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FACTORS LIMITING SEXUAL REPRODUCTION IN *PLATANUS WRIGHTII* IN SOUTHEASTERN ARIZONA

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ABSTRACT

Arizona sycamore (*Platanus wrightii*: Platanaceae) is a riparian tree of the southwestern United States and adjacent Mexico. It is failing to reproduce in certain canyons where mature, seed-producing trees of this species occur. Three hypotheses were tested to explain this reproductive failure: 1) the presence of domestic cattle prevents reproduction, 2) seeds produced in certain canyons are inviable, and 3) annual flash floods destroy seedlings and young saplings but not the large, mature trees.

Canyons, either grazed or ungrazed by domestic animals, were surveyed for the presence of seedlings and young trees. In the laboratory, seeds were tested for viability, germinability in petri dishes, and emergence of seedlings from soil. Canyons which possessed seedlings and young saplings were censused before and after flooding. From these efforts, we conclude that reproductive failure of Arizona sycamore in certain canyons cannot be explained either by activities of domestic animals or by a lack of viable, germinable seeds. Flash flooding events in some canyons washed out the seedlings and saplings present, but left viable larger trees. We also found that a permanent, high water table was essential to propagule survival.

Key words: sycamores, *Platanus*, reproduction, flooding, cattle grazing, seed viability, seed germination.

INTRODUCTION

Three species of the genus *Platanus* are indigenous to the United States (Elias 1980). One of these, *Platanus wrightii* Wats. (or *P. racemosa* Nutt. var. *wrightii* L. Benson), is native to southwestern New Mexico, southern Arizona, and adjacent northern Chihuahua and Sonora, Mexico (Kearney and Peebles 1969). This tree is a major component of the Upper Sonoran Life Zone according to Lowe (1977). Throughout its distribution, Arizona sycamore, also known as Wright's sycamore, is an important shade tree and furnishes important habitat for wildlife (Elias 1980; Bock and Bock 1984). Land managers in the Coconino and Coronado National Forests of Arizona and New Mexico have expressed special interest in this species because recreational users of these forests value the tree for its shade and beauty.

The reproductive phenology of Arizona sycamore is relevant to several aspects of this study. In southern Arizona, these monoecious trees flower in late spring. The seeds are ripe by October of the same calendar year, and a majority of fruits fall intact from the trees over the next several months. The trees reproduce by sexual and asexual means.

In some cases, self evident asexual reproduction takes place by means of stump sprouting or basal sprouting from an old tree. In other cases, routine observations

do not reveal the reproductive mode. Whole fruits drop from trees, and most individual seeds remain close by their fruit's axes. An axis may break apart slightly upon hitting the ground. Thus, sexual propagules (seedlings <2 cm in height) may occur in clumps. After reaching a height of a few centimeters, natural thinning of seedlings occurs, and scattered individuals result. In a few cases fruits may completely disperse their seeds.

Several times during the study we dug up small sycamores to try to determine the pattern of reproduction that had taken place, but in older plants it was difficult to ascertain because old interplant connections, which indicate asexual propagation, disappear in time. We found that asexually produced plants often were propagated from buried and partly buried branches of old trees. Such plants grew in a linear arrangement outlining the position of the buried branch.

Over the past several years, we have studied distribution patterns of Arizona sycamore in southeastern Arizona. In many drainages where large, healthy appearing specimens with diameters greater than 75 cm were found, the smaller age classes were rare or missing altogether. We proposed three hypotheses to explain the rarity or absence of young sycamores in certain canyons. 1). Seedlings and saplings might be destroyed by the browsing and trampling of domestic cattle. Certain local ranchers and biologists (e.g., Glinsky 1977; Kauffman, Krueger, and Vavra 1983) favor this idea. 2). Seeds from some canyons might not be viable or germinable. We found seed crops to be plentiful in all canyons of our study in all years when reproductively mature trees were present (Bock and Bock 1985), so we assumed seed crop failure was not a factor. 3). Young seedlings and saplings may be unable to withstand flash flooding that occurs almost annually in certain riparian canyons of this region. In order to test these ideas, we investigated the sycamore populations in eight canyons between 1981 and 1987.

