Ammobroma sonorae, an Endangered Parasitic Plant in Extremely Arid North America

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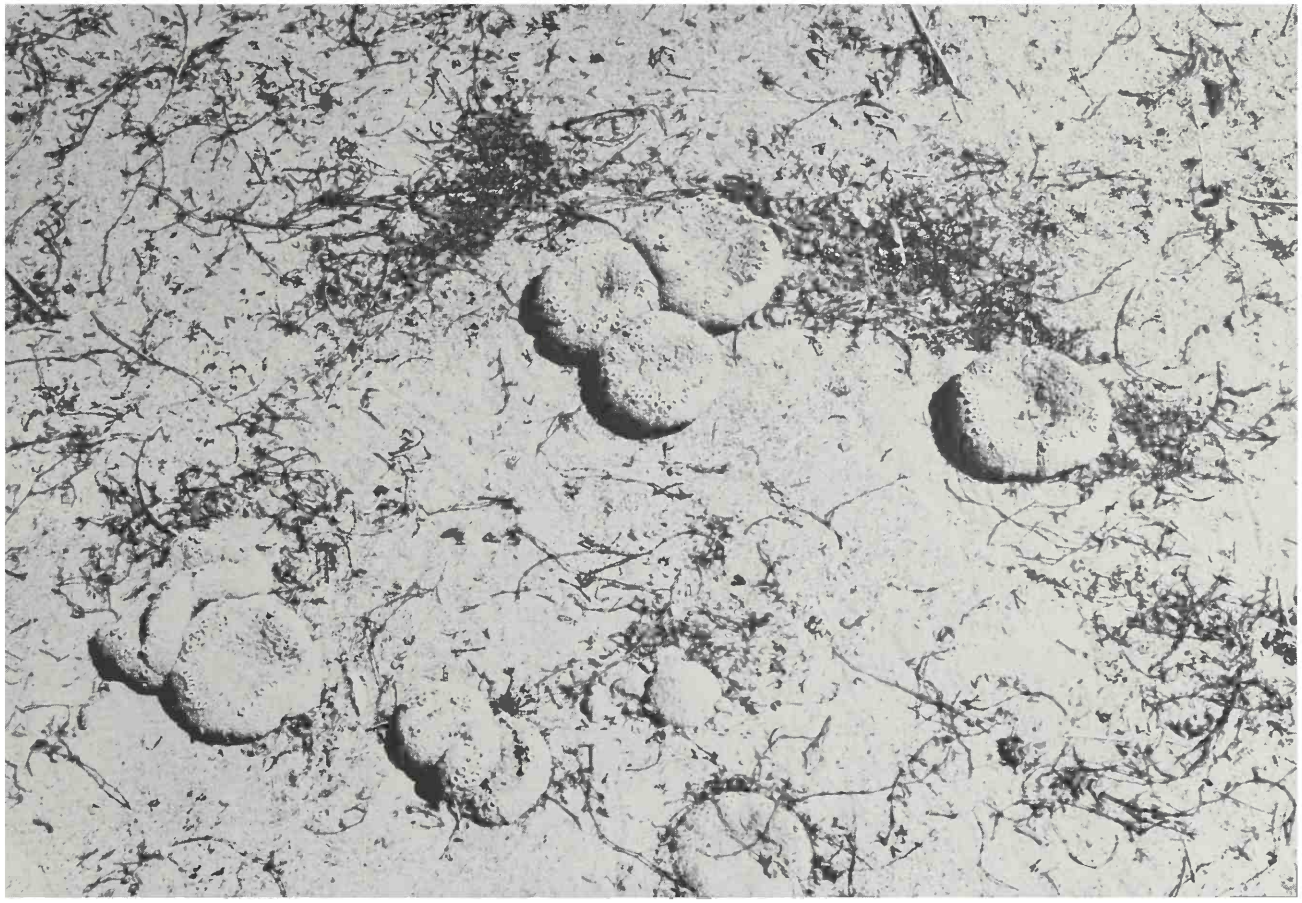
Scientists discovered the sand dune endemic *Ammobroma sonorae* in an unusual way: it was served to them for dinner by Sand Papago Indians (Gray, 1855). Later, Gray (1856) described the type locality of this species as "... the most desolate and forlornlooking spot for eighty miles around the head of the Gulf [of California], the sand hills looking like a terrible desert ..." But he added "... nature seems even here, where no rain had fallen for eight months, to have provided for the sustenance of man, one of the most nutritious and palatable vegetables ..."

In the century and a quarter that has elapsed since its initial scientific description by John Torrey, *Ammobroma sonorae* has remained an enigma. How can it be that one of America's most succulent wild foods is endemic to some of the hottest, driest, most barren areas on the continent? How does the plant make the transition from seeds dispersed atop burning apparently sterile sand to a life underground, a parasite attached to the host's roots as much as a meter and a half below this hostile surface? How did it diverge so dramatically from its closest relative, *Ammobroma culiacana* described by Dressler and Kuijt (1968)? The latter species is endemic to rocky subtropical thornscrub as much as 900 kilometers to the south and is parasitic on an entirely different set of hosts. Finally, how is it that *Ammobroma sonorae* survived hundreds of years of harvesting by native Americans, yet is thought to be endangered now that harvesting pressure has waned? These questions have yet to be firmly answered. Data from taxonomists, biogeographers, parasitologists, ethnobotanists and native gatherers provide some clues and form the basis for the following discussion.

