Fire Management of the Piassava Fiber Palm (*Attalea funifera*) in Eastern Brazil

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INTRODUCTION

The family of palms provides a diverse array of food, fuel, and fiber products to folk societies in the New World tropics. Economically valuable and yet usually undomesticated, palms are in many cases managed by fire during the slash-and-burn process. By sparing these as well as other woody species, forest inhabitants are able to create orchard-like concentrations of wild and semi-domesticated plants that can be exploited for decades after the plot has been abandoned (Alcorn 1981; Denevan et al. 1985; Posey 1984). Among the palms managed in this manner are the *guagara (Manicaria saccifera), jirot (Socratea sp.), jira (Socratea durissima)*, and *conga (Weifia georgii)* of Panama (Gordon 1982); the *coyal (Acrocomia mexicana), corozo (Orbignya sp.)*, and *palma real (Scheelea liebmannii)* of Tabasco, Mexico (Heizer 1955; Johannessen 1966; West et al. 1969); and the *babassú (Orbignya martiana)* of Brazil (Anderson 1983).

The ability of rainforest palms to survive and even thrive after burning presents an evolutionary puzzle. Why should so many species exhibit apparent adaptations to an ecological factor--in this case fire-that is infrequently a natural element in the ecosystem? The answer to this question is not immediately obvious, although it could involve coincidental preadaptation, immigration from a more arid region, or in situ adaptation to a fluctuating climate. But, regardless of its origin, fire resistance is a common characteristic of palms and one that has received some consideration.

Explanations of fire tolerance in palms have focused on various morphological attributes of the seed, the juvenile, or the adult stage. First, it has been suggested that palm seeds remain dormant in the soil seed bank for many years until induced to germinate by a fire (Hartley 1967; Rizzini 1963). This explanation, however, is inconsistent with the noted inability of palm seeds to retain viability under storage for any length of time. Second, previously established palm seedlings and juveniles may survive the effects of a fire because their subterranean terminal buds are safely removed from the heat of the flames (Anderson 1983; Brinkmann and Vieira 1971; Rawitscher 1948). Third, since the trunks of palms are fire resistant (Tomlinson 1979), it is possible that spared individuals serve as immediate seed sources for the re-vegetation of burned sites (Harlan 1975).

In the case of the piassava fiber palm (*Attalea funifera*) of eastern Brazil, folk wisdom and the local literature support the first explanation, that is, that seeds are induced to germinate by fire or by its indirect effects. Thus, Bondar (1942) and Valeriano (1934) attributed the luxuriant post-fire carpet of piassava seedlings to the stimulation of long-dormant seeds by the heat of the sun, whereas Moraes (1911) speculated that the heat of the fire directly induced germination.

This paper considers the role of fire as a management tool in piassava forests, and specifically examines the validity of the seed stimulation hypothesis. Using field germination experiments, the following questions are addressed: Do piassava seeds retain viability in the soil seed bank, or do they readily germinate? And if seed dormancy exists, is there evidence that buried seeds are induced to germinate by the heat of a fire, by the nutrient flush following a fire, or by the increased access to solar radiation?

PIASSAVA PALM

Piassava is endemic to the moist tropical forests of coastal Bahia, Brazil (Figure 1). The mean annual precipitation, which falls equally throughout the year, is on the order of 1500-2200 mm, and the mean annual temperature ranges from 23 °to 24° C (Voeks 1987). The topography of this region is visually dominated by a series of well-eroded sea terraces, or *tabuleiros*. Although usually covered by deep latosolic soils, these tabuleiros are in places mantled with tropical podzols (Braun and Ramalho 1980). Porous in texture and low in exchangeable bases, these silicious podzolic soils sustain a slightly-dwarfed evergreen *restinga* forest, of which piassava is a common member (Silva and Vinha 1982).

