J. Ethnobiol. 1 (1): 135-164 May 1981

DEVIL'S CLAW DOMESTICATION: EVIDENCE FROM SOUTHWESTERN INDIAN FIELDS

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ABSTRACT.—Devil's claw (*Proboscidea*; family Martyniaceae), herbaceous plants of deserts and grasslands, have been utilized for food and fiber by numerous Indian groups in southwestern North America. A white seeded devil's claw, with longer fruit providing more useful basketry fiber, has been cultivated by basketmakers in California, Nevada, Utah, Arizona and Sonora. Historically, this devil's claw taxa has been poorly understood, and has often not been recognized as being genetically distinct from wild *Proboscidea* spp. in the region.

Through morphological, ecological and chemical comparison with other *Proboscidea*, in the wild and under cultivation, certain distinguishing characteristics become apparent. The white seeded race appears to be most closely related to typical *Proboscidea parviflora* (Woot.) Woot. & Sandl., and their differences are in those characteristics most often altered via domestication. It is suggested that cultural selection by basket-making native farmers in the Southwest, and natural selection in their field environments can account for the distinctiveness of the white seeded devil's claw.

Additionally, ethnographic and linguistic information elucidate the white seeded race's affinity with *P. parviflora*, yet also its distinction as a native cultivated crop. After evaluating these various data, it is concluded that *P. parviflora* has undergone the evolutionary process of domestication, increasing its usefulness as a basketry fiber producer. It does not merit the status of a cultigen—or fully domesticated plant—since its survival from year to year is not entirely dependent on man's intentional planting. Yet, white seeded devil's claw is today highly associated with cultivation in a few Indian *rancherias* in Arizona.

INTRODUCTION

To *domesticate* a plant literally means to bring it into the human household. The process of domestication involves cultural selection for economic characters, as well as natural selection in the man-altered environment where the plants are grown. The intensity of these selective pressures is not constant through time nor through space. It varies with the demand for the economic product, the kind of horticulture or agriculture practiced by the people involved, and the degree of geographical or phenological isolation between the cultivated plants and their wild relatives.

Often, an incipient domesticate has not been recognized as such. This is because the cultivated plant may still have the appearance of its wild relatives. Additionally, the early stages of cultural adoption may not involve formal husbandry so much as simple seed selection, sowing and protection in an otherwise unmanaged environment, which looks "wild" to observers from another culture.

Given these conditions, it is not surprising that it took Europeans more than 2 centuries in southwestern North America before they questioned whether certain plants the Indians utilized were more than merely wild crops. In the case of devil's claw (*Proboscidea*), the use of the plant for food and fiber was recognized decades before its outright cultivation was noted (Fig. 1). Additional time passed before scientists first suggested the plant as a possible domesticate.

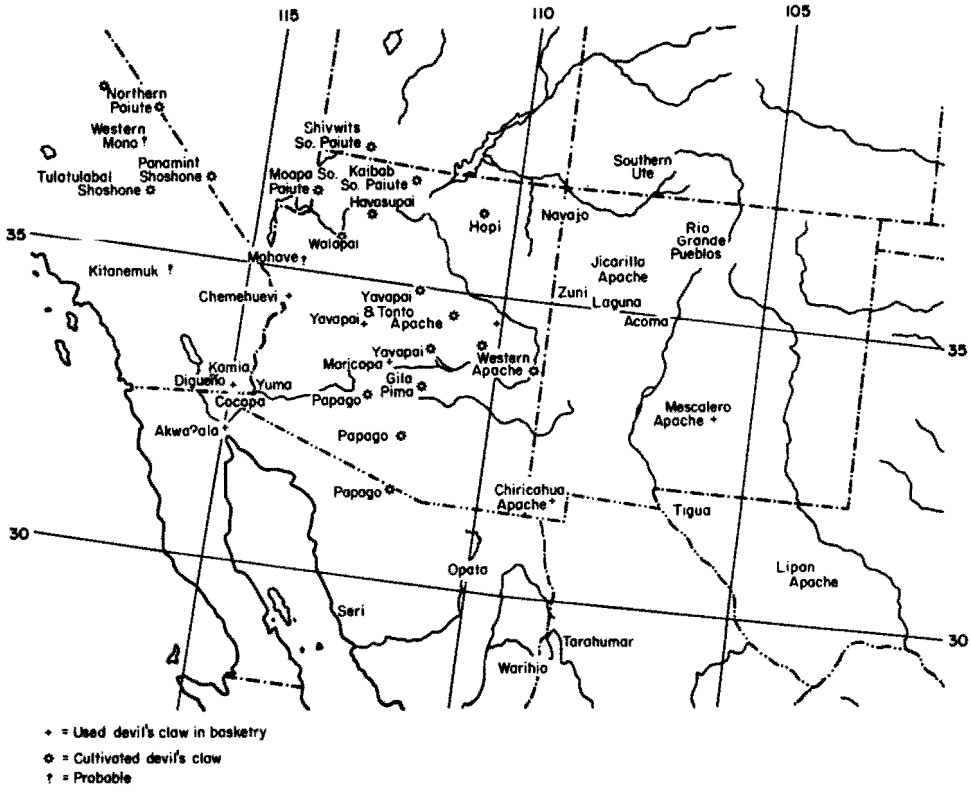

FIG. 1. Locations of tribes growing or using devil's claw (cartography by Alison Habel).

Early researchers suggested the presence of "introduced" kinds of devil's claw among the Indians. However, Castetter and Bell (1942:113, 202) were the first to realize that one kind was almost completely dependent upon cultivation. They noted that a second kind of annual devil's claw among the Pima and Papago was different from the wild kind in Arizona in respect to several characteristics. They claimed that this longer clawed, white seeded kind was found *only* under intentional cultivation or as a volunteer in agricultural fields.

Hevly has indicated (in Correll and Johnston 1970:1448) that strains of *Proboscidea parviflora* (Woot.) Woot. and Standl. semi-cultivated by Southwestern aboriginal groups are anomalous for *Proboscidea* in that they have white seeds. Recently, Yarnell (1977), without further data or analysis, concluded that *Proboscidea parviflora* was one of only 3 species definitely domesticated north of Mexico.

If one goes to the reservations of the Papago and Pima Indians today, one finds a somewhat more complicated situation than that described by Castetter and Bell (1942). Both black and white seeded devil's claw are cultivated in fields and gardens, additionally white seeded devil's claw can be found on roadsides and in arroyos within Papago *rancherias*, growing nearby the more common black seeded *Proboscidea parviflora* (Nabhan and Fritz 1977). Given this information alone, we feel that the data in Castetter and Bell's work do not place devil's claw in enough of a cultural and botanical context to convince the scientific community that domestication has actually occurred.

The proposed status of domesticate for *Proboscidea parviflora* has thus been largely unrecognized and untested. We will use the devil's claw example as a case study in how

anthropologists and botanists methodologically determine when a plant has undergone cultural selection and domestication, over and above mere cultivation. Additionally, we discuss problems in the interpretation of historic specimens and ethnographic data, and suggest some testable indicators of domestication.

In presenting hypotheses regarding how and where the domestication process might have occurred for *Proboscidea*, we wish to emphasize how much has yet to be learned. We hope to encourage further research of devil's claw as well as of other little-known crops. Such research is urgently needed, since many minor crops have been abandoned within this century as modern monocultural agriculture has usurped the land and water formerly allotted to smaller scale mixed crops.

Devil's claw cultivation is a case in point. Today it is practiced in only a few "islands" within its former range. Due to the demise of traditional basketry and agriculture among several Southwestern cultures, considerable native knowledge and *Proboscidea* germ plasm have eroded within the last half century.

DISCUSSION

Botanical Background and Historical Recognition

Within the New World family Martyniaceae, the genus *Proboscidea* is divided into 2 subgenera: *Dissolphia*, including 3 yellow-flowered perennial species; and *Proboscidea*, including 10 species, most of which are annual, with flowers of cream, pink or purplish hues (Van Eseltine 1929; Hevly in Correll and Johnston 1970; Hevly 1969a; 1970). We will be concerned with 3 annual species of the southwestern United States and adjacent Mexico: *Proboscidea fragrans* (Lindl.) Decne.; *P. louisianica* Miller (Thell.), and *P. parviflora* (Woot.) Woot. and Standl.

Partially overlapping in range, (eg., in Texas), these species are nevertheless phenetically distinct and macroscopically distinguishable (Table 1). However, the 3 species have been found to be experimentally cross-compatible. First generation (F^1) flowering and fruiting hybrids can easily be obtained, although F^1 fruits contain few seed (Anderson 1922: 141; Perry 1942; Hevly, unpubl. data). A more thorough treatment of the genetic and biogeographic relationships of these species is currently being prepared by Peter Bretting at Indiana University, in a taxonomic revision of the genus *Proboscidea*.

In the 1870s, Dr. Edward Palmer published 2 of the first specific notes on the use of Southwestern devil's claw. Palmer (1871:422) noted that the Apache Indians cooked the immature fruit of *Martynia violacea* for food, and utilized part of the ripened fruit as ornamentation in basketry. Additionally, Palmer (1875:112) described the preparation of fruit of *Martenia proboscides* as a black basketry ornamentation, as it is used "by all the tribes of Arizona." At the time that Palmer made these comments, only 2 annual species of devil's claw were recognized in North America, both with large calyces; *M. fragrans*, for which *M. violacea* is a synonym—with purple flowers; and *M. louisianica*, for which *Martenia proboscides* is a misspelled synonym—with white to pink flowers.

Neither article acknowledges if Palmer collected voucher specimens to substantiate these identifications; thus there is no way of checking the suggestion that 2 species were then utilized. The paucity of voucher specimens, as we shall see, has persisted into recent decades; it is still not clear if more than one devil's claw species has been utilized in Southwestern basketry.

During the decades that followed Palmer's articles, it became apparent that the most common kind of devil's claw in Arizona, New Mexico and adjacent Mexico is distinct from the above 2 species due to its smaller calyces, and differently colored flowers. This species was named *Martynia parviflora* Wooton in 1898, but was transferred along with *M. louisianica* and *M. frangrans* to the genus *Proboscidea* because their flower and fruit characteristics were incompatible with *Martynia* (Hevly 1969b).