Systematics and Biogeography of Lennoaceae

Torrey (1864) first described the characteristics of the genus *Ammobroma* and the family Lennoaceae. Torrey and other early taxonomists speculated that this family might be closely related to other parasitic plants, such as those in the Broom-Rape Family, the Orobanchaceae. More recently, Copeland (1935) and Drugg (1962) have argued on the basis of floral structure and pollen morphology that the Lennoaceae as a family is closely related to the Waterleaf Family, Hydrophyllaceae, and the Borage Family, Boraginaceae.

Kuijt (1969) indicated that the relationships within the family of *Lennoa, Pholisma* and *Ammobroma* are poorly understood: "since no systematic treatment exists, we are not certain how many species are involved." He also questioned whether the floral structures of *Pholisma* and *Lennoa* are distinctive enough to merit placing the species into two genera. Dressler and Kuijt (1968) also suggested

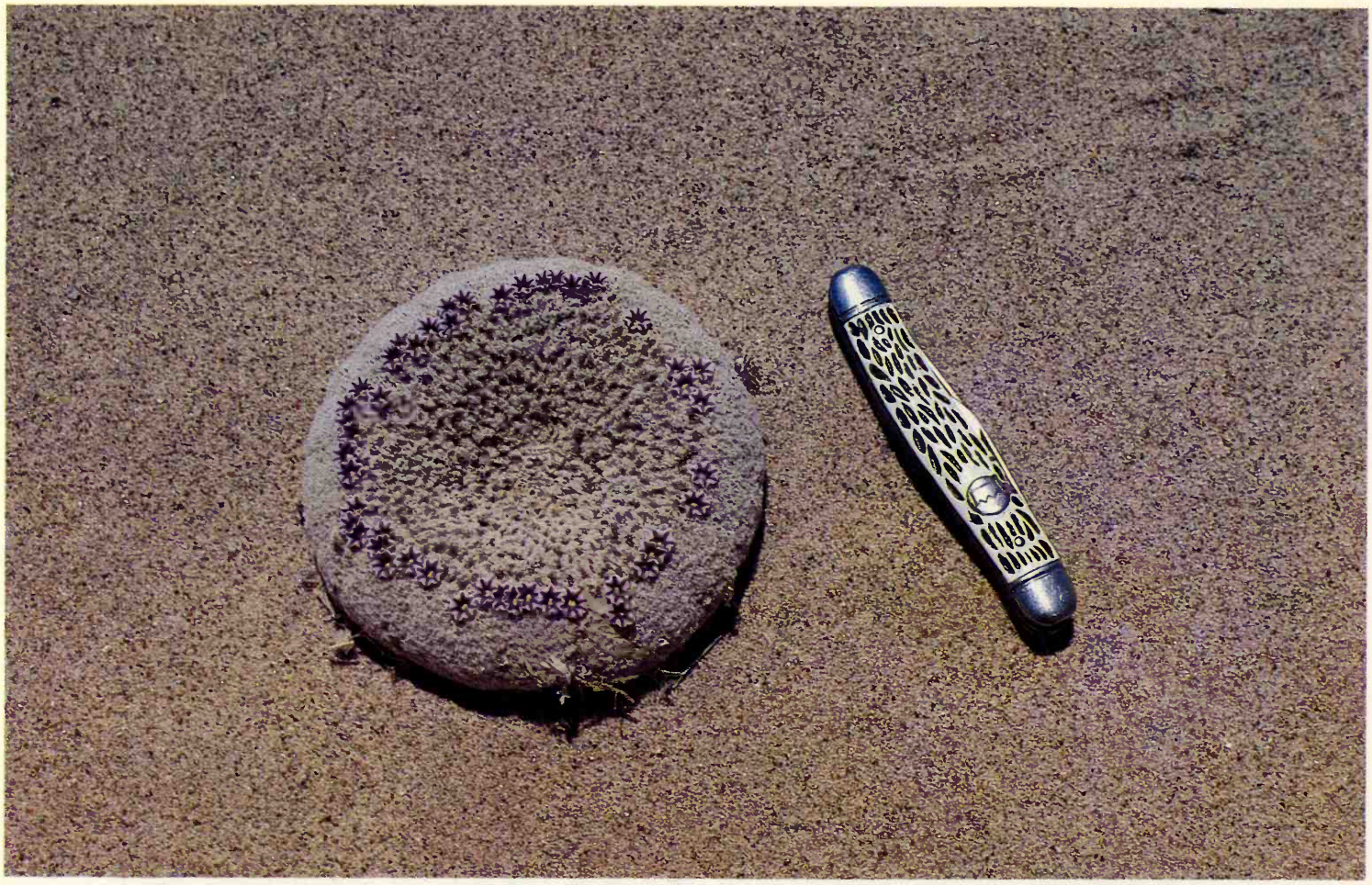


A thick stand of **Ammobroma sonorae** *next to old Highway 80 in the Algodones Dunes. Photograph by Gary Nabhan.*

