The Desert Tepary as a Food Resource

a journal symposium
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When tepary pods dehisce they twist and release the seeds. Photography by Helga Teiwes.
Guest Editorial

A Special Issue on the Tepary Bean. At the 1912 International Dry Farm Congress (Lethbridge, Alberta) the tepary bean was one of three domesticated legumes from Arizona Indians to receive special honors for flavor and reliability of yields under rainfed conditions. Soon afterward a promotional flyer from a seed company in Prescott, Arizona affirmed that this native desert legume promised "to become a country-wide food staple..." Van Camp, the greatest authority on beans in the world, says the Tepary is ideal for baking and contains possibilities which promise to give it high rank in the national dietary.

These promises never bore fruit. Within a decade, farmers and researchers in the arid and semi-arid West had become more devoted to development of irrigation made possible by diverting rivers and pumping groundwater. This resulted in a lessening of interest in crops which were suited to dry farming techniques. Although yields of common beans increase with ever-greater amounts of irrigation, yields of tepary beans—much higher than other beans at lower levels of irrigation—are then reduced by what may be called excessive irrigation (Peterson and Davis, Ann. Rep. Bean Improvement Coop. 25: 53-4, 1982). Given these circumstances, teparies were bound to lose out, and little was written about them by agricultural researchers in land-grant colleges and universities after 1918.

When a number of the contributors to this special issue began working with teparies in 1975, things looked dismal for the little bean. By the 1970's many tepary varieties collected at the beginning of the century by Robert Forbes and George Freeman on their visits to Arizona Indians were no longer available on reservations. Lawrence Kaplan (Econ. Bot. 19:358-68, 1965) noted that "at present time, this tepary (bean) is not cultivated on a commercial scale... on the Pacific coast of northern Mexico... In 1954, it was infrequent in that region." British bean expert Joseph Smartt in The Domestication and Exploitation of Plants and Animals (Aldine Publ., Chicago, 1969) was even more pessimistic regarding the future of teparies: "It is quite likely that this species will disappear from cultivation in a relatively short while."

Yet the tepary has not disappeared from cultivation; in fact, its planting and consumption are undergoing a revival. Why? First, the rising energy cost of pumping water has encouraged a search for crops that grow well on rain, runoff or minimal irrigation. Water conservation has been called the global environmental issue of the 1980's and is intimately tied to energy use. This is especially the case in Arizona where the total agricultural energy use per unit acre reached 500% of the national average, with 97% of the Arizona energy costs being irrigation-related (cf. USDA/FEC. Energy and United States Agriculture: 1974 Data Base. Washington, DC. 1976). In Pinal County, where more than one third of the area's irrigated acreage has gone out of production [Forbes 124(4): 56-63. 1979], at least one farmer has demonstrated that teparies can produce an economic harvest with considerably less irrigation than the crops his neighbors plant.

Second, the demand for "natural foods" has come to encompass native foods, from plants indigenous to a region, locally grown and unprocessed. For the first time in history, teparies have entered health food stores, rather than only being sold in Mexican and Indian markets.

Third, concern for conserving the genetic diversity of plant resources—a theme often touched upon in past issues of Desert Plants—has helped justify the collection and preservation of varieties of teparies and other beans that had persisted only in a few remote localities. Our efforts have tripled the number of tepary bean accesses in the USDA National Seed Storage Laboratory. Several seed exchanges and companies are now offering teparies for the first time.

Within the past few years, millions of readers who had never heard of a tepary bean before have been intrigued by its story, in the pages of National Geographic, Organic Gardening and Farming, Reader's Digest and other popular publications. Yet teparies are not a miracle crop. They cannot be planted at any time, at any place, without sufficient soil moisture, care and protection. While demonstrating considerable drought and heat tolerance, they remain vulnerable to certain insects and disease organisms. Chemically, they show many of the same deficiencies in key nutrients that are characteristic of the legume family as a whole. Their cooking time is longer than for pinto beans and not everyone likes their taste. Flatulence can be a problem. Although the current market price of teparies is two or three times that of other beans, it will probably never be high compared to other "new" crops such as jojoba, guayule and amaranth.

Nevertheless, teparies possess such interesting attributes that they seem assured a special place in the agricultural future of arid lands. In this remarkable story of the tepary comeback, the efforts of two men deserve special mention, for their contributions have often been neglected in other tepary publications. Over the last two decades, W. D. Hood and Louis Romero have grown more teparies than any other two men who ever lived. If it were not for them, teparies probably would not have persisted in Indian trading posts, nor would they be available to researchers or thousands of other people who have become curious about them. We dedicate this issue to two farmers as they are about to retire, W. D. Hood and Louis Romero, as well as to all the native Americans who grew teparies in the desert before them.
The Tepary Connection: A Visit With W. D. Hood

Martha Ames Burgess
Arizona-Sonora Desert Museum
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His voice is lost in a roaring symphony of percussion as he pulls a lever and his enormous machine jumps into organized stationary action. It could have been invented by Rube Goldberg, Tom Swift or the producers of "The Dark Crystal." It's an apparatus in the classic sense of the term, with its moving parts all visible and performing independent jots—shicka-shicha-shicha, dl-dd-dd-dd, clickity-clickity-clickity—in a framework of solid vibrating old cabinetry. A brass plate displays its name "Clipper." This is W. D. Hood's bean machine.

Climbing to the top of the built-in ladder and lifting the flap on the hopper, Louis Romero, Hood's helper and partner since 1938, indicates with arm gestures over the noise the exact place to put the harvested tepary beans into the machine. He points out the sequence through which the beans pass in the cleaning process, the various stiff and soft brushes which remove the pod husks, the graduated series of screens which sort the beans by size and separate them from possible stones picked up from the field with the mechanized harvester, and the trolley which conveys the beans from one process to another, finally dropping them fully cleaned and sorted into a hopper to await the packaging process. Meanwhile the removed bean pods and other debris are sent out another chute to another, finally dropping them fully cleaned and sorted into a hopper to await the packaging process. Meanwhile the removed bean pods and other debris are sent out another chute to another, finally dropping them fully cleaned and sorted into a hopper to await the packaging process.

The Clipper bean cleaning machine is the dominant component in Hood's spotless 30'x60' warehouse. It stands 15 feet high, bare-boned and archaic yet purposeful like a wise old man, next to a slick metallic new weighing and bagging machine whose unseen parts make a steady electric whir. The beans are conveyed up from the cleaner, measured into hundredweight lots and chuted into suspended burlap bags for storage.

Hood and Romero radiate quiet pride in their operation and indeed it is a joy to behold. I had visited them a few times and was spurred on to know more about what makes these two fine people tick. How did they get into the tepary bean business, anyway? I had to know. They have played such a significant role in helping the world know about this important food source. While the "organic movement" people and "alternative agriculturists" were spreading the word about "new" crops such as teparies, beating drums and tooting horns, Hood and Romero were out in their fields silently and without fanfare producing them, and in turn providing beans to peddlers, markets and consumers. Without any beans on the market, all the talk and writing about these beans would have been worthless.

I first met Mr. Hood and Mr. Romero in 1980 while in search of a large quantity of teparies to serve at a native foods workshop for members of the Arizona-Sonora Desert Museum. I had met Hood's beans unknowingly in trading posts across southwestern Arizona in previous years and finally found who their source was—surprisingly not a long-haired Papago Indian grower as I had envisioned, but a down-home modern Anglo farmer who reads the Wall Street Journal and Fortune Magazine.

I told Hood of our intent to help Desert Museum members and visitors, particularly newcomers to the Sonoran Desert, better understand human cultural adaptations to desert living, desert plant adaptations, water conservation, etc., through demonstrations using teparies and other desert edibles. He absolutely refused to sell any beans to us. Instead he donated two hundred pounds! His generosity has increased from year to year since then and has immeasurably helped the Desert Museum staff and volunteers to reach literally thousands of visitors through experiential learning using teparies. It is amazing how many relevant interpretations and messages about desert ecology one can convey to a neophyte once he has feasted on an ancient and honorable food such as the tepary bean served by a native American cook. A good way to the brain and to the emotions is indeed through the stomach. What an incredible tool the tepary has been in this environmental education program!

On September 9, 1982, I met with Mr. Hood to find out what first inspired him to start into the tepary bean business, a relatively unknown crop even ten years ago. I hoped with such an interview to share what he has learned with others who may wish to grow teparies commercially or on a larger, more mechanized scale than the kitchen garden.

Hood's first words in our interview were to say that he has grown teparies from the beginning as a business venture, and to disclaim any intent toward proselytizing for the tepary for its own intrinsic worth or for the world's future. He shows stubborn amazement that seed companies from New Mexico, futurists from Paolo Soleri's Arcosanti, organic gardening writers from Emmaus, Pennsylvania, and even growers in South Africa are constantly contacting him for information or seed stock. He is the Tepary Connection. Like it or not, Hood and Romero are heroes of our time. About fifteen years ago when they began growing teparies, no one else in the United States was growing them other than a handful of traditional Piman farmers clinging tenaciously to familial ways and...
hoarding a coffee tin of planting seed from one year to the next. The tepary bean was a cultivar close to extinction.

This is Hood’s story. As an irrigation farmer in the late 1960’s situated out from the town of Coolidge, Arizona, in the broad arable valley of the Gila River south and east of Phoenix, Hood was seeking a new late summer crop to introduce into a rotation cycle following the barley and winter wheat harvest. Being in a hot desert area, the ideal crop he looked for would have low water requirements, would produce nitrogen, and would not need to be harvested—only turned under as green manure. He would go for a desert-adapted legume.

He had done some research and knew that the tepary bean had been grown commercially several times in Utah and along the lower Colorado River with no lasting success. Prior to the first World War it was a dryland crop. Soon after that time, with changing technology, the larger pinto bean became the bean of favor commercially and, according to Hood, teparies were preferred only by southwestern ethnic groups. As oral tradition goes, a grower near Mesa, Arizona, by the name of LeBaron had obtained tepary seed from the University of Arizona Mesa Experiment station and planted 200 acres. It was a very successful year’s crop but LeBaron was unable to sell his unfashionable bean. The harvest remained many years in a dry warehouse near Chandler, Arizona—fortunately still good and viable—and that is where Hood obtained his initial supply of white teparies. “That was a good lesson,” Hood quipped. “Only grow what you need.” He also obtained by way of a peddler one large bag of mixed brown teparies grown in Sinaloa, Mexico, which were exceedingly variable and had to be sorted by color, removing many stones, cracked and shriveled beans and even corn, before they could be planted. Hood used to call his brown teparies “dorados” due to their golden color when freshly harvested. In order to maintain a "clean" product, never has he mixed the white with the brown stock in his own planting.

Hood and Romero are first class problem-solvers. They had their hands full from the outset with teparies, having no one to offer them agricultural extension style advice.

**Problem Number One**, the difficulty in getting new seed, was solved by the obvious decision to raise a certain quantity for future planting and thus be self-sustaining.

**Problem Number Two** was the initial assumption about nitrogen. Didn’t all legumes have bacteria in root nodules, which, beneficially for plants and planters, produce soil nitrogen? They found this to be not always true. With the help of Dr. Victoria Marcario of the Department of Plant Sciences at the University of Arizona, they probed for nitrogen fixers and found them to be spotty or apparently absent. They did however isolate some of the bacteria and with an elaborate process developed by the Nitra-gin Company, Inc. (Milwaukee, WI 53209), an inoculum was produced which could be introduced into the soil at a useful depth of six to eight inches below root crowns. But extreme heat of the desert soil seemed to interfere with effective establishment of the innoculum. Continued research by the University on techniques for improving nitrogen fixation in desert legumes is still needed.

Gratifyingly, Hood found that teparies grown in the summer in the Coolidge area were not affected by the usual local spectrum of crop [mostly cotton] feeding insects such as Lygaeus bug, stink bug, or flea hopper. Although these types were observed, there was no economic damage. However,
A tepary bean field on the Hood farm. Five weeks after planting. Photo by Helga Teiwes.

**Problem Number Three** soon loomed in the form of red spider mite and white fly—species which pierce and suck the plants' life supporting juices, pests which had never posed threats to his crops before. To dodge this problem in subsequent years Hood and Romero changed the planting date to March and April in order to be able to harvest before onset of the harmful insect season. No insecticides could be employed since the Environmental Protection Agency routinely prohibits use of such chemicals where they might be transmitted into food.

Water for Hood's out-of-town farm came from the San Carlos Project and sometimes it was necessary to face the prospect of an empty reservoir. **Problem Number Four.** Hood and Romero devised a plan to raise each crop of teparies for a yield commensurate with the water supply. For example one acre-foot of water plus any rainfall would produce only enough growth for green manure. If more water could be allotted, increased productivity generally resulted in usable quantities of beans. The farmers determined that they should save back ten bags of each seed type, white and brown, as seed stock against low water years, being confident of the bean’s long "shelf-life".

Thus far, the original goal of using teparies on a large scale was hardly being met. In his earlier years of tepary planting Hood would put in five to ten acres and harvest around 60 hundred-pound bags of beans, but goals for his tepary bean crop began changing as a market developed for the product. Hood claims it was the peddlers who helped make it a cash crop for him. A trader by the name of Klineman was running a "bread route" to several trading posts on the local Pima, Papago and Salt River Indian Reservations, and through him the Indians became consistently good customers. Lutheran missionaries at the village of Pisinimo on the western side of the large Papago Reservation were growing small quantities of beans and bringing them to Hood's machine for cleaning. They in turn would sell his teparies in Papagoland. In addition to these contacts, the Saguaro Spice Company in Phoenix would buy and distribute teparies to stores in Maricopa County in central Arizona. Hood's local outlet was Blackwater Trading Company near Coolidge. The market for the teparies was mostly native American. Noting the cultural preference, Hood observed that purchases (i.e. consumption) would slacken each summer because, in his words, teparies are "a hot food" and usually only eaten in cooler months. Now, in recent years a new Anglo demand has arisen with health food and bulk food markets: Cher's, AFCO and the Food Conspiracy in Tucson, stock teparies when available.

With more experience—and incentive—Hood was making some interesting observations about growing teparies under irrigated conditions. "The percentage of beans to foliage is higher with less water. But if you are raising teparies for yield-per-acre you need more water. A bean count on a small, low watered plant is 20 to 25 beans! This is remarkable." His is the voice of experience. "If you tried pintos or limas with the same conditions nothing would produce. A big [watered] tepary plant on good soil becomes a vine, with 100 beans per plant."

"Teparies are adapted to this [desert] area. They shed their flowers above 105° F but still thrive. They are making beans in Papagoland in September and October when it's cooler after summer rains. Coolidge is at the extreme for teparies. You see, our planting date is changed from the traditional. We are pun-
Hood's bean harvesting machine picks up the plants after drying on the ground for 5 or 6 days, threshes out the beans, threads up the vines and discards them back onto the field. They will be plowed under to mulch and fertilize the soil. Photo by Helga Teiwes.

ishing our plants with June heat to avoid the mites. If one were to start from scratch, try a desert elevation of about 3000 feet where it's just a little cooler."

In 1980 Hood "retired", sold the family farm outside of town and moved into town on a smaller farm a quarter section (160 acres) in size. No longer having sugar beets to bring income, he wanted to at least make the new acreage productive. I asked if growing teparies was for him now a hobby. Negative. "My object is to make money!" And it's lucky for us all that he has changed over the years to such a productive goal for tepary farming.

The new farm and its equipment have presented their own new problems. There is well water and the concomitant pump machinery, instead of San Carlos Project irrigation water. Hood talks business with the objectivity of an economist. "It's not really worth the capital investment for 60 acres worth of profit. The farm was marginal to begin with—with all the equipment." He is now up to an average yield of 500 bags and doesn't see the market growing appreciably. "That's not a good gross." A new combine just cost him $40,000.00, and the pump for the well now needs repair. Expenses are really beginning to pinch—Problem Number Five.

On the new farm weeds have become Problem Number Six. Being situated very close to residences, a church and two schools, use of herbicide chemicals on a routine basis is ruled out. To solve the weed invasion Hood has chosen to plant only one half the acreage at a time, never more than 60 acres or so. The first to third year of planting on the same acreage shows a gradual weed build-up from sparse to rampant. After the third year's harvest Hood lets the fields lie fallow and sprays herbicide when no crops are planted. The following year the alternate acreage is planted.

So far the average yield has been 9½ to 10 bags [one hundred pounds each] of clean beans per acre, his best yield being 14 bags. But he believes that with concentrated effort and good conditions an optimum yield could be double this.

I asked Mr. Hood for a more detailed picture of his mechanized planting, cultivating and harvesting process, so he took me out into the field where there remained several rows of teparies in the last stages of growth and other rows already cut and drying in place awaiting harvest in the dry September heat. We sank to our ankles in loose sandy loam as he pointed out the double rows of beans with a wheel track for the machinery between each pair of planted rows. He explained that watering is done down the middle of the paired rows and that the teparies are planted on the inner side or slope of the row hill in close proximity to the water. In this way compaction from tractor wheels never interferes with water percolation or root growth. When the plants get large they stand only about two feet off the ground, vining and merging their foliage between the paired rows. Cultivation depends on plant growth. When the vines are small, Hood and Romero cultivate along the row very close to the plants and as growth spreads they move away from the plant. A machine called a Coulter is used to chop a regular trimmed edge along the foliage to keep the track clear.

It is about a hundred days from planting to harvest. When the beans are mature each paired row of plants is root cut or "knifed" using an underground blade at a depth of six inches. The blade goes below the tap roots to cut feeder roots and slightly lift the plants. Because the tepary bean pods open easily at maturity when shaken, the root knife seems to produce the least disturbance, thereby preserving a maximum number of beans. The uprooted plants dry in place for seven or eight days or until pods are ready. Then Hood and Romero use a combine to harvest the paired row of dried vines. Hood says all of the equipment he uses is conventional machinery from the row planter on through every processor. "Any bean harvester would do," he advises openly.

