TEPARIES IN SOUTHWESTERN NORTH AMERICA

A Biogeographical and Ethnohistorical Study of *Phaseolus acutifolius*

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DEDICATION

To Dr. Howard Scott Gentry

*Ethnohistorically, wild and domesticated teparies (*Phaseolus acutifolius*: Leguminosae) are significant native food crops in southwestern North America. Their value rests in adaptations to arid environments, and high protein content and productivity. Use of wild teparies appears to be discontinued, but certain domesticated varieties are still grown by local commercial and subsistence farmers. The recent subsidence of tepary cultivation is related to breakdown of traditional economies and land use, and to the introduction of energy-intensive irrigated agriculture. An earlier and unsuccessful attempt to introduce teparies into modern agriculture was poorly timed. Teparies have considerable potential for low maintenance agriculture in arid and semi-arid lands.*

Wild and domesticated forms of the tepary bean, *Phaseolus acutifolius* Gray, have been utilized as a food resource in the Americas for more than five millenia. Since the first agronomic description of teparies by Freeman (28), they have been regarded as a drought-adapted, disease-resistant crop. Hendry (45) went so far as to say that teparies had a "singularly perfect adaptation to arid lands." While domesticated white teparies can produce as much as 2020 kg seed/ha (1800 lbs/acre) in water supplemented fields within the Sonoran Desert, more than 4,630 kg seed/ha (4,200 lbs/acre) have been harvested in areas where climatic conditions are less extreme (Table I). The beans store well, and protein content ranges from 21.1% to 32.49%. Teparies are nutritionally comparable or superior to most economic legumes (22).

Given these details alone, one would expect the tepary to be a valued food crop in arid lands, and that it would receive considerable attention from researchers. Yet Kaplan and other *Phaseolus* experts have had difficulty obtaining teparies since the 1950's, and it was reported that teparies were probably no longer commercially grown (52, 53). The Agricultural Research Service of the United States Department of Agriculture, which has maintained ten small lots of teparies in the National Seed Storage Laboratory for some time, has not been able to acquire additional seed until recently. Agronomists know little more about teparies than that which was published before 1920, and plant breeders have had only a fraction of tepary germ plasm available to them.

It appears that the abandonment of many locally adapted tepary stocks occurred while other, hybrid seed crops were rapidly being introduced along with modern energy-intensive agriculture. The simultaneous loss of other native seed stock is described by Clark (11), who notes that through neglect, millenia-long genetic continuities have been terminated.

When one recognizes the restricted genetic base upon which modern bean production rests, it becomes clear that increased vulnerability to diseases, droughts, and pests is a consequence of this trend. Nearly all bean production in the western United States is in two closely related hybrids of Idaho-bred pintos (*P. vulgaris*), which account for nearly 50%

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TABLE I

Domesticated Teparies — Production of Seed per Acre

kg. of seed	location	year	irrigation	source
407	McNeal, Az.	1910	dry-farmed	30
805	McNeal, Az.	1910	10 cm	30
1345*	Tucson, Az.	1911	yes	30
459.8#	Tucson, Az.	1911	yes	30
2235 (high)	State College, N.M.	1916	yes, but	33
1878 (low)	State College, N.M.	1916	dry-bedded	33
4633 (high)	Fresno, Ca.	1917	minimal	45
2536 (low)	Fresno, Ca.	1917	minimal	45
3475 (avg.)	Riverside, Ca.	1910s	?	46
896 (avg.)	Davis, Ca.	1910s	?	46
1368	Berkeley, Ca.	1910s	?	46
170	Smith River, Ca.	1910s	?	46
526 (avg.)	Goodwell, Ok.	1926 1932	dry-farmed	27
1967 (high)	Akron, Co.	1930	dry-farmed	5
602 (avg.)	Akron, Co.	1924 1934	dry-farmed	5
1980 (high)	Blackwater, Az.	1960s	2-3 irrig.	Ellis+
880 (low)	Blackwater, Az.	1960s		
2200 (avg.)	Mesa, Az.	1960s	yes	18
1362*	Mesa, Az.	1975	50 cm	Dennis,
1220#	Mesa, Az.	1975	50 cm	Parsons+

*,# - symbols designate the use of different tepary varieties at the same site.

+ - symbol designates personal communication regarding unpublished yield information.

of the nation's dry beans. Though the semi-aridity of the western region discourages the dispersal of many diseases, it has been concluded that "a serious epidemic is possible even in the West," such as the halo blight that hit Idaho in the mid-1960's (13).

Although modern agriculture has certainly left teparies by the wayside as it has other small-seeded New World cultivars, this trend does not fully describe the fate of the tepary. In fact the United States experienced a "tepary boom" earlier in this century. For a decade teparies were the subject of several intensive plant introduction programs. The boom, however, turned out to be a minor economic disaster (45):

> The tepary has not been recognized as a commercial product until the last three or four years, and there has been much difficulty in securing its acceptance on any of the markets of the east or west.... One carload which went to Washington, D.C., could not be sold, and the dissatisfied dealer attempted to sell it at a loss. Similar experiences have been reported for other parts of the country....