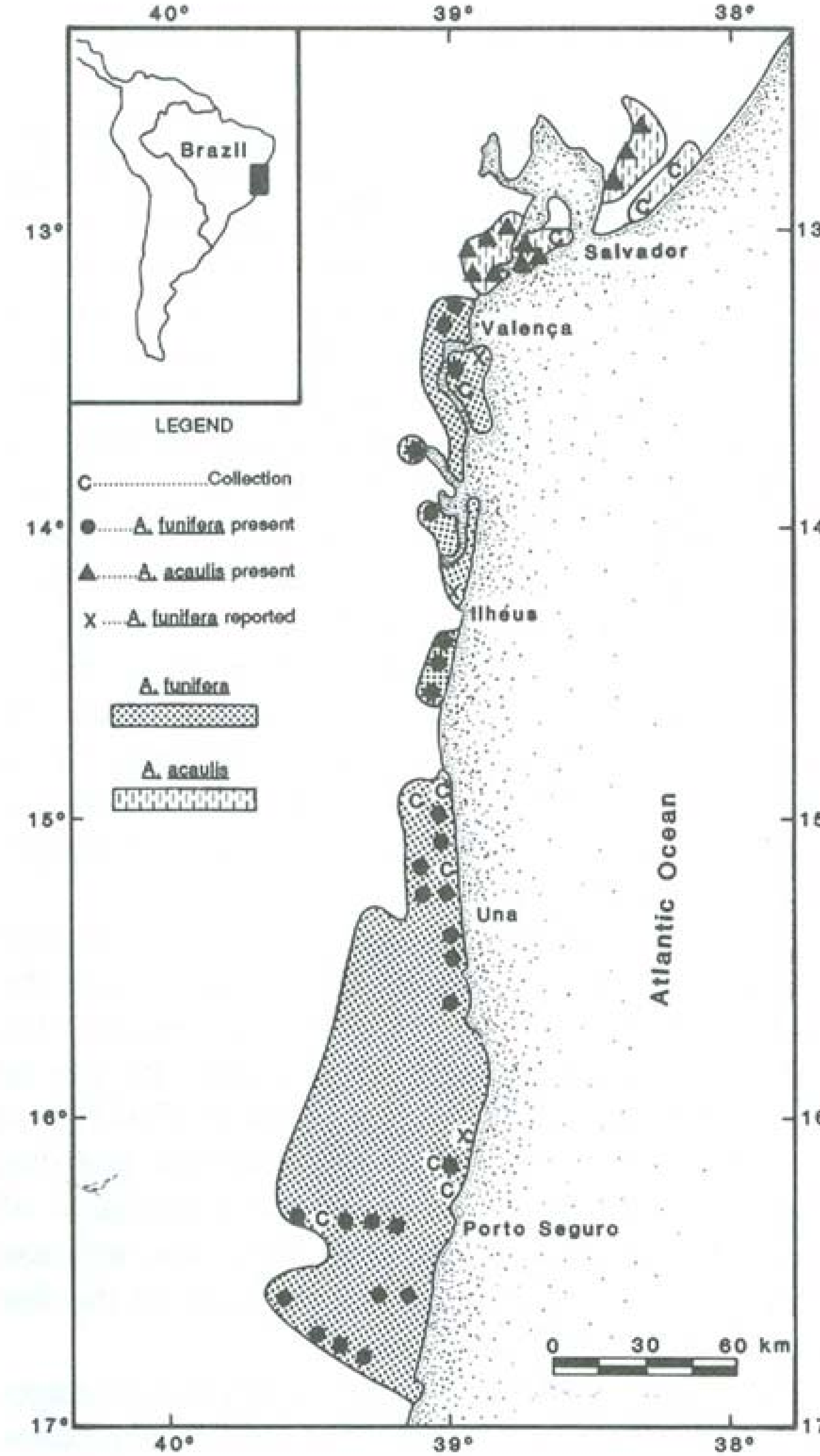

Fig. 1. Distribution of piassava (*Attalea funifera*) and its shrub form *A. acaulis*.

Piassava attains a height of 12 to 15 m, and is easily identified in the field due to the presence of 9-m-long fronds covered with drooping, aggregated leaflets (Figure 2). Inflorescences consist of massive, simply-branched panicles that are either male, female, or bisexual. Individual palms often change gender as they grow and reach the forest canopy, a condition associated with decreasing competition and increasing access to solar radiation (Voeks 1988a). Pollination is carried out by highly specialized beetles (*Phyllotrox tatianae* and *Mystrops sp.*), and is apparently facilitated by a flower mimicry system (Voeks 1985). Fruits weigh up to 500 gm, contain 1-3 seeds (kernels), and are much sought after by local residents who both eat the seeds raw and render them into cooking oil. Although fruits were in the past naturally dispersed by large forest rodents, over-hunting of these animals for food has for the most part eliminated this means of seed dispersal (Voeks 1987).