that the species of Lennoaceae may be best considered as congeneric: "the main generic feature of *Ammobroma,* i.e., the compact, laterally extended head, is insufficient by itself as a generic distinction." The recently discovered *Ammobroma culiacana* has an inflorescence morphologically intermediate between the thyrse of *Lennoa* and *Pholisma,* and the flat, coalesced or compacted head of *Ammobroma sonorae.* Nevertheless, Drugg's (1962) pollen morphology analysis revealed differences between the three genera, and indicated that phylogenetically *Ammobroma* appeared to be the most specialized or "advanced" of the three.

If one were to look at previously published journal articles on the two species of *Ammobroma,* it would appear that each is fairly localized, with considerable spatial and ecological gaps between them. There is roughly a 900 kilometer distance between the type localities of the two species. Armstrong (1980) has erroneously reported that *A. sonorae* is limited to the Algodones Dunes, which stretch from near Glamis, Imperial County, California into northern Mexico: "this chain of dunes in the only place in the world where *Ammobroma sonorae* is found." At the time of its description, *A. culiacana* had been found only twice, localized within 15 kilometers of Culiacan, Sinaloa on rocky ledges in thorn forest (Dressler and Kuijt, 1968).

In actuality, *Ammobroma sonorae* populations are scattered over a 6250 square kilometer area, from slightly west of the Salton Sea National Wildlife Refuge in Imperial County, California, southeastward to Bahia Adair on the Sea of Cortez coast of Sonora, Mexico. Within this area, they are largely restricted to dune chains produced by wind transport of sand from the beaches of prehistoric Lake Cahuilla and the Colorado River delta (Sykes, 1937; McCoy et al, 1967). Although the 120 square kilometer area of California's Algodones dunes remains the place where *Ammobroma sonorae* has been most intensively surveyed, there are also herbarium records of the species from Baja California Norte, Sonora, and Arizona (WESTEC, 1977). The most poorly explored area of its occurrence is no doubt the western third of the 7800 square kilometer Gran Desierto of Sonora, the largest active sand sea in America (Felger, 1980). My search for *Ammobroma* in sand fields east of there such as

