruits and monthly precipitation were not significant, the findings of Frankie et al. (1974) and Milton and Moll (1982) are similar to my data because summers in the LRGV of Texas are usually drier than other seasons. Figure 3 shows that rainfall is low in the summer months, and that September and October are the months with the most precipitation. Bowers and Dimmitt (1994) found that the seeds of *A. constricta* have hardened seed coats, but eventually germinate in response to the annual rainy season. The climatic data from 1958-1998 show that September is the wettest month in the LRGV. Thus, the formation of mature pods in the summer months may be in preparation for this rainy season. Vora (1990) stated that many species, especially leguminous species, in the LRGV drop their seeds in synchrony with autumn rains.

The percentage of *Chloroleucon ehano* individuals with mature not open fruits decreased steadily from July to November 1998. A slight increase in the percentage of individuals with mature not open fruit occurred in December 1998, but the percentage steadily decreased until February 1999. As temperatures increased, the percentage of individuals with mature not open fruits also increased.

Primack (1985) and Rathcke (1988) noted that the timing of flowering may actually be influenced by the amount of time needed for fruits to mature. Fruits may require a fixed amount of time for maturation (Primack, 1985), and fruiting must follow flowering, indicating interdependence between the phenophases (Fenner, 1998). Primack (1985)

stated that species with larger fruits require more time to mature, and thus should flower earlier than those species with smaller fruits. Furthermore, the type of fruit is influential (Primack, 1985), i.e., fruits with hardened pods may take longer to mature. My results support Primack's statements regarding time needed for fruit maturation. All fruits in my study were legumes with hardened coverings, i.e., there was no variation in the kind of fruit, so size was examined. *Chloroleucon ebano* had the largest fruits (11.4 cm long x 2.8 cm wide), and individuals took an average of 195 days to develop from flowers into mature not open fruits. Because *Acacia berlandieri* did not produce any mature not open fruit, *A. schaffneri* had the largest of the *Acacia* fruits (11.7 cm x .7 cm). The fruits of *A. schaffneri* took an average of 118.5 days to develop from flowers into mature not open fruit. *Acacia minnata* followed, taking an average of 91 days to develop from flowers into mature not open fruits (4.9 cm x .96 cm). *Acacia rigidula* had the smallest fruits (5.7 cm x .4 cm), and took the least time for fruit maturation (84 days). Based on literature reports (Correll and Johnston, 1979), *Acacia berlandieri* would have had the largest fruits (if any had been produced), followed by *A. schaffneri*. It is interesting to note that these two species were the species to flower earliest during 1999 and therefore, provided the longest time to produce fruit before September rains. These data support Primack's ideas regarding the influence of time needed for fruit maturation on the timing of flowering.

Significant differences in monthly percentage of individuals with mature not open fruits were found between all species during all months but November 1998, February 1999, and April 1999. *Acacia minnata* and *A. schaffneri* were most alike in their fruiting, in that significant differences only existed between these species during three months of

the study. This is not surprising, because both of these species produced more fruit as photoperiod and temperature increased.

Variation in mature not open fruits among sites

Examination of fruit production in *Acacia berlandieri*, *A. minata*, *A. rigidula*, and *A. schaffneri* between sites reveals interesting information. Fruiting in *A. berlandieri* was observed only at Yturria Brush Tract. The percentage of individuals with mature not open fruits was relatively low, reaching a peak of 30% in July 1998. Percentages of individuals producing mature not open fruits in *A. minata* at Castilla Ranch were higher during 1998 than during 1999. Conversely, percentages of individuals producing mature not open fruits in *A. minata* at Santa Ana were higher during 1999 than during 1998. A similar pattern was observed in *A. schaffneri* at Castilla Ranch and Yturria Brush Tract. The percentage of individuals producing mature not open fruits was higher in 1999 than in 1998 at Castilla Ranch, and the percentage of individuals producing mature not open fruit at Yturria Brush Tract was higher in 1998 (compared to 1999). Percentages of individuals producing mature not open fruits in *A. rigidula* at Castilla Ranch, Santa Ana NWR, and Yturria Brush Tract were higher in 1998, and the pods produced in 1998 were retained for a longer period of time than pods produced during 1999. This might be due to fruits being produced for a longer time in 1998, thus extending the maturation period. Conversely pods may have matured more rapidly in 1999. Baranelli (1995) found that low numbers of fruit characterize reproduction in *A. caven* in Argentina. Although flowers were produced, only a fraction of these became fruits. This is a common

occurrence in mimosoids like *Acacia* (Baranelli, 1995). Low fruit production may simply be a normal occurrence (with year to year variation) in the species I studied.