Fig. 2. Young piassava growing in a pasture near Porto Seguro.

The primary economic value of piassava is its sheath fiber. These 5-m strands of water-resistant fiber have long represented an important component of the regional export economy, first in the fashioning of anchor cables, and later in the manufacture of brooms and brushes (cf. Sousa 1938; Hooker 1849). During the twentieth century, piassava fiber exports have fallen markedly as a result of competition with plastic substitutes. Nevertheless, fiber production has risen sharply in the last few decades to meet a growing domestic demand, and at present over 60,000 tons of this raw material are extracted annually from the Bahian forests (Voeks 1988b).

Although successful planting schemes have recently taken place, piassava is traditionally managed by fire. Small patches of *restinga* forest are burned during the summer (December-March), after all but the piassavas have been hacked down and allowed to dry. Piassava seedlings quickly emerge from these blackened, nutrient-rich soils, and become commercially productive in 5 to 8 years. Because natural forest succession of the burned site is quite gradual, management by fire need only be repeated every 50 years or so in order to maintain dense stands of this palm (Voeks 1987).

METHODS

The presence or absence of seed dormancy was tested by germination experiments carried out approximately 11 km south of the city of Ilheus, Bahia. The site is inhabited by old second growth *restinga* forest that includes a considerable number of piassava palms. In order to avoid infestation problems with bruchid beetles (*Pachymerus nucleorum*), which attack after the fruit falls to the ground, we sought out seed sources from bunches that were just beginning to drop fruit. The pulpy husks (i.e. exo- and mesocarps), which are thought to act as rewards to seed dispersers and attractants to termites, were removed prior to planting. Fruits were planted in 1-m-diameter plots located along three transects running perpendicular to the slope. Each was buried in a horizontal position roughly one cm below the surface. A total of 183 fruits were sown from July to September, 1984. Germination success was noted on a monthly basis for one year, after which time many of the fruits were unearthed and the seeds examined for viability.

The effects of fire, sunlight, and post-fire nutrients on piassava germination were tested at the Pau Brasil Ecological Reserve, located about 20 km west of Porto Seguro. Uninfested seeds minus their husks were planted 3 m apart in four separate plots delineated in a 12-year-old second growth forest. Twenty-eight fruits were planted in each plot, and the plots measured 24 x 15 m.

At Plot 1, the forest was left intact. The soil at each planting point was cultivated slightly and the seeds were planted in January. Germination conditions at this plot were thus most similar to those experienced in undisturbed forest. The vegetation standing on Plot 2 was cut and completely removed, leaving a bare soil surface, and the seeds were planted in January. In this way, the possible effects of increased direct solar radiation could be separated from the other fire-related factors. At Plot 3, the forest was cut, allowed to dry about one month, and burned in late January. The seeds were planted in February. Seeds in this plot were thus exposed to direct solar radiation and the deposition of nutrient-rich ash, but not the actual heat of the fire. The vegetation at Plot 4 was cut, dried, the seeds were planted in January, and the plot was burned ten days later. Conditions at this plot most nearly paralleled those experienced during fire management of piassava. Germination was censused monthly during the following year.

In order to identfy pre- and post-fire edaphic changes, soil samples were collected and later analyzed by the staff at the Cacao Research Center (see Voeks 1987 for methods). Five-hundred-gram samples and replicates were extracted from the 0-5 cm, 45-50 cm, and 95-100 cm levels. Samples were taken one day before the burn from Plot No. 1, where the vegetation was left intact, and at intervals of two and six months after the burn from Plots 1, 2 and 3.