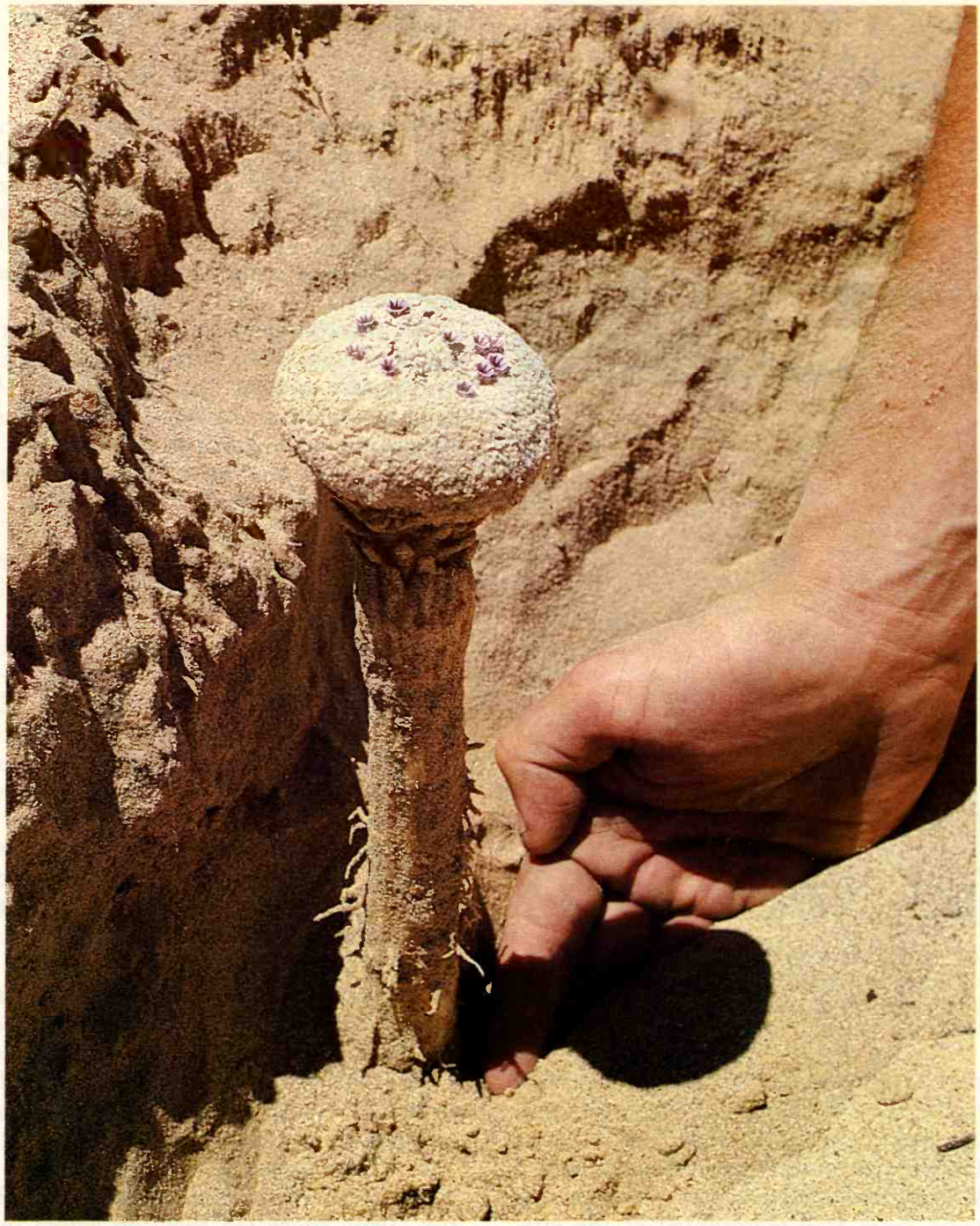


Ammobromma sonorae *between the Sierra del Rosario and San Luis, Sonora. Photograph by Matts Myhrman.*

the Mohawk Dunes and the Pinta Sands has as yet been fruitless.

Recently, Peter Warren and Deborah Goldberg recollected seeing an *Ammobroma* population two kilometers south of Los Tanques in the municipio of Alamos, Sonora. Returning during the spring of 1980, Peter Warren and I collected specimens of *A. culiacana* on the roots of *Jatropha platanifolia* in decomposing granite on the floor of short tree forest vegetation. The specimens are deposited in the Herbarium of the University of Arizona *(Warren and Nabhan, No. 1150).* The collection locality is nearly 400 kilometers north of the type locality of the species and its discovery suggests that *A. culiacana* may be scattered over a sizeable area of botanically unexplored subtropical vegetation along the west coast of Mexico.

It is possible to hypothesize a mode for the establishment of the disjunction between these two species via plate tectonic theory, given that *Ammobroma* or a Lennoaceous progenitor was in existence by the Miocene. Floras west of the San Andreas fault and Gulf rift, in southern California and Baja California, have been displaced northward at least 500 kilometers since the middle Miocene (Axelrod, 1979). Assuming that *A. culiacana* is more like the tropical progenitor of both species, *A.*

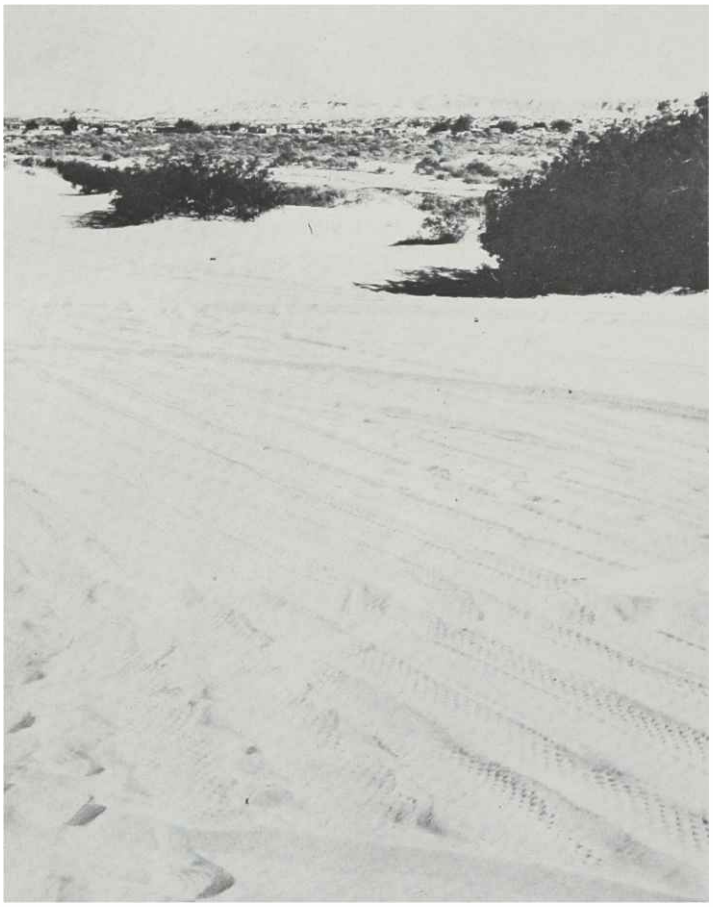


Ammobroma sonorae.

sonorae could have diverged into a more xeric species west of the San Andreas fault as peninsular California moved northward into a less mesic regime, and as the Sonoran Desert climate became more distinctively arid through time. The *A. sonorae* populations east of the fault are largely within the area in which the Colorado River has meandered and left alluvium for sand dune formation. Dispersal into this area from the other side of the fault would have been a simple matter. Assuming that the *A. sonorae* progenitor would have been situated at least 500 kilometers to the south, this would place it nearly adjacent to the newly discovered population of *A. culiacana*.