TABLE 1.—*Comparison of* Proboscidea *in the Southwest.*

CHARACTER	(SUGGESTED DOMESTICATE) WHITE-SEEDED RACE	UNDER CULTIVATION: P. PARVIFLORA	IN THE WILD P. PARVIFLORA	P. LOUISIANICA	P. FRAGRANS
Geographic distribution	Southern Nevada, southern Utah, southeast California, Arizona, & northeast Sonora	Arizona (a few tribes) & experimentally in Arizona & New Mexico	Arizona, south and west New Mexico, & Trans-Pecos Texas. North Mexico west of Sierra Madre. Rare in Californias; extremely rare in Nevada.	Southern U.S. to Colorado, eastern New Mexico & central Texas. Adventive in California, elsewhere.	Tran-Pecos Texas & northeastern Mexico east of the Sierra Madre.
Plant size	To 1.4m tall x 3m wide	To .9m tall x 1.8m wide	To .5m tall x 1.5m wide	To 17m tall x 1.2m wide	To .6m tall x 2m wide
Leaves	Sub-orbicular-ovate, sometimes deltoid-ovate; entire to 3-10 lobed; sinuses obtuse, denticultate; width up to 35cm; cordate to inequilateral at base.	Sub-orbiular-ovate to deltoid-ovate to deltoid-ovate; entire to 3-10 lobed; sinuses obtuse, denticulate; width up to 25 cm; cordate to inequilateral at base.	Bus-orbicular-ovate to deltoid-ovate; entire to 3-7 lobed; sinuses obtuse, denticulate; width up to 25 cm; cordate to inequilateral at base.	Orbicular-reniform to broadly ovate; entire to sinuate; width up to 30 cm; cordate at base.	Deltoid to broadly ovate; nearly entire to 5-7 lobed; sinuses acute; width up to 25cm; cordate to equalateral at base
Inflorescence	Surpassed by, or rarely equalling the foliage	Equalling or surpassed by the foliage	Equalling or surpassed by the foliage	Surpassing the foliage.	Surpassing the foliage.
FLOWERS:					
Calyx length	15-27mm; bracts 8-17mm	15-20mm; bracts 4-11mm	10-15mm; bracts 5-8mm	15-20mm; bracts 7-10mm	25mm; bracts 12mm
Corolla length	34-54mm	34-44mm	25-40mm	35-55mm	35-65mm
Corolla color	Dull white to pink; rarely reddish purple; limb often with faint purple blotches on upper lobes	Reddish-purple, pink to nearly white; limb often with purple on upper lobes	Reddish-purple, pink to nearly white; limb often with purple on upper lobes	Dull white to somewhat pinkish purple; purple blotches absent or blotches on upper lobes	Violet purple to reddish purple, rarely white; limb often with purple blotches
Corolla internal ornamentation	Bright yellow guidelines, & small red dots associated with them in lower half of tube; dark blotches absent	Bright yellow guidelines; & small red dots associated with them in lower tube; blotches usually lacking	Bright yellow guidelines; & small red dots associated with them in lower tube; blotches usually lacking	Yellow-orange guidelines, violet blotches, orange or red-purple dots around the entire tube.	Bright yellow guidelines; violet blotches & dark red-purple dots the entire tube length.
Filament pubescens	Gladular at or below their point of attachment but glabrous above the arcuately curved portion.	Glandular at or below their point of attachment but glabrous above the arcuately curved portion.	Glandular at or below their point of attachment but glabrous above the arcuately curved portion.	Glabrous, sparsely villous or tomentose below attachment point, glandular on arcuately curved portion.	Glabrous, sparsely villous or romentose below attachment point, glandular on arcuately curved portion
FRUIT:					
Number per plant	75-200	60-100	40-80	40-80	40-80
Claw/body ratio	2.5-3	2-2.5	2-2.5	1.5-3	ca. 1.6
Claw length	25.3±4.8cm	17.0±2.7cm	15.7±4.8cm	9-30cm	to 20cm
Pliability	Soft-pliable	Hard-brittle	Hard-brittle	Hard-brittle	Hard-brittle
Color	Darker black	Brown-black	Brown-black	Brown-black	Brown-black
SEED:					
Number per fruit	49.5±12	58.2±9	40-55?	15-67	
Size	.955-.059x.516.040mm	.984-.070x.527.055mm	8-10x4.5-6mm	7-10x5-6mm	6.5-8x4-5.5cm
Color	White-gray	Black-gray	Black-gray	Black-brown	Black-brown
Germination	More immediate, even	Delayed, uneven	Delayed, uneven	Delayed, uneven	Delayed, uneven
Per cent oil	39.2-40.3%	35-38.5%	35-40%	35-43.5%	39%
Per cent protein	23.9-25.5%	20-25%	20-30%	20-25%	
Pollination: (& compatibility) Insect visitors (*pollinator)	Crossing by bees (Some selfing?) *Perdita hurdi, Bombus sonorus, Apis melifera, Xenoglossa angustior, Melissodes sp.*, Xylocopa brasilionorum, Xylocopa orpifex androlenca*	Crossing by bees (Selfing 15% effective) *Xylocopa orpifex androlenca*	Crossing by bees (Selfing?)	Crossing by bees (Selfing rare or ineffective) *Melissodes communis*, Anthophora occidenialis*, Augochlorella striata*, Bombus fervidus*, Lasioglassum spp., Bombus americanorum*, Melissodes obliqua*.* (Phillippii, personal communication 1976)	Crossing by bees *Xylocopa spp., Bombus sonorus*

Over the hundred years since Palmer's introductory notes, the use of devil's claw has been recorded for more than 30 native culture groups in southwestern North America (Table 2). In addition to basketmakers' use of fiber splints from the dried fruit, devil's claw fruit and seed have been eaten, and used medicinally; the fruit have been made into tools and ornaments, and have been given supernatural significance. Again, because written references have seldom been accompanied by voucher specimens, and because obsolete nomenclature has often been utilized, we can only guess which devil's claw species various ethnographers have seen.

After the turn of the century, ethnographers began to comment on the planting and protection of devil's claw (Table 3). Russell (1908:133), Spier (1928:134), and Roberts (1929:141) imply that cultivation or lack of it was directly related to the abundance of wild

TABLE 2.—*Devil's claw use in southwestern North America: Early ethnographic references.*

Culture Group	Basketry Use	Other Use	Early References	Early Identifications	Other References
Santa Clara Pueblo		X	Robbins et al, 1916:57	*Martynia*	
Jemez Pueblo		X	Castetter, 1939:notes	*Martynia*	
Cochiti Pueblo		X	Lange, 1959:150		
Zuni Pueblo		X	Stevenson, 1909:46	*M. louisiana*	this report
Hopi Pueblo	X	X	Hough, 1897:33-44	*M. louisiana*	Whiting, 1939:92
Hano Pueblo			Robbins, et al, 1916:57	*Martynia*	
Apache (general)	X	X	Palmer, 1871:422	*M. violacea*	Palmer, 1875:112
Warm Springs Apache	X		Gifford, 1940:45	*Martynia*	
Mescalero Apache	X		Gifford, 1940:45	*Martynia*	
Chiricahua Apache		X	Gifford, 1940:45	*M. louisiana*	Castetter and Opler, 1936:45
Huachuca Apache	X		Gifford 1940:45	*Martynia*	
			Gifford, 1940:45	*Martynia*	
Cibeque Western Apache	X		Gifford, 1940:45	*Martynia*	Buskirk, 1949:164
White Mountain Western Apache	X		Mason, 1904:512	*M. louisiana*	Rea, 1977: notes
San Carlos Western Apache	X		Hrdlicka, 1905:404	cat's claw	Roberts, 1929:141
Western Yavapai	X	X	Corbusier, 1886:324	cat's claw	Gifford, 1936:281
Northeastern Yavapai	X		Gifford, 1936:281	*Martynia*	
Walapai	X		Mason, 1904:517	*Martynia*	McKennan, 1935:80
Havasupai	X		Voth, 1890s:11	*M. louisiana*	Spier, 1928:134
Southern Paiute (general)	X	X	Palmer, 1870s, noted in Bye, 1972:98		
Virgin River and Moapa So. Paiute	X	X	this report		
Shivwits So. Paiute	X		Stewart, 1942:340	*M. proboscidea*	Drucker, 1941:110
Kaibab So. Paiute	X		Stewart, 1942:340	*M. proboscidea*	Kelly, 1964:78, 80
Chemehuevi	X		Mason, 1904:519	*Martynia*	Stoffle and Evans, 1976:4
Kawaiisu	X		Merrill, 1923:7	*M. proboscidea*	Zigmond, 1978:202
Panamint Shoshone (Koso)	X		Coville, 1892:358	*M. proboscidea*	Merriam 1903:826
Death Valley Shoshone	X		Steward, 1941:338	*M. proboscidea*	Jaeger, 1941:248
Northern Paiute	X		Steward, 1941:338	*M. proboscidea*	
Western Mono	X		Merrill, 1923:7	*M. proboscidea*	
Kern River Tubatulabal	X		Merrill, 1923:7	*M. proboscidea*	Voegelin, 1938:80
Kitanemuk	X		Merrill, 1923:7	*M. proboscidea*	
Akwaʔala (Pai Pai)	X?		Drucker, 1941:110	*Martynia*	
Maricopa	X	X	Forde, 1931:124	*Martynia*	Spier, 1946:129
Gila Pima & Papago	X	X	Mason, 1904:519	*Martynia*	Russell, 1908:133
Yaqui		X	Watson, 1898:66	*M. palmeri*	
Seri		X	Felger & Moser, 1976:23	*P. altheaefolia*	
Warihio		X	Gentry, 1963:92	*M. annua, M. fragrans*	
Pima Bajo (Lowland Onovas)		X	Pennington, 1980	*P. arenaria*	Rea, 1978:notes
				P. sinaloensis	

TABLE 3.—*Ethnographic references to devil's claw cultivation.*

Culture Group	Citation	Quotation
Pima	Hrdlicka 1906:43	The cat's claw is cultivated by the Pima in their melon patches.
Pima	Russell 1908:133	The pods of the devil's claw, *Martynia fragrans* Lindl., furnish the third material necessary for the ordinary basket. The supply of wild plants is not large enough, and a few martynia seeds are planted each year by the basketmakers.
Papago & Pima	Kissell 1916:202	Although martynia grows wild, most of the Indians seed it in their fields, since they find the cultivated plant yields pods with hooks of greater length, finer grain and a better black.
Pima	Breazeale 1923:42	The martynia, or devil's claw grows wild ... but I have never seen it growing out upon the desert away from any cultivated field or wash. The Indians often plant a few stalks around their houses, as the wild varieties often have horns not suitable for basketry.;
Papago	Castetter & Underhill 1935:57	The black was ihu'k, the unicorn plant or devil's claw (*Martynia fragrans*) ... Now many sow the seed and raise a regular crop.
Pima & Papago	Castetter & Bell 1942:202	Only the white seeded form was grown, as its pods had longer, finer grained and deeper black black strips of epidermal tissue, and therefore more suitable for use in basketry. They were planted in hills ...
Pima	Curtin 1949:107	Ihuk is cultivated by the Pima for use in basket-making, although it grows wild on plains and mesas.
Papago	Dobyns 1952:211	Papagos domesticated *eohuk* (*Martynia louisiana*), the pod bark being their black material for basket designs.
Havasupai	Spier 1928:134-135	The second variety, with hooks 25 to 30 cm long, was introduced by Pagadjahuda, a Walapai. Although the wild plants are also used, it is customary to plant martynia at the same time as corn.
Havasupai	Whiting 1942:378	[Pagadjahuda planted a whole field of the introduced variety, selling a superior product. Another Havasupai woman, however, claimed she had herself introduced the plant from the Mohaves. Another thought the seeds had been obtained from the Hopi long ago, while still another suggested the Yavapai as a source.]
Havasupai	McKee, McKee & Herold 1975:13	... and an introduced variety with hooks about four inches longer is commonly cultivated. The latter yields adequate crops of the black claws for local use, so few basketmakers gather the smaller wild form.
Apache	Roberts 1929:141	... the San Carlos do not cultivate the plant as do some other tribes, for it is plentiful in their country in its wild state.
Tubatulabal Shoshone	Voegelin 1938:30	Coiled basketed decorated in ... black material from ... antennae of pods of devil's horn, *Martynia proboscidea* Glox ... which is classified as weed, grown occasionally in gardens now, pods sometimes saved
Shoshone & Northern Paiute	Steward 1941:338	NP-Fsp [Northern Paiute, Fish Springs, California, near Bishop]: procured it from Saline V., through TS said his father had planted it at Fish Springs ... S-Lida [Shonshoni of Lida, Nevada, north of Death Valley]: planted devil's claw in gardens.
Shoshone	Jaeger 1941:248	... *M. parviflora* ... was introduced into Death Valley eighty years ago by a brother of Hungry Bill, a Shoshone Indian, who visited Fort Mohave and found the Indians there making black patterns in their baskets from fiber of the fruits. He procured seeds and planted them in Johnson Canyon; the plant still flourishes there.
Shivwits & Kaibab Southern Paiute	Stewart 1942:340	Devil's claw (*Martynia proboscidea*) SK [Southern Paiute, Kaibab]: Use learned from SS [Southern Paiute, Shivwits] and material still purchased from them. (Kelly, ms, states seeds seeds have been planted near Mocassin, Arizona).
Kaibab Southern Paiute	Kelly 1964:80	With the development of decorated ware, seeds of *Martynia* (tuusupi *Martynia proboscidea*) obtained from St. George, Utah, planted locally.
Panamint-Death Valley Shoshone now near Bishop	Smith and Simpson 1964:46	Mamie Button's basket is woven of willow, Joshua tree roots and fibers from the fruit of devil's claw ... The dark brown designs are woven of *Martynia parviflora* which Mamie called devil's claw. The Hunters and Buttons cultivate this black-seeded annual in their garden for use in basket-making.

devil's claw in their area at the time. It is usually stated that devil's claw is grown for its fiber used in basketry, although in certain cultures (e.g. the Papago), seeds were no doubt eaten also.