We propose that the demise of tepary cultivation within certain areas of southwestern North America was a consequence of changing land-use trends and cultural preferences. It occurred primarily during a time of plenty, when there appeared to be little or no shortage

TABLE II
A Comparison of Wild and Domesticated Teparies
(*Phaseolus acutifolius*)

Character	Wild	Domesticated
Growthform	ephemeral (annual)	ephemeral (annual)
Habit	polynodal vines with long internodes	polynodal with long or short internodes (vines or semi-bushes)
Leaflet shape	nearly linear to ovate-lanceolate	ovate lanceolate
Pod dehiscence	explosively dehiscent	weakly, tardily dehiscent
Pod length	30-75 mm	50-90 mm
Pod width	3-9 mm	8-13 mm
Seeds per pod	2-10 (6 avg.)	2-7 (4 avg.)
Seed length	3.4-6.3 mm	6.6-12.0 mm (8.6 avg.)
Seed width	2.5-4.5 mm	4.4-7.8 mm (5.7 avg.)
Seed weight (dry)	17-58 mg	130-220 mg (150 avg.)
Delayed germination	yes	no
Seed color	cryptic; mottled grey-brown, black, etc.	white, orange-brown, black, buff, mottled, etc.

Data from field observations, herbaria specimens, and published reports (14, 23, 50, 51, 52).

of food, inexpensive energy, or water. Where traditional land use and food habits have remained relatively stable in the region, teparies have persisted as a customary food. Factors such as the introduction of pumps for irrigation, the economics of forage production versus human food production, and the change to cash-oriented economies have affected tepary cultivation throughout most of its range. If teparies are to be re-evaluated for further development, such problems deserve thorough consideration. We suggest that teparies are suitable for extensive cultivation in arid lands, but that further development be tempered in light of their natural and agricultural histories.

WILD TEPARIES

The type locality for wild *Phaseolus acutifolius* is near El Paso, Texas (40). Wild teparies are diploid ($2n = 2x = 22$) annuals with an indeterminate vining habit, cleistogamous flowers, explosively dehiscent pods, and non-glossy, variously colored seeds (Fig. 1, Table 2; 23). The species probably originated in Central America (E. E. Leppik, personal communication), where its closest relatives are perennial tropical vines (66). It is one of the few New World *Phaseolus* species that extend beyond subtropical and semi-arid lands into truly arid zones (Figure 2).

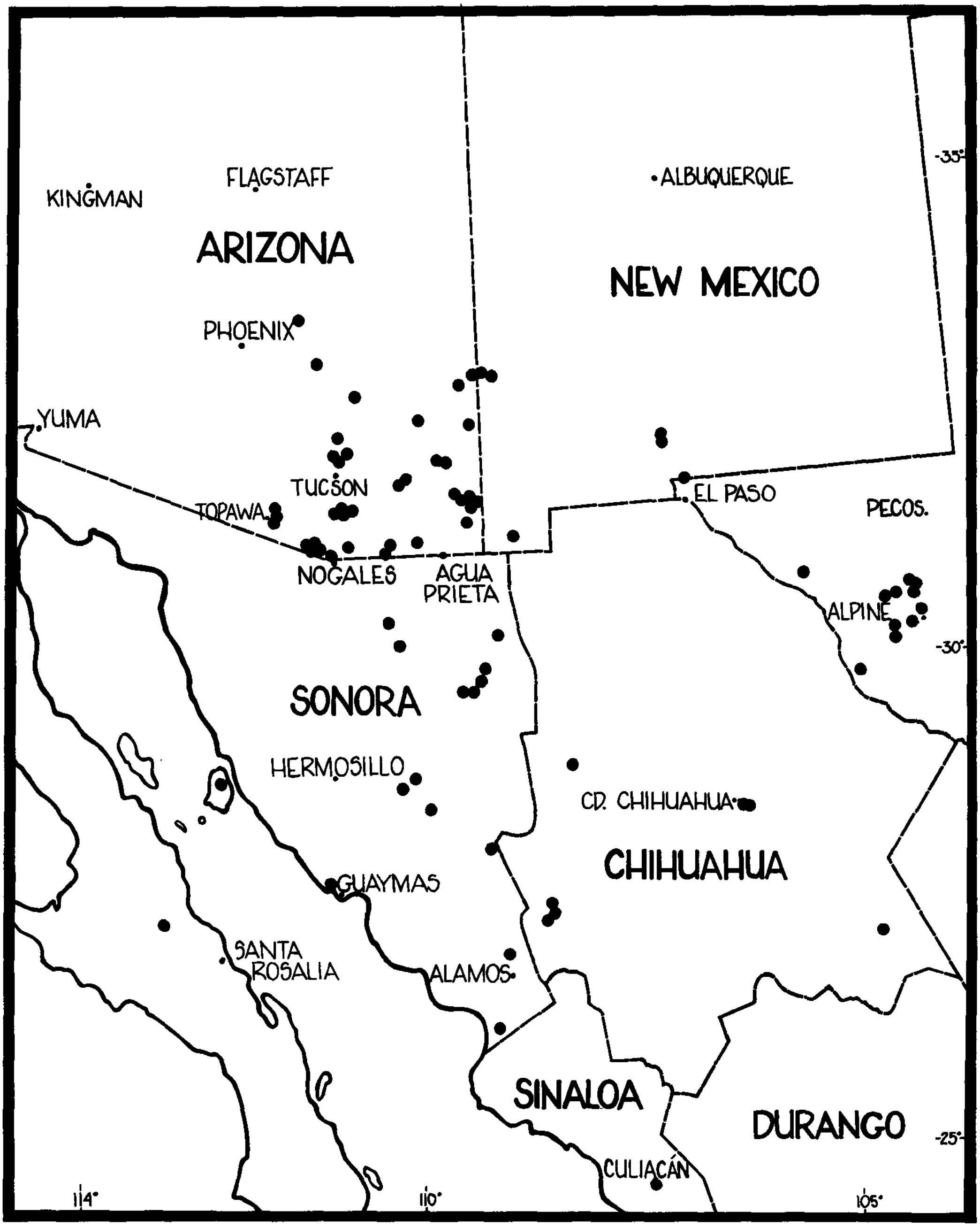

Fig. 2. Distribution of wild teparies in southwestern North America documented by herbarium and/or seed collections.