RESULTS AND DISCUSSION

In the predator-rich environment of the moist tropical realm, seed dormancy is thought to represent a poor reproductive strategy. Rather than risk being preyed upon by insects or vertebrates, most plant species, including palms, opt for immediate as opposed to delayed germination (Gómez-Pompa et al. 1972; Ng 1973; Vinha and Lobão 1982). Squirrels have been found to destroy 65-75 percent of the seed crop of the Mexican palm *Astrocaryum mexicanum* (Pinero and Sarukhan 1982), and the fallen seeds of numerous palms, including piassava, are heavily preyed upon by bruchid beetles (Bondar 1942; Southgate 1979). On the other hand, in the much researched case of African oil palm (*Elaeis guineensis*), a measure of seed dormancy does appear to exist. Laboratory experiments have shown that seeds often fail to germinate until exposed to extended high temperatures (Hussey 1959), conditions that are most often met in disturbed areas such as road-cuts and swidden sites. At the same time, Rees (1963) reported predation figures of 70-90 percent within two years of sowing the seeds of this palm, suggesting that there is considerable selection against seed dormancy. As regards palm germination in general, Comer (1966) suggests that what appear to be cases of dormancy may in fact represent no more than slow germination through the often massive, bone-hard endocarps.

In the piassava dormancy tests, only 40 of the 183 seeds (21.9 percent) germinated. In each case, at least seven months elapsed after planting before leaves appeared at the soil surface, and within 16 months of planting all of the seeds that were capable of germinating had already done so. Of the ungerminated seeds that were recovered, none were found to be viable. In most cases, the apparent cause of seed death was attack by termites. These data, in conjunction with germination experiments carried out under greenhouse conditions (Voeks 1987,255-256), indicate that although germination is slow, prolonged seed dormancy is nevertheless not a factor in piassava germination. This being the case, it follows that the rapid emergence of piassava seedlings after a fire cannot be related to stimulation of a piassava seed bank.

Table 1. Effects of burning and vegetation clearance on soil properties.

Depth (cm)	Forest Plot 1			Cleared Plot 2		Burned Plot 3		Significance $P < 0.05$
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)
pH								
0-5	5.0	4.8	5.05	5.5	5.4	7.0	6.1	b < d
45-50	4.8	4.6	4.75	4.6	4.8	5.3	5.6	b < d
95-100	4.9	4.6	4.85	4.4	4.5	4.8	5.1	
Aluminum (mEq/100 gm)								
0.5	0.5	0.3	0.2	0.1	0.2	0	0	
45-50	1.0	0.8	0.9	0.8	0.7	0.3	0.5	
95-100	1.1	1.1	1.0	1.2	1.2	0.9	0.4	
Calcium (mEq/100 gm)								
0-5	2.2	4.2	3.8	3.8	3.0	6.8	5.6	
45-50	0.1	0.7	0.2	0.5	0.9	1.8	0.7	
95-100	0.2	0.3	0.2	0.4	0.3	1.0	0.5	b < d
Magnesium (mEq/100 gm)								
0-5	0.5	0.6	0.6	0.6	0.4	0.9	0.7	
45-95	0	0	0	0.1	0.2	0.3	0.3	
95-100	0	0	0	0.1	0.1	0.2	0.5	c < e
Potassium (mEq/100 gm)								
0-5	0.12	0.14	0.11	0.08	0.04	0.26	0.10	
45-50	0.02	0.02	0.02	0.03	0.04	0.08	0.12	c < e
95-100	0.02	0.02	0.01	0.02	0.02	0.03	0.03	
Phosphorus (ppm)								
0-5	2.0	2.5	0	2.5	3.0	26.0	18.0	b < d, c < e,
45-50	1.0	0.5	0	1.5	0.5	1.5	0.5	b < d, g < e
95-100	1.0	0	0	1.5	0	0.5	0	b < d, d < f
Carbon (%)								

This conclusion is supported by the results of the soil analyses and the burning experiment. The differences in soil chemistry of the forested, burned, and cleared plots (Table 1) show that in several cases the growing conditions of the burned sites were significantly better than either the cleared or the forested plots. Magnesium, calcium, potassium. and particularly phosphorus were frequently present at higher levels at the burned plot. In addition, the soil pH was more neutral and potentially toxic aluminum was reduced. The only exception to these generally improved conditions was the percentage of organic carbon which, unlike in other burning experiments (Nye and Greenland 1964; Seubert et al. 1977), dropped significantly after the fire. It is thus conceivable that seed dormancy in piassava, if it existed, could be broken by these post-fire edaphic changes.