METHODS

This study was done at the following field sites. Lyle and O'Donnell canyons are on Audubon's Appleton-Whittell Research Ranch Sanctuary, near Elgin, in Santa Cruz County, Arizona. Corral and Harshaw canyons are near Patagonia, Santa Cruz Co., Arizona. Scotia and Sunnyside canyons are on the western slope of the Huachuca Mountains, Cochise Co. Garden Canyon (Ft. Huachuca Military Reservation), and Carr Canyon are on the east side of the Huachucas in Cochise County, Arizona. All sites were within the Coronado National Forest, except Garden Canyon which is on Ft. Huachuca. All sites contained numerous, reproductively mature specimens of Arizona sycamore.

To quantify the numbers of saplings and seedlings in a drainage, we placed measuring tapes down the middle of the canyon's stream bed, and searched areas on either side of the tape to the edge of the stream bed. The stream beds were between four and five meters in width. Each stream bed was studied for at least 750 m of its length; the details of this work are reported elsewhere (Bock and Bock 1985). If canyons possessed mature (fruit-producing) trees, saplings (prereproductive, and usually less than 25 cm in diameter), and seedlings (less than 2 cm in height), they were said to possess mixed size classes.

To test our hypothesis that cattle were responsible for the absence of young

sycamores, we searched for seedlings and saplings in grazed and ungrazed canyons. Data on grazing were quantified for each canyon by the following subjective system: 0 = absence of cattle throughout the years of the study; + = moderate, and ++ = heavy grazing. Grazing was considered to be heavy when non-woody vegetation and top-soil were missing between the riparian trees scattered along a drainage.

Our second hypothesis, that the absence of young trees in certain canyons was due to a lack of viable seeds, was tested by means of viability (tetrazolium), germination, and emergence tests on seeds collected at various times from four canyons. All seeds used in this study were collected from fruits still on the tree, so that the female parent and the age of the seed were known. Collections of seed from the October 1981, crop were made in Lyle Canyon in November 1981, and March and June 1982. Collections were made in four canyons (Lyle, O'Donnell, Corral, and Carr) for the 1982 crop. Of these four, the first two canyons possessed only mature trees at the time of seed collections, while the latter two possessed mixed age classes including seedlings, saplings, and mature trees. The seeds were tested at the University of Colorado and the Research Ranch.

When each seed lot was collected, 10 seeds per lot were split with a single edged razor blade, and tetrazolium chloride was pipetted over the sliced surfaces. The split seeds were stored in a lab bench drawer for two hours. Subsequently, the seeds were inspected under a dissecting scope, and pink color noted. The pink color indicates the presence of respiration and is taken as an indication that the seeds contain "live tissues" (Lindenbein 1965).

Seed germinability, defined here at the appearance of the radicle outside the seed coat, was tested by placing seeds in petri dishes between two pieces of filter paper wetted with tap water, and stored in laboratory drawers. The petri dishes were inspected daily for five weeks for germinating seeds, and water was added as indicated. The observations were concluded after five weeks, and the seeds and seedlings, if any, were discarded.

The ability of seedlings to emerge from the soil following germination, here called emergence, was tested by planting five seeds per pot in 4-in. plastic pots in University of California potting mixture. The pots were watered by regular soakings for the first two weeks. After seedlings appeared, the pots were watered on a regime that kept the soil moist. Seedlings appeared 10–14 days after planting. Pots were inspected over an eight-week period for seedlings. If no seedlings had emerged in a pot by eight weeks, the pot was discarded. Survivors were transplanted and kept in the greenhouse for at least a year. Some still are growing and are being used in ongoing research on *Platanus*.

The third hypothesis, that flash flooding controlled reproduction in *Platanus wrightii*, was based upon accidental findings early in our observations. In March 1981, a large number of sycamore saplings of uniform size were found in Lyle Canyon; they averaged about 25 cm in height and their ages, as determined by the late Dr. Wes Ferguson of University of Arizona's Tree Ring Laboratory, were approximately 11 years at that time. We tagged 100 of these trees with permanent aluminum tags in order to learn about growth rate in saplings.