The tepary's shortened life cycle is also anomalous within *Phaseolus*, in that it functions as a warm season "ephemeral" in arid climates. Information derived from a limited number of specimens agrees with Gentry's (35) generalization that "the flowers concur with the summer rains, first appearing in late August, with the pods ripening early in the fall dry season, most of them in October." Teparies probably require more water for germination and emergence than the amounts required for most warm season desert ephemerals (76). Most of the wild teparies collected in the Sonoran Desert region occur at elevations higher than the desert and at its geographic periphery (Figure 2).

Variation within the wild populations of teparies may be greater than was previously realized. Two varieties are recognized: *P. acutifolius* var. *tenuifolius* Gray, characterized by lanceolate leaflets; and var. *latifolius* Freeman, with wider, nearly ovate leaflets. Oddly enough, a nominate variety has not been maintained in the literature. The type specimen for the species has leaflets of an intermediate width (29), as do many other specimens in herbaria. Local or regional variations in seed size, color and chemistry have yet to be investigated.

The climatic and environmental range of the species is somewhat greater than usually described in the literature. Wild teparies range at least as far south as Guatemala, and as far north as central Arizona. Teparies have been collected at the 1,650 m summit of Cerro Azufre in Baja California, Mexico (Moran 18725, ARIZ), and from an extremely arid, volcanic scoria slope near the center of Tiburon Island in the Gulf of California (Felger et al. 22410, ARIZ). They have also been collected near sea level in the Sonoran Desert at San Carlos Bay near Guaymas, Sonora, Mexico (Gentry 4728, ARIZ).

There appear to be distinct habitat preferences and some ecological niche differentiation between the two sympatric varieties of wild teparies (61). The narrow-leaved var. *tenuifolius* is commonly found on grassy slopes or in woodland openings, vining on the ground or twining on grasses and forbs (throughout this article "leaved" refers actually to leaflet size and shape). The broad-leaved var. *latifolius* has been found most often in shady, shrub thickets on floodplain alluvia, climbing into the overstory. Where the two varieties are found within a few meters of one another, var. *tenuifolius* is often on the slope above a drainageway, whereas var. *latifolius* is most abundant on the bank or border of the watercourse.

In November, 1914, more than 6 kg (15 lbs) of wild tepary seed was harvested from sandy washes near the Santa Rosa Mountains, Pima County, in southern Arizona (31):

> Var. *latifolius* was found in abundance growing in thickets and climbing in great profusion upon the surrounding brush. Many of the vines ascended to a height of 10 to 12 feet and bore a bountiful crop of pods as high as 6 to 8 feet from the ground.

We sampled more than a dozen wild tepary localities for seed productivity in 1976. The sampling was done with 10 $\times$ 10 m quadrats. The most productive locality—near Rosemont, Pima County, Arizona—yielded 191 g of dry seed from 250 plants in a 100 m^2 quadrat. This allows an estimate of 20 kg/ha as a high yield for wild teparies under natural conditions. We suggest that early tepary cultivation and domestication may have resulted in a tenfold increase in bean yield per unit area.

Wild teparies were harvested by at least some Sonoran Desert peoples (8, 10, 24, 28). However, wild teparies have not been reported in the prehistory of the region. Their possible presence in the archaeological record is likely to be obscured by the gravel-like appearance of the seed. The Papago Indians continued to harvest wild teparies at least until after World War II, and they were occasionally sold at trading posts (D. Stewart, personal communication).

The Seri Indians harvested *P. acutifolius* var. *latifolius* on Tiburon Island in the Gulf of California as a major food resource (24). Seri harvest of this population persisted until the middle of this century. In 1976, Rosa Flores, a Seri woman, located this tepary at a traditional gathering place near the middle of Tiburon Island, after not having visited the area for 34 years. Traditionally the pods were gathered in the early morning while the air was still damp and relatively cool. If harvested at midday, the pods dehisce, scattering the seeds. Rosa Flores related that the women would pick mature pods and gather them into their skirts to carry to camp. The women would then roll the pods in their hands over blankets or deer skins until the beans were shelled. The seeds were boiled alone or with meat if it was available. The Seri relished them cooked with mule deer bones and meat. Concerning this tepary, Sara Villalobos, an elderly Seri woman, said:

> They are boiled just like regular beans [*P. vulgaris*]. You do not grind them at all [as on a *metate* or milling stone]. They cook right away—regular beans take a long time to cook because their skin is thick. You don't use a lot of water [to cook them]. You don't salt them because the water is sweet. [Mary Beck Moser, personal communication.]

It is unlikely that such gathering and processing of wild teparies has anywhere persisted.