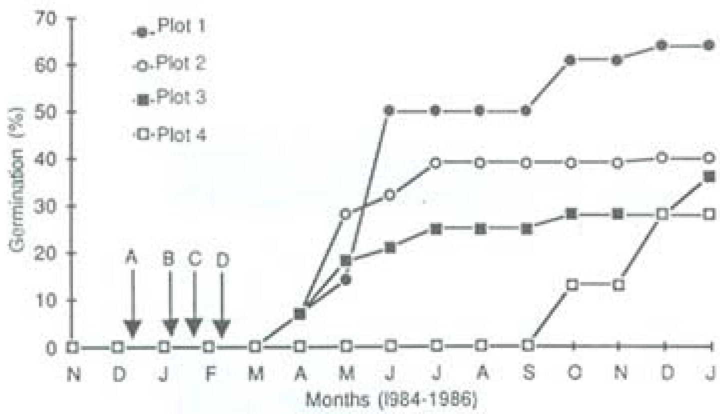

Fig. 3. Piassava germination following various treatments. Plot 1 was in second growth forest; Plot 2 was cleared of all vegetation prior to planting; Plot 3 was burned and then planted; Plot 4 was planted and then burned. A represents the date of seed collection; B is the date Plots 1, 2, and 3 were planted; C is the date Plots 3 and 4 were burned; D is the date Plot 3 was planted.

The results of the germination experiments reveal, however, that neither fire nor any of its indirect effects induce germination of piassava seeds (Fig. 3). On the contrary, the results are the opposite of what would be expected if fire were of any value to seed germination. The highest germination success was recorded at Plot 1, which most resembled undisturbed forest conditions. This was followed by Plot 2, which received direct sunlight, and Plot 3, which received both direct sunlight and the post-fire input of nutrients. Plot 4, which most resembled the slash-and-burn conditions to which this palm is subjected, registered considerably slower and overall lower levels of germination. In this case, as experimental conditions increasingly mirror traditional forest management, the germination success rate of this species reciprocally declines. Later recovery of seeds from the burned plot showed that they had been incinerated, a result noted in a similar experiment by Brinkmann and Vieira (1971). In summary, these findings fail to support the notion that piassava seeds witness improved germination as a result of increased access to sunlight, enhanced soil nutrient levels, or elevated soil temperatures.

The value of managing piassava palm forests with fire, although clearly not related to enhanced seed germination, was suggested by two further observations. First, this species exhibits a curious gerrmination pattern, initially noted by Bondar (1943), in which the seedling radicle first penetrates deeply into the soil.

After reaching a depth of nearly 1 m, the radicle differentiates, and the terminal bud slowly begins to grow toward the surface. The terminal bud of the young palm may not reach the surface for several years, but the juvenile leaves, with their long petioles, are thrust into the sunlight in a matter of weeks. Second, while clearing the sites for germination experiments, it was noted that the juvenile leaves regrew repeatedly after being cut off. Taken together, these observations suggest that during a fire, the terminal buds of piassava seedlings and juveniles remain alive below the surface of the soil whereas the leaves, which are burned by the flames, simply regrow after the fire has passed. It is thus proposed that post-fire germination of this species is a visual illusion produced by the rapid foliar regrowth of seedlings and juveniles.

The significance of this pattern of seedling establishment and growth to the management of piassava by fire is illustrated in Figure 4. Like other palm and tree species, piassava represents some percentage of the seedling and juvenile population in the forest (Figure 4a). But unlike the majority of rainforest species, young piassava palms survive the act of cutting and burning because their terminal buds are safely ensconced below the surface of the soil (Figure 4b). The leaves quickly regrow (Figure 4c) and, given the sunny, non-competitive, nutrient-rich environment, soon come to dominate the burned patch. The final result is a relatively monospecific and thus economically valuable forest of fiber-producing palms (Figure 4d).