Does Hood eat teparies himself? This was a testy question I had to ask. Yes, he does, and frequently! "I haven't had pinto beans in a long time." He likes to experiment with ways to cook them. "Of course the objection to all dry beans is flatulence. In order to reduce the effect I soak the teparies overnight and discard the water. I cook [boil] and discard the first water. I make a broth with ham hock and onion then I pressure cook for twenty minutes." He was hasty to say that he does not recommend his method to anyone else because of the possibility of a bean skin plugging the pressure cooker vent, which is a real safety hazard. Hood likes the high energy from eating teparies. "They're heavy and stick to your ribs. And you know, they are even better the second day after cooking." Eating teparies looks as if it agrees with him as he stands tall, heftly and strong.

W. D. Hood and Louis Romero now know far more about growing teparies than any county extension agent. It has been a process, in Hood's words, of "by guess and by God." Each year they have had to redesign the system and each problem has brought fresh innovation. I asked Hood what other advice might be given to prospective tepary growers. He apologetically admits he doesn't have a consistent formula to offer because each year has been different. The key, he suggests, is to know that growing teparies is going to be labor-intensive. Summing up his own reasons for farming teparies and presenting it almost as a gentle admonition, he advises "It's what you do for yourself."

Hood, at 62 with two children on their own independent careers and a grandson in his 20's who helps part time on the farm, feels that the challenges of growing teparies may be for a younger more vigorous farmer. His partner and friend Mr. Romero is 67, and the two sound as if they may want to treat themselves to a rest—while they're ahead.

Reflecting upon the way the history of farming has progressed in central Arizona, Hood muses on the irony of changes. Harnessing the major rivers such as the Salt and Colorado was developed for farming originally, and now most of the irrigation water goes to support municipal development. Communities grew up near the railroad which was put in to help transport farm products. Eventually the communities grew to a megalopolis consuming most of the arable land. "And now, the wealthy have gone to the foothills like Paradise Valley. That's where Phoenix belonged in the first place! . . . We're not like Mexico where they live on the rocky slopes and save the good low land for farming." It is a good lesson in geography to listen to him.

Since September of 1982 Mr. Hood has made some major decisions. With an irreparable pump and total dependence upon a well for irrigation, he and Romero have determined to call a halt to the tepary project. To the native Papago farmers growing teparies, garbanzos and devilsclaw in Pisinimo, Arizona with whom Hood has maintained a healthy exchange of products, seeking its services.

The Tepary Connection
If the mass media are any indication of national trends, the United States is currently undergoing a revival of bean consciousness. From *Gourmet* magazine to *Woman's Day*, we are monthly treated to articles giving us recipes for pink beans, white beans, red beans and black beans; large limas, baby limas, pintos and garbanzos.

The typical consumer may be overwhelmed when presented with such diversity, but it takes a true bean aficionado to know what is left out of these commercially contrived lists. I am speaking of teparies: white-brown, beige, red-brown and speckled.

I first became aware of teparies about ten years ago while researching recipes for the cookbook *American Indian Food and Lore* (Niethammer, 1974). One reference quoted an elderly Papago as saying that in the past tepary beans had been a particularly good traveling food because human beings could be well-nourished by eating these beans just once a day, whereas they would require two servings of another kind of bean. Smugly, I attributed this to typical aboriginal food ethnocentricity. Then about the time my book was published, Doris Calloway et al (1974) jolted me out of my own ethnocentricity by showing that teparies are more nutritious than certain other beans.

Alas, no one could ever accuse today's Americans of choosing their diets on the basis of nutrition and the few who do are regarded with some suspicion (hence the perjorative term health food "nut"). The Calloway study caused barely a ripple in the world's dormant tepary awareness. Despite their superior protein and mineral scores, it seems the only chance for teparies to take their rightful place alongside other beans in the glossy and colorful magazine layouts is for them to be regarded as particularly delicious. Once "discovered" by Craig Claiborne, James Beard, Julia Child and other culinary superstars, the relative rarity of teparies will no doubt elevate them to gourmet status.

But before the realization of this fantasy, there is work to be done, particularly as regards the "delicious" aspect of the plan. It is unfortunate that some of us palefaces who have adopted teparies from the Bean People have done more harm than good in our attempts to introduce them to our own race. Blinded by our delight with their nutritional and horticultural aspects, we attempted to cook them just as we did other beans, leave the seasoning to a last-minute bit of this and dash of that, and serve them unadorned from a big pot.

The results have too often been bland, uninteresting, and even undercooked. Those of our friends and students who might have become converts were unimpressed or worse, especially when later confronted by the flatulence (gas) which is a result of eating undercooked beans.

Eventually it became evident that if teparies are to regain the popularity they enjoyed in centuries past and, more importantly, be regarded as an acceptable food in the fast-approaching next century, they will have to be incorporated into a cuisine more contemporary and varied than that relished by the Papago a hundred years ago.

Because tepary beans are not alone in their forgotten status, I have written another cookbook entitled *Ancient Foods for Modern Kitchens* (in press) which attempts to incorporate teparies as well as cactus fruits, mesquite pods and edible greens into today's typical dishes.

Several of the recipes from this cookbook are printed at the
end of this article, but first, let us discuss various methods and steps for softening and cooking the rock-hard dried beans.

Presoaking—the Controversy

Because teparies seem to dry out more completely than other beans, it is essential that they be presoaked. Beans which have been stored a while should soak about 12 hours. Very fresh beans need slightly less soaking and have even been known to start sprouting during a long soak. During the soaking time they will absorb quite a quantity of water. The more water they take up, the easier they will be to cook, so use plenty. You can figure that two cups of dried beans will swell to about five cups during soaking.

Some controversy surrounds the question of what to do with the soaking water that is not absorbed. Some people think that this contains important nutrients and should be retained and used as cooking liquid.

However Dr. L. B. Rockland of the Western Regional Research Center of the U. S. Department of Agriculture has been looking into bean cooking methods and feels that the dried beans should be soaked, rinsed and drained, then cooked and drained again. He contends that the water contains anti-nutritional factors that inhibit the utilization of proteins and that discarding the water doesn’t appreciably change the mineral and vitamin content of the bean dish.

If you are using beans which have been stored it will be helpful to add 1/8 teaspoon baking soda to the soaking water for each 1 cup of beans.

Cooking—Many Choices

Commercially, teparies are available only in brown and white. The white variety is mild and similar to other small white beans while the brown ones have a hardier flavor.

I’ve always had difficulty estimating the exact length of time it might take a pot of teparies to cook, a fact I formerly blamed on my forgetfulness and inattention to detail. I have recently been most delighted to discover that the fault lies not with me but with the nature of the bean itself. Studies under the direction of Dr. Ann Tinsley at the University of Arizona School of Home Economics have shown that cooking times for teparies vary much more widely than times for other beans. Once again, science has validated reality.

Although cooking times may fluctuate depending on freshness, location of the fields, type of tepary and other yet undiscovered factors, it can generally be assumed that teparies will take considerably longer to cook than other beans.

With a heavy cast iron pot or an electric slow cooker plan on eight to twelve hours of cooking although beans stored for many years may take even longer. A pressure cooker will complete the job in anywhere from one-half hour to an hour and 15 minutes. Never fill the pressure cooker more than half full and use at least two quarts of water.

Some bean cooking experts suggest bringing water to boil in a pot and then adding the beans as a method of quickly softening the bean coat. It is also suggested that if you find you must add water during cooking, it should be hot water as a reduction in cooking temperature seems to have a toughening effect on the beans.

As chef you should also understand that a tepary that has finally become soft is not necessarily a fully-cooked bean. You must continue cooking the teparies until they have lost their starchy raw flavor, which with conventional methods may be as long as two additional hours.

As with other beans, teparies should be fully cooked before the addition of molasses, brown sugar, tomatoes, tomato sauce, catsup or vinegar. When added during cooking these ingredients tend to have a hardening effect.

Although teparies do take considerably longer to prepare than most of our modern convenience foods, the problem need not lie in the way of greater popular acceptance for teparies. Whatever cooking method you prefer, it makes sense to cook three or four times as many beans as you’ll need for one day, and divide the remainder into portions to be frozen for future fast-food meals.

Use the recipes below as suggestions and starting points. Develop your own creative uses for teparies, remembering, especially if you are a vegetarian, to combine them with wheat and corn for high protein scores.

Consider the development of delicious tepary recipes as a challenge for the future. And that goes for you, too, Craig and James and Julia.

CAMPING BEANS

"Instant" or pre-cooked beans are a very ancient form of traveling food. Sheila Moller contributed this recipe to the Sonoran Heritage Recipe Exchange, part of a class on desert food:

2 cups teparies or other beans
2 cloves garlic
1 onion
salt and pepper to taste

Clean the beans and soak them overnight. In the morning chop the garlic and onion and add to the beans. Cook until the beans are soft. Smash some of the beans against the side of the kettle or crockpot with the back of the spoon then stir them into the cooking liquid to form a thick, rich broth. Stir often and be careful that the beans do not burn. Season to taste.

Spread the beans on a cookie sheet or jelly roll pan and allow to dry out thoroughly. After the beans are dry they can be broken into chunks and taken on a backpacking trip. To fix them in camp, add water, heat and eat.

BEST BEAN LOAF

The outer covering of greens not only adds texture and visual appeal, it helps you get the loaf out of the pan in one piece.

5-6 large leaves savoy cabbage or chard
1 1/2 cups mashed tepary beans
1 1/2 cups cooked bulgur or rice
1 cup grated zucchini
1/2 cup chopped onion
1 tablespoon soy sauce
1/4 cup whole wheat bread crumbs
2 beaten eggs
1 teaspoon dry basil
1/4 teaspoon salt
1/4 teaspoon pepper

In a large saucepan of boiling salted water blanch the cabbage or chard leaves for about 3 minutes or until they are pliable. Drain the leaves in a colander and pat them dry. Line a well-greased loaf pan, 8% by 4% by 2% inches, with as many of the leaves as are needed smooth side down to cover the bottom and sides, leaving enough overhang to fold over and cover the top.

Try to mash the teparies with as little liquid as possible. Combine
with the remaining ingredients and mix well. Spoon the mixture into the loaf pan, rap the pan sharply on the counter to expel any bubbles and smooth the top. Fold the overhanging leaves over the mixture and cover the pan with foil.

Place the loaf pan in a larger flat pan, pour in an inch or two of hot water into the larger pan and bake the loaf at 350° F for 1 hour or until a toothpick inserted in the center comes out clean. Let the loaf stand for about 10 minutes to settle. Unmold on a platter, blot up any liquid with paper towels. Garnish the platter and slice with a very sharp knife.

Serve with a sauce such as spiced tomato, yogurt flavored with mustard, garlic and tahini, or Sunflower Tomatillo Sauce.

**LAYERED TEPARY ENCHILADAS**

The combination of teparies, corn and cheese makes this dish rich in protein without meat.

2 cups cooked teparies
1 cup cooked corn kernels
1 small can tomato sauce
1/2 cup shredded longhorn or jack cheese
corn tortillas
chili powder or chili paste to taste
1/4 teaspoon cumin or to taste oil

Heat oil in small frying pan and fry tortillas one by one briefly until limp but not crisp. Combine teparies, corn kernels and tomato sauce. Season to taste with chili and cumin. For each individual serving, place a tortilla on a plate, add a layer of beans, then repeat twice ending with beans. Top with shredded cheese. Makes two servings.

**TUSCANY-STYLE BEANS**

2 cups cooked teparies (preferably white)
2 tablespoons butter
3 tablespoons olive oil
2-3 tablespoons minced fresh sage
or 1 1/2 teaspoons dried sage
1 large or 2 small tomatoes
salt and pepper

Drain the beans. Heat together the butter and olive oil in large frying pan or sauce pan. Add the beans, sage and salt and pepper. Core the tomato, chop coarsely and whirl in a blender until pureed. Add to beans. Cook until hot.

**PASTA E FAGIOLI**

2 1/2 cups cooked teparies
1 1/2 cups bean liquid
8 ounces shell macaroni
3 tablespoons olive oil
2 cups sliced carrot
1 clove garlic, crushed
2 cups diced, peeled tomato
1 teaspoon dried basil leaves
1/2 teaspoon dried oregano leaves
1/4 teaspoon pepper
1 cup steamed broccoli spears
grated Parmesan cheese

Cook macaroni following package directions. Meanwhile in hot oil in a large skillet saute onion, carrot and garlic until soft but not brown. Add tomato and spices. Cover pan and cook gently for 15 minutes.

In a large saucepan or kettle, combine beans, macaroni, and vegetable mixture. Add the bean liquid. Bring to a boil, cover and simmer 15 minutes until flavors blend. Stir often to prevent sticking. At the end, add broccoli spears, heat, and turn into attractive serving dish. Sprinkle with Parmesan cheese. Serves 8.

**TEPARY VEGETARIAN PÂTE**

So rich it tastes sinful; so healthy you can supper on hors d’oeuvres alone. The best appliance for this is a food mill or food processor. A blender can be used but you’ll need to add more bean broth to make the mixture wetter.

2 cups cooked teparies or other beans with very little broth
1 stalk celery
1 large carrot
1 onion
1 tablespoon olive oil
1-2 cloves garlic
1/4 cup sunflower seeds
2 tablespoons wheat germ
1 tablespoon soy sauce
1 tablespoon wine vinegar
1/4 teaspoon basil
1/4 teaspoon oregano

Chop celery and carrot and steam or cook in a little water until tender. Chop onion and garlic and sauté in oil. Grind sunflower seeds to a meal in blender or mill. Combine teparies, cooked vegetables, sunflower meal, wheat germ, soy sauce, wine vinegar and spices and process until smooth.

Add one of the following flavor combinations or invent your own:

1/4 teaspoon cumino
2 tablespoons green taco sauce or chopped green chiles OR
2 tablespoons sherry
1/4 teaspoon nutmeg
1/4 cup chopped pecans

**References**


The Nutritional Significance of Tepary Bean Consumption

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University of Arizona, Tucson

The ubiquity of legume crops as an integral part of both primitive and advanced agricultural systems is well documented (Aykroyd and Doughty, 1964; Bressani, 1975; Doughty and Orraca-Tetteh, 1966; Duke, 1981; National Academy of Sciences, 1979; Orraca-Tetteh, 1973; Smartt, 1976). A recent compendium edited by Duke (1981) lists information concerning nearly 150 species of economically important legumes serving a variety of non-nutritional functions (medicinal, industrial and agricultural) as well as providing both food and feed commodities. Pulses used as foods can be divided into two groups on the basis of seed composition. Starch is a predominant component within the mature seed of grain legumes, whereas oilseed legumes store a substantial quantity of energy in the form of vegetable oil. All pulses contain appreciable levels of protein. The grain legumes considered to be important in alleviating protein malnutrition throughout the world are listed in Table 1. The important oilseed legumes included in this table are also eaten directly or are consumed indirectly in processed foodstuffs. In nutritional importance, pulses are second only to cereals as dietary constituents derived from plant sources.

It is well known that early residents of the American Southwest incorporated grain legumes, either wild or domesticated, into their daily diets. One such legume, the tepary bean (Phaseolus acutifolius Gray) which contributed substantially to the nutritional well-being of early settlers of both Spanish and Indian cultures, has remained an important food source for people of this area. It is for this reason that we attempt to evaluate the nutritional significance of tepary consumption in the context of dietary quality of pulses in general, and arid land legumes in particular.

Legume Consumption

Although legumes can be produced in most environments, the extent of bean production and consumption varies considerably among nationalities and cultures. Legume crops important in world trade are few; the diversity of pulses used in the diets of localized cultural groups abounds. Indigenous pulses, gathered from wild stands or planted from familialy maintained seed stocks are sometimes sold in local markets, and are usually prepared using traditional recipes. A pattern of frequent legume use generally relates to the present or past non-availability of a stable animal protein source. Smartt (1976) suggests that the dependence of pre-Columbian civilizations upon a stable source of dietary protein from seeds of cereals, legumes and cucurbits was necessitated by a lack of animals domesticated for the production of meat. The restricted supply of protein sources provided by game and fish directly influenced the development of cultures such as the Aztec and Mayan civilizations.

The high per capita pulse consumption among southwestern Indians has most likely evolved for reasons of stability in protein supply. Nabhan et al. (1979) have indicated the requirements of a staple food as being one which is "readily available in abundance" and "easily stored in large amounts". Supporting evidence for the abundance in legume supply, whether gathered from wild sources or produced by floodwater farming techniques, has been discussed in detail by these authors.

Tepary Consumption

The gathering of wild teparies by certain Sonoran peoples persisted as part of food procurement until after World War II, but the significance of this wild bean as a current foodstuff is reported to be minimal (Nabhan and Felger, 1978). Data concerning nutritional parameters of wild tepary varieties were included in this manuscript solely as interesting information with historic significance.

Evidence indicates the wide-spread use of domesticated teparies (P. acutifolius var. latifolius) before the arrival of the Spanish explorers. The importance of these pulses was great enough that Pima, Hopi and other groups recall tepary beans as being among their earliest crops (Nabhan et al., 1979). Domesticated tepary beans produced and consumed today often belong to one of two general types based on seed
calculated that Hopi tribespeople generally consume beans at similar levels as did their ancestors [Nabhan et al., manuscript in preparation]. The consumption of tepary beans and other indigenous legume foods has decreased, however, due to the availability of alternate sources of beans and the decline in traditional farming practices. "Pintos are now more readily available through surplus commodity and food stamp programs, while costing two-thirds of what teparies cost in trading posts" [Nabhan et al., 1979].

Patterns in Hopi bean consumption today have been described as consisting mainly of pinto beans which are not necessarily prepared using traditional techniques. Locally produced pulses are then used occasionally to add variety to the menu for ceremonial purposes [Nabhan, et al., manuscript in preparation]. A similar shift in pulse use to a predominance of pintos has been noted in Papago culture.

"...the causes of decline (in floodwater farming and thus, tepary consumption) are found in other modernization processes through which the Papago have entered into the national economy as wage-earners. As they have become more involved in modernization, their values have been transformed to the extent that the prestige associated with traditional subsistence skills has diminished." [Nabhan et al., 1980]

The alteration of legume content and/or type in the diet has nutritional impact on various southwestern Indian groups. Accurate assessment of the magnitude of this impact would require an in-depth investigation of changes in: 1) composition of diet, 2) rate of pulse consumption, 3) nutrient content, quality and availability (digestibility) among various legumes, 4) the level of antinutritional factors present in currently consumed pulses as well as 5) changes in methods of preparation which may affect several of the previously listed factors. Although a thorough assessment of the nutritional significance in tepary use decline may not be possible at this time, this manuscript will summarize present knowledge concerning the nutritive value of these beans and compare teparies to other pulse sources.