There have been several experimental cultivations of wild teparies. They were thought to have potential as a forage crop. Freeman and Uphof (32) reported that 6.8 kg (15 lbs) of wild tepary seeds from southern Arizona yielded 395.5 kg (872 lbs) of dry hay when broadcast in a field near Yuma, Arizona. In 1940, the Soil Conservation Service in Albuquerque, New Mexico, grew wild var. *latifolius* alongside domesticates (8). We are experimentally growing wild teparies from several localities at a University of Arizona Experimental Farm in Tucson.

Gentry(36) suggests the use of wild *P. acutifolius* and wild *P. vulgaris* as bridges between the two species in bean breeding programs. He notes that

> ...wild beans have not been used for crop improvement for several thousand years. Our recent collections of bean germ plasm mean that geneticists can make a new start at improving one of the world's most important food resources. A new era in bean breeding is just beginning.

DOMESTICATED TEPARIES

The *old era* of bean selection in the New World began more than 8,000 years ago. Kaplan (51–54) provides excellent reviews of archaeological information regarding domesticated beans, and draws attention to tepary domesticates found in strata dated 5,000 years B.P. from Tehuacan Valley, Mexico. Prior to this discovery, it had been argued that as the center of diversity for tepary domesticates, southwestern North America was also their center of origin (7). The Tehuacan teparies, three millenia older than any records from the Southwest region, aroused skepticism regarding this center of diversity/center of origin correlation. Currently, the use of locations of early prehistoric occurrences is also regarded with much skepticism. The recently summarized research of Burkhart, Berglund-Brucher, and Brucher (2) concerning the wild progenitors of *Phaseolus vulgaris* cultivars suggests that beans may have been selected from wild populations and domesticated in widely separated regions. We doubt that the archaeological record, when used by itself, could reveal such multiple origins of a domesticated species.

Domesticated teparies are classified as *Phaseolus acutifolius* var. *latifolius* Freeman, in recognition of their vegetative similarities to broad-leaved wild teparies. They differ from wild teparies in several features (Table II), particularly in seed characteristics. Freeman (30) further categorized domesticated teparies by seed color and shape, superficially describing 46 genotypes or lines (42) found in southern Arizona at the time. Kaplan (51) recognizes only 8 types (cultivated races, *sensu* Harlan and de Wet, 42) of tepary domesticates on the basis of seed morphology and color patterns. Additionally, agronomists have utilized a land race or cultivar classification for commercial seed, e.g., Redfield white teparies (34), derived from a particular type. These classifications reveal little in regard to biogeographic origin and diffusion of teparies. One difficulty is that similarly colored "sports" derived from two distinct populations may appear as if they are from the same lot. Chemotaxonomic methods such as electrophoresis may be useful in establishing a varietal classification that reflects phylogenetic relationships (56).

Archaeological material includes tepary domesticates found charred in hearths, or well preserved in clay vessels in houses and caves. The discovery of 42 kg of teparies in Kelly Cave, Catron County, New Mexico, indicates that prehistorically teparies were grown and stored in substantial quantities (15). In terms of relative abundance under cultivation, it is likely that the importance of teparies in the Sonoran Desert was surpassed only by maize (8, 9). In 1716, prior to major Spanish influence in agriculture, the *papavi* or *tepari* was regarded as the principal harvest crop of the Papago (81).

A provisional list of native names for tepary domesticates suggests the extent of their use in southwestern North America (Table III). Several peoples utilize modifications of the cognate *muni*, which in some cultures is a generic term for beans (71; D. Matson, personal communication). Other peoples, such as the Northern Pima, who were tepary "specialists," utilize a separate term for teparies while still using *muñi* for *Phaseolus vulgaris* varieties. Significantly, white teparies were one of the first crops created for the Pima in a version of their origin myth (44). Cultivation of teparies by these culture groups is in most cases documented by ethnographic literature; although in a few cases farming teparies or certain types

TABLE III

Folk Nomenclature for Teparies in Southwestern North America

Culture	Name	Source
Sia (Keres) Pueblo	suramak	L. A. White, notes
Zuni Pueblo	tsikapu´ ult pintu pa nó·kwína	3 3 A. Rea and G. P. Nabhan, notes
Hopi Pueblos	cacai-mori-vosi tcatcai´ móri	A. F. Whiting & V. Jones, notes & 78 A. F. Whiting & V. Jones, notes & 78
Southern Paiute	mo:ri:	70
Walapai	ᵃmati´gᵃ	58
Havasupai	madiga	74
Western Yavapai	marika	39
Maricopa	maR̲ik	9
Yuma	mare´k	9
Mohave	marik	9
Cocopa	amaLix	38
Desert Kamia	marik	37
Cahuilla	tevinymalen tevas·malem	1 J. P. Harrington, notes
Gila River Pima	b/p avI pavf(ĩ̂)	A. Rea and G. P. Nabhan, notes 69
Papago	bavi * cuck bavi	60 60
Opata	te:pari yorimuñ	T. Sheridan and G. P. Nabhan, notes & 26 T. Sheridan and G. P. Nabhan, notes & 26
Seri	teépar * ʔaáp	M. B. Moser and R. S. Felger, notes & 24 M. B. Moser and R. S. Felger, notes & 24
Mayo	yori muni	48
Tarahumar	muní muniki	64 64

* = wild beans from uncultivated Phaseolus acutifolius.

of teparies may not have begun until this century (7). For instance, a Kaibab Paiute woman said that white teparies were first grown on her reservation within the last two years with seed obtained from a Mohave Indian man who lives among the Shivwits Paiute (A. Rea, personal communication). This illustrates how complicated a cultural diffusion process may be.