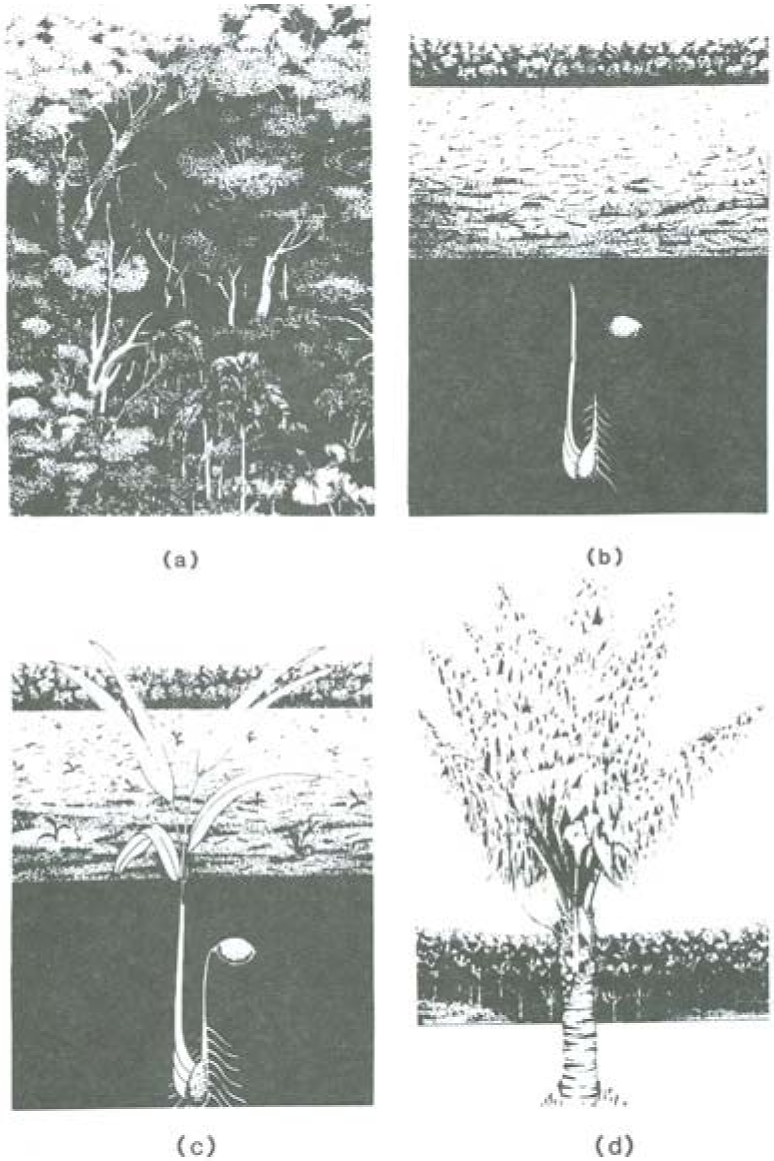

Figure 4. Schematic representation of fire management of piassava: (a) shows rainforest prior to cutting and burning; (b) illustrates survival of piassava below the soil surface; (c) shows piassava leaves regrowing immediately following fire; (d) shows monospecific stand of adult piassavas several years after burning. Raymond E. Crist

CONCLUSIONS

The piassava fiber palm (*Attalea funifera*) inhabits the moist tropical forests of Bahia, Brazil. Extraction of its leaf fiber for the eventual manufacture of brooms and brushes has long represented a significant contribution to the economy of the region. In order to increase the abundance of this native species, locals periodically cut and burn the rainnforest, a disturbance that leads to nearly monotypic stands of this palm.

Field experiments were conducted in order to identify the effects of burning on piassava germination. Contrary to local opinion, the effects of fire were found to be wholly detrimental to seed germination. Seeds do not have the power of dormancy, and neither the chemical alterations of the soil, nor the direct solar radiation, nor the heat associated with the fire to enhance germination in any way. Observations suggest, however, that the post-fire flush of young piassava represents regrowth of previously existing, subterranean seedlings and juveniles. Piasssava quickly comes to dominate these charred sites and, given the abundant soil nutrients, sunlight, and space to grow, soon forms dense stands of fiber-producing palms.

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