A possible dietary role for tepary in other arid environments will also be suggested.

### The Nutritive Value of Tepary Beans and Other Grain Legumes

A nutritional comparison of tepary beans to other legumes must include a discussion of the nutritive value of beans in general. An overview of this subject can be obtained by reading excellent reviews by Aykroyd and Doughty [1964]; Bressani [1975]; Dutra de Oliveira [1973]; Leveille et al. [1978]; Orraca-Tetteh [1973]; Patwardhan [1962]; Smartt [1976].

#### Protein Content

The major nutrient one obtains by consuming beans is obviously that of protein. Protein contents among grain legume species can vary as much as 15-40% [Earle and Jones, 1962], with common varieties displaying 20-30% (Table 2). Several studies have listed crude protein levels for domesticated teparies [Tables 3 and 4]. The protein values reported span from 13.0-32.2% with more commonly determined levels ranging from 22.0-24.0%. Analysis of the Nabhan-University of Arizona collection of teparies revealed a mean protein content of 23.2 and a broad protein level range of 13.0-28.8% over 39 samples. Diversity in protein content may be controlled in part by inheritance, although racial differences were not evident from published literature. White and brown seeded types were reported by Calloway et al. [1974] to contain 24.3 and 24.0% protein respectively. Nabhan et al. [1980] determined white seeded tepary protein values varying from 18.9-27.3% and almost identical levels in brown seeded types, ranging from 18.1-27.1%.

The environmental influence of irrigation regimes upon protein contents of teparies has been studied in detail [Nabhan et al., 1980]. Traditional floodwater farming techniques were found to produce beans of comparable seed size which had significantly higher protein contents (mean of 25.0%) than those grown off-reservation in conventionally irrigated fields (mean of 21.6%). Experimentation to elucidate the physiological mechanisms underlying this phenomenon heretofore have not been undertaken. However, environmental effects on protein content and quality of common bean and other grain legumes.
have been well documented and are discussed in reviews published by Bressani (1975) and Smartt (1976).

Wild tepary samples from the Nabhan-University of Arizona collection averaged 24.5% crude protein, but exhibited a more restricted range of values (from 23.3-25.4%) than did domesticated teparies. Waines (1978) reported a similar mean protein content (24.5%; range 22.4-25.9%) for 9 samples of wild teparies grown under cultivation.

Scientific concern about the decline in tepary use by southwestern Indians was sparked by a study comparing the nutritive value of distributed surplus commodities with foods traditionally produced and consumed (Calloway et al., 1974). The findings indicated that teparies were higher in crude protein (24.0-24.3%) than the pinto bean (crude protein 20.9%) commonly dispensed through the surplus commodity program. In a study of Hopi legumes [Nabhan et al., in prep.], protein contents of introduced pintos were found to be lowest (19.3%) compared to teparies sold at reservation trading posts (23.6%) and to traditionally grown common and tepary beans. Reservation grown teparies and common beans (dry and green) compared in this study averaged 22.9% and 25.6% respectively. A greater difference between P. vulgaris and P. acutifolius mean protein contents was indicated by seed stocks grown under irrigated conditions, with common beans averaging 5.4% more protein than teparies (Waines, 1978).

When compared with common legumes produced throughout the world (Table 2), the crude levels of protein usually exhibited by tepary (22.0-24.0%) correspond favorably. Although commodity pintos have been shown to possess inferior protein levels, other P. vulgaris beans grown on or off reservation have been reported to contain higher protein contents than teparies (Calloway et al., 1974; Nabhan et al., in prep.; Waines, 1978). An evaluation of nutritional impact from changing dietary habits of southwestern Indians based solely on protein content would suggest possible adverse effects from increased commodity pinto consumption rather than from decreased tepary consumption per se. Immediate nutritional impact of increased pinto consumption upon protein intake of various tribes may be negligible as long as surplus commodities are readily available. There is, however, an inherent risk in increased dependence upon commodity pintos at the expense of local legume production and consumption.

**Protein Quality.** Nutritional comparison among bean sources cannot be made on protein content alone, but must also consider the quality of the protein and its relative digestibility. Protein quality can be evaluated chemically by analysis of amino acid constituents (the biochemical building blocks of the protein molecule) or biologically through measurement of growth and development of test animals consuming a diet containing the protein source in question. Several types of quality measurements are commonly used, each with specific implications. Those mentioned below in the discussion of bean protein quality are listed and explained in Table 5. Digestibility of proteins is most commonly determined in vivo using the laboratory rat or other animals when appropriate.

### Table 2. Proximate composition of common grain legumes.

<table>
<thead>
<tr>
<th>Species</th>
<th>Moisture</th>
<th>Crude Protein</th>
<th>Crude Fat</th>
<th>Carbohydrates</th>
<th>Ash</th>
<th>Calories per 100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus cajan</td>
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<td>20.9</td>
<td>1.7</td>
<td>8.0</td>
<td>3.5</td>
<td>343</td>
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<tr>
<td>Cicer arietinum</td>
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<td>20.1</td>
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<td>2.9</td>
<td>358</td>
</tr>
<tr>
<td>Lablab niger</td>
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<td>1.0</td>
<td>4.6</td>
<td>3.1</td>
<td>340</td>
</tr>
<tr>
<td>Lathyrus sativus</td>
<td>10</td>
<td>25.0</td>
<td>1.8</td>
<td>15.0</td>
<td>3.0</td>
<td>293</td>
</tr>
<tr>
<td>Lens esculenta</td>
<td>11</td>
<td>24.2</td>
<td>1.3</td>
<td>3.1</td>
<td>2.2</td>
<td>346</td>
</tr>
<tr>
<td>Phaseolus aureus</td>
<td>11</td>
<td>23.9</td>
<td>1.9</td>
<td>4.2</td>
<td>3.4</td>
<td>340</td>
</tr>
<tr>
<td>Phaseolus lunatus</td>
<td>11</td>
<td>19.7</td>
<td>1.1</td>
<td>4.4</td>
<td>3.4</td>
<td>341</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>11</td>
<td>22.1</td>
<td>1.7</td>
<td>4.2</td>
<td>3.8</td>
<td>341</td>
</tr>
<tr>
<td>Pisum sativum</td>
<td>11</td>
<td>22.5</td>
<td>1.8</td>
<td>5.5</td>
<td>2.6</td>
<td>346</td>
</tr>
<tr>
<td>Vicia faba</td>
<td>11</td>
<td>23.4</td>
<td>2.0</td>
<td>7.8</td>
<td>3.4</td>
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<tr>
<td>Vigna sinensis</td>
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<td>23.4</td>
<td>1.8</td>
<td>4.3</td>
<td>3.5</td>
<td>342</td>
</tr>
</tbody>
</table>

1Adapted from Aykroyd and Doughty, 1964.
2Calculated by difference, including fiber, starch and other carbohydrates.

### Table 3. Published values of domesticated tepary protein levels.

<table>
<thead>
<tr>
<th>Data Source</th>
<th>Sample Size</th>
<th>Protein Content (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Garcia, 1917</td>
<td>19.7</td>
<td></td>
</tr>
<tr>
<td>Freeman, 1918</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td>Hendry, 1918</td>
<td>20.3-27.0</td>
<td></td>
</tr>
<tr>
<td>Cerfelli et al., 1959</td>
<td>21.2</td>
<td></td>
</tr>
<tr>
<td>Earle and Jones, 1962</td>
<td>32.2</td>
<td></td>
</tr>
<tr>
<td>Aykroyd and Doughty, 1964</td>
<td>24.0</td>
<td></td>
</tr>
<tr>
<td>National Research Council, 1971</td>
<td>24.5</td>
<td></td>
</tr>
<tr>
<td>Dupin et al., 1973</td>
<td>19.3</td>
<td></td>
</tr>
<tr>
<td>Calloway et al., 1974</td>
<td>24.0-24.3</td>
<td></td>
</tr>
<tr>
<td>Nabhan, 1976</td>
<td>23.3-24.1</td>
<td></td>
</tr>
<tr>
<td>Felger and Nabhan, 1976</td>
<td>23.2-32.2</td>
<td></td>
</tr>
<tr>
<td>Smartt, 1976</td>
<td>22.2</td>
<td></td>
</tr>
<tr>
<td>Waines, 1978</td>
<td>17.2-27.0</td>
<td></td>
</tr>
<tr>
<td>National Academy of Sciences, 1979</td>
<td>23.0-25.0</td>
<td></td>
</tr>
<tr>
<td>Duke, 1981</td>
<td>24.5</td>
<td></td>
</tr>
</tbody>
</table>

1Adapted from Nabhan et al., 1980. Beans were grown under varied environments. Values cited herein from Nabhan, 1976 and Felger and Nabhan, 1976, are part of the Nabhan-University of Arizona collection (see Table 4).

Typically, 20-24 types of amino acids are present in food proteins. The adult human body is capable of synthesizing all but 8 of these constituents (termed essential amino acids) which must be obtained from the diet (Table 6). As the body has no effective method to store essential amino acids, a relatively constant dietary supply of all 8 must be present in balanced amounts for proper growth and maintenance of body tissues. Thus, the quality of any single food protein is only as good as its balance of essential amino acids. Essential amino acids present in inadequate amounts are said to be "limiting." Commenting on data reported by Aykroyd and Doughty (1964) concerning the protein quality of commonly used legumes, Smartt (1976) states that:...in all cases where it is possible to define first and second limiting amino acids these are always tryptophan and the sulphur amino acids. It can be concluded therefore that this is probably a general feature of legumes as a whole. In no pulse does the level of sulphur amino acids reach the level in the FAO provisional pattern and in only one case is this level reached for tryptophan, namely the soya bean. All the pulses listed contain more than the provisional level for leucine and phenylalanine. Lysine and threonine are below the level only in the peanut. Overall, the most satisfactory pulse protein from the standpoint of the FAO provisional pattern is that of the soya bean.

1FAO Provisional Pattern—A percentage amino acid pattern of a hypothetical protein assumed to be optimal for human growth and development by the Food and Agriculture Organization of the United Nations, Committee on Protein Requirements. The protein Score of the FAO provisional pattern is 100.
Favorable protein score of 74.

Wild teparies assayed contained a sulfur amino acid content of the FAO provisional pattern revealed these beans to be deficient in tryptophan and sulfur amino acids. As is true with most domesticated teparies agreed well with those of an amino acid profile (Aykroyd and Doughty, 1964). As is true with most common grain legumes range from 26 -66 (for broad bean and both lima and pintos and introduced commercial teparies containing higher levels of cysteine/methionine than reservation grown samples of either species.

One commonly used procedure for biological evaluation of protein quality is the determination of a Protein Efficiency Ratio (PER) and the poorest protein utilization. As was demonstrated by their PERs, white teparies appeared to be more efficient at promoting growth than either the brown tepary or pinto bean diets. In a separate study employing rats fed diets containing white tepary protein, Cos- sack (1960) determined values for PER and NPR to be 0.65 and 1.92 respectively. In comparison with in vivo determinations of protein quality characterizing other grain legumes (Table 7), PERs associated with tepary diets were low, but reflected the general performance of members of this family as protein sources. Preliminary experimentation suggested increased PER values obtained from tepary bean diets which had been supplemented with methionine. Consuming proteins from several plant sources increases the likelihood of obtaining a dietary protein content which meets or exceeds the quality requirements for growth and body maintenance. Indigenous Southwestern populations circumvented a potentially severe nutritional problem by including complementary sources of protein from corn and other grains in the diet at levels substantial enough to supply the necessary quantities of cysteine and methionine. Cereal proteins are usually deficient in lysine, a basic amino acid fortunately present at adequate levels in most bean proteins. The addition of squash seed and other vegetable proteins to this diet completed the balance of essential amino acids, allowing indigenous populations to thrive when sources of meat protein were difficult to obtain.

There is now ample evidence to suggest that humans serendipitously discovered the advantages of the beans-corn dietary combination through the natural association of climbing legume and corn progenitors throughout Latin America. Nevertheless, cereals and legumes are eaten in combination with one another throughout the world. In experimentation with laboratory rats, the quality of protein is highest when pulses comprise from 40% to 60% of the protein in the diet. Based on Indian (Asian) dietary habits, Phansalkar et al. (1957, as reported in Bressani, 1975) determined specific cereal-legume combinations: corn:common bean or cowpea (5:5), corn:soybean (6:4), rice:common bean (8:2), and wheat:common bean (7:3:27). Protein scores based on the FAO provisional amino acid pattern for common grain legumes range from 26-66 (for broad bean and both lima bean and certain cowpeas respectively) (Table 7). Sulfur amino acids are reported to be the first limiting amino acids in all three cases (Aykroyd and Doughty, 1964).

Essential amino acid patterns for wild and domesticated tepary samples were compiled and listed in Table 6. Mean values reported for domesticated teparies agreed well with those of an amino acid profile published by Aykroyd and Doughty (1964). As is true with most legume samples, a comparison of tepary amino acid levels with those of the FAO provisional pattern revealed these beans to be deficient in tryptophan and sulfur amino acids. Wild teparies assayed contained a slightly lower methionine level than did the average domesticated seed stock. Based on the mean amino acid profile of domesticated teparies, a protein score of 36 was calculated, with tryptophan appearing to be most limiting. Nabhan et al. (1979) reported sulfur amino acids to be most deficient in tepary beans resulting in a much more favorable protein score of 74. For the domesticated teparies studied, the mean value of most essential amino acids was intermediate in the range of values displayed by common grain legumes (Tables 6 and 8). Tepary mean values for phenylalanine and tryptophan were uncommonly low. When tyrosine was considered jointly with phenylalanine, the mean aromatic amino acid content of these beans fell within the range reported for grain legumes.

In a study contrasting several Hopi bean varieties (Nabhan et al., manuscript in preparation), lima beans were found to exhibit the most satisfactory overall amino acid pattern. All beans studied were deficient in either tryptophan or sulfur amino acids with commodity pintos and introduced commercial teparies containing higher levels of cysteine/methionine than reservation grown samples of either species.

Table 4. Proximate composition of tepary beans.1

<table>
<thead>
<tr>
<th>Component</th>
<th>Wild Teparies</th>
<th>Domesticated Teparies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample Size</td>
<td>Mean</td>
</tr>
<tr>
<td>Moisture [%]</td>
<td>4</td>
<td>6.7</td>
</tr>
<tr>
<td>Crude Protein [%]</td>
<td>6</td>
<td>24.5</td>
</tr>
<tr>
<td>Crude Fat [%]</td>
<td>4</td>
<td>1.4</td>
</tr>
<tr>
<td>Carbohydrates</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total Carbohydrates</td>
<td>1</td>
<td>59.0</td>
</tr>
<tr>
<td>Fiber [%]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ash [%]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Calories per 100g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1Values from the Nabhan-University of Arizona collection of tepary beans acquired from 1976 to present, consisting of published and unpublished data, including data from Nabhan, 1978; Nabhan et al., 1979; Nabhan et al., 1980; Nabhan et al., manuscript in preparation. Beans came from diverse environments.
2Calculated by difference.
3Estimated from proximate analysis.

Continued on page 50
It is fitting that the Papago's mythological world has an abundance of beans in the heavens and on earth. The Desert People were long ago nicknamed the Babavy or Babavi O'odham [Tepary Bean People] by their Pima-speaking relatives, because they grew and ate so many beans. This term Papavi O'odham was reshaped into Papabota by the first European tongues that tried to mutter those native sounds, and later the utterance was simplified to Papago.

While many popular publications give the impression that maize was the foremost staple of all native American agriculturists, this may not have been true for the Papago. As early as 1716, Padre Luis Velarde commented that the principal harvest of the Papagos living on the "sterile lands" west of the Rio Santa Cruz was the "beans called papavi," [Wyllys, 1931]. Two centuries later, an Indian Agent to the Papago reported that their production of legumes far and away surpassed that of corn:

"Last year the rainfall was abnormally light, yet these arid-land agriculturalists, ever fighting the desert, which is always seeking its own, succeeded in forcing the desert to yield 300,000 pounds of corn, 1,800,000 pounds of beans, and about $25,000 in value of pumpkins, squash, watermelons, and garden truck." (McDowell, 1919).

As late as the 1940s, "an average Papago was consuming about 300 g of beans daily [Ross, 1944]. This level of legume consumption probably gives the Papago the dubious distinction of being the "bean-eatingest" people in the New World [Nabhan, Berry and Weber, 1979], if we compare it to published levels of legume consumption by other ethnic groups [Aykroyd and Doughty, 1964].

Today, interest in Papago teparies goes far beyond their desert homeland. A number of publications within the last five years have suggested the feasibility of transferring this Sonoran Desert germplasm to other arid lands where farmers are in need of crops better adapted to environmental stress [National Academy of Sciences, 1979; Theisen et al., 1978]. Yet despite the growing worldwide awareness of teparies, there has been remarkably little literature providing a sense of the context in which these beans have been nurtured over centuries. Much of their evolution as a crop has taken place in the modest multicropped desert fields such as those of the Papago—data from growth chambers, greenhouses, and rain-sheltered experimental fields in humid areas don't give as good a notion of their performance. If teparies are to be introduced into new areas in developing countries, their native context, may provide guidelines so that inappropriate conditions will not be chosen, and the introductions won't be as likely to fail.

Realizing this, we decided to spend time with the real tepary bean experts—elderly Papago farmers of the Arizona-Sonora borderlands. They agreed to let us document the practices which have enabled their culture to produce these nutritious food plants in a water-limited environment that may well be as arid as any that unmechanized agriculture ever ventured into [Nabhan and Hutchinson in prep.]. An Indian agent to the Papagos wagered a challenge in the 1880s:

"... place the same number of whites on a barren, sandy desert such as they live on, and tell them to subsist there; the probability is that they would become extinct (Howard, 1887).