Although split devil's claw fiber splints have been found in cave deposits dating roughly A.D. 1150 in Arizona (Exhausted Cave - Hevly and Hudgens MS) and New Mexico (Bluhm 1960), the antiquity of devil's claw cultivation is an open question: Did cultivation for basketry fiber occur in previous centuries, unrecognized or ignored by chroniclers, or did it begin this last century to keep pace with basketry sales?

Beginning with Spier (1928:134-135), there are statements that a longer clawed cultivated variety is introduced rather than being indigenous to the localities where it is grown. Kissell (1916:202) implies that the wild devil's claw in Papago country is seeded in their fields, and that cultivation produces longer clawed fruit with better qualities for basketry.

From the 1930s onward, specimens accompanied by limited ethnographic data were deposited in museums and herbaria (Table 4). Associated field notes are often unfortunately ambiguous. For instance, Percy Train's note that at Moapa, Nevada, devil's claw is "In Indian field," does not clarify whether or not he collected an intentionally planted crop, a self-seeded feral plant, or a wild "weedy" volunteer. Particularly in terms of fruit size, we don't know if collectors chose an atypically large fruit, a representative individual, or a conveniently small fruit that could be "pressed and mounted" easily. Botanists continued to label their specimens with obsolete nomenclature, and of course anthropologists were no more aware that finer taxonomic distinctions were possible. Fig. 2 maps the sites of cultivation.

Castetter and his colleagues, during their studies of Pima and Papago ethnobotany, amassed considerable information regarding devil's claw cultivation. Yet even their information is ambiguous on some major points, and at times it is contradictory. Castetter and Underhill (1935:57) note that *Martynia fragrans* grows wild in Papago country (sic), but long ago, women began to protect fertile patches of it; later they began to sow its seeds. Castetter and Bell (1942:113) identify as *M. louisianica* both the wild black seeded variety, and the white seeded, longer clawed kind that "never grew wild," but is propagated by planting in holes. They doubted that Pimans who asserted that devil's claw has been cultivated for a long time, and suggested that only wild *Martynia* was utilized before a commercial stimulus increased basketry production.

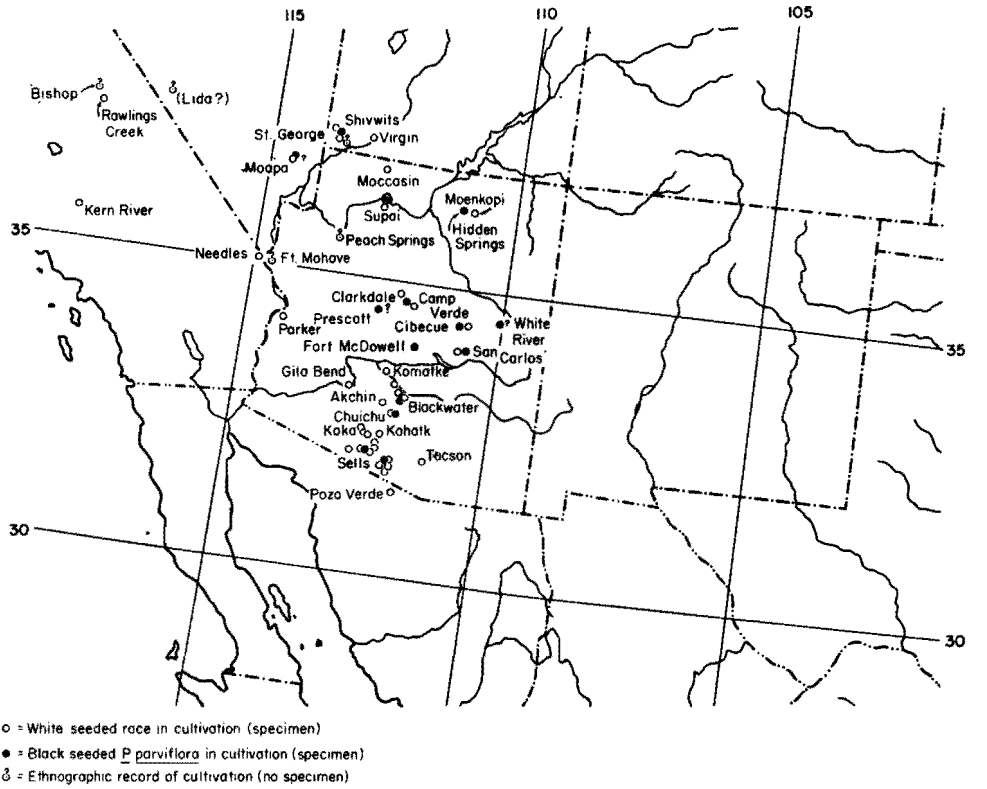

FIG. 2. Locations of devil's claw cultivation by Native Americans (cartography by Alison Habel).

TABLE 4a.—*Possible records of the suggested domesticate in museums and herbaria.*

Original ID	Locality	Culture	Collector & #	Date	Museum or Herbaria	Suggestive Characteristics
M. probosidea	Weldon, Kern Co., Calif.	Tubatulabal Shoshone	E.W. Voegelin #13	7/7/32	UC	"used for black basketry material...
M. louisianica?	Monolith, Paiute Mts. Kern Co., Calif.	Kawaiisu	Zigmond 57/2	7/22/37	F	(no notes on specimen, but Zigmond (1978) suggests it was introduced from Needles, with claw length of 20 cm)
P. louisianica?	Keene, Kern Co., Calif.	Shoshone?	J.D. Woolsey	9/04	UC	"Escaped" (No other notes: inference same as above)
M. louisianica	Moapa Indian Reservation, Clark Co., Nevada	Moapa Southern Paiute	Percy Train #1917	6/6/38	NY, ARIZ	"In Indian field." (Light flower color. Leaves surpassing inflorescence. Rare in wild in Nevada)
M. louisianica	Moapa Indian Agency, Clark Co., Nevada	Moapa Southern Paiute	Eva Murphey #675	9/27/37	RENO, UC	"Garden...Rich soil." (Claws 21 & 24.3 cm; white seed; leaves surpassing inflorescence)
M. louisianica	Virgin, Washington Co., Utah	Virgin River Southern Paiute?	Marcus Jones #6086	9/27/1894	UC, NY, US, MBG	(Rare in Utah. Claws 8, 27, 26, 22.2 cm; leaves large, up to 19 x 17 cm)
M. proboscidea	Havasupai Canyon, Coconino Co., Ariz.	Havasupai	Elzada Clover #5179	7/17/40	ARIZ	"In fields. Used by Indians in basket weaving." (Fruit immature; possibly the wild race, but too young to tell).
P. parviflora	Havasu Canyon, Coconino Co., Ariz.	Havasupai	A.F. Whiting #1047/B4504	10/18-25/40	MNA	Long claw (32.3 cm); white seed. Planted in fields. *halaa' kakiyula* hooked long). Used in basketry
P. parviflora?	Havasupai Canyon, near Navajo Falls, Coconino Co., Ariz.	Havasupai	C.F. Deaver #4454	10/3/53	NAU	White seed, claws up to 17 cm on immature fruit. Not clear if in fields or beyond.
M. parviflora	Wilkerson Ranch, Rawson Creek, 6 mi so. of Bishop, Inyo Co., Calif.	Panamint Death Valley, Shonshone	R. Enfield for G. Smith	8/14/64	San Bernadino Co. Museum	White seed, claws 25.5 cm. "The Hunters & Buttons cultivated this black-seeded (sic) annual in their gardens."
P. parviflora	Seed from Kitt Peak, Papago Indian Reservation, Pima Co., Ariz.	Papago	Vorsila Bohrer #1257, 1258	10/27/67	ARIZ	"White seed; flowers white with purple spot." (Claws 15.5-25.5 cm.)
Proboscidea	Little Tucson, Papago Indian Reservation, Pima Co., Ariz.	Papago E-74	Wetmore Dodge	to 12/38	ASM	"Cultivated e'hook. The soft variety is white. A white seed is called s-noik..." (claw 27 cm; white seeds).
P. parviflora	Fresnal, Papago Indian Reservation, Pima Co., Ariz.	Papago #7916	R.H. Peebles		ARIZ	"Flowers light purple...Papago name 'Ee' kuk.' Used in basketry." (White seed, claw 21 cm).
Proboscidea	Pozo Verde, Sonora, Mexico	Papago	Edmund Faubert #54-30, 31	11/19-28/74	CRN, INAH	(White seed, claw 18 cm.)

?=Some doubt as to identification due to lack of field notes, or poor quality of specimen.

TABLE 4b.—*Our collections of culturally utilized devil's claw in herbaria.*

Proposed Status	Locality	Culture	Collector & #	Date	Herb	Suggestive Characteristics
Wild	Oraibi, Navajo Co., Ariz. 5,675 ft.	Hopi	Whiting 854/B2851	9/14/37	MNA	Immature. Roadside. Tolerated weed when in fields. Used in kachinas, for awls; associated with lightning and rain bringing. *tumo ala.*
Domesticate	Supai Village, Coconino Co., Ariz. 5,600 ft.	Havasupai	Whiting 1047/B4504	10/18-25/40	MNA	Long claws, white seed. Planted in fields. halaa kakiyula-(hooked long). Used in basketry.
Wild	Supai Village, Coconinq Co., Ariz. 5,600 ft.	Havasupai	Whiting 1047/B4505	10/18-25/40	MNA	Short claw, black seed. Wild in fields and waste places near the village. Tolerated when self-seeded in fields. Used in basketry.
Domesticate	Clarksdale, Yavapai Co., Ariz. 3,400 ft. Seed grown in Cornville	Apache	Whiting 3099/B24, 344 and 3099/B24, 311	6/19/76, 6/21/76	MNA	Seedlings cultivated from white-gray seed. Cultivated in Clarkdale for basketry fiber.
Domesticate	Supai Village, Coconino Co., Ariz. 5,600 ft. Seed grown in Cornville	Havasupai	Whiting 3099/B24, 343 from R.C. Euler	7/23/76	MNA	White seed, low claws. Cultivated in Supai for basketry fiber.
Domesticate	Topowa, Pima Co., Ariz. 2,474 ft.	Papago	Bretting and Nabhan x465	8/14/76	ARIZ	Volunteer in garden with squash, being watered to produce fiber for basketry. Pale flower. Large leaves.
Domesticate	Anegam, Pima Co., Ariz. 2,400-3,000 ft.	Papago	Bretting and Nabhan x467	8/14/76	ARIZ	White seed, long claws, pale flowers. Planted and irrigated in dooryard garden; also volunteers watered and tolerated in watermelon patch. Grown to sell to basketmakers.
Domesticate	Chiawuli Tak, Pima Co., Ariz. ca 2,500 ft.	Papago	Nabhan x526B	10/1/76	ARIZ	Cultivated annual up to .8 cm tall x 1.5 m diam. White seeds, claws 24 cm. Corolla color variable in population. Grown in 15 x 15 m patches in rainwater-fed field. *I-hug.*
Domesticate	Coolidge-Gila River Reservation area, Pinal Co., Ariz. Seed grown in Tucson	Pima	Nabhan 585	7/26/76	ARIZ	Corolla white, with purple on lobes, seed white, leaf 22 x 16 cm. Cultivated for basketry fiber by Gila Pima.
Domesticate	Komatke, Maricopa Co., Ariz. 1,040 ft. Seed grown in Tucson	Pima	Nabhan 584	8/1/76	ARIZ	Corolla white, with purple on lobes, claws 24 cm, seed white, leaf 16 x 16 cm. Cultivar grown for basketry in "old fields."
Domesticate & cultivated wild	San Simon, near Tracy, Pima Co., Ariz.	Papago	Nabhan x534	10/76	ARIZ	Both long clawed (18 cm) white seeded race and black seeded "wild type" (13.5) cultivated in garden behind house. Irrigated. Grown to sell as basketry fiber.
Wild	Santa Rosa, Pima Co., Ariz.	Papago	Nabhan x535	10/76	ARIZ	Wild plant .4 m tall, claws 14 cm avg., black seed. In Santa Rosa wash.
Feral Domesticate?	Santa Rosa, Pima Co., Ariz.	Papago	Nabhan x569	10/76	ARIZ	White and gray seed in claws 12.5 cm avg. On semi-erect plant in roadside disturbance area with *Cucurbitas* and *Amaranthus.* Presumed to be feral or genetically influenced by domesticates grown nearby.
Wild	Santa Rosa, Pima Co., Ariz.	Papago	Nabhan x570	11/76	ARIZ	Dark seed, claws 27 cm. avg., wild plant 100 m from closest houseyard (where domesticate is grown). In depression on side of dirt road.
Wild	Supai Village, Coconino Co., Ariz., 5,600 ft. Seed grown in Tucson	Havasupai	Nabhan 584-II from R.C. Euler	8/1/76	ARIZ	Corolla white, claw 17 cm., black seed. Wild around village.