Climatic factors, however, may have played a role in influencing the production of fruits. At Castilla Ranch, the production of mature not open fruits increased in *A. mimuta* and *A. schaffneri* as daylength increased. Precipitation influenced the production of mature not open fruits in *A. mimuta*, with production of pods increasing as precipitation increased. Additionally, production of mature not open fruits in *A. rigidula* and *A. schaffneri* increased as temperature increased. It is unlikely that variations in photoperiod or temperature caused the variation in fruit production in *A. rigidula* and *A. schaffneri* as these climatic factors do not vary much between sites. It is more likely that local observer precipitation data for Rio Grande City was different than the actual rainfall at Castilla Ranch. More precipitation may have occurred in 1998 at Castilla Ranch than in 1999, and this may have affected the production of fruit. At Santa Ana NWR, mature not open fruit production increased in *Acacia mimuta* as photoperiod, precipitation, and temperature increased. Mature not open fruit production in *Chloroleucon ebano* increased as photoperiod and temperature increased at Santa Ana NWR.

The percentage of *C. ebano* individuals that produced fruit at Santa Ana NWR and Yturria Brush Tract in 1999 was equal to or less than the percentage produced in 1998. Fruits were produced in modest numbers at both sites. Perhaps variation in precipitation is responsible for the differences in fruit production. However, it is also likely that the age of the individuals influenced the production of fruits. To maintain consistency between individuals studied, I chose individuals of the approximately same

size so that individuals would likely be near the same age. At Santa Ana NWR and Yturria Brush Tract, copious numbers of flowers and fruits were observed on extremely large individuals during summer 1999. Because these large individuals were not similar to the sizes of the majority of individuals at the two sites, they were not chosen and were not censused. It likely that such large individuals have substantial root systems and more leaf surface area for photosynthesis, and are able to reproduce during dry times, when younger individuals may be devoting more energy to growth.

At Yturria Brush Tract, mature not open fruit production in *Acacia schaffneri* and *C. ebano* increased as photoperiod and temperature increased. Variation in precipitation is most likely responsible for the differences in fruit production that occurred between sites in these species.

Mature open fruits between sites

Milton and Moll (1982) reported that the shedding of pods and seeds in *Acacia longifolia*, *A. melanozylon*, and *A. saligna* occurred during the late summer. Shedding of pods and seeds in *A. rigidula* occurred through summer and fall in 1998, and through the summer in 1999. It is interesting that at all sites, mature open fruits in *A. rigidula* were retained through October 1998, but in 1999, mature open fruits were retained only through July. The percentage of individuals with mature open fruit from August 1998 to October 1998 was consistently lower at Santa Ana NWR than at Castilla Ranch or Yturria Brush Tract. Castilla Ranch had higher percentages of individuals with mature open fruits than Santa Ana NWR for this time period, but lower percentages than Yturria

Brush Tract. Individuals at Santa Ana NWR produced more mature open fruits as temperature increased.

Significant differences in monthly percentage of *Chloroleucon ebano* individuals with mature open fruits existed between Santa Ana NWR and Yturria Brush Tract from August 1998 through March 1999, and in June and July 1999. These differences occurred because mature open fruits were present at Yturria Brush Tract only from August 1998 through March 1999 and from June to July 1999. More mature open fruits were produced at Yturria Brush Tract as precipitation increased.

Vegetative Growth

Shoot elongation among species

Nilsen and Muller (1981) found that high temperature, coupled with long photoperiod, increases shoot elongation. Lieth (1974) stated that the breaking of dormancy in buds is more influenced by temperature than by daylength. Growth periods in *Acacia* species are often correlated with temperature or moisture (New, 1984). Milton and Moll (1982) found that there was a positive correlation between shoot elongation in *A. cyclops* and *A. saligna* in South Africa and mean monthly temperature. I also found significant positive correlations between monthly shoot elongation and mean monthly temperature in *A. minata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano*.