The following photographs and descriptions are a result of our firsthand observations of tepary beans in Papago fields, gardens and kitchens, from 1975 to 1982. Occasionally, we
Wild teparies are usually gray in color with brownish
venation or mottling, and are smaller than domesticated
white tepary beans. The photogram shows their actual size.

will refer to former practices we have learned of through oral
history interviews. However, for additional details regarding
historic Papago bean cultivation, we refer readers to Castetter
and Bell [1942], and the report of the Applied Remote Sensing
Program (1982).

Field Preparation
Oidag cikpan, as the Papago call farmwork, begins long
before tepary beans are ready to plant. During the pre-season
drought months, we have often found our Papago friends
working the early morning hours in their fields, in preparation
for the rains. Fences must be mended, tools repaired, and
residues from the previous crops must be cut, burnt, or
disked-under.

The timing of these activities and others depends upon the
kind of field to be planted, its location, and the seasonal
scheduling associated with it. In irrigated fields such as those
at San Xavier, and in a few select runoff fields such as those at
Topawa, an early crop of teparies can be planted in late
February or early March, if ditches are functioning. Histor-
ically, such early plantings allowed two “summer” crops at a
number of Papago localities [Wilson, 1983]. However, most
Papago farmers only plant teparies once, with late summer
rains capable of producing runoff, which have an average
arrival time in Sells during the week of July 20-27.

Although the Papago are best known for their ak-ciñ (arroyo
mouth) fields where stormwaters naturally spread out over a
cultivated alluvial fan, they irrigate their crops in other ways
as well. Other field types include:
1. Ditch diversion from a wash channel to a floodplain field
   (at Fresnal Village, Ak-Ciñ, Topawa and elsewhere);
2. Stormwater collection in a charco (dirt tank) reservoir, for
   later diversion onto fields (at Little Tucson, Big Fields and
   Plenty Dogs);
3. Through-flow impeded by water-spreading berms or
   brush weirs (at Big Fields, Little Tucson, Topawa and elsewhere);
4. Ditch diversion from spring-fed oases (at Quitovac, and
   formerly Quitobaquito);
5. Ditch diversion from earthen-or-masonry-dammed reser-
   voirs (at Pia Oik and Menager’s Dam);
6. Pumped groundwater irrigation (at San Xavier, Santa
   Cruz, Ak-Ciñ, and Kohadk).

Each of these field systems is managed differently, and
preparation/maintenance time varies. Communal work neces-
Delores Lewis is a Papago farmer in Big Fields (Ge Oidag) village, where he plants teparies in two fields irrigated by storm runoff.

Sary for maintaining ditches to several fields is seldom done today, and most remaining fields are isolated from one another. Only four percent of the runoff field acreage used in 1913 in nine villages just west of the Baboquivaris is cultivated today (Reichhardt, in Applied Remote Sensing Program, 1982). Some former Papago fields in Mexico, like that at Suvuk in the extremely arid Pinacate Desert, are now being used intermittently by Mexican farmers (Nabhan and Hutchinson, in prep.). Many Papago farmers have instead taken up faucet-fed gardening in the last decade. Here we will focus on the work associated with the fields which utilize flowing floodwaters, including the classic ak-ciini and arroyo diversion fields that characterize the great dying farming heritage of the Papago.

Floodwater farmers must learn to read how a wash is changing, whether it is meandering or deepening. They then must modify their water control structures to slow or heal erosion, to minimize meanders that might leave their fields high and dry, or to more evenly spread water out around their crops. They do this by carefully positioning low (0.3-1.5 meter) earthen berms, as well as brush weirs in strategic locations.

The brush weir is constructed of 1-2 m. tall mesquite posts planted in the ground 1-2 m. apart in a line 5-20 m. long; mesquite branches and snakeweed brush are woven in between the posts. Called sajiida koli, (brush fences), these water spreaders form a permeable filter that dissipates the energy of floodwaters, and allows the water and associated floodwashed humus to be deposited just downstream from the weir. In this way, field soils are renewed with moisture, nutrients and water-holding organic matter while the erosive force of the flood is softened.

When fences, weirs, tools and ditches have been repaired, the farmers return to their larders or storage sheds where heirloom, hand-selected seeds for planting have been kept. The seeds remain covered and the sowers stay in waiting, in the shade of ramadas, until the summer rains begin.

Planting and Cultivating

When . . . the rain moistens the earth, bury them four together and watch them . . . not letting animals eat or trample them, or grass or weeds come up.—Juan Dolores, in Saxton and Saxton (1973).

By late June, soil moisture is greatly depleted in the Sonoran Desert; surface soil temperatures in Papago fields reach above 50°C. The first rain of the season does not always drench and cool the soil enough to satisfy Papago farmers. Some believe
A summer storm over Kitt Peak brings welcomed rain and floodwaters to Papago fields, washes and charcos.

The water-flattened grass is evidence of sheet flooding slightly upstream from a tepary field at Kohadk.
A brush weir on an arroyo at Fresnal Village (Jiawuli Dak). Instead of water being diverted into the ditch in the left background, it flows to the right, past the broken-down weir.

A brush weir was built incorporating an overhanging mesquite branch, at Fresnal Village (Jiawuli Dak).
In Pia Oik (Pi Ooik), this charco reservoir is seldom empty, but during June, 1977, it was completely dry after a spring drought.

The same reservoir is full after the summer rains, as seen in August 1977.
While one man guides the plow, another leads the horses. Rows are plowed about 3 meters apart, and turned towards the middle.
that the heat stored below the soil surface will dry out and negate the effects of the first rain, so that it is preferable to plow and plant after the second drenching rain. Sometimes a storm misses a field, but washes flowing from the mountains upstream bring enough water to allow for planting. Papago farmers would formerly make torches, and go out into fields at night to direct such mountain storm flows into their fields with spadework.

Our Papago acquaintances were accustomed to plowing their fields using a team of mules or horses and moldboard plow. If draft animals were unavailable, a tractor might be rented from a neighbor. As the walking plow opened a 15-25 cm. deep furrow, 4 (to 8) seeds were tossed into it by the plowman or someone a few paces behind him. These clusters of seeds were spaced roughly 1 m. apart in several fields; however, some Papago farmers now prefer continuous row or bed planting. On the next circuit with the team, the plow buried the seeds as it turned the soil from the adjacent row onto them.

Usually 4-12 rows of teparies are planted as a block on either side of a block of Papago sixty day flour corn, sweet cane sorghum, red or pinto beans. White teparies are usually planted

*A check dam of low mesquite posts and interwoven cross-branches spreads water and detritus evenly over this field section at Ge Oidag.*
Seeds are planted on the slope of the freshly turned, moist soil. Usually they are sown by hand while walking behind the plow.
Papago fields at Menager's Dam Village.

Fields at Pia Oik [Pi 'Ooik] after summer rains.
After five weeks, tepary seeds are already developing inside bean pods. Note that the leaves are solar-tracking (angling toward the sun).
Tepary beans, black-eyed peas, wild amaranths and lovegrass compete for moisture in the late summer at Ge Oidag.

Six to eight weeks after planting, the tepary plants have ripened pods. They turn yellow, dry further, then sometimes split.
A traditional, circular bean threshing floor has been prepared at Cold Fields (Shepi Oidag) village.

A mixture of white and yellow-brown tepary beans are found under a pile of partially threshed vines at Kohadk.
Phillip Saucedo pulls the tepary bean plant up by its roots, and turns it upside down for drying.

Phillip Saucedo's cousin Dora Mariano helps him "beat the beans" at Menager's Dam.

Teparies are crudely winnowed a first time in the wind to separate pods and sticks from beans.

Crop Success or Failure?

The unpredictability of rains in the desert makes floodwater farming a gamble. Over the centuries, however, both the Papago and their teparies have developed ways to minimize the risk of drought. The Papago have buffered themselves against the unpredictability through their learned knowledge or folk science of desert farming, which provides guidelines for the optimal time and place for planting. The beans, through both natural and cultural selection, have evolved adaptive features that over time have become genetically predominant.

By channelling the runoff of a large watershed onto a small field, Papago farmers effectively "multiply" the rainfall available to plants in their cultivated plots. Additionally, they sometimes modify watercourses or clear shrubby vegetation upstream from their fields (Cooke and Reeves, 1977), increasing runoff yields per unit area. By planting as soon as the soil approaches field capacity, they also minimize the potential of soil water deficits during the period of emergence and early growth. Unfortunately, we have no idea how much soil moisture is utilized by teparies over a growing season under such conditions, nor are estimates of the amount of runoff available to Papago fields very definitive (Applied Remote Sensing Program, 1982).

Teparies are usually classified as a drought-escaping ephemeral crop, since they are capable of completing their life cycle prior to most late season droughts, which at Sells begin an average of eight weeks after the first summer floods. They
begin to fruit in less than 45 days after planting, and may have nearly all their pods ripe in less than 70 to 75 days, when pintos under the same conditions have most of their pods still green [Nabhan et al., 1980; Nabhan and Hutchinson, in prep.]. When soil moisture is available, tepary leaves track the sun more continuously and have higher noon transpiration rates than pinto beans, which appear to close their stomata and angle their leaves perpendicular to the sun during intense midday heat [Dubetz 1969; Nabhan and Hutchinson in prep.]. Such responses (as those of teparies) are characteristic of summer desert ephemerals that maintain high photosynthetic rates which enable them to rapidly mature [Ehleringer and Forsyth, 1980].

If they fail to escape drought, desert ephemerals have generally been regarded to be as vulnerable as mesophytes to water deficits. This is not true for teparies, which are also capable of dehydration postponement, and ultimately, relative dehydration tolerance. By rapidly rooting to greater depths than do other beans, teparies essentially postpone water stress by tapping a greater reservoir of soil moisture [Thomas and Waines, 1981; Thomas, 1983]. In the Pinacate, as soil moisture was depleted, more and more tepary leaves in a canopy changed their angle perpendicular to the sun’s rays, thereby slowing transpirative losses. As a drought ended the Pinacate growing season, the matured teparies had essentially the same midday water potential (-15 bars) as the immature pinto beans [Nabhan and Hutchinson, in prep.]. Yet because teparies can adjust osmotically to maintain higher cell turgor and continue growing at the same water potential as other beans [Parsons and Howe, 1980], the same drought theoretically may not have affected their internal water status to the same extent. Overall, teparies maintain steadier photosynthetic and respiratory rates under high water deficits than do drought-susceptible common beans [Coyne and Serrano, 1963].

Despite these advantages which keep teparies from failing as frequently as pinto or red beans, they are not invincible. Early season droughts can deplete surface soil moisture to the extent that seedlings of all crops wilt and die. More frequently, desert cottontails, black tailed jackrabbits, sphinx moth larvae and cattle are responsible for tepary crop failures in Papago fields. In minor droughts that allow germination of plants in water-supplemented fields, but not as much elsewhere, these animals are attracted to the relative greenery of fields for their forage. Rabbits and hares apparently prefer tepary vines over other crop plants.

When teparies do survive such climatic and biological assaults, Papago fields yield the equivalent of 200 to 900 kg/ha (roughly the same as pounds per acre), with their wide plant spacing the key variable in yield per unit area. Our oral interviews and observations corroborate numerous reports that teparies will produce a modest crop even in drought years when pinto or red beans fail. According to several sources, four out of five plantings produce harvestable tepary yields [Nabhan et al., 1979].

**Harvesting and Cleaning**

*When they ripen, pull them up and pile them where you've cleared a place. Then get a stick to beat them with. The seed will be removed. When the wind blows, you will take them in your hands and throw them up, and it will blow away the stalks and leave the seed.*

—Juan Dolores, in Saxton and Saxton [1973].

Go out to a Papago field in October or early November, and you will see the straw-colored roots of teparies, bottom up to the sun. After being hand-pulled, piled and dried like this for 4-7 days, one of two kinds of threshing (mohunakud) may
Roasted corn (gai’wsa), and tepary beans sit in open containers for three to four days to dry further.

To completely clean this basket-full of beans, Dora worked less than ten minutes.

After drying, the beans are put away in containers, here in an old hardpaper detergent can with a clamp-on lid.
Unlike some common beans, teparies do not necessarily require presoaking. They look like this after ten minutes in water.

The beans are washed, then simmered for two hours. Then a heaping tablespoon of lard and an even tablespoon of salt are typically added as the only seasoning.
Dora Mariano and her sister enjoy a typical Papago meal at Menager's Dam, in the southwestern corner of the reservation.

Ladies from the arts and crafts co-op in Sells share a delicious lunch of teparies, salad, chile and tortillas.
Cooking

Teparies have a mild but distinctive flavor. In an informal test, four out of five Papagos recognized the particular tastes and textures of the two different varieties even when blindfolded! Dry teparies are always boiled, usually for more than 3 hours, sometimes all day. The taste of teparies in Papago clay bean pots is still praised. Today, they are prepared mostly for special family occasions. In 1979, Nancy Garcia wrote down this traditional recipe for posol [posole] from her family elders [Meals for Millions/Save the Children, 1979]:

1 cup yellow tepary beans
1 cup whole parched corn
beef chicharrones (pre-cooked)
1 teaspoon salt
1 clove garlic
4 cups water
1 red chile (if you like)

Put all the ingredients except meat in a large pot and boil for about 3 hours. The last 1/2 hour, add the chicharrones. Serve, adding chiltépines ['itoi Ko'okol] to taste.

Teparies, cooked by themselves, are often eaten with wheat tortillas and chile as part of several consecutive meals
Still favored by many Papago, tepary beans are not always commercially available to them. Mary Eleando buys the last bags at “Low Store” in Sells.

reheating). There is among some families a taboo against giving dogs brown teparies as part of the kitchen scraps; the dog would get sick otherwise.

Today, with the aid of food stamps, many Papago families buy their pinto and tepary beans at trading posts. The tepary price is often double or triple that of pinto beans, but pintos are also distributed to low income families through the federal commodities program so that not all Papago need to buy them. Sonoran-grown teparies, red and sulfur beans are also sold at The Gate, a restricted border crossing and weekend food market on the western slope of the Baboquivaris.

Because of the ready availability of beans from many sources, there has been until recently little economic incentive for the Papago to grow their own beans. Nevertheless, the Papago Nutrition Improvement Program and the Meals for Millions Foundation have distributed true Papago tepary varieties and Mr. Hood’s tepary selections to many families in villages on the reservation, some of whom have been encouraged to plant their runoff fields and gardens. On the west side of the reservation, the Papago Small Farms Project grew 10,000 pounds of teparies at the irrigated Santa Cruz farm in 1982, selling half of them to reservation customers (Anonymous, 1982). Labelled “Papago Beans” [although they include teparies from the Colorado River Reservation and from Mr. Hood instead of just true Papago tepary seedstocks], the brand is one of the first “new” quality commercial products from the reservation in years. The BIA is funding a training program at Santa Cruz, to provide young Papago with the skills needed to grow teparies and other food crops on their own land. As an issue of the Papago Runner reported, “This is one idea people are hoping will amount to a hill of beans.”

**Literature Cited**

Anonymous. 1982. They’re betting that their idea will amount to a big hill of beans. Papago Runner. December 23, p. 3.


Tepary beans, Emory's oak acorns (bellotas), chile, and Mexican-American medicines were formerly featured in the window of Casa Valenzia in Coolidge.
Cultivation and Use of Teparies in Sonora, Mexico

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The tepary bean [Phaseolus acutifolius A. Gray] in Sonora constitutes a crop represented by land races. There is no evidence that this bean has been hybridized by man in either the U.S.A. or Mexico. Fr. Juan Nembigh [1970] wrote that teparies were planted in Sonora as early as the 1760's and, it is likely that the prehistoric inhabitants of the area also cultivated them. Although a number of authors have reported the cultivation of teparies in Sonora during the twentieth century [c.f. Castetter and Underhill, 1935; Nabhan and Felger, 1978; Sheridan and Nabhan, 1978; Pennington, 1980], little is known of present day techniques and uses for this native crop in the Sonoran region.

In May 1981, we visited Sonora, Mexico, to investigate the distribution and use of teparies in the Rio Sonora Valley. The specific project goals were: to locate areas where teparies are grown; to ascertain when and how they are planted and harvested, and by whom; to obtain information on the irrigation and fertilizer needs of the crop, and on pests and diseases; to determine if grown for domestic or commercial reasons; and to enquire the use of teparies, and the preference for them in relation to other beans.

We crossed the international border at Nogales and headed south along Highway 15, then east on Highway 2, then south through the headwaters of the Rio Sonora Valley system to Hermosillo, and then west on Highway 16 towards Kino Bay.

In Sonora, tepary localities were found by asking inhabitants and shop keepers if they knew anyone in the area who grew or sold tepary beans. When directed to growers or sellers, we would contact them, introduce ourselves, explain our study interests, and ask if we might obtain information about their tepary cultivation. In all cases, the persons contacted were friendly and very cooperative. The female project member was especially helpful when asking information of women in the absence of men.

The locations for our enquiries are listed in Table 1, which also presents the usual number of crops grown a year, the time of tepary planting and harvesting, and the color of the beans planted. Most farmers planted white teparies, and two grew both white and brown types. Many of the samples of white teparies in Sonora were mixtures of types which might include seeds with cotyledons that stayed green, or a few seeds with brown, grey or black seed coat.

Areas planted to tepary in Mexico varied from a few rows to several hectares [Table 2], but the native farmers never planted more than half a hectare. We saw only one spring planting of teparies other than at the large farm in San Carlos, Sonora. Little rain fell in winter, 1981, which accounted for the lack of most spring crops. The small spring planting at Sinoquipe, Son. used water from the adjacent river via a canal system. Plants at this location were sown in rows in groups of 2-4 seeds. The roots of these tepary plants were nodulated naturally by rhizobia. The use of nitrogen and phosphorus fertilizer varied, with about half of the locations using no fertilizer at all. Higher seed yields appeared from the farm that used...
Also, one of the authors (J.G.W.) had previously bought silo. Our informant in Campo de San Carlos said he and in the central market and supermarkets in Hermosillo, and Agua Prieta (Nabhan and Felger, 1978).