Teparies were traditionally cultivated through a variety of methods, depending on

TABLE IV

Bean Cultivation/Irrigation Methods Used in Southwestern North America

People and region	Range of annual rain	Method	Sources
Hopi, Northeast Arizona	138-225 mm (Oraibi)	Dry-farming in sand dunes on mesa tops where roots reach capillary fringe or sub-superficial moisture; seepage areas in colluvial soil of mesa sides planted; also, stream irrigation at Moenkopi.	41, 78
Pima at Gila-Salt Rivers	73-368 mm (Laveen)	Stream diversion by canal into floodplain fields; ak-chin also practiced.	8, A. Rea and G. Nabhan, notes
Papago, Southern Arizona	170-480 mm (Sells)	Ak-chin/temporal: runoff collected in plugged arroyos; area behind plug then planted while wet.	6, 7, 8
Yumans on Lower Colorado River	10-140 mm (Yuma)	Planted in holes 375 mm deep in floodplain swales that had been inundated the prior season.	9
Cahuilla, Coachella Valley, California	0-280 mm (Indio, Thermal)	Planted in small patches under mesquite and arrowweed in seepage and floodwater areas.	1
Opata and Pima in Eastern Sonora	440-540 mm (Cucurpe, Opodepe)	Acequia: canal diversion off intermittent river. Temporal: summer rain runoff diversion into fields near arroyos.	26, 68
Tarahumar, Chihuahua	360-390 mm (Balleza, Nonoava)	Wasa floodplain plots cultivated after high water stages; arroyo-plugging and terracing in uplands.	64

water availability, soil moisture-retention capacity, length of growing season, and cultural habits. Table IV indicates the diversity of agronomic environments within which teparies have been farmed. Significantly, there is a continuum from "dry land" agriculture (where the only available water is the precipitation that falls upon the field under cultivation) to irrigated agriculture. In most cases, rainwater was accumulated from a "catchment basin" larger in area than the cultivated field itself. Likewise irrigation water diverted from flooding arroyos or intermittent streams was nevertheless rainfall-dependent (Table IV).

Rainfall or floodwater dependent cultivation methods are of several kinds. In *temporal* fields, in Sonora and southern Arizona, the surface runoff of small canyons accumulates in washes (*arroyos*), and is diverted to fields through hand dug ditches (26). Teparies planted in *temporales* during late summer rains may receive only one or two "irrigations" from this diverted rainwater. Because of their rapid growth this may be sufficient watering

TABLE V

The Range in Protein Quality of Domesticated Tepary Beans as Determined by Chemical Analysis and Computed Scores

essential amino acids in whole seed flour	mg of amino acid[a]/ 1 g N	amino acid score (test/reference[b])	most limiting of amino acids[c]
Isoleucine	280-310	70-77	4
Leucine	480-530	68-76	3
Lysine	410-420	74-76	6
Methionine + cystine (sulfur amino acids)	80-170	23-49	1
Phenylalanine + tyrosine (aromatic amino acids)	520-530	87-88	7
Threonine	250	62	2
Tryptophan	-	-	c
Valine	360-380	72-76	5

a - Data from two sources: One test of a water-free unknown domesticated tepary race by R. Cerighelli, F. Busson, J. Toury and B. Bergeret in 1960 (see 43). Also, two races tested by A. Longo and G. Nabhan, University of Arizona, Tucson, 1975. Tucson tests utilized common white and red-brown races from Pima Indians, grown under garden conditions. Test performed in duplicate, utilizing 110 mg samples; nitrogen analysis by micro-kjeldahl procedure using Kirk-type distillation apparatus; hydrolysis at 145° C for 4 hours, and hydrolysis vials evacuated by Duo-Seal vacuum pump.

b - Reference score utilized here is the FAO/WHO 1973 amino acid score based on an ideal protein first described by Block and Mitchell in 1946 (see 80). Energy and protein requirements. Report of a joint FAO/WHO expert committee. WHO Technical Report Series 522 (Geneva, Switzerland: World Health Organization), pp. 61-63.

c - Limiting amino acids are listed with lowest numbers as most limiting, excluding consideration of tryptophan, which was not evaluated in these tests. The sulfur amino acids are likely the most limiting amino acids, nevertheless; their limitation on protein quality is characteristic of *Phaseolus* and other legumes.

for seed production. Yuman Indians on the lower Colorado River planted in floodplain depressions that had been inundated a few months earlier, and did not necessarily have to supplement the plants with additional moisture (9). In contrast, the Hopi at Hotevilla do not divert rainwater into their mesa top bean fields, but take advantage of the peculiar holding capacities of the soils in their sand dune fields (41).

Joseph Giff, a River Pima farmer, estimates that teparies grown on the floodplain of the Gila River can be harvested in 60 to 75 days after planting. He told us that timing of water is crucial to a good, quick crop. "Starving teparies of water" until they begin to flower and fruit insures that more growth will go into bean rather than foliage production. Teparies on the Gila River Indian Reservation are seldom damaged by insects or disease, and are reported to tolerate drought longer than most crops (J. Giff, personal communication).