The correlation between monthly shoot elongation and mean monthly temperature in *A. berlandieri* was positive, but not significant. Such results are unexpected, based on

information provided by Nilsen and Muller (1981), Milton and Moll (1982), and New (1984) and the trends observed in the other species I studied. Because temperatures between sites did not vary greatly, it is likely that another factor, such photoperiod or precipitation (in conjunction with temperature), is responsible for such results. New (1984) stated that periods of growth often are significantly correlated with temperature and/or moisture in *Acacia* species. Nilsen and Muller (1981) reported that in chaparral plants, shoot elongation responds mainly to water conditions. Shoot elongation in chaparral plants, however, is also affected by photoperiod, with greater rates of growth occurring during long photoperiods during times of sufficient water.

Shoot Elongation Between Sites

There were no significant differences in monthly shoot elongation between sites in *A. berlandieri* or *A. schuffneri*. Such results are expected since photoperiod and temperature do not vary much between sites, and thus these climatic factors would have similar effects on the individuals. The differences that exist between sites among species may be explained by the effect of precipitation on the individuals at the different sites. Also, variation in monthly shoot elongation between sites frequently involves one particular site—Santa Ana NWR. Santa Ana NWR was involved in four of the five instances where significant differences existed between sites. Monthly shoot elongation between sites was different in *A. minima* in June 1999 only at Castilla Ranch and Santa Ana NWR, and in *Chloroleucon ebanum* in November 1998 and August 1999 only at Santa Ana NWR and Yturria Brush Tract. *Acacia rigidula* exhibited differences in shoot elongation at Castilla Ranch and Santa Ana NWR in August 1999 only and at Santa Ana NWR from

June 1999 through August 1999. Furthermore, shoot elongation values in *A. minima* at Santa Ana NWR were lower than Yturria Brush Tract from May through August 1999. The monthly shoot elongation values of *C. ebano* at Santa Ana NWR were higher than those at Yturria Brush Tract from April through August 1999. Although photoperiod and temperature appear to be the most influential meteorological factors affecting shoot elongation, variation in precipitation between sites may explain why the shoot elongation values of individuals at Santa Ana NWR were often significantly different from the values of individuals at Castilla Ranch and Yturria Brush Tract.

Leaf Viability

It is common for drought deciduousness to occur during summer months when temperatures are high, photoperiod is long, and precipitation is low (Frankie et al., 1974; Nilsen and Muller, 1981; Milton and Moll, 1982). Abscission of leaves during times of water stress reduces the amount of water lost through transpiration via leaf surface area (Frankie et al., 1974; Nilsen and Muller, 1981; Milton and Moll, 1982). Individuals of all species with abscised foliage were common during July through September 1998. However, percentages of *Acacia* individuals with abscised foliage also increased in February and March 1999. This corresponds to the period when flowers were produced. Nilsen and Muller (1981) stated that the loss of leaves directly after flower production is common in many drought-deciduous species. Flower production and the abscission of leaves in *Lotus scoparius* is simultaneous (Nilsen and Muller, 1981). Frankie et al. (1974) reported that similar patterns are observed in *Erythrina cochleata*

and *Jacaratia dolichaula*. Such events may serve to “advertise” the newly formed flowers to prospective pollinators.

Moreover, leaf abscission in response to the production of mature fruits has also been documented. Frankie et al. (1974) reported that leaf abscission occurred in *Tovomotopsis multiflora* when fruits matured: possibly to advertise fruits to potential dispersing agents. The percentages of individuals with abscised leaves were higher than other months from July to September 1998, so it is difficult to determine whether this was the result of the influence of climatic factors, or whether it is an adaptation for fruit dispersal. Since *Acacia* individuals did not exhibit leaf abscission during summer 1999, it is likely that the leaf abscission of the previous year cannot be explained as an adaptation for seed dispersal. The increased percentages of leaf abscission in 1998 are likely best explained as drought adaptation to low rainfall and high temperatures. Percentages of *Chloroleucon ebano* individuals with abscised leaves were higher in summer of 1998 and 1999, than in other seasons of the years. Leaf abscission increased in *C. ebano* at Yturria Brush Tract as temperature increased, but decreased in *A. berlandieri* at Santa Ana NWR as precipitation increased. This is confusing, since one would expect precipitation and leaf abscission to be inversely correlated. It may be possible that climatic data for each site varied from the local observer climatic data, and that climatic factors such as precipitation have a greater influence on leaf viability than the results show. Differences in leaf conditions among species between sites may also be related to variation in climatic data at the actual sites which are not apparent in the climatic data provided by the local observers.