TABLE 4b. continued.

Proposed Status	Locality	Culture	Collector & #	Date	Herb	Suggestive Characteristics
Domesticate	Ak-chin near Maricopa, Pinal Co., Ariz. Seed grown in Tucson	Papago	Nabhan 662 from Fritz & Nabhan 617a	8/5/77	ARIZ	Corolla, pale cream; infl. surpassed to equalling foliage, white seed. Grown in backyard, with watering, for basketry fiber. *E hook*.
Wild?	Blackwater area, Pinal Co., Ariz. 1,400 ft. Seed grown in Tucson	Papago?	Nabhan 663 from 610d	8/5/77	ARIZ	Black seed, 4 carpelled fruit, claws short. Leaves smaller than domesticate, flowers pale, infl. equalling or surpassed by foliage. Produces fruit with 2, 3, and 4 carpels. Obtained from Blackwater Trading Post.
Domesticate	Chuichu, Pinal Co., Ariz. 1,400-1,500 ft.	Papago	Nabhan 664 from 568b	8/5/77	ARIZ	Corollas pale cream, infl. surpassed by or equalling foliage, white seed. Grown in yard for basketry fiber. *E hook*.
Black seeded incipient domesticate	Cibecue, Navajo Co., Ariz. 4,940 ft.	Cibecue Apache	Nabhan 665	8/9/77	ARIZ	Corollas pale, claws extremely long, seeds black. Apaches report white seeds in population too. Apparently some grown, some weeds. In field with maize, beans, sunflowers. Used in basketry.
Wild	Below Old Oraibi, Navajo Co., Ariz. 5,400 ft.	Hopi	Nabhan 1035	8/15/78	ARIZ	Apparent agrestal volunteer in sandy plowed field of cucurbits, below mesa. Short claws, black seeds.
Wild?	5 mi. east of Cibecue, Navajo Co., Ariz. 6,600 ft.	Apache	Nabhan 1032	8/12/78	ARIZ	Apparent volunteer in dry farmed cornfield; not seen in surrounding wild lands. Immature seedlings; synaptospermous from old fruit.
Domesticate	San Carlos, Gila Co., Ariz. 5,300 ft.	Apache	Nabhan 1031, 1007 Nabhan 1007	8/12/78; 7/16/78 7/16/78	ARIZ ARIZ	Dooryard garden, intentionally cultivated. Plants .7 m tall, large leaves, pale flowers, prolific. Used in basketry.
Domesticate	Little Tucson, Pima Co., Ariz. 2,400 ft.	Papago	Nabhan 863b	8/4/78	ARIZ	Dooryard garden. Pale flowers, large fruit. Plants .5 m tall. *I-hug*.
Wild	Whiteriver, Navajo Co., Ariz. 5,300 ft.	Apache	Nabhan 1013	7/17/78	ARIZ	Apparent volunteers in maize and beanfield, 312 plants in 50 m. Black seeds, short claws. Harvested for fiber.
Wild	San Carlos, Gila Co., Ariz. 5,300 ft.	Apache	Nabhan 1005	7/16/78	ARIZ	Roadside by field, volunteer weed. 30 cm tall, 1.3 m across. 1mm fruit, pale flowers.
Wild	San Carlos, Gila Co., Ariz. 5,300 ft.	Apache	Nabhan 1006	7/16/78	ARIZ	Volunteer, thick, weedy patch in maize field. Pale flowers, black seed.
Wild	Fresnal Village (Chiwuli Tak) Pima Co., Ariz. 2,500 ft.	Papago	Nabhan 705	9/11/78	ARIZ	Volunteer in fallow field. Red-purple to cream flowers, black seeds. 15-45 cm tall.
Domesticate	Supai Village, Coconino Co., Ariz. 5,600 ft.	Havasupai	Nabhan 899	8/22/78	ARIZ	In plowed field. Flowers unusually pale. Fruit immature. Used in basketry. Plant 1.5 m tall x tall x 2 m across *Halak(a)*
Wild	Supai Village, Coconino Co., Ariz. 5,600 ft.	Havasupai	Nabhan 889	8/19/78	ARIZ	Diversion-irrigated field. Plants 1m tall, black seeds, smaller fruit than domesticate, in mixed patch of both races.
Domesticate	Supai Village, Coconino Co., Ariz. 5,600	Havasupai	Nabhan 890	8/19/78	ARIZ	Diversion-irrigated field. Plants 1-1.5 m tall, white seeds, claws as much as 30 cm. In mixed patch of both races.

TABLE 4b. continued.

Proposed Status	Locality	Culture	Collector & #	Date	Herb	Suggestive Characteristics
Wild?	Supai Village, Coconino Co., Ariz. 5,600 ft.	Havasupai	Nabhan 900	8/20/78	ARIZ	In plowed field. White corolla with purple and yellow. Fruit immature. Plant 1.5 m tall x 2 m across. Apparently feral and protected. Used in basketry. *Halak(a)*
Feral Domesticate?	Peach Springs, Mohave Co., 4,800 ft.	Havasupai, Walapai	Nabhan 904	8/21/78	ARIZ	Immature seedling feral in yard of Sarah Cook, Havasupai basketmaker among the Walapai. Probably volunteer from fruit brought up from Supai.
Feral Domesticate?	Lower Moenkopi, Coconino Co., Ariz. 4,777 ft.	Hopi	Nabhan 884	8/15/78	ARIZ	River diversion bean and melon field. Agrestal or protected plant, apparently not intentionally sown. Plants 1.5 m across, large fruit, white seeds, leaves 25 x 25 cm. Used by Hopi woman making Paiute baskets. *Tumoala.*
Feral Domesticate?	Lower Moenkopi, Navajo Co., Ariz. 4,777 ft.	Hopi	Nabhan 1102	8/23/79	ARIZ	Not intentionally planted. Scattered in tepary plot. Plants 4 m tall, 1.7 m across. White seed,; claw 36 cm, body 11 cm.
Feral Domesticate	Kaibab, Mohave Co., Ariz. ca. 4,600 ft.	Kaibab So. Paiute	Nabhan 1106	8/24/79	ARIZ	Volunteering plants in partially cultivated, irrigated field. Plants .35 m tall. White seed, claw 20.8 cm, body 9.9 cm.
Feral Domesticate or wild?	Shivwits to Irving Rd., Washington Co., Utah, ca 4,000 ft.	Paiute? or none	Nabhan 1113	8/25/79	ARIZ	Volunteering plants in meadow/field, scattered. Plants 1 m tall, 2.2 m across. White seed, claw 36 cm long.
Wild under Cultivation	Shivwits, Washington Co., Utah ca. 4,000 ft.	Shivwits So. Paiute	Nabhan 1114	8/25/79	ARIZ	Apparently intentionally cultivated. Plants up to .7 m tall. Black seed, claw 18 cm long.
Domesticate	Shivwits, Washington Co., Utah ca. 4,000 ft.	Shivwits So. Paiute	Nebhan 1115	8/25/79	ARIZ	Cultivated and tended, in tomato field. Plants .5 m tall, 2 m across. White seed, claw 23 cm long
Wild	Fort McDowell, Maricopa Co., Ariz. 1,400 ft.	Yavapai (& Apache?)	Nabhan 1021	7/24/78	ARIZ	Roadside near field. Black seeds, claw 20 cm. Plants 30 cm tall. *Helagah.*
Wild	2 mi. west of Casa Blanca, Pinal Co., Ariz. ca. 1,200 ft.	Pima	Nabhan 1018	7/24/78	ARIZ	Ruderal weed between road and cottonfield. Plants .5 m tall, 1 m across. Black seeds.
Wild	Middle Verde, Yavapai Co., Ariz., ca 3,200 ft.	Yavapai-Apache	Nabhan 1025	7/25/78	ARIZ	Tolerated agrestal weed in irrigated, mixed crop field. Flowers dark pink and purple. Fruit moderately long with black seeds.
Domesticate	Queen's Well, Pima Co., Ariz. ca. 2,500 ft.	Papago	Nabhan 1029	8/1/79	ARIZ	Hand irrigated dooryard garden. Pale flowers, immature plants. White seed obtained from owners. Fruit used as basketry fiber. *I-hug.*

Castetter and Bell's conclusions were based primarily upon several interviews between 1938-40; we have not come across any voucher specimens collected by them, or notes on the plants themselves. In the interviews, only the white seeded variety is noted as being cultivated, and only the black seeded variety is mentioned as growing away from fields. For one interview, notes imply that a Pima farmer responded negatively to the question of whether his people cultivated wild plants, but later acknowledged that devil's claw is cultivated (Castetter 1939:44). Dobyns (1952:211) concluded that the Papago had domesticated devil's claw based on similar (unpublished) observations.

Yarnell (1977) has concluded that the distinctive characteristics of the cultivated form described by Castetter and Bell—white vs. black seeds, longer "pods," plus finer grained and deeper black pod-epidermis—justify its status as a cultigen. He suggests that several centuries of artificial selection is a reasonable estimate for the duration of the domestication process in devil's claw. Yarnell also hypothesizes that the original motivation for cultivation was possibly the food-value of the pods and seeds, and that more recently, cultivation has emphasized basketry material production. He does not mention the presence of the domesticate in culture groups other than the Pima-Papago.

We feel that with the limited data which Yarnell had available, it would be difficult to refute 2 arguments against his conclusion: 1) How do we know that the white seeded variety is not another "wild" species of devil's claw imported into the area, which is cultivated while the other indigenous species are not? 2) How do we know that cultivation practices alone do not result in the longer, finer claws? Could the white seed color be due to the early harvesting of cultivated fruits, which would keep the seed from ripening to a black color? Thus, is it the treatment of the plants rather than distinct genetic material due to domestication which account for the apparent differences?

TABLE 5.—*A comparison of relative association with man-made habitats of two races of* Proboscidea parviflora.

HABITAT	WILD RACE BLACK SEEDS	DOMESTICATES WHITE SEEDS
A. Undisturbed or protected range	N=23	N=18
B. Minimally-managed & grazed range or deserts	+	
C. Overgrazed & manipulated range	+	
D. Floodplains	13%	+
E. Riverbeds & arroyo channels	17.3%	5.5%
F. Managed meadows & corrals	4.3%	
G. Roadsides, paths & cleared areas	30.1%	11%
H. Abandoned fields	4.3%	5.5%
I. Dumps, houseyards (uncultivated) & plant-processing areas	4.3%	11%
J. Cultivated *temporal* (runoff) fields	13%	5.5%
K. Cultivated irrigated fields	+	5.5%
L. Cultivated (kitchen) gardens	13%	55%

(Documentation from specimens collected in Pimeria Alta: southern Arizona and northern Sonora. Method based on index for comparing weediness in related plant taxa (Hart 1976). "+" indicates lack of specimen, but valid observation.)

Additionally, we have discovered that Castetter and Bell's "clean" correlation of white seeds with agricultural fields, and black seeds with "wild" environments does not hold true in Pima-Papago country today (Table 5). We have located several fields and gardens where Indians are propagating black seeds, and have also found white seeded fruit on plants growing away from fields, although always within Papago *rancherias*.

We therefore doubt that Yarnell's inductive reasoning that *Proboscidea parviflora* must be domesticated has really settled the matter. His contribution is, on the other hand, that he has brought the suggestion of domestication of a native arid land plant to the attention of a wider audience. We would like to answer his challenge, by providing a methodology for evaluating whether devil's claw, or any other plant, has been domesticated.