The field plots on Indian reservations which we have observed are mixed species gardens with less than two hectares under cultivation. In the Northern Piman village of Kohatk, Arizona, a runoff agriculture plot approximately 15 × 25 m included 150–200 white and red-brown tepary plants, 125 maize plants, and fewer than twenty plants each of a *Sorghum* variety, domesticated devil's claw (*Proboscidea* cf. *parviflora*), and walnut squash (*Cucurbita mixta*). The teparies in this floodplain plot had ripened by late October, and had been pulled up and piled to dry before threshing (Nabhan 567, ARIZ).

Bohrer (4) reviews methods for preparing beans in the Southwest. Teparies were often parched, and then either ground and boiled, or simply boiled. Teparies were also boiled without parching, and only occasionally eaten as a green bean (9). Commonly eaten with meal or whole kernels of maize, the high percentage of lysine in tepary protein complements lysine-limited maize amino acids in a manner similar to *P. vulgaris*. There appears to be some nutritional variation between different types of teparies (Table V).

Teparies remain a customary, even favored food among the Northern Pima in Arizona and Sonora and descendants of the Opata in Sonora. The Hopi continue to grow white teparies for food. The post-1900 distribution of native cultivation of teparies in southwestern North America is shown in Figure 3 and summarized in Table VI.

MEXICAN-AMERICAN AGRICULTURAL HISTORY

In northern Mexico the white tepary is widely accepted beyond traditional Indian communities, and is marketed to Mexican-Americans in border towns such as Nogales and Douglas-Agua Prieta on the Arizona-Sonora border. Yet early Spanish-speaking influences in Sonora tended to overlook the native tepary's value, considering it to be a *frijol degenerado* 'bean degenerate' (73). Missionaries thought that the large-seeded, broad-leaved *P. vulgaris* types, which they had brought from further south in Mexico to desert peoples, had degenerated into small-seeded teparies within the hostile environment.

Jesuit missionaries of the 17th and 18th centuries nevertheless introduced many grains and legumes to take the place of Indian crops and some of these have survived in the region. In Sonora today, the tepary coexists with cool season garbanzos, peas, fava beans, and with old and new varieties of warm season *P. vulgaris*. In Mexico, the cultivated tepary is called *tepari, escomite*, or *garbancillo bolando*, and has been nicknamed *todasaguas* (73) due to its ability to grow in "all waters" and all seasons. Early Spanish travelers also referred to teparies by native names for beans, such as *yorimuni*, as they noted its presence in the Greater Southwest (48). Conversely, many of the legumes introduced by the Spanish have been given Indian names. By the mid-18th century, the *pueblos* 'towns' and *rancherias* 'ranch complexes' of Sonora appeared as a bean-grower's heaven to the Jesuit missionary Pfeffercorn (65):

> The beans are of different kinds and colors — white, black, red, yellow and speckled. Legumes, especially beans, prosper so well that one malter generally yields thirty.

Bean production in northern Mexico was undoubtedly augmented by the Spanish Colonial introduction of new irrigation technologies (68), and in places by increased social organization for larger scale irrigation systems. Combining native and Hispanic elements, gravity-fed *acequia* canal systems were developed in Sonora that were adapted to local geomorphology and surface flows. Although rainfall-dependent *temporal* and other techniques (see Table IV) continue to be utilized by some Sonoran farmers, river diversion canals have formed the mainstay to Sonora's agricultural economy through most of the last three centuries.

Mestizo farmers in Sonora, Mexico, grow teparies in monocultural fields planted during late summer, or in "mixed gardens" at almost any time of the year. In a field less than one hectare on the Rio San Ignacio floodplain near Magdalena, Sonora, white teparies were grown in mixed rows in 1975 with pinto and yellow beans (*P. vulgaris*), long green chilis, white maize, onions and a mustard green (*quelite*) *Brassica* cf. *kaber* (Nabhan 236 and 292,

TABLE VI

Ethnographically Documented Use of Teparies in Southwestern North America — A Cultural Survey

Culture	Wild teparies	Domesticated teparies: One race (type)	Domesticated teparies: Two or more races (types)
Tewa Pueblos		X	
Southern Tiwa Pueblos		X	
Towa Pueblos		X	
Eastern Keres Pueblos		X	
Western Keres Pueblos		X	
Zuni Pueblo		X	X
Hopi Pueblos		X	X
Kayenta Navajo		X	
Kaibab Southern Paiute		X	
Shivwits Southern Paiute		X	
Walapai		X	?
Havasupai		X	X
Western Yavapai		X	X
Chemehuevi		X	
Maricopa		X	X
Yuma		X	X
Mohave		X	X
Cocopa		X	X
Desert Kamia		X	
Cahuilla		X	
Gila River Pima		X	X
Papago	X	X	X
Southern Pima		X	
Opata		X	
Yaqui	X	X	
Seri	X		
Mayo		X	
Tarahumar		X	

List compiled from numerous ethnographies and ethnographic bean collections, as well as from new interviews and specimen collections. Much information is adapted from previous surveys (7, 51, 52, 71).

ARIZ). A government-set price ceiling on food staples has made it more profitable for farmers to grow forages than beans as cash crops. The white tepary, however, continues to be grown for home use, trade, and small-scale marketing. In addition, a few Sonora, Mexico, farmers smuggle truckloads of their white and red-brown teparies across the border to the Papago Indian reservation in Arizona, where they can sell them for higher prices.