Leaf Maturation Time

The largest leaves were produced in *Acacia berlandieri*, yet they took fewer days to mature than the smallest leaves (produced by *A. rigidula*). The leaves of *A. minyata*, *A. schaffneri*, and *Chloroleucon ebano* also were larger than those of *A. rigidula*, but took fewer days to reach maturity. Fenner (1998) stated that photoperiod may play a major role in leaf production in environments where water is not a limiting factor. Perhaps a larger (absolute) surface area enables large leaves to receive more sunlight than smaller leaves, and accelerates the process of maturation.

Significance of the Study

Despite the importance of *Acacia* species in many ecosystems, there has been little research on their ecology, especially in the areas of growth and reproduction (New, 1984). Only a small fraction of the 900 species have been studied in detail, and the studies that have been conducted have focused on the economic roles of the species (New, 1984). Smith-Ramirez et al. (1998) stated that, excluding their own study on Chilean rain forest Myrtaceae, no other studies had been conducted on the timing of the three reproductive phases of plants (flowering, fruiting, and seed germination) in phylogenetically related species within a plant community. This study is the first to provide information on these three phenophases in a suite of *Acacia* species in North America. Most of the phenology information available on species of *Acacia* in the lower RGV deals with flowering times. Limited information is available on the timing of fruit production and maturation in *A. minyata*, *A. rigidula*, and *Chloroleucon ebano* (Cox and Leslie, 1988; Vora, 1990), and no information is available for *A. berlandieri* and *A.*

schaffneri. Detailed information on shoot elongation and leaf maturation time has not been published for any of the species I studied. Vora conducted the only other phenological study in the LRGV on *A. minuata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano*. His study provides some phenological information, but it is general and lacks quantification. Herein I provide the precise timing of the phenophases and assess variation among species and among sites within a species.

Vora (1990) stated that growth and reproduction in many of the species he studied (which included *Acacia minuata*, *A. rigidula*, *A. schaffneri*, and *Chloroleucon ebano*) were influenced by precipitation. The strength of this influence is unclear, because quantification was not provided in his paper. I found that precipitation had a significant positive correlation with flowering and the production and maturation of fruits in *A. minuata*, but flowering, fruiting, and shoot elongation were influenced more by photoperiod and temperature. Perhaps a long-term study or field experiments on the phenology of the species in the LRGV could identify the crucial factors. Ghazanfar (1997) conducted a three year phenology study of desert plants in northern Oman and concluded that at least ten years of study would be required to fully examine the variability in phenology and climate. The influence of precipitation on the phenology of the species was difficult to assess because precipitation was not measured at the precise sites where phenology was determined. Rain gauges and automated recorders can be established, but they are expensive. Overall, climatic factors were shown to influence the onset and duration of phenophases of the species studied, and there was greater similarity

in phenology among the *Acacia* species than there was between any of the *Acacia* species and *C. ebanum*.

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VITA

Melissa R. Eddy was born at Fort Wainwright, Alaska, on June 8, 1969. She is the older of two children born to David R. Rios, Sr. and Jane Williams Rios. Her permanent mailing address is 2501 Zenaida Avenue, McAllen, Texas, 78504-5506. She received her high school diploma from McAllen Memorial High School in May 1987. She attended the University of Texas-Pan American as an undergraduate where she was employed as a teaching assistant, and received a Bachelor of Science with a major in Biology in May 1992. She entered the Biology Graduate Program at the University of Texas-Pan American in June 1993. Since receiving her undergraduate degree, she has been employed full-time at McAllen Memorial High School as an Advanced Placement Biology instructor.