Each time we visited a canyon, we noted whether the stream bed was dry, or wet indicating a high water table, or possessed of flowing water. These observations later became important to our conclusions.

Table 1. Patterns of cattle grazing and tree size classes in canyons possessing Arizona sycamore (*Platanus wrightii*). Mixed = trees from mixed age and size classes. Uniform = only mature trees, dbh > 75 cm. 0 = no seedlings or no grazing present; +, ++ = increasing occurrence.

Site	Grazing	Seedlings			Size classes
		1982	1983	1984	
Carr	+	++	+	+	mixed
Corral	++	+	0	+	mixed
Garden	0	+	+	0	mixed
Harshaw	++	0	0	0	uniform
Lyle	0	0	++	+	uniform
O'Donnell	0	0	0	0	uniform
Scotia	+	+	+	0	mixed
Sunnyside	+	0	0	0	mixed

RESULTS

We compared the presence or absence of domestic cattle with size classes present in the eight canyons (Table 1). Seedlings were present in one ungrazed canyon and three grazed ones in 1982, and in two ungrazed and two grazed canyons in 1983 and 1984. Seedlings were found in stands of mixed age classes (mature trees, saplings, and seedlings all present) and in pure stands of mature trees. Only in Carr Canyon were seedlings found in all three summers. In Corral Canyon there was no year-to-year survival of seedlings between 1981 and 1987. Considering each canyon in each of the three years as an independent test ($n = 24$, Table 1), seedlings were present in 7 of 15 grazed situations, and seedlings also were present in 5 of 9 ungrazed situations (Chi-square contingency score = 0.16, $P = 0.90$).

All seeds showed high emergence during the autumn and winter of the year the seeds were formed (Table 2). Successful emergence was tightly linked to time of seed collection. Seeds harvested in the first autumn of maturation showed highest emergence. Emergence percentage decreased as time since seed set progressed past that first autumn. By the onset of the following year's flowers (June), emergence approached 0%. Germination rates for seeds collected in June were higher in petri-dish tests than was seedling emergence when the seeds were planted in pots (Table 2). Seed viability and germinability tests produced similar patterns, but seed viability was maintained at a higher level than germinability.

Every canyon in this study at some time during the study experienced flash floods. In August 1981, two "35-year" flash floods occurred in Lyle Canyon. A careful search was made in mid-August, but none of the tagged (or untagged) 11-year-old saplings or aluminum tags were found; nor have any been found in subsequent searches. In early summer, 1983, thousands of tiny, new sycamore seedlings were growing in Lyle Canyon (over 37,000 were censused). Thousands of seedlings, perhaps up to 75% of the original 37,000, died from desiccation during May and June 1983. Predictably, May and June are the hottest, driest months in this region; and they occur just prior to the onset of summer rains. Two flash floods occurred in August 1983, in all canyons of the study. In January 1984, only 149 individuals from this crop were located. Twenty-two seedlings survived to early summer, 1985, but none were found by summer's end, nor in

Table 2. Seed viability, germination in petri dishes (G), and emergence from soil (E) tests on *Platanus wrightii.*

Collection date	No. of source trees	No. of seeds	% Germination or % emergence	% Viability (n = 10 seeds)
		(Seeds set in October 1981)		
Nov. 1981	10	500	86.2% (E)	90%
Mar. 1982	10	1000	75.6% (E)	90%
June 1982	37	5680	0.8% (E)	30%
June 1982	37	500	4.5% (G)	30%
		(Seeds set in October 1982)		
Oct. 1982	18	810	79.5% (E)	100%
Jan. 1983	11	130	56.0% (E)	80%
June 1983	14	130	0.7% (E)	20%
June 1983	14	500	6.1% (G)	20%

searches held in Lyle Canyon during 1986 and 1987. By contrast, in Carr Canyon, seedlings persisted throughout the study period with recruitment of new seedlings observed for each year of the study (1981–1987).