Ecology of *Ammobroma*

Gray (1856) first described *A. sonorae* within its habitat as "very abundant in the hills, all except the top buried in the sand, apparently attached to some other root or substance." Edward Palmer was the first to collect specimens of the shrubs which this parasite attaches itself to (Vasey and Rose, 1891). Over the years the number of host species known to science has increased to six, representing four families: White Bursage *(Ambrosia dumosa)*, Dune Buckwheat *(Eriogonum deserticola)*, Emory Dalea *(Psorothamnus emoryi)*, Arrowweed *(Tessaria sericea)*, Palmer Coldenia *(Tiquilia palmeri)*, and Plicate Coldenia *(Tiquilia plicata)*.



Destruction of dune vegetation, including Ammobroma habitat, by dune buggies at El Golfo de Santa Clara, Sonora. Photograph by Gary Nabhan.

In contrast, *Ammobroma culiacana* has been found attached only to species of Euphorbiaceae, either *Euphorbia* or *Jatropha*. The Los Tanques population in Sonoran short tree forest was attached exclusively to *Jatropha platanifolia,* even though other *Jatropha* were well-represented at the site. This suggests that *A. sonorae* may have evolved to be less host-specific. Finding and attaching onto a particular shrub may have been a limiting factor in its sand dune habitat where total cover by all perennial species is small.

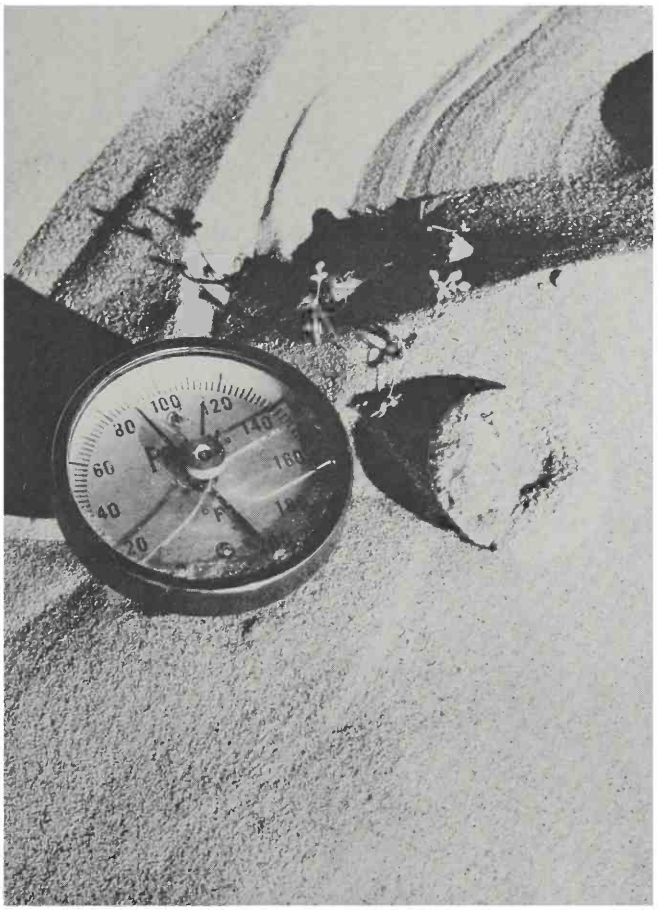
At Los Tanques, Sonora, *A. culiacana* plants were attached to the lateral roots of hosts at a 5–15 cm depth below the surface of decomposing granite and leaf litter. *Ammobroma sonorae* has adapted to a more extreme environment, on sandy plains and semi-stabilized, low dune slopes. The depth of its attachment to its host can vary from 0.3–1.5 m below the sand surface (Cothrun, 1969). Such deep attachment may reflect accretion of sand around the host, after original attachment at a shallower level. Nevertheless, it and other dune endemics can probably undergo germination and growth at deeper levels than non-adapted plants. Sand is an easier medium for plant tissues to grow through than heavier soils and during favorable seasons *A. sonorae* may send a stem curving through nearly two meters of sand so that it may flower on the surface.

Yet, through most of the year the plant remains in a zone of cool, moist sand well below the hot, highly evaporative surface. On May 4, 1980, I measured sand temperatures in the Algodones Dunes on the surface and at a depth of 300 mm (ca. 12 inches). During early afternoon, when air temperatures ranged around 36.7°–37.7°C (98–100°F), the surface of the sand next to *A. sonorae* flowers was 57.7°–61.0°C (136°–141°F). At a depth of 300 mm, the moist sand was only 25.0°–26.6°C (77°–80°). The sand felt wet and more cohesive below 200 mm.