Domestication: Definitions and Testable Principles

In using the term *cultivated plant*, people often confuse the process of cultivation (i.e., planting, and tending plants and their environment) with the status of the plant itself. By the plant's status, we mean whether or not its genotype is different from the genotype of plants growing in the wild. A propagated plant may have the same genotype as untended plants in the wild, even though the conditions in a garden environment may influence its phenotype so that it appears different. When the genotype is different due to direct human influences, the plant is often termed a cultivated (or better), domesticated plant.

In order for us to consider the status of devil's claw, it is necessary to be more specific about our use of the term *domesticate*. Indeed, there are numerous definitions and descriptions of what a domesticated plant is (Table 6). Utilizing different definitions, one might actually come to conflicting conclusions regarding which of the world's plants are domesticated.

As a foundation for our study, we will use the explanation offered by Harlan (1975:63-64): "In the case of domesticated plants and animals, we mean that they have been altered genetically from their wild state and have come to be at home with man. Since domestication is an evolutionary process, there will be found all degrees of plant and animal association with man and a range of morphological differentiation from forms identical to wild races to fully domesticated races. A fully domesticated plant or animal is completely dependent upon man for survival. Therefore, domestication implies a change in ecological adaptation, and this is usually associated with morphological differentiation."

To this basic explanation, it must be added that the intended human influences such as selection of desirable characteristics are joined by "accidental" or indirect selective pressures (Baker 1972:32). The most significant indirect human influence is the modification of environments, particularly the maintenance of agricultural environments, where plants then undergo "natural" selection.

This process of natural selection in and adaptation to agricultural environments may begin before the plants are actually cultivated. Whitaker and Bemis (1975:367-368) point out that plants adapted to disturbed soils may rapidly increase their geographic ranges by following man and his edaphic disturbance; this in turn affects their genetic variabilities. They hypothesize that certain cultigens evolved a high degree of dependence upon manmade conditions, as well as numerous protentially useful characteristics, before humans began to cultivate and directly select these characteristics.

Because so many economic characteristics of domesticated plants can develop without direct human selection, and are in fact common in agricultural weeds, we must be cautious in utilizing these characteristics as indicators of domestication. Thus the presence of any subset of indicative features in a plant cannot "prove" in itself that domestication has occurred. The data must be viewed within the context of plant's natural history and use, known instances of selection, and other factors. Otherwise, we may be contrasting a weedy race of a species with a less opportunistic race in a manner in which the weedy race appears to be a domesticate.

TABLE 6.—*Domestication: Alternative definitions and explanations.*

Quotation	Citation
"domestication ... complete and regular reproduction of the species through more or less controlled and selective breeding in the company of man.	Meggitt 1965:23
... the crucial feature of domestication is man's control over the breeding of his domesticates. He improves his crops by sowing only selected seeds ...	Watson and Watson 1971:5
Domestication implies that the plants or animals have been manipulated to such an extent that genetic changes have occurred resulting in new races or species ... Cultivation, with the attendant element of human selectivity, conscious or unconscious, frequently results in genetic changes. Even so, there will be an intermediate stage where plants are sown and harvested but show no morphological changes. Helbaek ... has therefore distinguished between 'cultivated' plants that have been sown and harvested but show no morphological alternations, and 'domesticated' plants where morphological change has occurred.	Bender 1975:1.52
... domesticates show both intended and accidental results from human actions, including selection.	Baker 1972:32
The stages of domestication are as follows: a) loose contacts, with free breeding. b) confinement to human environment, with breeding in captivity. c) selective breeding organized by man, to obtain certain characteristics, and occasional crossing with wild forms. d) economic considerations of man leading to the planned 'development' of breeds with certain desirable properties. e) wild ancestors persecuted or exterminated.	Zeuner 1963:63
The cultivated plant never originates directly from the wild species, in perfect form, but evolves step by step over a long period of time. The farther it has come along, that is, the earlier it was taken under cultivation or the more intensely bred and selected, the fewer wild characters will be found in it ... Their occurrence [wild-plant characters] in cultivated plants must thus be taken as a sign that a plant has not yet completed its evolution from a wild species to a cultivated plant.	Schwanitz 1966:63
The most immediately apparent change under domestication is in morphological characters such as size, shape and color, particularly of the part of the plant used by man ... Up until now, crop plants have not evolved by any processes different from those operating in wild plants. The ultimate source of variability is mutation ... The new forms produced are then subject to selection, but in crop plants new variants have to pass the test of human selection as well as, or sometimes instead of, natural selection.	Pickersgill and Heiser 1976:55

Nevertheless, we have gleaned from the literature a number of morphological and ecological characteristics which commonly change through the process of domesticating a plant (Table 7). Hypothesizing that these changes would occur in any *Proboscidea* if domesticated, we can use these indicators to examine the "real life situation." Individual characteristics which may be found in any useful plant, wild or cultivated, or in weeds, will be interpreted in light of these other possibilities.

We have made 2 major assumptions in applying these indicators to the problem of possible *Proboscidea* domestication. We have assumed that if devil's claw has been domesticated, the process increased the quantity or quality of the products which have been most pervasively and intensively utilized—the fiber in the dried fruit, and the seed. Thus we

TABLE 7.—*General trends in plant domestication, in reference to devil's claw.*

	Apparent difference in white seeded race	Should change if domesticated for seed	for fiber	Change possibly due to deliberate human selection	Change possibly to selective pressures associated with harvest	Change possibly due to selective pressures in cultivated environment	General trend in domestication process discussed in
Feature							
Disproportionate enlargement of desired plant produce	X	?	X	X		X	Schwanitz 1966:30; Baker 1972:32; Harlan 1975:137
Increase in leaf size	X	X	X			X	Schwanitz 1966:14, 21
Increase in size of other parts	X	X	X			X	Schwanitz 1966:14, 28
More determinate growth habit				X	X	X	Harlan 1975:137; Baker 1972:33
Change in color of product	X	X	X	X			Harlan 1975:138; Yarnell 1977
Change in texture of product	X						Harlan 1975: 138
Change in protein/carbohydrate ratio (usually a decrease)	?	X		X		X	Harlan 1975:127, 131
Reduced toxicity of edible parts							Baker 1972:33; Schwanitz 1966:28-42
Loss of differential dormancy (or of germination-delaying mechanisms)	X	X	X			X	Baker 1972:34; Harlan 1975:132; Schwanitz 1966:43
More uniform maturation, more simultaneity in ripening					X		Schwanitz 1966:44; Harlan 1975:127
Difference in life span	?				X	X	Schwanitz 1966:44-44
Greater yield of desired produce	X	X	X	X		X	Schwanitz 1966:29; Baker 1972:34
Loss of natural seed dispersal mechanisms, or of synaptospermy		X		X	X	X	Schwanitz 1966:32; Baker 1972:34; Pickersgill and Heiser 1976:60
Greater frequency of unusual variants surviving	?	X	X	X		X	Harlan 1975:138; Pickersgill and Heiser 1976:60
"Bottleneck effect" in overall genetic variability	X	X	X			X	Pickersgill and Heiser 1976:60-61

hypothesize that devil's claw was domesticated either for basketry material, for a food product, or for both, and not for other reasons: its value as an ornamental or religious item, the use of the young fruit as a vegetable, etc.

Secondly, we have decided to compare the white seeded, supposedly longer clawed devil's claw cultivated by Southwest Indians with the 3 most common annual *Proboscidea* in the Southwest. In particular, most of our quantitative comparisons are with wild *Probosicidea parviflora*, as it occurs in Arizona spontaneously, and when brought into cultivation.

In doing so, we have ruled out that the annual white seeded devil's claw 1) belongs in another genus; 2) is more closely related to *Proboscidea* perennials in either subgenus; 3) is more closely related to other annual *Proboscidea* in the Southwest, or elsewhere.

Our emphasis on comparison with Arizona populations of *Proboscidea parviflora* is in part due to logistics, since that material is more readily available to us. However, Table 1 makes evident that the white seeded devil's claw is more phenetically similar to wild *P. parviflora* than to *P. fragrans* or *P. louisianica*, as we understand these taxa today. Furthermore, Yarnell's suggestion that the white seeded devil's claw is a *Proboscidea parviflora* cultigen warrants our most critical attention. We will nevertheless note similarities to *P. louisianica* and *P. fragrans* whenever possible, and allow as an alternative hypothesis the development of the white seeded devil's claw from interspecific hybridization or introgression (Fig. 3).

Finally, following Harlan and DeWet (1971:509-517), we will avoid using the terms variety, cultivar, line, strain, type, or kind for the rest of the discussion, due to their indiscriminate use in the past. Temporarily, we will refer to the suggested domesticate simply as the "white seeded race" of *Proboscidea*, without assuming that it is a domesticated, weedy or spontaneous race of any particular species. Also, for the purposes of brevity, we will refer to all black seeded *P. parviflora* as the *P. parviflora* spontaneous race, even though there may conceivably be domesticated or weedy black seeded races which we are ignorantly lumping into this one category. We will also refer to the spontaneous race as wild or typical black seeded *P. parviflora*, depending upon the context.

Skewed Distributional Range

The geographic range and ecological niche which the white seeded race occupy should be regarded in light of the distribution of wild *Proboscidea* in general. Yet it is somewhat difficult to determine the "natural" distributional range of annual *Proboscidea* spp. in the Southwest. Whereas there are "core geographical areas" where each species is commonly found (Table 1), the intrinsic dispersibility of their fruit has allowed them to be transported by animals (including man) to many isolated localities far away from these cores.

Large native herbivores undoubtedly participated in the long distance dispersal of devil's claw to disjunct localities even before man and his domesticated animals became involved in this process. Natural historians have described the shape of devil's claw fruit as one ideally adapted to catching and persisting in the fetlocks of ungulates. They have hypothesized that this mechanism was responsible for the dispersal of *P. louisianica* to South Africa, and to a locality in Great Britain (Bancroft 1932:62-64).

The habitats which annual devil's claw frequent are often corridors which allow further geographical extension of their range by animal, water or wind transport. The habitat preferences of the 3 species of annual *Proboscidea* indicate adaptation to sporadically disturbed soils, particularly the sandy loams of floodplains and gravels of roadsides. Historic human modification of Southwestern floodplain environments, particularly through agriculture and road-building may have dramatically altered distributions from prehistoric times. Additionally, such modification maintains niches with disturbed soil where deliberately transported plants such as *P. louisianica* in the Palm Springs area, can establish themselves after escaping from cultivation (Robbins 1940: 86)

Although the distribution of the *P. fragrans*, *P. louisianica* and *P. parviflora* remain