The price per kilogram varied from 12 -25 pesos in Mexico. Teparies are sold in only when there was a surplus. The price per kilogram farmers grew teparies for domestic use and sold them chants, with limited domestic use (Table 5). The smaller and San Carlos grew teparies mostly for sale to mer-

produced by insects, including aphids. Only one farmer mentioned infection by rust (chahuistle) and another at Sinoquipe (Table 4). One farmer at Unamishi (1) men-

The extent of irrigation varied with the amount of the winter and summer rains, but most locations used some irrigation water if it was available (Table 3). Most farmers asked said that teparies would produce a crop with less water than the pinto common bean (P. vulgaris L.) land race Garrapata. Some farmers said that teparies grow better in poor sandy soil than common beans. The large farm at San Carlos planted and harvested mechanically: the other smaller farmers planted and harvested by hand. The farm at Huepac was also mechanized, but we do not have information on the size of the farm.

The main tepary pests were grasshoppers (chapulin) and leaf miner, which we saw on crops in the field in Sinoquipe (Table 4). One farmer at Unamishi (1) mentioned infection by rust (chahuistle) and another at Huepac mentioned damage due to honey dew (manteca) produced by insects, including aphids. Only one farmer used an insecticide, and one had tried a herbicide.

The larger farmers at Cumeral, San Ignacio, Huepac and San Carlos grew teparies mostly for sale to merchants, with limited domestic use (Table 5). The smaller farmers grew teparies for domestic use and sold them only when there was a surplus. The price per kilogram varied from 12-25 pesos in Mexico. Teparies are sold in the markets and abarrotes in an area between Phoenix, Hermosillo, and Agua Prieta (Nabhan and Felger, 1978).

Table 1. Locations for information of planting dates, harvest dates and color of tepary beans (Phaseolus acutifolius).

<table>
<thead>
<tr>
<th>Location</th>
<th>Number of Growing Seasons</th>
<th>When Planted</th>
<th>When Harvested</th>
<th>Color of Bean Planted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumeral, So.</td>
<td>1</td>
<td>15 Aug.</td>
<td>15 Nov.</td>
<td>white, brown</td>
</tr>
<tr>
<td>San Ignacio, So.</td>
<td>2</td>
<td>10-19 Mar.</td>
<td>June</td>
<td>white</td>
</tr>
<tr>
<td>Imarís, So.</td>
<td>2</td>
<td>15-20 Aug.</td>
<td>Oct.-Nov.</td>
<td>white, brown</td>
</tr>
<tr>
<td>Unamishí, So. (1)</td>
<td>2</td>
<td>Feb.</td>
<td>Aug.</td>
<td>white, brown</td>
</tr>
<tr>
<td>Unamishí, So. (2)</td>
<td>2</td>
<td>Apr.</td>
<td>July</td>
<td>white</td>
</tr>
<tr>
<td>Bacoachi, So.</td>
<td>2</td>
<td>1st wk. Mid.</td>
<td>1st wk. July</td>
<td>white</td>
</tr>
<tr>
<td>Sinoquie, So.</td>
<td>1</td>
<td>mid-Mar.</td>
<td>end of June</td>
<td>white, grey &amp; black</td>
</tr>
<tr>
<td>Huepac, So.</td>
<td>2</td>
<td>Mar.</td>
<td>Aug.</td>
<td>white</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (1)</td>
<td>1</td>
<td>1st days Mar.</td>
<td>1st wk. June</td>
<td>white</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (2)</td>
<td>1</td>
<td>late Feb. early Mar.</td>
<td>June</td>
<td>white</td>
</tr>
</tbody>
</table>

1Depends on when the rain comes.
2This information came from the proprietor of an abarrote (a small general store).
3These are the beans he sells; he buys them from Phoenix.
4There were two separate crops on the same farm; one was a commer-

fertilizer on the tepary crop, or on previous crops [San Carlos].

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sillo. Our informant in Campo de San Carlos said he grew teparies for sale to markets in Hermosillo. There is therefore, a small but specialized market for teparies, and there is the possibility of some international trade in this minor native crop.

In Sonora, teparies are eaten in stews (caldo) broths and soups (cosido). Only one location mentioned eating boiled teparies as is, or mashing them for refried beans. The constitution of the caldo was remarkably similar in most locations (Table 5). Of those asked, all locations reported the tepary as having a distinct smell and taste, though not an objectionable one, compared to that of common beans. While the local pinto beans (garrapata) were eaten three times daily in most places as refried beans, the tepary was eaten once weekly to once monthly at most (this includes the location where tepary use was entirely domestic). It is very interesting that the tepary is at the bottom of each bean preference list of the different locations. Two or three cultivars of common beans were always placed ahead of tepary beans, even though the ranking of the cultivars differed. The most preferred bean was the local garrapata pinto, which is distinguishable from those grown in the U.S. The yellow amarillo cv. was usually the second preference. At San Ignacio, the yorimuni or black eyed pea (Vigna unguiculata) introduced by the Spanish, eaten as a green bean, was preferred above the tepary. A future question might be why the least preferred bean in the area studied was grown at all. Most of the locations in Sonora were aware that the tepary is a very old bean, and that it was connected with the prehistoric inhabitants of the area.

This preliminary investigation provides us with previously unreported information about tepary cultivation in Sonora. The survey results also give us a base upon which we can ask more detailed questions concerning such categories as the yield of teparies and the relation-

ship to irrigation and fertilizer use. We may also collect more information about soils, insect pests, diseases, use

Table 2. Amount of land planted to tepary, estimates of amount sown and harvested and fertilizer use.

<table>
<thead>
<tr>
<th>Location</th>
<th>How Much Land Planted</th>
<th>Seed Planted</th>
<th>Seed Harvested</th>
<th>Fertilizer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumeral, So.</td>
<td>.5 ha</td>
<td>100 k</td>
<td>1000 k</td>
<td>200 k/ha urea and guano</td>
</tr>
<tr>
<td>San Ignacio, So.</td>
<td>.5 ha</td>
<td>20 k</td>
<td>450 k</td>
<td>Follar urca, and triple de 17 (17N: 17P: 17K)</td>
</tr>
<tr>
<td>Unamishí, So. (1)</td>
<td>?</td>
<td>15 k</td>
<td>500 k</td>
<td>?</td>
</tr>
<tr>
<td>Unamishí, So. (2)</td>
<td>?</td>
<td>25-5 k</td>
<td>200 k</td>
<td>?</td>
</tr>
<tr>
<td>Bacoachi, So.</td>
<td>5 -6 k</td>
<td>10-20 k</td>
<td>ca. 300 k</td>
<td>?</td>
</tr>
<tr>
<td>Sinoquie, So.</td>
<td>.5 k</td>
<td>6 k</td>
<td>6 k</td>
<td>?</td>
</tr>
<tr>
<td>Huepac, So.</td>
<td>.25 ha</td>
<td>1 k</td>
<td>60-80 k</td>
<td>urea 25 k/ha phosphorus 8 k/ha</td>
</tr>
<tr>
<td>Campo de San</td>
<td>4 -5 ha</td>
<td>50 k/ha</td>
<td>1500 k/ha</td>
<td>?</td>
</tr>
<tr>
<td>Carlos, So. (1)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Campo de San</td>
<td>4 -5 ha</td>
<td>50 k/ha</td>
<td>1500 k/ha</td>
<td>?</td>
</tr>
<tr>
<td>Carlos, So. (2)</td>
<td>?</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
</tbody>
</table>
Tepary planting at Campo de San Carlos, Sonora. May 1981.

Tepary planting at Sinoquipe, Sonora, May 1981.
White and brown tepary beans.

Tepary plant at Sinoquipe, Sonora. May 1981.
Table 3. Irrigation practices of tepary crop, soil characteristics and planting and harvesting information.

<table>
<thead>
<tr>
<th>Location</th>
<th>Irrigation</th>
<th>Soil Information</th>
<th>Mechanized or Manual Labor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumeral, So.</td>
<td>depends on rain, if normal, then each 10/12 days; if low, then each 4-6 days</td>
<td>River bottom sandy loam</td>
<td>manual</td>
</tr>
<tr>
<td>San Ignacio, So.</td>
<td>irrigates before planting then 8-10 days later then each 8-20 days 8 hrs. each time</td>
<td>tepary grows better in sandy soil; in good soil big plants grow, but with low yield, in sandy soil small plants, high yield</td>
<td>manual</td>
</tr>
<tr>
<td>Unamishi, So. (1)</td>
<td>uses river water</td>
<td>?</td>
<td>manual</td>
</tr>
<tr>
<td>Unamishi, So. (2)</td>
<td>depends entirely on rainfall; there are two rainy seasons: June-Sept., Nov.-Jan.</td>
<td>tepary will grow in sandy soil, garrapata will not</td>
<td>manual</td>
</tr>
<tr>
<td>Bacoachi, So.</td>
<td>dry plant, irrigate up then each 30 days twice only for season</td>
<td>?</td>
<td>mechanized</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (1)</td>
<td>a small field had received overflow irrigation from adjacent property accidentally, property owner decided to experiment and planted seed in the wet ground, no other irrigation was given; plants produced pods</td>
<td>?</td>
<td>mechanized</td>
</tr>
</tbody>
</table>

Table 4. Incidence of pests, diseases and weeds on tepary crops.

<table>
<thead>
<tr>
<th>Location</th>
<th>Pest</th>
<th>Disease</th>
<th>Insecticide</th>
<th>Herbicide</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumeral, So.</td>
<td>insects</td>
<td>lanate</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>San Ignacio, So.</td>
<td>langasta</td>
<td>chahuistle (rust)</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Unamishi, So. (1)</td>
<td>leaf hopper chaulupa</td>
<td>¿</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Unamishi, So. (2)</td>
<td>leaf hopper</td>
<td>¿</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Bacoachi, So.</td>
<td>leaf hopper</td>
<td>¿</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Sinoquipe, So.</td>
<td>leaf miner</td>
<td>¿</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Huepac, So.</td>
<td>chapulin</td>
<td>manteca (honey dew)</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (1)</td>
<td>¿</td>
<td>¿</td>
<td>no</td>
<td>no</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (2)</td>
<td>¿</td>
<td>no</td>
<td>no</td>
<td>no</td>
</tr>
</tbody>
</table>

Table 5. Domestic and commercial use of tepary beans, method of cooking and preference in relation to other cultivars of beans grown.

<table>
<thead>
<tr>
<th>Location</th>
<th>Domestic Use</th>
<th>Commercial Use</th>
<th>How Cooked</th>
<th>Order of Bean Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cumeral, So.</td>
<td>yes, 15 p/k</td>
<td>no</td>
<td>caldo</td>
<td>garrapata cutamundi tepary</td>
</tr>
<tr>
<td>San Ignacio, So.</td>
<td>limited</td>
<td>yes, sales in Magdelena, Santa Ana, Hermosillo, Nogales</td>
<td>cook 25 min. then eat as is or mash in caldo or cosido, Mexican soup</td>
<td>garrapata amarillo yorimuni tepary</td>
</tr>
<tr>
<td>Unamishi, So. (1)</td>
<td>limited</td>
<td>yes, 5 p/k</td>
<td>caldo with meat and vegetables</td>
<td>garrapata amarillo various others tepary at bottom of list</td>
</tr>
<tr>
<td>Unamishi, So. (2)</td>
<td>almost entirely</td>
<td>if there is a surplus, 14 p/k</td>
<td>caldito with many vegetables caldo, all green vegetables; bone, meat, garbanzo beans; cook 3 hrs.</td>
<td>garrapata amarillo tepary</td>
</tr>
<tr>
<td>Bacoachi, So.</td>
<td>yes, 12/13 p/k</td>
<td>if there is a surplus, 14 p/k</td>
<td>caldo with onion, green chile, meat; bone, cilantro, cook 2 hrs.</td>
<td>garrapata amarillo tepary</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (1)</td>
<td>limited</td>
<td>yes</td>
<td>caldo</td>
<td>?</td>
</tr>
<tr>
<td>Campo de San Carlos, So. (2)</td>
<td>limited</td>
<td>¿</td>
<td>¿</td>
<td>?</td>
</tr>
</tbody>
</table>

The use of insecticides and herbicides and other cultural practices. We need to know more about the planting and harvesting of teparies in relation to frost, for some adult teparies appear to show frost tolerance. It may also prove valuable to gather more information on cultural preferences and traditions, and why teparies continue to be grown. We did not ascertain whether use of teparies has a medicinal or religious significance. This type of data may help in improving the success of extending culture of teparies to other semi-arid areas of the world.

References
Teparies as a Source of Useful Traits for Improving Common Beans

Claire V. Thomas
Richard M. Manshardt
and J. Giles Waines
Department of Botany and Plant Sciences
University of California, Riverside

The tepary bean \( \textit{Phaseolus acutifolius} \) is of interest for its intrinsic value as an under-exploited crop adapted to hot arid climates, and as a potential donor of desirable traits to the common bean \( \textit{P. vulgaris} \) through interspecific hybridization. Teparies possess several traits that could be valuable if transferred to common beans. Teparies are more heat and drought resistant than common beans. They tolerate higher salt (Marcarian, 1981) and boron concentrations in the soil (C. J. Lovatt, personal communication; J. G. Waines, unpubl.). They are tolerant of damage by lesser cornstalk borer, \textit{Elasmopalpus lignosellus} Zeller (Thomas, 1983). They show field resistance to charcoal rot, caused by \textit{Macrophomina phaseolina} (Tassil Goid (Thomas, 1983). All of these factors combine to produce a plant that performs well in hot, semiarid climates. In addition, they show high levels of resistance to \textit{Xanthomonas phaseoli} (E.E Sm.) Dows, the bacterium that causes common blight of beans (Coyne and Schuster, 1973).

Teparies are routinely grown during the summer in parts of the American Southwest and adjacent Mexico, where they set pods when temperatures are too high for pod formation in common beans. They are able to mature seed under conditions so dry that common beans die or yield poorly because of drought (Freeman, 1912; Nabhan and Felger, 1978). Our own experience with field-grown plants at the University of California Experiment Station at Riverside demonstrates these differences. Three tepary and three common bean varieties were planted May 14, 1980 and July 9, 1981 (Thomas, 1983). They were furrow irrigated for 48 hours after planting, but received no further irrigation or rain prior to maturity. All common beans gave zero yield in both years, but teparies gave yields of up to 420 kg/ha in 1980, and 1,000 kg/ha in 1981 based on 1.25 sq. meter plots of 100 plants each. Temperatures during flowering averaged a high of 35°C and a low of 17°C in both years. Teparies can give very high yields when grown with some irrigation and slightly cooler temperatures at the University of California South Coast Field Station, Irvine. Tepary lines there have yielded 3524 kg/ha and 3916 kg/ha (W.H. Isom, personal communication). Common bean cultivars in the same trial yielded only 1659 to 2059 kg/ha. This difference was attributed in part to a differential reaction to ozone smog damage.

Teparies are poorly adapted to cool and humid growing conditions. Wild teparies are unable to germinate with winter rains because soil temperatures are too low. Although domesticated teparies show a wider temperature tolerance than wild ones, they do not germinate rapidly unless soils are very warm. They are likely to rot in soils which are cool and wet. After germination, teparies grown at low temperatures remained stunted. The internodes fail to elongate, forming a rosette. The leaves are small and thick (Hendry, 1919; Thomas, 1983). Tepary plants that are not drought stressed remain green until killed by frost. This causes problems in humid areas because seeds may germinate on the plant (Duke, 1981) or rains may interfere with harvesting (Hendry, 1919). Even when hand-harvested, teparies grown in cool areas have depressed yields under irrigation. In Minnesota field trials, teparies yielded 1242 kg/ha when irrigated and 2230 kg/ha unirrigated, whereas commercial common bean cultivars in the same trial gave 1863 kg/ha when irrigated and 1421 kg/ha when not irrigated (Petersen and Davis, 1982). Teparies are also more subject to disease and insect attacks when grown in cool, humid areas (Duke, 1981; Kaiser, 1981). Production of common beans in hot...
semi-arid tropical and subtropical regions could obviously be expanded by introduction of drought and heat resistance from teparies. Even in cooler climates, temporary hot and/or dry spells usually depress bean yields. Because many tepary varieties show day-length sensitivity and have optimum flower production at a day length of 12 hours or less (Pratt and Erickson, 1982), they may flower too late to mature seed before frost at high latitudes. It would be advisable to select tepary lines that flower well during long days for use in hybridization programs. Such lines are available (Garver, 1934; Pratt and Erickson, 1982).

The physiological and morphological components of the superior heat and drought adaptation in tepary beans are still under investigation. The heat resistance of teparies may be partly a result of their drought resistance and vice versa. In growth chamber studies, Parsons and Davis (1979) observed that teparies showed lower transpiration rates and suffered less chlorophyll loss and leaf senescence than common beans subjected to the same conditions (Parsons and Davis, 1978). This was probably because teparies have smaller, thinner leaves better able than common beans to dissipate heat (Nabhan, 1979). Both species orient their leaves to avoid the sun at midday (Parson, 1979), but water-stressed tepary plants orient their leaves perpendicular to the sun's rays in early morning and late afternoon when the stressed common beans avoid the sun by orienting leaves parallel to the rays, as we have observed at Riverside. This should allow teparies more hours of active photosynthesis than common beans when drought-stressed.

When grown outdoors at Riverside in 1.5 m tall pots on stored soil moisture and sampled at two-week intervals (Figure 4), teparies had longer roots than common beans at the same stage for every sampling period (Thomas, 1983). In the field, teparies may have more water available for growth than common beans due to a deeper root system. Studies at Riverside (Thomas, 1983) using a neutron depth moisture probe showed that tepary roots penetrated deeper than 2 m when grown on stored soil moisture, whereas common beans were not observed to extract water from much lower than 1 m.

At Riverside, under water-limited conditions in the field, teparies maintained better plant water status during flowering than common beans, showing an average of 0.2 megapascals higher plant water potential at midday and 0.1 megapascals higher at predawn. Parsons and Howe (1980) showed that teparies maintained higher turgor than common beans, partly by osmotic adjustment, and were able to maintain greater wall elasticity; both of which phenomena should allow continued growth. Coyne and Serrano (1963) documented that drought-stressed tepary leaves and petioles had higher sucrose and total soluble solids content than common beans. These results imply that teparies maintained higher rates of photosynthesis, although CO₂ uptake was not measured directly.