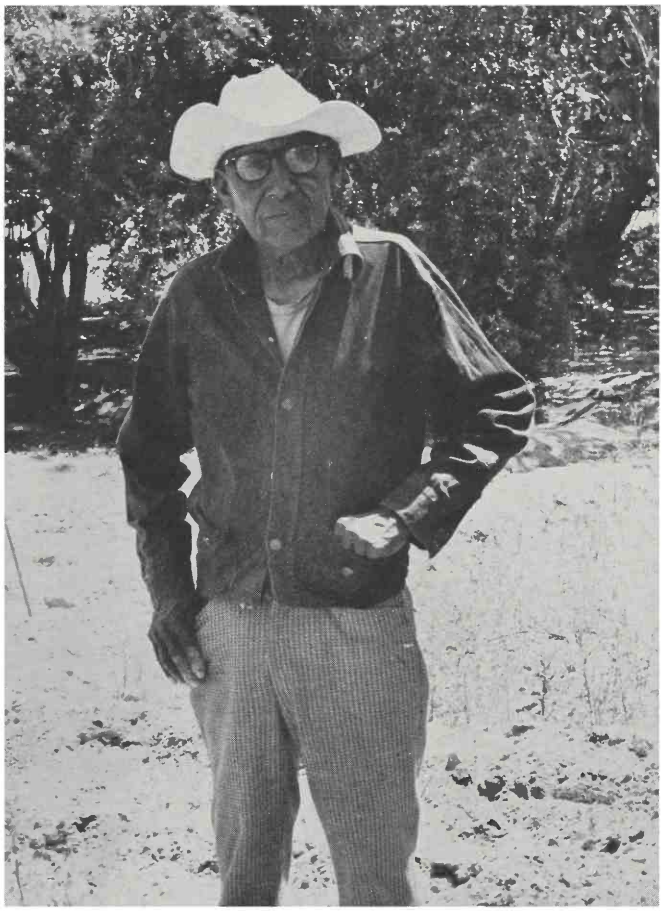
It is nevertheless remarkable that *Ammobroma sonorae* flowers can be fertilized and set seed on a surface so hot and exposed that it would critically stress the reproduction of other less tolerant species. Its adaptive strategy for dealing with potentially extreme light and heat loads may be to absorb as little radiation as possible. A wooly mat of gray hairs cushions developing seeds from direct exposure, covering the floral disc and adjacent upper stem surfaces, both of which lack chlorophyll. A fine layer of sand frequently accumulates on the wooly mat and reflects much radiation back toward the atmosphere. Additionally, preliminary measurements indicate that the tawny gray mat itself is highly reflective at most wavelengths, so that *Ammobroma sonorae* may be similar to other desert plants which reflect substantially more radiation than do more mesophytic species (see Gates et al, 1965).

Two hypotheses have been set forth to explain how *Ammobroma sonorae* reaches its host. Cothrun (1969) suggested that the whole inflorescence may break off and be rolled by the wind, spilling seeds as it goes. These seeds would tend to be trapped by hummocks of vegetation breaking their path and drifting sand could then bury them. It has been suggested (WESTEC, 1977) that Kangaroo Rats might deposit fragments of *Ammobroma* inflorescences in their burrows, dispersing seed into deeper layers of sand in the process.

Only a few of the thousands of seeds produced per plant may reach the root zone of a suitable host. Kuijt (1969) and Cothrun (1969) have concluded that the seeds must receive a chemical stimulant from the host to achieve germination and attachment. Cothrun's (1969) application of known germination stimulants failed to systematically break the inhibitors in *Ammobroma sonorae* seeds. His studies



Ammobroma sonorae *and soil temperature probe at the Algodones Dunes, Imperial Valley, California. Photograph by Gary Nabhan.*



Luciano, the Papago elder of Quitovac, Sonora, recalling eating Ammobroma in the dunes far to the west of his oasis village. Photograph by Gary Nabhan.

did document that the parasite invades the host by a combination of physical intrusion by the haustorium and apparent enzymatic digestion of the xylem of the host roots.

Much of the life history of *A. sonorae* remains hidden since only the flowering disc of the plant ever surfaces above the sand, and this for only a brief period each year. The timing of stem extension and flowering is largely keyed to the occurrence of winter rains, but Harold Ormsby has observed active *Ammobroma* growth in November in an artificially watered sand field near the border town of San Luis (Cothrun, 1969). Regardless of the moisture source, flowering does not necessarily occur in the same population at the same time every year, this varying from early March to late May. The non-reproductive parts of the plant may die back to the host root infestation during drought, or may remain fleshy and take up moisture and nutrients on their own. Thackery and Gilman (1931) suggested that active rootlets of *Ammobroma* represent a departure from "pure parasitism," and Thackery (1953) later found an example of *A. sonorae* biomass outweighing its Arrowweed host by more than thirty times. The implication by Thackery was that the parasite was not overtaxing its host, but instead gathering water on its own to supplement that which was provided by the host.