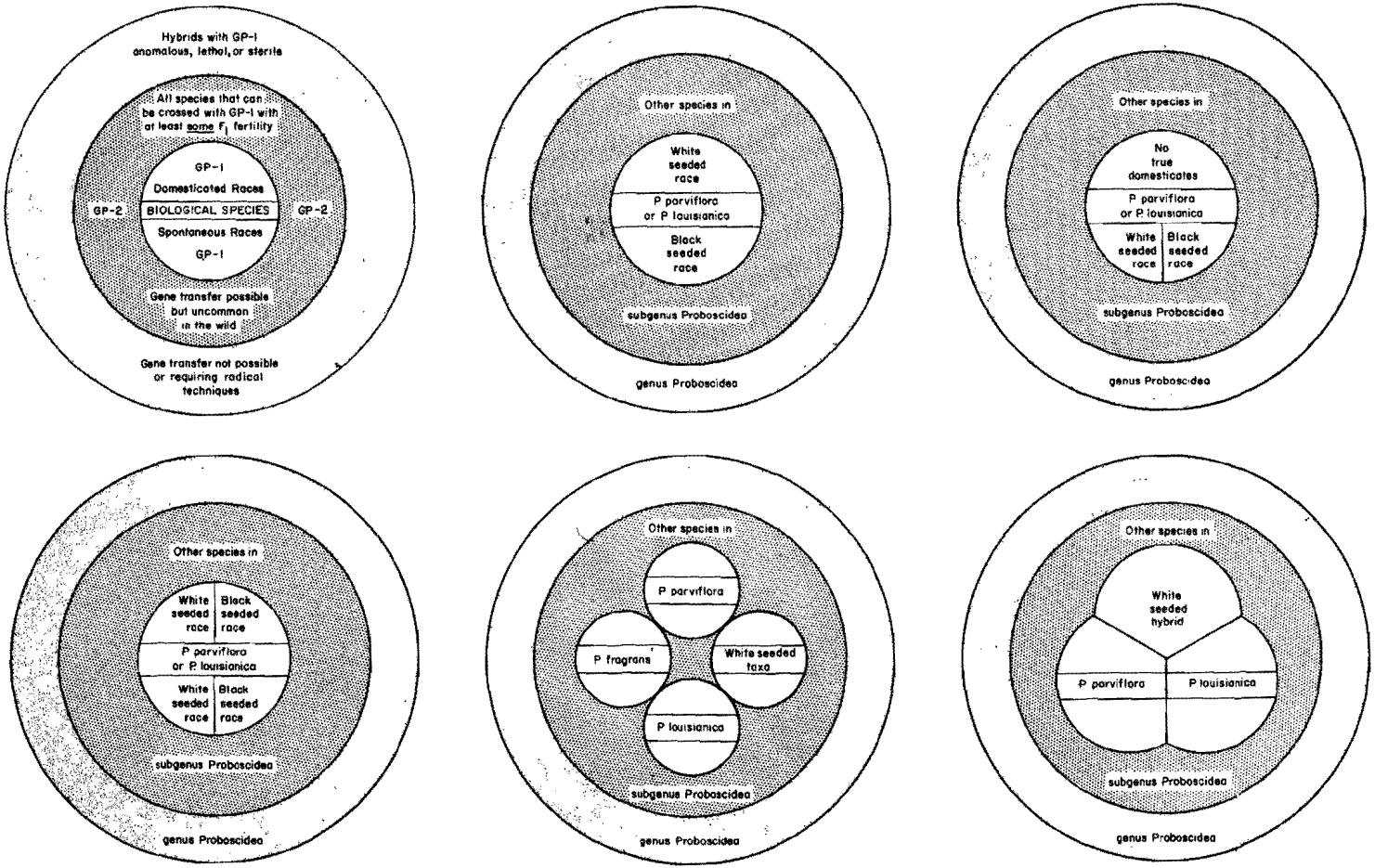

FIG. 3. Alternative hypotheses for gene pools relationships to the domesticate. Legend in upper left follows Harlan (1975).

problematic, the range of the white seeded race is nevertheless peculiarly skewed in relation to them: 1) it is highly specific to the *rancherias* of native peoples of the Southwest's true deserts and nearby uplands. 2) It appears to extend northwest beyond where annual *Proboscidea* is commonly found in the wild in northern Arizona, southeastern California, and southern Nevada. 3) Its range overlaps to the greatest extent with the range of *P. parviflora*.

Today, the black seeded annual *Proboscidea* are strongly associated with man-disturbed environments, yet the degree of association is even higher for the white seeded race. A survey of annual *Proboscidea* specimens collected in one particular area—the aboriginal territory of Northern Piman groups in Arizona and Sonora—illustrates this point (Table 5). All available seed or herbaria specimens with detailed habitat notes were utilized to compare the location of the white seeded race and spontaneous *P. parviflora*, regardless of whether or not they were cultivated in those locations.

Although the presence of *P. parviflora* in fields and on pathways around human settlements indicates weediness and dependence on human disturbance, it ranges beyond these habitats to a greater extent that the white seeded race does. Beyond cultivated fields and yards, the white seeded race has only been collected within disturbance habitats in *rancherias*.

Although it is not possible to prove that all these plants are recent "escapes" from cultivation, subjective information suggests that the plants are feral cultivates. Papago informants have volunteered that white seeded plants growing in their yards "planted themselves" from seed that blew over from nearby devil's claw processing areas (see Table 8, for processing site explanations). In both cases, large stands of the white seeded race were cultivated within the *rancheria*.

If the white seeded race were domesticated from *P. parviflora*, it is possible that the status of black seeded races as agricultural weeds played an intermediate role in this process. Since black seeded *P. parviflora* is considered a tolerated weed in fields beyond the range of devil's claw cultivation today—among the Hopi and Apache in Arizona (Whiting 1939:92 and Anonymous 1976), and among mestizos in eastern Sonora—it is doubtful that in this case a weed race evolved as a result of introgression betwen domesticated and spontaneous races (see Harlan 1965:173-176).

Finally, the white seeded race, because it can grow without intentional planting by man, is not an obligatory cultivate or cultigen. According to Harlan's definition, it can not be a fully domesticated plant in the strict sense, since it can survive to some extent without direct dependence on man.

Seed Characteristics

If domesticated for the food value of its seed, devil's claw should have undergone changes in several of a number of characteristics, including a) number of seed per fruit; b) seed size; c) change in the nutritive value of the seed; d) change in seed coat color or texture; e) change in seed dispersal pattern; and f) loss of germination-delaying mechanisms. Several of these characteristics might also be affected if devil's claw was domesticated for the fiber in its fruit, particularly c, e and f.

We compared the number of seed per fruit in the white seeded race (n=69, from 4 populations), with the number in black seeded *P. parviflora* (n=50, from 3 populations), there is no statistical difference at the .05 level for the 53.0 + 9.8 seed per fruit of the white seeded race, and the 53.9 + 8.3 seed per fruit of the black seeded race.

These sample sizes are relatively small, and the populations analyzed do not allow considerations of variation within the region. From these data alone, however, it is apparent that there are no major differences in the seed number of the 2 kinds of fruit. We will therefore assume that the number of seed per fruit in the white seeded race has probably not been determined by deliberate human selection, or modified by selective pressures associated with cultivation and harvest.

TABLE 8.—*Behavioral chain for Pima and Papago use of devil's claw.*

Purpose	Activities		Material Correlates	Time/Frequency	Location	Wastes
To insure supply of fruit for processing	Broadcast or plant seed in holes 5 cm; clear weeds in 1 m circle around hole.	Find wild population nearby on floodplain & protect	Hoe or dibble stick; brush	May or later	Floodplain or garden	Weeds
To acquire fruit when still pliant & prior to weathering	Harvest green fruit when claw tips become sharp			Before first frost	In field or in wild	Unusable fruit (too small or deformed)
To keep fruit pliant	Pile green fruit in sun, cover with ash, let dry (Papago)	Soak in pottery bowl (Pima)	Ashes, or water and containers	Usually fall, for a week	Fieldside or by house	Ashes
To straighten & keep usable fruit for future use	Husk fruit of remnant epidermis; hook dried fruit into hoop			After drying	Same	Husked epidermis, & broken fruit
To preserve for later use	Hang or covershoop		Twine or cover	Fall & after	Under ramada	
To soften & ready dried fruit for splint-making	Unhook desired number of claws; soak in bowl	Unhook small number of claws; bury in sand & drench	Bowl or bucket; water	As needed, overnight or 2 days	Near house	
To strip splints of fibers from fruit	Slit claw tip with awl, & run awl under fiber. Peel 2 fiber splints off with teeth, from tip to claw/body transition		Awl or knife, teeth	After soaking	Ramada work area	Imperfect, torn splints
To store splints for future use	Bind splints into a bundle		Twine	While stripping	Same	
To thresh seeds from splinted fruit		Beat with stick & pry open	Stick, fingers	Anytime	Near house	Splinted, deseeded fruit
To eat seeds (snack)		Crack seedcoat	Teeth	Anytime	Same	Seedcoats
To ready splints for immediate use	soak in bowl		Bowl & water	As needed	House or ramada	
To tape splint for use	Pull splint through hole in can (after 1918)	Scrape with knife and/or rock tool	Tin can or rock, & knife	Just prior to use in basket	House or ramada work area	Splint scrapings, rock tool
To work splints into basket design	Cross under previous splint, wrap around rod, snip off or tuck under where design ends		Awl, pick or knife	As needed	Same	Snipped splint remains

In terms of seed size, the 3 annual species of *Proboscidea* with which we are concerned, all fall within the general range of 7-11 mm long x 4-6 mm wide x 2-4 mm thick. Size of a particular seed is affected by its place in the ovary, as well as by maturity of the fruit and other factors. Size variation within a fruit is considerable.

We measured seed sizes of all seed in only 2 average-sized fruit of the white seed race, and 2 averaged sized fruit of black seeded *P. parviflora*, grown in the same irrigated field. Mean sizes and ranges at one standard deviation are given in Table 1. These data suggest a slightly greater volume of the white seeds, but without a substantial sample, we will refrain from further speculation. A severalfold difference in seed volume, such as that between domesticated beans and their wild progenitors, is nevertheless not evident with these devil's claw.

In terms of nutritive value, *Proboscidea* seed are non-toxic with high oil and protein content. Because of interest in the 1950s in developing devil's claw into a commercial oil seed, numerous chemurgic analyses of Southwestern *Proboscidea* were undertaken. After compiling protein and oil values in the literature (Earle and Jones 1962: 245; Ghosh and Beal 1979:748), we see that the seed of Southwest annuals normally range between 35-43% oil, and 20-35% protein.

Two acquisitions of the white seeded race and one of the black seeded *P. parviflora*, grown in the same irrigated field in 1976, have been analyzed by nutritional biochemist Dr. James Berry. The white seeds cultivated by the Pima contained 40.3% oil and 25.5% protein, values remarkably high for *Proboscidea*. The white seeded race cultivated by the Havasupai, and the black seeded race originally growing wild in their area yielded 39.2% and 38.3% oil, plus 23.9% and 23.2% protein respectively (Barry et al. in press). Thus the white seeds apparently have a slightly higher nutritional content that black seeded *P. parviflora*, or at least they are at the high end of the range for *Proboscidea*. It is possible that selective pressures in the cultivated environment, or deliberate human selection for the fruit or seed have resulted in relatively more energy being funnelled into these reproductive parts of the plant.

We mentioned earlier that the white-gray seed coat of the commonly cultivated race is atypical for the genus *Proboscidea*. In analogy, Yarnell (1977) has pointed out that lighter colored seed distinguishes domesticated *Amaranthus* from its wild progenitors. In devil's claw, it can either be hypothesized that 1) natives found this character in the wild, and brought it into cultivation; 2) it was expressed after selective pressures associated with harvesting were initiated, or 3) it is a function of the greater frequency of variants, including recessives, which survive in cultivated environments.

It is probable that the lighter color is determined by one or a few major genes, i.e., it is a quantitative character. A crossing program to determine the inheritance of characters such as this is now in progress (Peter Bretting, personal communication). Seed coat morphology study by electron microscope has not yet identified any differences between races.

In terms of seed dispersal, Sappenfield (1954:1) has calculated that approximately 10% of wild *Proboscidea* seed "shatter," or drop as the fruit dry and the claws split and curl. From our simple observations, we estimate that roughly 4-12% of the fruit's total seed are released as the white seeded fruit begins to dehisce. In spite of these crude estimates, we doubt that there are major differences in the seed dispersal of the various races and species. Certainly, there is not a dramatic difference in fruit dehiscence as there is between wild and domesticated legumes (Harlan 1975:138-139).

Germination delaying mechanisms in wild *Proboscidea* include 1) germination inhibitors of the seed and 2) the leathery-textured ovary walls behind which the seed are trapped unless the fruit is physically torn apart. Through differential dormacy wild *Proboscidea* spp. avoid "putting all their eggs in one basket;" the proverbial basket here being the unpredictable moisture conditions of the Southwest.

Anderson (1968:171) has determined that the germination inhibitors in wild *Proboscidea* include a) seed coat thickness; b) a water soluble chemical inhibitor in the seed coat; and c) a dark requirement, or light sensitivity factor in the embryo. Because of these inhibitors,

agronomists have had difficulties getting good field germination with wild *Proboscidea* brought into cultivation (Quinones, personal communication).

Our attempts at utilizing a standard laboratory test to determine possible differences in rate and per cent of germination were somewhat unsatisfactory. At 85° and then at 90°F, we obtained 40% germination in one sample of the white seeded race, but there was no germination of one other sample of white seeds, and 2 samples of black seeded *P. parviflora* (n=25, at each temperature).