The only aspect of physiological heat resistance in teparies that has been examined is thermal stability of enzymes. Both malic dehydrogenase (Kinbacher et al., 1967) and fraction I protein (Sullivan and Kinbacher, 1967) showed much higher heat stability in extracts from heat-hardened teparies com-

(upper)

**Figure 1.** Greenhouse grown plants 'Masterpiece' (left), F₁ hybrid 'Masterpiece' x L320 (middle), wild P. acutifolius ssp. tenuifolius, L320 (right).

(lower left)

**Figure 2.** Flowers and bracts from tepary PI 321638 (left), F₁ hybrid PI 321638 x 'Masterpiece' (middle), and the common bean, 'Masterpiece' (right).

(lower right)

**Figure 3.** Field trial of rooting depth of teparies and common beans when grown with stored soil moisture at Riverside, CA, 1981. Plants in foreground are teparies, dead plants at center were common beans.

**Figure 4.** Common bean (Small White 53) and tepary (PI 321638) plants grown in 1.5 m tall pots on stored soil moisture. Pairs were sampled 2, 4, 6, and 8 weeks after planting. The left plant in each pair is the common bean.
pared to teparies that received no heat preconditioning. Such enzyme stability upon exposure to high temperatures is considered to contribute to heat tolerance in plants.

Field trials indicate that teparies tolerate much higher soil concentrations of salt (Marcarian, 1981) and boron (C.J. Lovatt, personal communication; J.G. Waines, unpubl.) than do common beans. These traits are important in water-limited conditions where soil concentrations of salts and boron may be high, especially in low areas with poor drainage or where irrigation water carries high concentrations of dissolved salts or boron.

Teparies are more tolerant of drought-related disease and insect damage than common beans. In the 1980 Riverside field trials referred to above common beans were killed not only by drought but also by charcoal rot caused by the fungus *Macrophomina phaseolina* (Tassi) Goid. In 1981 (Figure 3), common beans were decimated by a heavy infestation of the lesser cornstalk borer, *Elasmopalpus lignosellus* Zeller. Only a few tepary plants showed charcoal rot symptoms in 1980, and none died. Virtually all common bean plants showed symptoms, and all died. In 1981, the corn borer infestation was heavy. All but one common bean plant (out of 1200) died, but the three tepary varieties showed different levels of tolerance to the insect damage. Sixty-one percent of PI 321638, 55% of L 172, and 28% of PI 310801 plants survived. Corn borer damage could be seen at the soil line in many of the tepary plants that managed to mature pods and senesce normally. This indicates that teparies are tolerant of the damage caused by this insect, but not resistant to infection. Teparies have also been reported to show resistance to the leaf hopper, *Empoasca kramerii* Ross and Moore (CIAT, 1979), an insect that is seldom a problem in hot, dry areas.

Some teparies also possess a higher degree of resistance to common bacterial blight caused by *Xanthomonas phaseoli* (E.E Sm.) Dows, than is found in most common beans (Coyne and Schuster, 1973; Cafati and Saettler, 1980). This disease is not a problem in dry areas, but causes much damage to beans in warm, humid locations. Resistance to this bacterium has been reportedly transferred from teparies to common beans (Honma, 1956). Great Northern Nebraska #1, selection 27, which was derived from this cross, although tolerant of some strains of *X. phaseoli*, is susceptible to others (Schuster et al., 1973). Some
varieties of teparies have also been reported to show tolerance of rust caused by *Uromyces appendiculatus* (Pers.) Unger and bean golden mosaic virus (CIAT, 1977 and 1979).

A trait like drought resistance is certainly complex and has both morphological and physiological components. If all components of the system must work together to achieve a high degree of drought resistance, then this trait will probably be difficult to transfer completely. However, if one or two components can be shown to be of major importance, then success may be more easily realized. It seems possible that certain characters of teparies such as rooting depth may be sufficiently important to select for individually, but a high level of drought resistance probably depends on integration of several systems, and may be more difficult to transfer.

Certain desirable traits may be easier than others to transfer from teparies to common beans. The smaller the number of genes controlling a trait, the easier it should be to transfer from one species to another. Disease and insect resistance are sometimes under the control of a single gene, and can be easily transferred. Although the genetics of resistance to common bean blight or charcoal rot, and of tolerance to lesser cornstalk borer, have not been elucidated for teparies, it is quite possible that these traits may be simply inherited. The transfer of a complex trait controlled by many genes seems especially difficult when considered in light of the problems encountered in making the interspecific hybrids and obtaining progeny from them.

Because of doubts expressed by some workers (Smartt, 1970; Smartt, 1979; Pratt, 1983) regarding authenticity of some reported hybrids, it is important to confirm hybridity by the use of markers. Useful marker traits are growth habit, day-length sensitivity flower color, calyx bract size (Figure 2) and leaf shape in crosses utilizing var. *acutifolius* (including *tenuifolius*) (Figure 1).

There are two major problems that must be overcome in any interspecific hybridization program for teparies and common beans. The first is the difficulty of producing hybrid seed on the plant, since hybrid embryos typically abort before seed is fully developed unless embryo culture is used. One exception to this was seen in our crosses of a wild common bean, PI 325676, with several wild tepary lines. Pods from these crosses developed normally and eventually yielded dry mature seed which varied from plump to shrivelled. The seeds did not all germinate, but several hybrid plants were obtained. All other hybrid genotypes produced at Riverside required embryo culture to salvage abortive embryos, the techniques and results of which are described elsewhere.

For the interspecific crosses we made in October and November, 1981, the most important factor determining the success of F₁ hybrid production was the genotype of the female parent. Of the seven common bean cultivars used as female parents in crosses with five tepary lines, California Light Red Kidney-M (mosaic resistant) and Masterpiece were most efficient in F₁ hybrid production, yielding 0.92 and 0.87 mature F₁
plants per cross-pollination, respectively. Consequently, the majority of F1 hybrids produced at Riverside involved these common bean cultivars. There was no relationship between the number of hybrid embryos produced by a common bean cultivar in crosses with teparies and the number of embryos that survived to maturity. Among tepary lines which we used as female parents in crosses with common beans, PI 321638 was the most efficient in the production of F1 hybrid plants.

The second problem that must be overcome when attempting to transfer germplasm between these species is the sterility of the F1 hybrid, which has been overcome only by backcrossing to the parental species, or by production of partially fertile allotetraploids through colchicine treatment.

Fertility of F1 hybrids, as measured by pollen stainability in acetocarmine, was also influenced by the genotype of the female parent. In all cases, pollen stainability was low, ranging from 1% to 27%. However, pollen stainability of F1 plants derived from California Light Red Kidney-M was significantly greater than that of F1's derived from Masterpiece [17% vs. 6%].

In spite of the high degree of sterility, we have obtained a few backcross seeds using pollen from tepary and common bean parental types and a few allotetraploid plants from colchicine-treated F1 cuttings [Figure 6]. This seed was increased for several generations in the greenhouse, and fertility improved considerably.

Some of our backcross-derived common bean/tepary hybrid material was grown with irrigation at the South Coast Field Station, Irvine, in 1980. Fertility and seed set were very good. Seed derived from this planting was grown in summer 1981 at Riverside where day temperatures were in a range of 32-45°C [Thomas, 1983]. The field was irrigated for 48 hours immediately after planting. Then one treatment received no more water, while the other was watered every other week. Low yields [165-826 kg/ha] in the irrigated treatments, plus a general late season pod-set, indicated that heat resistance probably was not inherited by these lines from the tepary parent. However, common bean backcross lines yielded on average twice as much as the common bean parents in one trial and three times as much in a second trial. Two backcross/second generation common bean backcross lines yielded on average twice as much in a second trial as the common bean parents in one trial and three times as much in a second trial. Two backcross/second generation plots yielded approximately half the tepary mean yield, whereas the best common bean plot was only 20% of the tepary mean. We are currently increasing seed for additional replicated field trials.

Root length studies conducted in pots that were 1.5 m tall showed that the common bean backcross lines derived from interspecific hybrids had roots as long as the tepary parent and significantly longer than the common bean parent.

Field trials of the U.S. Department of Agriculture conducted by Dr. George Freytag at Isabella, Puerto Rico, using lines derived from our interspecific hybrids showed these lines to be more resistant to common blight than susceptible common bean varieties at indigenous field infection levels. Additional tests are being conducted by Dr. Steve Temple at CIAT, Cali, Colombia; preliminary results indicate the presence of resistance in the hybrids.

It is difficult to transfer genes between P. vulgaris and P. acutifolius. The barriers imposed by embryo culture, F1 sterility, and genetic complexity of some desired traits can all be circumvented. However, the low rate of success at each stage ensures that gene transfer will be limited and subject to "bottle-necks," thereby making it unlikely that there will ever be a large amount of genetic exchange between these species. In spite of the difficulties, transfer of traits from one species to another is possible. Since teparies possess so many traits that could greatly increase the range of adaptation and resistance to natural enemies of common beans, transfer seems well worth the trouble.

References
Sources of Tepary Seed and Rhizobia

The following sources are listed by headings which indicate whom the source is able to serve on a regular basis, given amount of seed available and objectives. We urge gardeners and development projects not to request seed from basic germplasm collections meant for breeders and long term maintenance of genetic resources. There have also been recent reports of bean common mosaic virus carried by tepary seed being distributed by several sources; please inquire whether or not seed is virus-free, particularly if you are growing other kinds of beans where you plan to plant teparies. Aphids transmit this virus, and recommended techniques for aphid control in your area can help reduce the chances of further infection.

Seed and Inocula for gardeners and Farmers (Small Quantities Available Only)—Write for Catalogs for Current prices

Inocula:
Nitragin Corporation
Milwaukee, Wisconsin 53209

Seed:
Native Seeds/SEARCH (4 varieties of teparies)
3950 W. New York Drive
Tucson, Arizona 85745

Plants of the Southwest (2 varieties)
1570 Pacheco St., Building E 15
Santa Fe, New Mexico 87510

Le Marché (2 varieties)
Seeds International
P.O. Box 566
Dixon, California 95620

G. Seed Company (2 varieties)
P.O. Box 702
Tonasket, Washington 98855

Westwind Seeds (1 variety)
2509 N. Campbell Avenue, #139
Tucson, Arizona 85719

Redwood City Seed Company (2 varieties)
P.O. Box 361
Redwood City, California 94064

Seed Exchange (Membership $6.00)
Seed Saver's Exchange
Rural Route 2
Princeton, Missouri 64673

Basic Germplasm and Inocula Collections for Basic Research and Conservation.
Centro Internacional de Agricultura Tropical (CIAT)
Fuentes de Recursos Geneticos del Frijol
Apartado Aero 6713
Cali, Columbia

USDA Western Region Plant Introduction Station
USDA/ARS
59 Johnson Hall
Pullman, WA 99164

Dr. R. Marechal, legumes Taxonomist
Faculte des Sciences Agronomique
DE L'ETAT, 5800
Gembloux, BELGIUM

Inocula:
Sheldon Whitney
Maui Branch Station
Hawaii Agriculture Experiment Station
P.O. Box 187
Kula, Maui, Hawaii 96790

Seed for Development Projects Overseas
A. Bozzini, Chief
Crop and Grassland Service
Food and Agriculture Organization of the United Nations
Via delle Terme di Caracalla 00100
Rome, Italy

Mr. Jeffrey Gritzner
Board on Science and Technology for International Development
National Research Council
2101 Constitution Avenue
Washington, D.C. 20418

Seed for Farmers and Gardeners in U.S. Indian Communities (For Papago, Pima and Yaqui):
Meals for Millions/Freedom from Hunger Foundation
P.O. Box 42622
Tucson, Arizona 85733

(For Other Tribes)
Native Seeds/SEARCH
3950 W. New York Drive
Tucson, Arizona 85745
Table 5. Explanation of several protein and starch quality measurements.

<table>
<thead>
<tr>
<th>Quality Measurement and Mathematical Definition</th>
<th>Verbal Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protein Score (similar to a Chemical or Amino Acid Score)</td>
<td>This measurement is based on chemical analyses only and suggests the possible outcome of protein use in the diet. It compares the content of the most limiting amino acid in the test protein with its content in a reference protein (FAO Provisional Pattern—See Table 6) which has been judged to be ideal for support of growth and maintenance. Higher values indicate better proteins.</td>
</tr>
<tr>
<td>% most limit, amino acid in test protein X 100 % amino acid in reference protein</td>
<td></td>
</tr>
<tr>
<td>Protein Efficiency Ratio (PER)</td>
<td>This is a biological test, usually employing laboratory rats which measures the efficiency of a protein to support growth. Low PERs resulting from poor weight gains indicate imbalances in amino acid contents which limit the ability of the organism to utilize dietary protein. High PERs suggest that the opposite condition exists. PERs of test proteins are usually compared to those obtained using a control diet of whole egg or a comparably superior protein.</td>
</tr>
<tr>
<td>body weight gain with test protein protein consumed</td>
<td></td>
</tr>
<tr>
<td>Net Protein Ratio (NPR)</td>
<td>This test is a modification of the determination of PER. The calculation of NPR corrects the quality measurement to account for obligatory losses in protein through body metabolism which would normally be unavailable for the support of growth. High values indicate superior test proteins.</td>
</tr>
<tr>
<td>body weight gain with test protein [loss of weight with protein free diet] protein consumed</td>
<td></td>
</tr>
<tr>
<td>Nitrogen Balance</td>
<td>A positive nitrogen balance indicates the availability of adequate protein and essential amino acid supply for growth and maintenance. Negative nitrogen balances result from un replenished losses of endogenous amino acids or utilized dietary protein due to imbalances in amino acid supplies.</td>
</tr>
<tr>
<td>[nitrogen in protein] consumed - [nitrogen lost through excretion of feces and urine]</td>
<td></td>
</tr>
<tr>
<td>Protein or Starch Digestibility (also known as Apparent Digestibility or In Vivo Digestibility)</td>
<td>This technique measures the digestibility of any given nutrient with respect to the digestibility of the diet as a whole. An indigestible, inert indicator such as chromic oxide is commonly employed. Its level in feed is concentrated in feces in proportion to the level of components absorbed through the intestinal wall. A measure of this concentration suggests the portion of the diet digested. The level of diet digestibility is used to correct the determination of nutrient digestibility.</td>
</tr>
<tr>
<td>1 - [% indicator in feed % indicator in feces] X % nutrient in feces % nutrient in feed</td>
<td></td>
</tr>
<tr>
<td>Enzymatic Starch Digestibility (also known as In vitro Starch Digestibility)</td>
<td>This is a laboratory test which mimics digestion of starch in the small intestine. The starch digesting enzyme alpha-amylase found in the alimentary canal is allowed to hydrolyze (degrade) starch to sugar under conditions approximating those found in the gut. After a given time period, sugar content of the suspension is determined, indicating the digestibility of the starch.</td>
</tr>
<tr>
<td>100 X content of sugar after hydrolysis initial content of sugar as starch</td>
<td></td>
</tr>
</tbody>
</table>

Table 6. The essential amino acids for human growth and maintenance and their content in common grain legumes.1

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>Characteristics [or Grouping]</th>
<th>Range of Amino Acid Contents (% of Protein)</th>
<th>FAO Provisional Pattern2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isoleucine</td>
<td>Branched Carbon Chain</td>
<td>3.8-6.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Leucine</td>
<td>Branched Carbon Chain</td>
<td>6.6-9.0</td>
<td>4.8</td>
</tr>
<tr>
<td>Lysine</td>
<td>Basic [containing 2 nitrogen atoms]</td>
<td>5.6-7.4</td>
<td>4.2</td>
</tr>
<tr>
<td>Methionine</td>
<td>Containing 1 Sulfur Atom</td>
<td>0.5-1.6</td>
<td>2.8</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>Containing an Aromatic Carbon Ring</td>
<td>4.2-8.6</td>
<td>1.4</td>
</tr>
<tr>
<td>Threonine</td>
<td>Containing a Hydroxyl Group</td>
<td>3.2-4.8</td>
<td>1.4</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>Containing an Aromatic Carbon Ring</td>
<td>0.5-1.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Valine</td>
<td>Branched Carbon Chain</td>
<td>4.6-6.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Cysteine + Methionine3</td>
<td>Containing Sulfur Atoms</td>
<td>1.1-3.0</td>
<td>4.2</td>
</tr>
<tr>
<td>Phenylalanine + Tyrosine4</td>
<td>Containing Aromatic Carbon Rings</td>
<td>6.4-12.0</td>
<td>5.6</td>
</tr>
</tbody>
</table>

1Adapted from Aykroyd and Doughty, 1964.
2FAO Provisional Pattern—A percentage amino acid pattern of a hypothetical protein assumed to be optimal for human growth and development by the Food and Agriculture Organization of the United Nations, Committee on Protein Requirements.
3Since the biosynthesis of cysteine requires that a sulfur atom be donated by methionine (i.e., methionine is sacrificed during cysteine synthesis), these two amino acids are often jointly considered in an evaluation of protein quality.
4Since the biosynthesis of tyrosine requires the carbon skeleton of phenylalanine, these two amino acids are often jointly considered in the evaluation of protein quality.
Levels of protein digestibility characterize certain legume species. For example, percent protein digestibility estimates for legumes range from 52-92% in common beans (Bressani, 1975) and from 34-92% (Patwardhan, 1962) (Table 7). Low feces when beans are consumed. (Bressani, 1975) gastrointestinal enzymes. In any case, significant losses of nitrogen occur in discharge from the intestine or by a resistance to protein hydrolysis by the present, it is not known whether these effects are caused by a more rapid digestion of the amino acids. An in vivo experiment involving nitrogen balances (Table 5) of adult males fed a variety of diets, revealed the digestibility of protein to be one consisting of common beans (12.5%), corn (12.5%), milk (25%), and wheat (50%) proteins (Clark et al., 1973).