Ethnobotany

Near the Sea of Cortez coastline of Sonora in 1694, Juan Mateo Manje (1954) encountered "... poor people who lived by eating roots of wild sweet potatoes, honey, mesquite beans and other fruits." These nomads later became known as the Sand Papago, the westernmost Piman-speaking people of the Sonoran Desert. They have been called by other Papagos *Hia C-ed O'odham*, meaning "sand dunes-dwelling people," or rarely *S-o'odham S-ma:c O'odham* (Childs, 1954). Their underground plant food could not have been a true sweet potato, it surely must have been *Ammobroma sonorae.*

Manje's journal note was the earliest, but not the only suggestion that Ammobroma was a major food

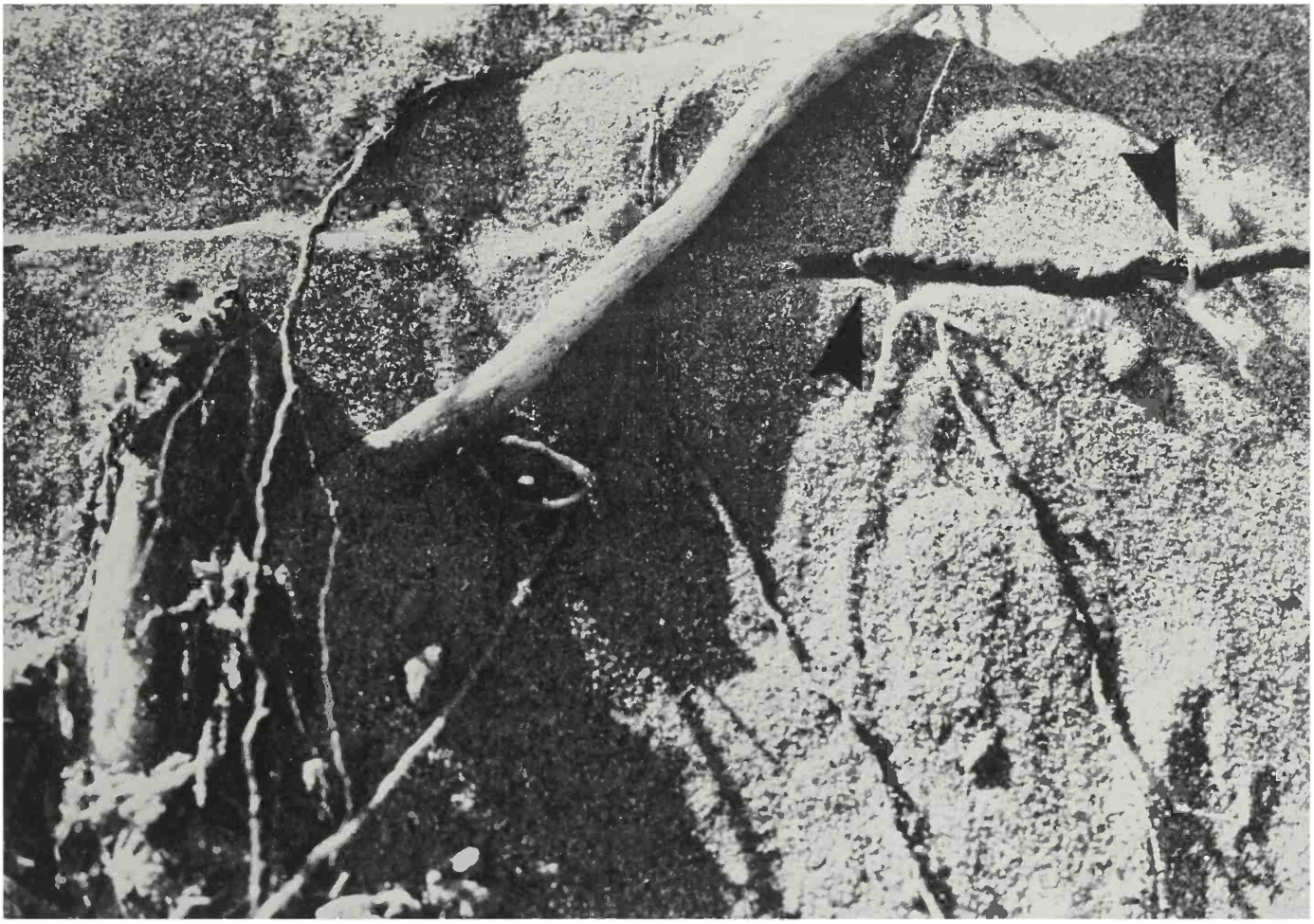
Ammobroma culiacana *growing with and parasitic on Jatropha platanifolia 11.9 miles south of Los Tanques (north of Los Alamos) Sonora. Photo courtesy of George Yatskievych.*

for these marginally agricultural people. Lumholtz (1912) tells us that for the Papago hermit named Caravajales, "... the 'roots of the sand' form his principal means of subsistence. In fact he lives almost entirely on these camotes, and is able to find them out of season." The Mexican-American term for "roots of the dunes," *camotes de los medanos,* was noted by Lumholtz and is still used by Spanish-speakers in western Sonora to describe *Ammobroma.* As evidence for his belief that the Pinacate Sand Papago were "intelligent, healthy and able-bodied, and able to make a good living in absolute desert," Lumholtz (1912) noted that they were keen enough to harvest *Ammobroma* "all the year round, though after May that part of the plant which is above ground withers away ..."

To prepare Ammobroma, Papagos visited by Gray (1855) roasted the stem on the hot coals of a campfire for twenty minutes. Gray (1856) later added that the plant was also dried in the sun, then ground with pods of Mesquite *(Prosopis glandulosa)* on a grinding stone to form *pinole,* the flour-like staple food that Southwestern Indians took with them nearly everywhere.