DISCUSSION AND CONCLUSIONS

Our first hypothesis, that cattle were directly responsible for the absence of young sycamores, was rejected. The presence or absence of seedlings did not correspond with the presence or absence of grazing by domestic animals (Table 1). Carr Canyon, the only canyon which produced surviving seedlings for all summers of the study, is lightly grazed by domestic cattle. Undoubtedly, cattle can have a direct impact on reproduction in Arizona sycamore. Cattle must sometimes kill seedlings by trampling them. We found no references in range science literature to domestic stock browsing sycamore foliage, nor did we observe cattle feeding on seedlings and very small trees. However, in Corral Canyon the cattle browsed saplings and leaves from low hanging branches on mature Arizona sycamores. The browse lines were approximately 1.5 m above the ground. We assume that this canyon, a severely overgrazed study site, lacked more suitable fodder for the animals. The saplings and mature trees survived browsing.

Grazing and browsing activities of cattle do not appear to be a direct cause of reproductive failure in Arizona sycamore, but historically, cattle may have contributed indirectly to this failure. As early as the mid-1840s, large herds of free-ranging cattle were present in the study area (Hastings and Turner 1965). Subsequently, the Apaches chased the Mexican ranchers away, and reduced the feral cattle numbers (ibid.). After the Civil War, the area was recolonized by American ranchers, and livestock numbers increased steadily until 1893 when the combined forces of prolonged drought and destruction of vegetation through overgrazing led to an estimated 50 to 75% livestock mortality (Bahre 1977). Some workers attribute the dramatic arroyo cutting episodes of the 1880s and early 1890s to the activities of the cattle (ibid.). Arroyo cutting, the formation of steep-banked, narrow stream beds, is facilitated in this region when the soil binding vegetation is removed, especially from the areas around water sources. We observed great amounts of bank erosion in Corral Canyon where cattle activities were most

pronounced. We conclude that the steep banks and channelized stream beds in some of the canyons, notably Lyle, O'Donnell, and Harshaw, may be attributable to past activities of domestic cattle. It is in these canyons that flash floods possess the most kinetic energy, and bring about greatest change in the stream's contours and vegetation. In Corral and Harshaw canyons, the threat of arroyo cutting is ongoing. Thus, cattle may be implicated indirectly and to an unknown extent in the reproductive failure of Arizona sycamore in the canyons of southeastern Arizona.

The results of our seed tests lead us to reject the hypothesis that lack of viable seed crops caused reproductive failure. Tetrazolium tests for viability, as well as petri-dish and pot tests for germinability, showed that appropriate propagules were present each year to enable reproduction to occur by means of seeds. Seeds collected from fall through spring following seed set showed successful germination (Table 2). However, by June almost all seeds had lost the ability to emerge from the soil. The percent germination for the June seeds was somewhat higher when the seeds were cultured on filter paper, but these seeds frequently showed stunted hypocotyls. Since the hypocotyl in this species lifted the cotyledons and epicotyl above the soil surface (pers. obs.), our results from the pot studies may better reflect failure of seedling emergence than germination failure (Baker 1966).

Our third hypothesis, that scouring which accompanies flash flooding may prevent successful seedling survival and emergence in Arizona sycamores, appears to fit the canyons where mixed age classes are missing, namely Harshaw, Lyle, and O'Donnell. In Lyle Canyon, saplings growing for as long as 10 years still had not reached sufficient size to withstand the scouring effects of flash floods. Their stature was stunted in comparison with greenhouse grown plants, which reached comparable heights (30 cm) in a few months following germination. It may be that nonlethal episodes of flash flooding and periodic droughts serve to keep the young sycamores stunted until their stem and root systems develop sufficiently to withstand these periodic stresses.

Our original hypotheses did not consider the role of annual water table levels in reproductive patterns of Arizona sycamore. However, Arizona sycamore trees appear to reproduce under conditions where their seeds and young seedlings are kept moist until the onset of summer rains, and this initial seedling establishment must be followed by a lengthy period when the seedlings and saplings are protected from uprooting by flash floods. This hypothesis agrees with our observations and experimental data. Carr Canyon appears to be a prototype for sites where successful sexual reproduction by Arizona sycamore is likely to occur. The stream bed is moist throughout the year. Also, the watershed it drains is limited, and the stream bed is wide. Managers may find this model of use in planning programs for the introduction or maintenance of Arizona sycamore.

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FOOTNOTE

[1] Both addresses apply to both authors.