Experimental diets usually employed are simplifications of normal human diets, which usually contain a variety of vegetable components (Aykroyd and Doughty, 1964). These components, while affecting protein quality only slightly, may provide other nutrients essential to body maintenance and growth.

Protein Digestibility. In addition to considerations of quantity and quality of bean proteins, one must also regard the digestibility of this nutrient when assessing the nutritional impact of legume proteins. Such small differences in protein quality may provide other nutrients essential to body maintenance and growth.

Table 7. Nutritive value of common grain legume proteins.\(^1\)

<table>
<thead>
<tr>
<th>Species</th>
<th>Protein Score</th>
<th>First Limiting Amino Acid</th>
<th>Protein Efficiency Ratio</th>
<th>Digestibility Coefficient [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus cajan</td>
<td>38</td>
<td>sulfur(^2)</td>
<td>*1.7</td>
<td>59-90</td>
</tr>
<tr>
<td>Cicer arietinum</td>
<td>57</td>
<td>tryptophan</td>
<td>0.7-2.0</td>
<td>76-92</td>
</tr>
<tr>
<td>Lablab niger</td>
<td>*</td>
<td></td>
<td>*</td>
<td>56-76</td>
</tr>
<tr>
<td>Lathyrus sativum</td>
<td>*</td>
<td></td>
<td></td>
<td>90-91</td>
</tr>
<tr>
<td>Lens esculenta</td>
<td>36</td>
<td>sulfur</td>
<td>0.1-0.9</td>
<td>78-92</td>
</tr>
<tr>
<td>Phaseolus aureus</td>
<td>40</td>
<td>sulfur</td>
<td>0.9-1.5</td>
<td>75-91</td>
</tr>
<tr>
<td>Phaseolus lunatus</td>
<td>66</td>
<td>sulfur/tryptophan</td>
<td>*1.2</td>
<td>34</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>46</td>
<td>sulfur</td>
<td>*</td>
<td>56-64</td>
</tr>
<tr>
<td>Pisum sativum</td>
<td>58</td>
<td>sulfur</td>
<td>*1.2</td>
<td>61-91</td>
</tr>
<tr>
<td>Vicia faba</td>
<td>26</td>
<td>sulfur</td>
<td>1.2</td>
<td></td>
</tr>
<tr>
<td>Vigna sinensis</td>
<td>66</td>
<td>tryptophan</td>
<td>0.5-1.3</td>
<td>58-83</td>
</tr>
</tbody>
</table>

\(^1\)Adapted from: Aykroyd and Doughty (1964) and Patwardhan (1962).
\(^2\)Cysteine + Methionine.
\(^3\)Negative weight gain, calculation of PER infeasible.

Table 8. The essential amino acid patterns of tepary beans.\(^1\)

<table>
<thead>
<tr>
<th>Amino Acid</th>
<th>FAO Provisional Pattern</th>
<th>Wild Teparies</th>
<th>Domesticated Teparies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sample Size</td>
<td>Mean</td>
<td>Range</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>4.2</td>
<td>2</td>
<td>5.1</td>
</tr>
<tr>
<td>Leucine</td>
<td>4.8</td>
<td>2</td>
<td>9.6</td>
</tr>
<tr>
<td>Lysine</td>
<td>4.2</td>
<td>2</td>
<td>7.7</td>
</tr>
<tr>
<td>Methionine</td>
<td>4.2</td>
<td>2</td>
<td>0.8</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>2</td>
<td>6.5</td>
<td>6.1-6.8</td>
</tr>
<tr>
<td>Threonine</td>
<td>2.8</td>
<td>2</td>
<td>4.4</td>
</tr>
<tr>
<td>Tryptophan</td>
<td>1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Valine</td>
<td>4.2</td>
<td>2</td>
<td>6.3</td>
</tr>
<tr>
<td>Sulfur Amino Acids</td>
<td>4.3</td>
<td>2</td>
<td>2.6</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>5.6</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^1\)Values from the Nabhan-University of Arizona collection of tepary beans acquired from 1976 to present, consisting of published and unpublished data, including material from Nabhan and Felger, 1978; Nabhan et al., manuscript in preparation.

Nabhan et al. (1979) listed protein scores for several whole meal tepary-corn or tepary-wheat combinations as reviewed in Table 10. The addition of dairy products to the diet can significantly improve the balance of amino acids. An in vivo experiment involving nitrogen balances (Table 5) of adult males fed a variety of diets, revealed the protein digestibility coefficient of 64.9% with rats fed a diet containing white tepary protein. This value was considered to be low in relation to the digestibility of other grain legume proteins, but was comparable to values for more digestible varieties of P. vulgaris. Variability in digestion coefficients within any species can be substantial. Unfortunately, precise experimental evidence is not available which would lead to selection of cultivars with high digestibility values (Bressani, 1975).

Poor levels of protein digestibility associated with certain legumes may be caused by a variety of factors, singly or in concert. These factors include: the effect of incomplete starch or carbohydrate digestion, the presence of antinutritional factors which inhibit the function of digestive tract enzymes or intestinal absorption, the effect of processing or preparation and cooking of pulses and the possible existence of protein conjugates which resist digestion.

Present knowledge concerning the influence of starch upon the digestibility of protein and other nutrients was recently and extensively reviewed by Dreher et al. (in prep.) Vegetable protein sources almost always contain appreciable levels of starch, which, depending on its physical and chemical characteristics, may affect protein utilization and the bioavailability of certain amino acids. Uncooked legume starches were reported to inhibit digestion and utilization of proteins to a greater degree than did those of cereals. Geervani and Theophilus (1981), using diets containing casein [a protein isolated from milk which is known to be highly digestible], studied the effects of several isolated bean starches on protein utilization. Some bean...
The degree of nutritive improvement effected by heat treatment var-
of this review. These effects form the rationale for extensive efforts in
Jaffe, 1975, 1980; Liener and Kakade, 1980; Patwardhan, 1962; Smartt,
their ability to agglutinate red blood cells) do not inhibit digestive
enzymes. Lectins (sometimes call phytohemagglutinins because of
protein losses suffered through increased synthesis of intestinal
protein from the diet is compounded substantially by endogenous
the alimentary canal undigested. The severity of loss in utilizable
counterparts, allowing much of the dietary protein to pass through
these inhibitors bind with and inactivate their intestinal enzyme
trypsin (another intestinal protein-digesting enzyme). When ingested,
partially responsible for protein digestion) and the Bowman-Birk
inhibitor, which restricts the action of trypsin (an intestinal enzyme
(Table 11). The two most common inhibitor types are the Kunitz
inhibitors (Liener and Kakade, 1980) and lectins (Jaffe, 1980) are of
restrict protein utilization. Among these protein classes, protease
inhibitors (unspecified as to inhibitor type) and lectins were assayed
native legume seeds was undertaken by Thorn (1981). Levels of trypsin
inhibitors and lectins brought about by this process

Antinutritional factors commonly found in legume seeds include
several classes of proteins which, when ingested, act enzymatically to
restrict protein utilization. Among these protein classes, protease
inhibitors [Liener and Kakade, 1980] and lectins [Jaffe, 1980] are of
significant importance. Levels of protease inhibitors isolated from
soybean and other legumes vary considerably as do their properties
[Table 11]. The two most common inhibitor types are the Kunitz
inhibitor, which restricts the action of trypsin [an intestinal enzyme
partially responsible for protein digestion] and the Bowman-Birk
inhibitor which suppresses the function of both trypsin and chymo-
trypsin [another intestinal protein-digesting enzyme]. When ingested,
these inhibitors bind with and inactivate their intestinal enzyme
counterparts, allowing much of the dietary protein to pass through
the alimentary canal undigested. The severity of loss in utilisable
protein from the diet is compounded substantially by endogenous
protein losses suffered through increased synthesis of intestinal
enzymes. Lectins [sometimes call phytohemagglutinins because of
their ability to agglutinate red blood cells] do not inhibit digestive
enzymes, but seem to affect protein digestibility by restricting intesti-
nal absorption.

The positive effects of cooking or heating on the nutritive value of
pulses are well documented [Bressani, 1975; Dutra de Oliveira, 1973;
Jaffe, 1975, 1980; Liener and Kakade, 1980; Patwardhan, 1962; Smartt,
1976] and an in-depth discussion of the evidence is beyond the scope
of this review. These effects form the rationale for extensive efforts in
soybean processing undertaken wherever this pulse is used. The
increased nutritive value is due in part to an increase in utilisable
dietary protein. Protein quality itself probably does not change; its
increased nutritive value is due in part to an increase in utilisable
protein from the diet is compounded substantially by endogenous

starches are reported to be an important factor in limiting the digestibility
of pulses [Jaffe, 1980; Liener and Kakade, 1980]. Among the several
classes of antinutritional factors in legumes, the effects of heat treatment
on the nutritive value of common bean starch digestibility have shown this
material to be poorly di-
percent reduction in inhibition activity associated with autoclaved samples. In a study of several Mexican cultivars of
common bean, Sotelo-Lopez et al. [1978] recorded trypsin inhibitor
activities at similar levels to those found by Thorn for domesticated
soybeans. The wild tepary accession studied contained almost twice as much trypsin inhibitor as its domesticated
counterparts, but could still be considered intermediate in concentra-
tion of this enzyme. The probability of most trypsin inhibitor being
inactivated by normal cooking procedures appeared to be high, as was
indicated by the percent reduction in inhibition activity associated
with autoclaved samples. In a study of several Mexican cultivars of
common bean, Sotelo-Lopez et al. [1978] recorded trypsin inhibitor
activities at similar levels to those found by Thorn for domesticated

<table>
<thead>
<tr>
<th>Species</th>
<th>Protease Inhibitors</th>
<th>Lectins</th>
<th>Effects of Heat Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cajanus colum</td>
<td>+</td>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>Cicer arietinum</td>
<td>+</td>
<td>0</td>
<td>+0,1</td>
</tr>
<tr>
<td>Lablab niger</td>
<td>+</td>
<td>+</td>
<td>+7</td>
</tr>
<tr>
<td>Laburnus sativus</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Lens esculenta</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phaseolus aureus</td>
<td>+</td>
<td>+</td>
<td>+0</td>
</tr>
<tr>
<td>Phaseolus hauatus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pisum sativum</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Vicia faba</td>
<td>+0,1</td>
<td>+</td>
<td>+0</td>
</tr>
<tr>
<td>Vigna sinensis</td>
<td>+</td>
<td>?</td>
<td>+0</td>
</tr>
</tbody>
</table>

Source: Smartt, 1976.

1Presence (+), absence (0), insufficient evidence (?).
2Positive effect (+), negative effect (-), no effect (0).
3Adapted from Thorn, 1981.
4One sample.
5Four samples.

### Table 9. Protein efficiency ratios and net protein ratios associated with tepary bean, pinto bean and whole egg diets.

<table>
<thead>
<tr>
<th>Diet Description</th>
<th>Total Feed Consumption [g]</th>
<th>Total Protein Intake [g]</th>
<th>Weight Gain [+] or Loss [-]</th>
<th>Protein Efficiency Ratio</th>
<th>Net Protein Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. wild tepary</td>
<td>65.7</td>
<td>4.8</td>
<td>-0.5</td>
<td>0.23</td>
<td>1.96</td>
</tr>
<tr>
<td>2. white tepary</td>
<td>121.5</td>
<td>9.0</td>
<td>+0.2</td>
<td>0.59</td>
<td>2.13</td>
</tr>
<tr>
<td>3. white tepary</td>
<td>148.2</td>
<td>11.3</td>
<td>-0.2</td>
<td>*</td>
<td>1.64</td>
</tr>
<tr>
<td>4. brown tepary</td>
<td>115.8</td>
<td>8.1</td>
<td>+0.2</td>
<td>*</td>
<td>1.59</td>
</tr>
<tr>
<td>5. brown tepary</td>
<td>122.4</td>
<td>9.0</td>
<td>-0.2</td>
<td>*</td>
<td>1.69</td>
</tr>
<tr>
<td>6. pinto</td>
<td>144.0</td>
<td>11.1</td>
<td>-0.4</td>
<td>*</td>
<td>1.69</td>
</tr>
<tr>
<td>7. whole egg control</td>
<td>210.0</td>
<td>16.6</td>
<td>+12.7</td>
<td>2.36</td>
<td>4.20</td>
</tr>
</tbody>
</table>

1Isoitenous diets (7% protein) fed for 3 weeks to weanling mice.
2Negative weight gain, calculation of PER infeasible.

### Table 10. Protein scores of several tepary-cereal combinations.

<table>
<thead>
<tr>
<th>Whole Meal Combinations</th>
<th>% Protein of the Diet</th>
<th>Protein Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>tepary 67%-wheat 33%</td>
<td>21.1</td>
<td>95</td>
</tr>
<tr>
<td>tepary 67%-corn 33%</td>
<td>17.4</td>
<td>92</td>
</tr>
<tr>
<td>tepary 50%-wheat 50%</td>
<td>19.5</td>
<td>93</td>
</tr>
<tr>
<td>pepary 50%-corn 50%</td>
<td>16.9</td>
<td>97</td>
</tr>
<tr>
<td>tepary 100%</td>
<td>25.0</td>
<td>74</td>
</tr>
<tr>
<td>wheat 100%</td>
<td>14.0</td>
<td>56</td>
</tr>
<tr>
<td>corn 100%</td>
<td>8.8</td>
<td>46</td>
</tr>
</tbody>
</table>

1Adapted from Weber in Nabhan et al., 1979.
2Tepary values calculated without the benefit of analysis for trypto-

### Table 11. Presence or absence of protease inhibitors and lectins in common grain legumes and the effects of heat treatment on their nutritive value.

<table>
<thead>
<tr>
<th>Species</th>
<th>Protease Inhibitors</th>
<th>Lectins</th>
<th>Effects of Heat Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cicer arietinum</td>
<td>+</td>
<td>0</td>
<td>+0</td>
</tr>
<tr>
<td>Lablab niger</td>
<td>+</td>
<td>+</td>
<td>+7</td>
</tr>
<tr>
<td>Laburnus sativus</td>
<td>?</td>
<td>?</td>
<td>?</td>
</tr>
<tr>
<td>Lens esculenta</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phaseolus aureus</td>
<td>+</td>
<td>+</td>
<td>+0</td>
</tr>
<tr>
<td>Phaseolus hauatus</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>+</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Pisum sativum</td>
<td>0</td>
<td>+</td>
<td>0</td>
</tr>
<tr>
<td>Vicia faba</td>
<td>+0,1</td>
<td>+</td>
<td>+0</td>
</tr>
<tr>
<td>Vigna sinensis</td>
<td>+</td>
<td>?</td>
<td>+0</td>
</tr>
</tbody>
</table>

Source: Smartt, 1976.

1Presence (+), absence (0), insufficient evidence (?).
2Positive effect (+), negative effect (-), no effect (0).
3Adapted from Thorn, 1981.
4One sample.
5Four samples.

### Table 12. Antinutritional factors present in tepary beans.

<table>
<thead>
<tr>
<th>Antinutritional Factor</th>
<th>Wild Tepary 2</th>
<th>Domesticated Tepary 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trypsin Inhibitor</td>
<td>intermediate</td>
<td>intermediate</td>
</tr>
<tr>
<td>Content Reduction by Heat Treatment (%)</td>
<td>93</td>
<td>68 - 80</td>
</tr>
<tr>
<td>Lectin</td>
<td>very high</td>
<td>very high</td>
</tr>
<tr>
<td>Content Reduction by Heat Treatment (%)</td>
<td>100</td>
<td>90 - 100</td>
</tr>
<tr>
<td>Phytic Acid Content</td>
<td>1.02</td>
<td>0.60-0.75</td>
</tr>
<tr>
<td>Flatulento Sugar Contents</td>
<td>0.05</td>
<td>0.28-0.98</td>
</tr>
<tr>
<td>Raffinose</td>
<td>1.10</td>
<td>3.27-5.45</td>
</tr>
</tbody>
</table>

1Adapted from Thorn, 1981.
2One sample.
3Four samples.
tepary samples. Upon cooking, the common bean samples also lost 73-88% of their trypsin inhibitor activity.

Measurements of lectin content in tepary samples revealed very high levels of this antinutritional factor which were heretofore unprecedented [Thorn, 1981]. Fortunately, these factors appeared to be extremely heat labile indicating their ineffectiveness to disrupt protein digestion in adequately cooked tepary bean foodstuffs. Lectins from P. vulgaris species which contain modest levels of these inhibitors were also rendered inactive by heat treatment [Sotelo-Lopez et al., 1978].

Trypsin inhibitors and lectins present in tepary beans, although at levels from moderate to very high, pose no nutritional problems as long as these beans are consumed by cultures with an abundance of cooking fuel. Most southwestern Indian groups have adequate facilities to thoroughly cook legume-based foods, as recipes often involve simmering beans for extended periods of time. The digestibility of protein from foods containing these beans may be severely impaired by inadequate preparation, limiting the usefulness of this species in fuel-poor areas otherwise well suited to its introduction. Current studies are underway at the University of Arizona to determine the relationship between cooking time and the protease inhibitor activity of tepary samples.

An additional factor potentially antagonistic to the digestion of pulse protein is the presence of protein conjugates [Smartt, 1976]. These associations of proteins with hemicelluloses or phytin (an antinutritional factor with deleterious effects on mineral availability discussed below) have not been extensively studied, so their possible effects on protein availability have not been fully established. Investigations of tepary protein quality have not uncovered the presence of protein conjugates. However, a definitive evaluation concerning their possible existence and their effect upon protein utilization awaits well planned experimentation.

Overall, the protein quality of teparies resembles that of common beans. Protein scores exhibited by samples of either species are low. For both species, values of PER are either low or negative (incalculable) and protein digestibilities of raw samples are poor. Antinutritional factors of tepary beans, although present at higher levels in whole seed than in common bean samples, are equally heat labile when compared with P. vulgaris varieties. Just as protein content is affected by both genetic and environmental influences, protein quality may also depend upon inherent traits and their interactions with the environmental conditions of crop growth. Therefore, generalizations based on the limited data available concerning the superiority of protein quality among tepary races or the nutritional effects of tepary use decline may be subject to a high level of error. Determination of "interchangeability" among species, with respect to protein quality awaits development of an expanded data base.