Fig. 3. Distribution of post-1900 native cultivation of domesticated teparies in southwestern North America documented by herbarium and/or seed collections. Cultivation of a single race or type is shown with a circle (●), and cultivation of two or more races at a locality is shown with a triangle (▲).

ANGLO-AMERICAN AGRICULTURAL HISTORY

Soon after Anglo-American agronomists came into contact with the tepary, their promotion of this native bean ushered in a whole new era in its agricultural history. With recognition of its suitability for dry farming in semiarid lands, a quantum jump in its agronomic distribution occurred. Through the efforts of George F. Freeman and associates at the Arizona Agricultural Experiment Station, tepary selection and testing programs were begun throughout the region. Varieties that had been grown exclusively by Indians in Arizona for hundreds of years suddenly became available to agriculturists in twenty-eight states and countries (59). *Phaseolus acutifolius* aroused the interest of plant breeders and agronomists as far away as South Africa and Russia.

A dryland farming movement at the turn of this century set the stage for the development of the tepary as a modern agronomic crop. During the second half of the 19th century European-Americans realized that many of their agricultural materials and methods were unsuitable for the semi-arid western United States (57). In localities where the annual rainfall averaged less than 50 cm, and varied greatly from year to year, cropping systems derived from temperate zones failed. As a result, immigrants to the Great Plains began testing new systems of cultivation that could fit the region's conditions.

The most widely promoted system of dryland farming techniques, which Hardy Webster Campbell expounded about 1902, soon proved impractical in many localities due to peculiar climatic or edaphic conditions (67). While controversy raged over various dry farming techniques, the United States Department of Agriculture took the conservative stand that no single system was adaptable to all regions. The USDA thus began encouraging the use of drought-hardy plants that might lend stability to any agricultural system initiated in the rainfall-variable West. Subsequently a worldwide search for drought-adapted crop varieties blossomed. Agricultural experiment stations began introduction and mass selection and breeding programs for more hardy cultivars (67).

In Arizona, drought-adapted varieties of maize and beans grown by the Papago Indians were brought to the attention of agronomist George F. Freeman. He noted that the Indians' folk nomenclature recognized a group of beans other than those which were obviously varieties of *Phaseolus vulgaris*. After thorough taxonomic and agronomic comparisons with other *Phaseolus*, Freeman published the first scientific descriptions of these native beans, the *Phaseolus acutifolius* var. *latifolius* domesticates (28, 29). For nearly a decade, Freeman tested various tepary stocks under dryland and minimally irrigated conditions; compared phenology and yield with other dry beans and forage crops; coordinated nutritional analyses; and sought other seed stocks of wild and domesticated teparies. Freeman's 1918 revision (30) of his 1912 monograph (28) serves as a summary of much of this research.

It quickly became clear to agronomists that teparies were better at evading drought (because of a shortened life cycle) and tolerating drought than *P. vulgaris* cultivars. These qualities made teparies ideal for dry farming in semi-arid parts of the Southwest. In wet years, without irrigation, teparies achieved or surpassed the average Arizona bean yield of 560 kg/ha, and produced some beans in drought years when other crops completely failed. Thus, a bulletin on dry farming in the semi-arid valleys of Arizona concluded that teparies were "practically the only seed crop that can be produced in anything like paying quantities without supplemental water" (12).

Statements such as this encouraged a Southwestern railroad line to distribute tepary seed to newly settled farmers along its route. At the same time, the USDA Office of Seed Distribution sent out 25,000 lbs (ca. 11,360 kg) of teparies (59). Apparently agricultural agents also distributed tepary varieties to Indians such as the Havasupai who may not have previously grown them (7).

By 1915, the tepary boom had begun. Farmers in Arizona, New Mexico, California and elsewhere were turning marginally productive land over to its cultivation. Agronomic research at a number of locations in California (45) and New Mexico (33) allowed the first regional comparisons of tepary yields under various conditions (see Table I). After commercial introduction to California in 1914, tepary cultivation was expanded onto no less than 42,000 ha by 1918 (45).

Teparies, mostly of a white race, suddenly became available alongside other dry beans in markets across the country. Although less expensive, they appeared small and unattractive next to the navy and other common beans. Anglo-Americans apparently objected to their strong flavor and odor when cooked, and when undercooked, to the resulting flatulence. Attempts at wholesaling larger quantities to restaurants failed, and the bottom began to fall out of the tepary business.

Realizing that rapid dispersal of an economic plant does not necessarily lead to rapid establishment and acceptance, agriculturalists retreated from their optimistic promotionalism to reassess the tepary. Hendry (46) noted that tepary growth and production became abnormal in the subhumid coastal climates of California, suggesting that teparies had been introduced into climates to which they were not adapted. The edible, digestible and cooking qualities of teparies were defended by food scientists (19, 49), yet the native beans were never again nationally marketed as human food. Freeman (30) began to emphasize their use as a forage and orchard cover crop, and claimed that tepary hay was nutritionally comparable to alfalfa hay. It was also shown that teparies outproduce other forage legumes when dry farmed in the Great Plains, where they remained as a minor forage crop for many years (5, 27, 34).