Our field plot observations indicate some difference in per cent emergence under irrigated conditions. In 1977, one month after an April 21 planting, 65% of the white seed had emerged (n=55, from 9 acquisitions) and 16% of the black seed of 2 *P. parviflora* had emerged (N#25, from 4 acquisitions).

We suspect that the white-seeded race may have lost at least one of its germination inhibitors, possibly due to long term selective pressures associated with planting seed, and utilizing seed from plants in surviving cultivated populations. Further paired tests are needed to determine a) if field emergence differences are significant for larger sample sizes and b) if an inhibitor which the black seeds have that is possibly absent in the white seeds can be isolated. We doubt whether other germination delaying mechanisms, such as the persistance of seed behind the placentae walls, are different for the white seeded race.

Floral Morphology and Ecology

Flower size, shape and color are characters which are sometimes altered indirectly through human selection for the economic products of a plant. If a plant, through domestication, comes to produce fruit much larger than that of its wild progenitors, the calyx size may be increased too in order to accommodate the fruit. Or often, linkages affect several characters at once, so that a flower color may increase in frequency in a population, due to its genic association with a selected character. On the other hand, overall floral design is fairly conservative, and within a species is little affected by short term selective pressures.

In addition, floral ecology is certainly affected by cultivation and domestication. For instance, in South America, where wild and domesticated tomatoes originate, they are predominately cross-pollinated by insects; when taken beyond the range of their pollination agents, they have evolved into a self pollinating plant (Rick 1976).

Such ecological factors may eventually work as selective pressures influencing floral characters. A species variable for flower color, dependent upon cross pollination by bees, may swamp bee populations in number when cultivated in large stands. Particularly bright flowers might have a selective advantage over less intense flowers by attracting a greater percentage of the available bees. Depending on the inheritance of flower color, this may influence the frequency of allelles affecting color over time.

In terms of flower size, our data indicate that while cultivation increases the lengths of the corolla, calyx and bracts of black seeded *P. parviflora*, these characters are still considerably longer in the white seeded race. In fact, the white seeded race overlaps in these characters as much or more with *P. fragrans* and *P. louisianica* as with *P. parviflora*.

Several hypotheses can be proposed to explain this situation: 1) In the white seeded race, floral part sizes reflect a closer affinity with *P. louisianica* or *P. fragrans*. 2) A larger flower size has developed in the white seeded race while being domesticated from *P. parviflora*; the larger size accommodates the larger fruit. 3) It reflects introgression between 2 of the species.

Flower shape in the white seeded race is generally the same as that in *P. parviflora*. Among the largest flowers of the white seeded race, there is a tendency to be slightly more ventricose, though not as much as typical *P. louisianica* and *P. fragrans*. It is noteworthy that a wild, long clawed (32 cm), black seeded specimen collected on the Gila River Indian Reservation at the Pima village of Sacaton had a similar ventricose flower shape (Peebles, Kearney and Harrison #75, ARIZ). In addition, its flowers were mostly purple; because of these characters, Kearney and Peebles (1960:795) suggested its affinity with *P. fragrans* even though that species is nowhere else in Arizona. Again, does this reflect hybridization between different

races or species, or simple introduction? Abberrant flower shapes, including ones with an extra lobe and a wider tube, have been found in low frequencies on plants within cultivated plots of the white seeded race.

Flower color determination in wild annual *Proboscidea* is not well understood. Perry (1942:43-47) reported that reciprocal crosses between *P. fragrans* and *P. louisianica*, and subsequent backcrosses, indicate that purple flower color dominates white flower color. Perry suggested that color inheritance was due to a single gene.

However, reciprocal crosses between 4 annual *Proboscidea* by Hevly (unpubl. notes) do not substantiate that purple flower color is dominate over white, since F^1 plants were intermediate. F^2 plants tended to have darker flower colors, but the F^2 population size was not large enough to suggest genotypic frequencies.

Most flowers of the white seeded race have similar color patterning and internal ornamentation as wild *P. parviflora*; however, all colors are usually less intense. Often, corolla color is pale cream or white, but we have also seen pink and reddish-purple flowers on white seeded plants on the Papago Reservation. However, these darker flowers were in a population within 50 m of where black seeded *P. parviflora* is cultivated. Does the variability in flower color in this white seeded population reflect the introgression of typical *P. parviflora* in the white seeded race?

We should note that white or pale cream flower color is not specific to the white seeded race; it also occurs in *P. louisianica*, and infrequently in wild *P. parviflora*. It has been suggested that different fruit types—of distinct lengths and shapes—are associated with different flower color types in *P. parviflora* (Paur 1952:1), but we have noticed no such clear cut relationships. Finally, it is noteworthy that in other floral characters (e.g. corolla ornamentation, filament pubescens, and inflorescence position) the white seeded race is most similar to *P. parviflora*.

The pollination ecology of devil's claw has received an increasing amount of attention in recent years, but the picture is far from complete. Hurd and Linsley (1963:249-250) reported the apparent cross-pollination of perrenial *Proboscidea altheifolia* by the corolla-cutting bee *Perdita hurdi*. However, their repeated examinations of wild *P. parviflora* flowers failed to show bee visitation for pollen, or a relationship with this bee. Dr. P.H. Timberlake (personal communication) has subsequently become aware of one example of *Perdita hurdi* visitation to annual *Proboscidea* in Mexico. To our knowledge, there are yet no reports of this bee pollinating wild *P. parviflora* in the United States.

Thieret (1976:175-176) reports the insect visitors, including pollinators, to *P. louisianica* flowers on wild plants in Oklahoma and in his garden in Utah (see Table 1). Preliminary experiments with pollinator exlusion, plus self and cross-pollination, suggest that *P. louisianica* fruits do not develop if pollinators are excluded of if artificially selfed (Thieret 1976:177). However, other investigators report that hand pollination of *P. louisianica* yields about 50% fruit set regardless of whether plants are self- or cross-pollinated (Moegenson, personal communication; Phillippii, personal communication).

Self-pollination, though still probably not the key pattern in wild populations, may also be effective in black seeded *P. parviflora*. In an experimental cultivated plot in New Mexico, of *P. parviflora* (and other species?), 15% of the 500 inflorescences bagged for self-pollination produced some seed (Anonymous 1953:16).

Dr. Floyd Werner has identified for us a few of the fairly frequent bee visitors to cultivated plots of the white seeded race (Table 1), but we do not have concrete confirmation of actual pollination by any of these hymenopterids. Most noteworthy is our discovery of *Perdita hurdi* in the flowers of a large, annually planted houseyard plot of the white seeded race at the Papago village of Santa Rosa.

Exclusion experiments and detailed field observations on both Indian-cultivated plots of the white seeded race and black seeded *P. parviflora*, and in spontaneously occurring stands of *P. parviflora*, are needed to determine: 1) Will selfing occur in these populations, and have the selective pressures of cultivation in large stands increased the frequency of selfing in the

white seeded race? 2) Is the frequency of visitations by various bee species different in cultivated plots as opposed to spontaneously occurring populations? 3) If *P. hurdi* is in fact pollinating the cultivated white seeded race, but not small stands of *P. parviflora* in the wild, is this due to greater reliability or abundance of reward for the bee, akin to that provided by perennial *Proboscidea*?

Fruit Size and Morphology

Among the features which might be modified, if *Proboscidea* were domesticated for their fruit's fiber, are: a) a disproportionate increase in the fibrous "claw" part of the fruit; b) changes in texture, color and quality of the fiber; c) a greater yield of fruit per plant d) an altered frequency of unusual fruit shapes surviving. If large seed were selected in the domestication process, changes might include a) a disproportionate increase in the seed-holding "body" part of the fruit, where the ovaries are; b) reduction in fruit dehiscence (see seed dispersal discussion); and possibly c and d as above. Additionally, because mean fruit lengths of populations vary within wild *Proboscidea* species ranges, a bottleneck effect might occur, where the wild populations would be more variable than the domesticated populations. The "bottleneck" in variability would be the original selection of germ plasm undergoing domestication from only a small portion of the "available" genetic variability within compatible races of species.

Table 9 indicates that there is significant differences in the claw/body ratios of the fruit of the white seeded race, and typical *P. parviflora*, in the wild and under cultivation. We defined the "claw" and "body" of the fruit in a somewhat arbitrary way, but were consistent in how these features were measured. The claw, as we defined it, is the appendage of the dried fruit from which the Indians derive their fiber splints (Fig. 4).

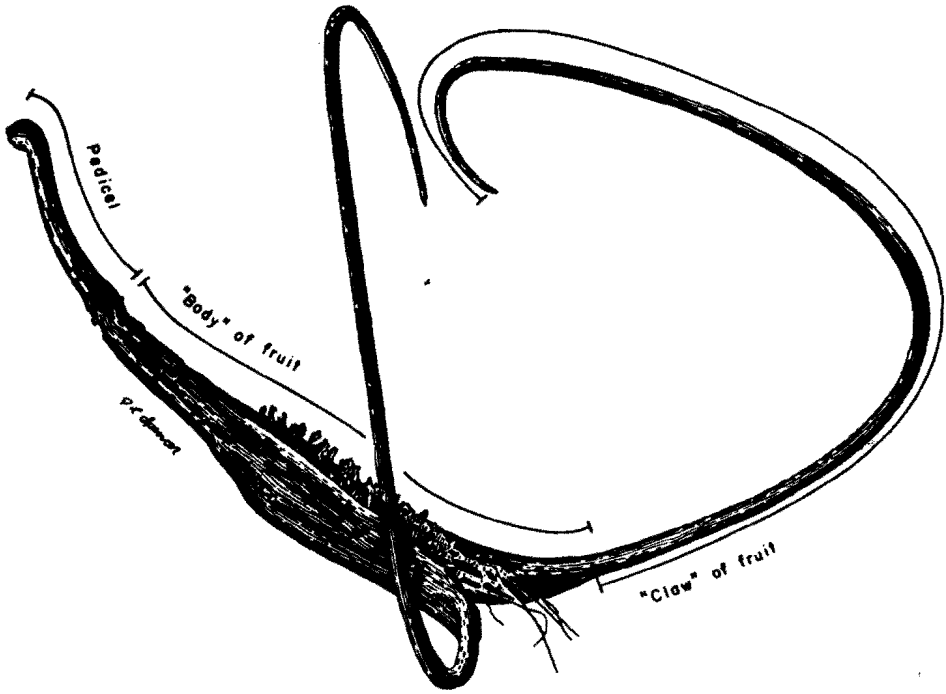

FIG. 4. Claw and body measurements of fruit of devil's claw (drawing by Judy Spencer).

TABLE 9.—*Claw/Body ratios for the white seeded race and the black seeded* P. parviflora.

Seed Source	Locality Grown	X claw/X body	Sample
White seeded race, cultivated:			
Havasupai Indian	Cornville	2.99	36
Apache Indian	Cornville	2.59	37
Pima Indian	Tucson	2.59	28
Papago Indian	Topowa	2.84	35
Black seeded race, cultivated by Indians:			
Papago Indian	Chiawulí Tak	2.32	31
Black seeded race, spontaneously; or cultivated#:*			
Navajo Indian*	Wupatki	2.34	10
Havasupai Indian#	Tucson	2.21	21
Mestizo, for Papago*	Nogales	2.29	26
Botanists*	Tecoripa	2.21	15

The 2.5+ claw/body ratio of the white seeded race may not necessarily indicate that a disproportionate increase in the usable part has occurred via domestication. Hevly has noted that in *P. louisianica* fruit, the ratio may vary from 1.5-3 (in Correll and Johnston 1969:1449), and it is possible that populations of *P. parviflora* and *P. fragrans* unavailable to us may have fruit which have a ratio greater than 2.5. The white-seeded race could have simply been chosen from such wild material, without selective pressures for longer claws being active within the cultivated environment. It is noteworthy that Gila River Pima remember wild populations of *P. parviflora* with exceptionally long claws that are located as much as 150 km away from their present homes. If the white seeded race has had part of its fruit disproportionately enlarged via cultural selection, it appears that selection was for fiber and not for seed-holding capacity.