In May, 1980, I brought a sample of *A. sonorae* to Luciano, the oldest permanent Papago resident of Quitovac, Sonora. He quickly identified the plant by its Papago name, *hia tadk,* meaning "sand [dunes] root." Luciano recalled eating the plant when he was younger and noted that it was also prepared as a food similar to *carne seca,* being cut into strips and dried, then rehydrated when it was needed for a meal.

Other, non-Piman-speaking, peoples also used *Ammobroma* as food, but the regularity of use is not known. Ethnobotanical explorer Edward Palmer found that the plant was eaten raw, boiled or roasted among Yuman-speaking people at Colonia Lerdo, Sonora (Vasey and Rose, 1891). These are the people who call themselves *Kukpas,* or the Cocopas, who presently live near Somerton, Arizona, and along the Rio Hardy in Baja California Norte. Palmer commented that "whites and Indians alike resort to it when travelling, as a valuable substitute for water. It has a pleasant taste, much resembling the sweet potato ... The Cocopa Indians call it 'Oyutch.'" Gifford's (1931) monograph of the Kamia culture of southeastern California suggests that *Ammobroma* may well have been one of the dunes plants that they harvested, although it was not specifically mentioned.



Below ground view of **Ammobroma sonorae** *near point of attachment. Arrows indicate attachments to root of host. Photograph by Gary Nabhan.*

Although Sand Papagos are known to have harvested *Ammobroma sonorae* into the 1930's (Gordon, 1931), the traditional use of this food waned as both the western Papagos and Yuman-speaking groups were relocated away from where the plants grew in abundance. Any use of *A. culiacana* by Indians dwelling further south in Mexico has yet to be documented.

An Endangered Plant?

Ayensu and DeFillips (1978) list *Ammobroma sonorae* as a candidate endangered species of the continental United States. They defined endangered species as those which "are in danger of extinction throughout all or a significant portion of their range," noting that this species is endangered in California, while probably being unaware that it ranges into Arizona too. It is also listed in the Inventory of Rare and Endangered Plants published by the California Native Plant Society (Armstrong, 1980). However, *Ammobroma sonorae* is not yet officially listed by the U.S. Fish and Wildlife Service as an endangered plant for which interstate commerce and harvesting from public lands is forbidden.

Regardless of official designation, botanists are concerned because *A. sonorae* is rarely encountered today. To some extent, that is a function of the limited number of dunes formed within the range of the species and the infrequency with which botanists brave the heat to seek out plants in this area during late spring.

In places where dunes habitat exists today (e.g. the Algodones chain), *A. sonorae* can be "fairly abundant ... during favorable years ..." (Armstrong, 1980; see also WESTEC, 1977). In areas where native Americans historically harvested *A. sonorae* year round, there is no indication from the literature that they actually decreased the size of the plant's populations. It remains to be investigated whether harvesting the top portions of one or two stems on the same host plant might stimulate or reduce *Ammobroma* branching and abundance, an observation first made by Rodney Engard (personal communication).

What has affected *Ammobroma sonorae* is outright destruction of habitat—bulldozing or clearing of native dune vegetation, including potential host plants. Center-pivot and canal irrigated fields have

been established in southwestern Yuma County, Arizona, in an area where *Ammobroma* was collected historically. Armstrong (1980) relates the story of a movie company wanting to remove excess "brush" that would ruin the "Saharan" effect of their scene; the "brush" included *Ammobroma* and its hosts.

Motorized, off-road vehicles (ORVs) pose another threat to these parasites and their hosts, both through running over live plants and by causing soil compaction. On major holiday weekends, as many as 10,000–15,000 people have used the Algodones Dunes for recreation, primarily driving dune buggies through dunes within one or two kilometers of paved roads (WESTEC, 1977). The Bureau of Land Management has excluded ORVs from parts of the Algodones Dunes and there remain large areas in these dunes where *Ammobroma* habitat is seldom reached by ORVs. Yet dune buggies still denude large areas of sand-adapted vegetation in Arizona and Sonora, particularly on the coast near El Golfo de Santa Clara where the plant has been found [*cf. specimen collected by Niemi in the University of Arizona herbarium*]. An additional threat to probable Ammobroma habitat along the Arizona border is that much of the area falls within the bombing and gunnery range of Luke Air Force Base, where destruction of vegetative cover by military maneuvers is obvious.

While *A. sonorae* is officially protected from habitat destruction in the Algodones Dunes Research Natural Area, a Registered National Natural Landmark in California, its persistence elsewhere is in no way insured. Within the United States it is threatened with extinction or is already gone from a significant portion of its former range. It rightly deserves status as an endangered species. What may allow it to survive is its own hardiness—its ability to grow in certain places too arid and isolated to attract many people. Even in the path of man, it can be indefatigible. In 1967, David Cothrun [*cf. specimen in University of Arizona Herbarium*] found *Ammobroma sonorae* "... just off the edge of old U.S. 80, and growing through 6 inches of soft tar ..."

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