Several other factors probably combined to bring about the further decline of tepary production. The introduction of gasoline powered pumps allowed access to groundwater and irrigation of lands which could previously only have been dry farmed. Although the first groundwater pumping began in Arizona about 1902, before the tepary boom, the rapid expansion of groundwater-irrigated agriculture occurred from 1918 to the late 1920's (77). The Sulphur Springs Valley, formerly a prominent dry farming area, became dotted with wells. Much acreage was converted into alfalfa, small grains, and fruits that required more soil moisture and longer growing seasons, yet returned more as cash crops than dry farmed cultivars. It appeared that drought-hardy crops were no longer crucial to the existence of agriculture in arid zones. Gas powered pumps and an unaccepting market had left teparies in the dust by 1930.

In northern Mexico and on Southwestern Indian reservations, the conversion to groundwater-based agriculture took place more gradually, yet an additional factor was leading to the abandonment of traditional crops in these areas. Indians were working for wages, either seasonally or full-time, in cotton fields and in other industries. This not only interfered with work in their traditional agricultural fields, but among the Papago and others, the traditional barter and gift economy was almost entirely replaced by the cash economy (20).

Ak-chin farming (see Table IV) of teparies was continued only by those who did not get jobs and buy all their food from stores. Through this process, many locally adapted tepary stocks fell out of use, and the last generation of Papago farmers to know the finer points of *ak-chin* farming is now dying.

A revival of dry farming was attempted during World War II when gasoline for farm pumps became restricted. Yet the Dust Bowl of the 1930's had made people wary of dry farming. The deep-tillage and fallowing of fields in the season prior to planting, a soil moisture-retention technique that had been advocated by dry farm promoter Campbell, backfired on the wind-swept plains. Dry farmed tepary fields on the plains and broad valleys were also susceptible to severe wind erosion immediately after harvests: Western farmers customarily uprooted and transported whole plants away from the field, rather than cutting them to stubble and mulch for soil protection. Farmers were thus warned that teparies and other beans were not fit for production in large areas on plains (i.e., monoculture), and should only be grown in strips between crops providing winter ground cover (5).

In spite of the factors discouraging tepary cultivation, at least two races continue to be sold commercially in Sonora and on or near Indian reservations. These teparies are most often grown in small irrigated fields and sold for supplemental income at local markets or trading posts. The two commercial races and other, rarer seed stocks, persist as items of exchange within families on reservations.

A few non-Indian agri-businessmen also grow teparies (18), to sell through trading posts on nearby reservations, or in open air markets within urban *barrios* 'districts.' One commercial producer has little difficulty selling his harvest of 12 ha (30 acres) to retailers each season. Raising both spring and late summer crops of teparies most years, applying three irrigations per crop in the Sonoran Desert, a modern tepary grower has fewer production costs compared to those needed for other crops. However, finding machinery to harvest and clean the seed is difficult in some localities. In 1975, in Arizona teparies were sold wholesale for $20/100 lb (45.5 kg) bag, and marketed retail in trading posts for $0.50 to $1.38/lb. Considered a scarce commodity by more traditional Indians, teparies drew much higher prices than pinto beans on some reservations. At the same time, poorly cleaned teparies from the Rio Sonora valley in Sonora were sold for $0.20 to $0.25/lb in border towns.

CURRENT PROSPECTS

Because of its adaptations to arid lands and use as a traditional desert crop, some interest in the tepary has been sustained. The tepary has been utilized in physiological research as a classic example of drought and heat tolerance (17, 55, 75). Perhaps the most significant event in recent bean breeding is Honma's interspecific cross, *P. vulgaris* × *P. acutifolius*, accomplished via tissue culture (47). This hybrid transferred the tepary's tolerance to *Xanthosoma phaseoli*, the causal agent of common bean blight, to the Great Northern cultivar of *P. vulgaris*. Honma had been unable to find a useful level of tolerance in other beans, and progeny from his interspecific hybrid made possible the development of blight tolerance in other *Phaseolus* cultivars around the world.

Another wave of interest in the tepary has been generated by popular ethnobotanical publications, which give appreciation to the tepary's place in the native American cuisine (63). Organically grown teparies have recently become available in health food stores in Tucson, being perceived as a nutritious staple and an "Indian food" novelty item.

The most significant use of the tepary may be in the development of new desert-adapted agroecosystems (25). Few crops grown in arid lands today could survive independent of large water and petrochemical supplements. As high energy inputs and ecological disturbances associated with industrial agriculture have become evident, low maintenance agricultural systems adapted to various biomes have been proposed as alternatives (16). The tepary has been identified as one drought tolerant resource that could be incorporated into climatically adapted multiple cropping systems (21).

In arid zones, the production of most crops is limited by the high evaporation rates, lack of precipitation and surface water, and/or by increasingly prohibitive costs of pumping fossil groundwater. Agriculture based on drought-adapted crops provides an alternative. It can conserve water at the most crucial point, i.e., at the end of the supply and delivery system (62). Quick-maturing crops that need not be watered over an extended period of time are especially valuable. Teparies could be grown in interspaces between arid land perennials such as mesquite (*Prosopis*) and jojoba (*Simmondsia*), which do not produce for several years after establishment. Such crops would be particularly suited for marginally arable lands of developing countries where large scale irrigation and mechanization are unavailable, as well as for all arid zones when excessive fresh water and petrochemical inputs are no longer feasible (25). The tepary may become an important crop for arid and semi-arid regions.

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