We have measured the claw lengths of populations of the white seeded race, as well as those of typical *P. parviflora*, when a) harvested from the wild and b) grown in irrigated and *temporal* fields (Table 10). Statistical analyses of our data are summarized in Table 11. In the analysis of variance in and between populations of localities with 5 or more fruit of the cultivated white seeded race and wild and cultivated black seeded *P. parviflora*, one or more populations are distinct at the .01 level of significance. Utilizing all localities with one or more fruit, including those of presumably "feral" white seeds, the distinction between populations is still significant. This is due primarily to the extremely high values for the white seeded race under cultivation.

The greatest apparent difference in claw lengths is between the white seeded race when under cultivation, and all the other material measured, cultivated or uncultivated. The cultivated white seed claws measure 25.3 cm ± 4.3 cm, whereas all other means fall below 20 cm, and the ranges at one standard deviation do not extend above 23 cm.

To better illustrate the relationships between different germ plasm under different treatments, pooled variances were utilized to contrast combinations of these populations. When considered together, the white seeded race is significantly different from each of the black seeded *P. parviflora* treatments at the .01 level of confidence.

TABLE 10.—*Samples of claw length listed by source and locality.*

Locality and Source	Mean (X)	Range (σ)	Population (n)
A- White seeded race cultivated and/or irrigated	25.3 cm	±4.3 cm	249
A-1 Cataract Canyon #(Havasupai)	26.1	3.9	62
A-2 Cataract Canyon (Havasupai)	25.0	0.7	2
A-3 Cataract Canyon *(Havasupai)	34.0	0.0	1
A-4 Camp Verde *(Apache)	26.9	4.1	36
A-5 Moapa, Nevada (Southern Paiute)	24.3	0.0	1
A-6 Kern Co., California (Tubatulabal)	32.7	0.0	1
A-7 Komatke #(Gila River Pima)	23.2	3.3	52
A-8 Casa Blanca #(Gila River Pima)	22.6	1.6	8
A-9 Blackwater (Gila River Pima)	22.6	2.9	17
A-10 Chuichu (Papago)	25.8	1.8	2
A-11 Santa Rosa (Papago)	22.5	3.7	3
A-12 Covered Wells (Papago)	25.8	0.0	1
A-13 Kitt Peak (Papago)	20.5	3.0	10
A-14 Ali Chukson (Papago)	27.0	0.0	1
A-15 San Simon (Papago)	25.6	3.8	7
A-16 Chiawuli Tak (Papago)	21.0	0.0	1
A-17 Topowa (Papago)	28.2	4.7	40
A-18 Ahegam (Papago)	23.2	0.0	1
A-19 Sells (Papago)	24.1	5.5	3
B- White seeded race cultivated (feral?)	18.5	3.9	6
B-1 Kaka (Papago)	12.4	0.0	1
B-2 Santa Rosa (Papago)	20.0	1.2	2
B-3 Covered Wells (Papago)	19.4	3.9	3
C- Black seeded *P. parviflora*, spontaneous	15.7	4.8	127
C-1 Cataract Canyon (Havasupai)	25.5	0.0	1
C-2 Wupatki (Navajo)	17.4	2.1	10
C-3 Sacaton	32.0	0.0	1
C-4 Sacaton	27.5	0.0	1
C-5 Ventana	14.5	3.3	37
C-6 Ventana	9.0	1.5	7
C-7 Wilcox	18.5	0.0	1
C-8 Rosemont	11.7	4.6	15
C-9 Hereford	13.5	1.6	12
C-10 Agua Prieta, Sonora	17.4	0.0	1
C-11 Nogales (Mestizo for Papago)	20.2	3.3	26
C-12 Tecoripa, Sonora	15.7	3.0	15
D- Blackseed, cultivated by Indians	19.6	3.1	31
D-1 Chiawuli Tak (Papago)	19.6	3.1	31
E- Black seed cultivated and/or irrigated	16.5	2.6	148
E-1 Cornville*	17.1	1.6	19
E-2 Sacaton	22.8	1.0	2
E-3 Cataract Canyon #	15.8	2.5	78
E-4 Tucson #	15.1	1.5	16
E-5 Tucson #	18.3	2.8	17
E-6 Southern Arizona #	17.9	2.6	16

*grown in 1976 in Cornville, Arizona. #grown in 1976 in Tucson, Arizona.

TABLE 11.—*Statistical evaluation of claw measurements (see Table 10 for identifications of populatons A-E).*

1. Analysis of variance within and between populations for localities with 5 or more measurements (B is exluded): observed $F_{3,17} = 25.25$; greater than tabular $F_{3,17} = 5.18$. Therefore at least one population is significantly different at the .01 level of confidence.
2. Analysis of variance within and between populations for all localities (B is included): observed $F_{4,36} = 30.12$; greater than tabular $F_{4,36} = 3.58$. Therefore at least one population is different at the .01 level of confidence.
3. Contrast of pooled variance of combined populations via contrast coefficient matrix:
   (A + B) vs (D + E) - Pooled variance T value = -1.195
   Therefore pooled populations not significantly distinct at .01 level of confidence.
4. Contrast of Indian cultivated (d) black seed vs experimentally cultivated (e) black seeded *P. parviflora* (see conclusions...):
   D = 19.55 ± 1.14 (SE x T) vs E = 516.49 ± 0.41 (SE x T)
   Therefore populations significantly distinct at .05 level of confidence.

The comparison of spontaneously-growing black seeded *P. parviflora* with the black seeds in cultivated treatments is most revealing. The pooled variance analysis shows no significant difference between the uncultivated and cultivated *P. parviflora*. One variable interpretation of this analysis is that cultivation does not dramatically affect claw length of *P. parviflora*.

In general, these data suggest that claw lengths are more genetically than environmentally determined. The noticable exception to this general rule is the small size of feral white seeded claws. Yet because of our extremely limited sample of uncultivated white seeded fruit, we hesitate in considering this a major contradiction of the general trend. Until additional data indicate otherwise, we conclude that the white seeded race is genetically different from *P. parviflora* in this economic characteristic, even if there is still gene flow between these taxa.

Table I indicates that there are some relative differences in the color, texture and quality of the claws and their fiber. These differences have been pointed out to us by native basketmakers, and will be discussed later. It is possible that these presumably quantitative characters have been gradually modified through cultural selection.

Our data on fruit yield are relatively subjective; we do not yet have good records for all taxa grown under the same conditions. However, we have counted at least 150 ripening fruit on a single plant in a Papago garden at Sells, and project that its yield could easily surpass 200 fruit over the entire growing season. None of the wild seed which we have brought into cultivation have approached this productivity, although several of our white seeded plants yielded at least 80-120 fruit.

There are also little data on the frequency of fruit variants, or mutants, surviving in wild and cultivated populations of *Proboscidea*. However, 3- and 4-clawed fruit are a curiosity readily collected by Pima and Papago basketmakers. They have provided us with a multiple clawed fruit with white seeds, and 2 informants have recalled 3-clawed germ plasm that was supposedly maintained for several generations. We have only come across one 3-clawed black seeded fruit, brought into a Blackwater, Arizona trading post by an Indian. Because of the difference in the relative number of cultivated versus wild fruit we have examined, we cannot yet hypothesize whether the statistical frequency of surviving variants is actually higher among cultivated white seeded fruit.

Finally, it is notable that a number of Papago basketmakers volunteer that they "plant only the seeds of the longest ones, because when the plants come up, they make more big devil's claw." In other words, conscious selection for long claws is continuing. The majority of the Papago and Pima who note this selection also associate white seeds with intrinsically larger fruit.

CONCLUSIONS

In evaluating the available biological data in light of the alternative hypotheses presented (Fig. 3), we will attempt to answer the following questions: With which established *Proboscidea* taxa does the white seeded race show the greatest affinity? How does it differ from this taxa? Are the differences similar to those between wild species, are they the effects of cultivation, or do they indicate true domestication? If so, what drove the domestication process: selective pressures for food or fiber?

Although the white seeded race has a geographic range which does not fall completely within the range of any of the recognized annual species, it has a great deal of overlap with *P. parviflora*, and little with *P. louisianica* or *P. fragrans*. The area where it may extend beyond the range of the recognized wild annual *Proboscidea* is in Nevada, where but one truly wild *P. parviflora* occurrence has been recorded (Dr. Wesley Niles, personal communication) and parts of eastern California. However, given the ease of dispersibility of devil's claw, we conclude that geographic range is in itself a poor indicator of affinities within the *Probosicidea* genus.

There is little doubt, however, that in regard to floral morphology, color and ornamentation, the white seeded devil's claw is most similar to *P. parviflora*, rather than *P. fragrans* or *P. louisianica*. Additionally, the feature of the foliage surpassing the inflorescence is shared with *P. parviflora* but not with *P. louisianica* or *P. fragrans*.

These features are not always clear on pressed herbaria specimens, so that collections noting white flower color, with relatively large flowers, have often been referred to as *P. louisianica* on these latter features alone. We are confident, however, that the flowers of the white seeded devil's claw show much more affinity with *P. parviflora* than with typical *P. louisianica*, except in terms of flower size, a trait easily influenced by both cultivation and selection.

Other diagnostic characters, such as leaf shape and filament pubescens bear out an affinity with *P. parviflora*. Less diagnostic features such as seed size and number of seed per fruit, oil and protein content also illustrate that the white seeded race and black seeded *P. parviflora* are within the same general range.

The characteristics in which the white seeded race diverges the most from typical *P. parviflora* are *not* those which distinguish wild species from one another, but those most commonly influenced by domestication. These include disproportionate enlargement of an economic product (the claw), increase in quality of the product (darker and more pliable), seed color change, and loss of delayed germination.

Other slight differences in characters, such as yield, leaf size, calyx and corolla size, and oil content are in features easily accounted for by indirect cultural selection. We conclude that the white seeded race does appear to have been domesticated from wild *P. parviflora*, since the spontaneous race of *P. parviflora* does not "take on" these characteristics when simply brought into cultivation.

Because the claw has been enlarged to a greater extent than the seed-holding body of the fruit, we feel that selection for fiber rather than food has been the driving force of domestication. Fiber quality has been considerably modified, whereas seed characteristics such as size, number per fruit, dispersibility, and protein have remained relatively the same. These characteristics are usually altered significantly when a plant is domesticated for the food value of its seed. The seed features, e.g.s., loss of delayed germination, white seed color, which have developed in the domesticate could evolve under pressures from cultivation and deliberate human selection for fiber as easily for food.

Thus we recognize numerous features which suggest disruptive selection of *P. parviflora* in cultivated environments and deliberate human selection, resulting in the evolution of a distinct white seeded race. This process is continuing, but to our knowledge has not yet developed a fully domesticated, obligatory cultigen. The presence of presumably feral white seeded devil's claw in Pápago *rancherias* indicates that the domesticate is highly associated but not entirely dependent on humans and their intentional planting of seeds. It is possible, however, that in the Kern County, California and southern Nevada, beyond the range where

wild annual *Proboscidea* are commonly found, that the survival of the white seeded race was more dependent on cultivation than it is in the Papago *rancherias*.

Finally, it is worth emphasizing that the situation is much more complex than simply having wild black seed and domesticated white seed. Characteristics such as slightly smaller floral parts, and more grayish hues in the white seeds suggest that "the domesticated qualities" of Camp Verde Apache devil's claw are not as pronounced as those of the Papago and Havasupai. The black seed which the Papago cultivate have claws 19.6 ± 3.1 cm, significantly longer than the black seeded claws which we brought into cultivation (Tables 10 and 11). Does this indicate incipient domestication, or merely that the Papago selected seed from longer claws in the wild to begin with? The frequent association of wild devil's claw with the gardens of Apache basketmakers on the Fort Apache Indian Reservation (Anonymous 1976), may well illustrate the "self-domestication" process discussed by Whitaker and Bemis (1975:325-368).

Bretting (personal communication) is undertaking a systematic crossing program of various acquistions of white seeded and black seeded *P. parviflora*, including some of our collections. Presently, variation within the white seeded domesticate's gene pool, as well as within *P. parviflora* in general, is poorly understood. We encourage others to investigate this variation, eliciting information from native basketmakers on less obvious characters that they recognize. To clarify the selective pressures driving devil's claw domestication, we urge scientists to actively work in the settings where this process took place - the agricultural fields and gardens of Southwestern *rancheria* people.

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