**Carbohydrate.** Legume carbohydrates include starch, fiber, pectin and sugar components, of which starch is the most significant nutritionally. Grain legumes are composed of nearly 60% starch which is generally well utilized and provides most of the caloric value of these foods (Table 2). Dreher et al. [manuscript in preparation] describe legume starches as being intermediate in digestibility between highly digestible cereal and poorly digested root/tuber starches. Poor starch digestion may contribute to loss of protein digestibility, flatus production and in severe cases, diarrhea (Hellendoorn, 1973). Starch granules are a mixture of two carbohydrate polymers, amylose and amylopectin. The ratio of these components and their physical arrangement within the starch granule determine the susceptibility of this material to starch degrading enzymes. Bean starches are usually high in amylose content, a characteristic which renders them less digestible than cereal starches. Pigeon pea starch [64% amylose] and wrinkled pea starch [63-70% amylose], both of which are unusually high in this component, resist enzymatic degradation (Geervani and Theophilus, 1981; Fleming and Vose, 1979; Dreher et al., manuscript in preparation) whereas bean starches comprised of 25-35% amylose are found to be readily digestible. Raw starches isolated from Phaseolus spp which are typically within the 25-35% amylose range commonly show in vivo digestibility coefficients from 90-100% [Dreher et al. manuscript in preparation; Fleming and Vose, 1979]. *In vitro* measurements of digestibility associated with these starches, involving quantification of enzymatic activity upon a starch substrate, are reported as being much broader in range (21-91%).

<table>
<thead>
<tr>
<th>Species</th>
<th>Calcium mg/100g</th>
<th>Iron mg/100g</th>
<th>Thiamin mg/100g</th>
<th>Riboflavin mg/100g</th>
<th>Niacin mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caladium caudae</td>
<td>129</td>
<td>5.8</td>
<td>0.50</td>
<td>0.14</td>
<td>2.3</td>
</tr>
<tr>
<td>Cicer orienteum</td>
<td>149</td>
<td>7.2</td>
<td>0.40</td>
<td>0.18</td>
<td>1.6</td>
</tr>
<tr>
<td>Lablab niger</td>
<td>92</td>
<td>4.6</td>
<td>0.63</td>
<td>0.16</td>
<td>1.6</td>
</tr>
<tr>
<td>Lathrus sativus</td>
<td>110</td>
<td>5.6</td>
<td>0.10</td>
<td>0.40</td>
<td></td>
</tr>
<tr>
<td>Lens esculenta</td>
<td>56</td>
<td>6.1</td>
<td>0.50</td>
<td>0.21</td>
<td>1.8</td>
</tr>
<tr>
<td>Phaseolus aureus</td>
<td>145</td>
<td>7.8</td>
<td>0.56</td>
<td>0.17</td>
<td>2.0</td>
</tr>
<tr>
<td>Phaseolus lunatus</td>
<td>84</td>
<td>5.2</td>
<td>0.46</td>
<td>0.16</td>
<td>1.8</td>
</tr>
<tr>
<td>Phaseolus vulgaris</td>
<td>137</td>
<td>6.7</td>
<td>0.54</td>
<td>0.18</td>
<td>2.1</td>
</tr>
<tr>
<td>Psia sativa</td>
<td>64</td>
<td>4.8</td>
<td>0.72</td>
<td>0.15</td>
<td>2.4</td>
</tr>
<tr>
<td>Vicia faba</td>
<td>90</td>
<td>3.6</td>
<td>0.54</td>
<td>0.29</td>
<td>2.3</td>
</tr>
<tr>
<td>Vigna sinensis</td>
<td>76</td>
<td>5.7</td>
<td>0.92</td>
<td>0.18</td>
<td>1.9</td>
</tr>
</tbody>
</table>

1 Adapted from Aykroyd and Doughty, 1964.

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Average Content mg/100g</th>
<th>Range mg/100g</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium</td>
<td>210.8</td>
<td>126-445.8</td>
</tr>
<tr>
<td>Iron</td>
<td>6.6</td>
<td>0.2-12.6</td>
</tr>
<tr>
<td>Magnesium</td>
<td>172.9</td>
<td>94.8-281.2</td>
</tr>
<tr>
<td>Zinc</td>
<td>3.3</td>
<td>1.7-6.1</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>31.0</td>
<td>60.0-432.1</td>
</tr>
<tr>
<td>Potassium</td>
<td>1554.6</td>
<td>1501.4-1697.8</td>
</tr>
<tr>
<td>Copper</td>
<td>1.3</td>
<td>0.6-3.7</td>
</tr>
<tr>
<td>Sodium</td>
<td>34.2</td>
<td>6.7-66.7</td>
</tr>
<tr>
<td>Manganese</td>
<td>1.8</td>
<td>0.9-3.6</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.1</td>
<td>0.1-0.2</td>
</tr>
</tbody>
</table>

1 Values from the Naban-University of Arizona collection of tepary beans acquired from 1976 to present.

Most researchers report an increase in *in vitro* digestibility of bean starches in response to cooking or heat treatment. Digestibility of common bean starch may also be curtailed by the presence of a proteinaceous inhibitor within the seed which suppresses the action of alpha-amylase, a starch digesting enzyme [Marshall, 1975].

An in-depth investigation into the physical and chemical nature of tepary bean starch was directed by Abbas. Starch was found to comprise 41% of the whole seed. Granule morphology was similar to that of other bean starches with granule diameters averaging 33-34 microns, nearly twice the average size of those isolated from corn. When analyzed for its chemical components, this material displayed an amylose/amylopectin ratio of 30/70, which is common for beans within the genus Phaseolus. A determination of *in vivo* digestibility of raw tepary bean starch indicated that this material was poorly digested (digestibility coefficient 8%). As is commonly found with other raw or cooked tepary bean starch digestibility have yet to be determined *in vivo*. If these tests were undertaken, values of tepary starch digestibility and the effects of this material upon protein digestibility might closely resemble measurements of these parameters reported for other members within the genus [Geervani and Theophilus, 1981]. It can be assumed that tepary starch is readily digestible when cooked, and imparts no nutritional barriers to the use of this pulse in the diet. The species has not been assayed for the possible presence of alpha-amylase inhibitors found in some varieties of common bean.

Legume seeds also contain a modest level of free sugars which, for the most part, have little nutritional significance. However, ingested flatulent sugars [raffinose, stachyose and verbascose], present in most beans at typical levels of 5-8% of their dry weight [Rackis, 1975], are indigestible and can cause problems ranging in severity from socially embarrassing flatulence to abdominal cramps, nausea and diarrhea [Lienert, 1980]. Flatus is actually a variable mixture of gases [Hellendoorn, 1973; Lienert, 1980] including carbon dioxide, hydrogen, methane, nitrogen and others. These gases are metabolic products of...
Flavulent sugar levels occurring in wild teparies were reported to be very low [1.15%] in comparison with the range of 5-8% commonly found in most legume samples (Thorn, 1981; Table 12). The domesticated teparies analyzed revealed higher total flavulent sugar contents than found in their wild counterparts, and were considered to exhibit common levels of these anti-nutritional factors [Fleming, 1981; Rakcis, 1975]. As in most Phaseolus species, the predominant flavulent sugar present in teparies was found to be stachyose.

The dietary fiber associated with beans may have positive nutritional effects [Leveille et al., 1978]. In most pulse species, fiber content is low, comprising 3-5% of the total weight of the seed (Table 2). Fiber contents of teparies listed in Table 4 are comparatively high, but within the range of values reported for common grain legumes. The average fiber content of this bean species is reported to be 6.5% [Duke, 1981] reports a slightly lower fiber content of 3.4% associated with this species.

**Fats:** Crude fat (vegetable oil) contents for grain legumes are also low [typically 1-2% of the seed weight] (Table 2), and may contribute significantly to the nutritive value of these foods only as carriers of fat soluble vitamins. In contrast, oilseeds legumes contain substantial quantities of vegetable fats which are major commodities of industry and world trade. The nutritive value of these oils has been the subject of extensive scientific study because of its scope, can only be mentioned here in passing. The vegetable oils of pulses contain a high proportion of polyunsaturated components, some of which are essential to the human diet.

The crude fat contents of tepary samples [0.4-2.4%] as reported in Table 4 are typical of all common grain legumes. A chemical analysis of these oils indicated an average level of 70% unsaturated fat, a finding which concurs with data collected from other legume species.

**Minerals:** Pulses were reported to be important sources of calcium, iron, magnesium, and zinc in several species [Nabhan et al., in prep.]. Although the average calcium content of pulses was found to be low [100mg/100g, Patwardhan, 1962], this mineral was present at higher levels than encountered in most cereals [Aykroyd and Dougherty, 1964] (Table 13). Beans were considered to be excellent sources of iron by Aykroyd and Dougherty (1964) and of phosphorus and potassium by Leveille et al. (1978).

A significant portion of the Nabhan-University of Arizona collection has been assayed for content of 11 different minerals (Table 14). Various additional accounts of tepary bean mineral analyses have been published [Calloway et al., 1974; Nabhan et al., in prep., data included as part of Table 14]. Ranges in mineral content were quite diverse, suggesting an interdependence of soil nutrients available to the growing plant and mineral levels present in the seed. Nabhan et al. (in prep.) reported the possible association of high soil levels and sodium content present in beans grown at a particular Hopi location. Other correlative patterns were more obscure.

The mean calcium level of teparies listed in Table 14 is higher than values reported by Calloway et al. (1974) for teparies or commodity pintos, or for values associated with common grain legumes (Table 13). In a study of Hopi beans, Nabhan et al. (in prep., data included as part of Table 14) encountered calcium contents ranging from 127-330mg/100g in common beans and 139-213mg/100g in tepary bean samples.

Iron content in Nabhan-University of Arizona tepary samples was found to vary tremendously, with an exhibited mean of 6.6mg/100g. This mean was intermediate among iron content means reported for common grain legumes and resembled the average iron level associated with P. vulgaris.

Variation in magnesium levels of tepary samples was somewhat diminished in respect to the three previously discussed minerals. Nabhan et al. (in prep.) report magnesium content means of 166.8, 168.6 and 160.6mg/100g for Hopi grown samples of common, tepary and lima beans respectively.

Zinc and phosphorus values varied widely among tepary samples and displayed means similar to those found in common and green bean varieties. Potassium was present in tepary seed at higher levels than for any other mineral assayed. This characteristic is generally consistent throughout the Plant Kingdom as potassium often comprises 50% of the total plant ash weight [Sutcliffe and Baker, 1974].

Mineral availability from pulse sources is potentially limited by the presence of phytin [phytic acid], a phosphorus containing molecule which can bind with either protein or certain minerals. The natural occurrence of phytin in seed meals, its chemistry and nutritional implications with respect to mineral absorption were reviewed by both Erdman (1979) and Reddy et al. (1982). Analysis of phytin content in 50 cultivars of common bean established a range of 0.54-1.58% for this compound within this species (Lolas and Markakis, 1975). Total phosphorus content correlated well with phytin content, with phytin levels accounting for 50-60% and 54-82% of that present in soybeans and common beans respectively [Erdman, 1979; Lolas and Markakis, 1975]. Phytin levels in some legume species were reduced to some extent by soaking and cooking processes, but were most dramatically affected by canning in brine [Reddy et al., 1982].

Phytic acid contents of both wild and domesticated teparies are one-third to one-half less than those attributed to soybean and resemble values for this characteristic reported for common beans. Domesticates exhibit less phytin content than do wild beans, with brown and white teparies averaging 0.61 and 0.73% of this compound. The effects of this material upon mineral uptake and utilization from tepary diets are unknown at this time.

**Vitamins:** Beans are said to be fair to good sources of thiamin [vitamin B1] and riboflavin [vitamin B2] (Table 13), while being recognized as deficient in vitamins A and C [Patwardhan, 1962; Aykroyd and Dougherty, 1964]. Most pulses contain appreciable levels of niacin, with exceptionally high levels of this nutrient [16mg/100g] found in peanuts. Beans are also good sources of vitamin E and pantothentic acid.

Vitamin analyses of Nabhan-University of Arizona tepary samples are underway, with insufficient data collected at this time to warrant further mention. Duke [1981] however, specifies levels of 0.33, 0.12, and 2.80 mg/100g of sample for thiamin, riboflavin and niacin respectively. In comparison with other grain legumes, teparies appear to be a good source of niacin, a mediocre source of riboflavin and a poor source of thiamin (Table 13).

**Toxic Factors:** Apart from the antinutritional factors previously mentioned [i.e. protease and alpha-amylase inhibitors, lectins, flavulent sugars and phytin], individual pulse species may also contain one or more toxic constituents associated with the Leguminosae. These additional factors include: cyanogenic [cyanide-producing] compounds, saponins, alkaloids, goitrogenic [goiter-producing] compounds as well as several toxins of unknown origin. The consumption of certain species may result in diseased states such as lathyrisis and favism [Smartt, 1976]. Of these toxic factors which might potentially be present in teparies, only cyanogenic compounds have been assayed and found to be undetectable [Thorn, 1981].

**Summary of Nutritive Value of Teparies and Common Grain Legumes:** The nutritive value of common grain legume and tepary consumption can be summarized in part through the information listed in Table 15. Values are based on nutrient levels for a hypothetical "average" pulse and for an "average" domesticated tepary consumed at a rate of 50g/day. This consumption level is similar to usage patterns reported for peoples of Mexico [Smartt, 1976] and is one-sixth the consumption rate cited by Nabhan and Teiwes [1983] for the "average" Papago tribe member.

Legumes provide an appreciable percentage of the daily protein requirement. Very little difference exists between the average grain legume and the average tepary bean in their ability to supply this essential nutrient. Cysteine, methionine and tryptophan, which are deficient in most grain legumes are also deficient in tepary samples assayed for these compounds, with tryptophan levels being uncommonly low in the latter pulse.

Biological determinations of protein quality [as measured by calculation of PERs] show tepary protein to be less suited for use as a single dietary source of this nutrient than most common grain legumes, but as suitable as varieties of P. vulgaris. Legume protein although deficient in several essential amino acids, can be included in a diet with cereals and other vegetable materials resulting in a balance of these compounds which is suitable for body growth and maintenance. This
Table 15. Percentage of the recommended dietary allowance supplied by daily consumption of 50g of an "average tepary bean" and a hypothetical "average" grain legume.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>Content in 50g 'Average' Grain Legume</th>
<th>Content in 50g 'Average' Tepary Bean</th>
<th>RDA Adult Range</th>
<th>Portion of RDA Supplied by Grain Legume [%]</th>
<th>Portion of RDA Supplied by Tepary Bean [%]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calories</td>
<td>170</td>
<td>160</td>
<td>1800-2900</td>
<td>5.9-9.4</td>
<td>5.5-8.9</td>
</tr>
<tr>
<td>Protein</td>
<td>11.3g</td>
<td>11.6g</td>
<td>18.5-24.5</td>
<td>20.2-25.7</td>
<td>20.7-26.4</td>
</tr>
<tr>
<td>Thiamin</td>
<td>0.26mg</td>
<td>0.17mg</td>
<td>1.0-1.55mg</td>
<td>17.7-26.5</td>
<td>11.3-17.0</td>
</tr>
<tr>
<td>Riboflavin</td>
<td>0.10mg</td>
<td>0.06mg</td>
<td>1.2-1.7mg</td>
<td>5.9-8.3</td>
<td>3.5-5.0</td>
</tr>
<tr>
<td>Nicacin</td>
<td>1.00mg</td>
<td>1.40mg</td>
<td>13-19mg</td>
<td>5.3-7.7</td>
<td>7.4-10.8</td>
</tr>
<tr>
<td>Calcium</td>
<td>51.5mg</td>
<td>105.4mg</td>
<td>6.4</td>
<td>60.7-100%</td>
<td>13.2</td>
</tr>
<tr>
<td>Iron</td>
<td>2.9mg</td>
<td>3.3mg</td>
<td>10-18mg</td>
<td>15.8-28.5</td>
<td>18.3-33.0</td>
</tr>
</tbody>
</table>

2 Healthy adults (not pregnant or lactating) who are 19 years of age or older.
3 Source: Duke, 1981.

protein is readily available when several antinutritional factors are absent or when proper preparation and cooking practices have rendered them ineffectual. Although common levels of protease inhibitors and extremely high lectin contents are found among tepary samples, they have been shown to be heat sensitive. Inhibitory effects of these molecules upon protein digestion of tepary diets will only be manifested if consumed by cultures with inadequate cooking fuel supplies.

Grain legumes are not good sources of vegetable oil, a characteristic which is also inherent in tepary beans.

Starch which is present in all grain legumes provides the bulk of needed dietary calories. Tepary beans are similar in carbohydrate content to other grain legumes and when consumed in equal amounts, provide a similar portion of the daily energy requirement. Although tepary starch digestibility is poor in its raw state, normal cooking procedures render this material readily digestible. Flatulent sugars present in teparies and other legumes detract from the value of these commodities as food sources, but with proper handling and processing, their effects can be minimized.

The average grain legume depicted in Table 15 is a good source of thiamin and a relatively poor source of both riboflavin and niacin. The average tepary contains less thiamin and riboflavin, but more niacin than the hypothetical average pulse.

The calcium content of the tepary sample supplied over twice as much of the daily dietary requirement of this mineral than did the average grain legume, whereas contributions of needed iron from either pulse source were comparable. High phytin contents associated with beans may limit the availability of both protein and minerals.

Nutritional Significance of Tepary Consumption

Information currently available on the nutritional aspects of tepary beans is based on analytical results from single or limited seed stocks. The volume of analyses needed to delineate inherent differences in nutritional quality among tepary races or varieties, or to adequately compare the nutritional quality of teparys to that of other legumes has yet to be completed. Environmental effects of cropping techniques, harvest and storage conditions as well as preparation and cooking methods upon nutritional quality are unknown or poorly understood.

Nevertheless, an overall view of the known nutritional attributes of tepary beans results in acknowledgement of the similarities of this legume with common beans and other grain legumes consumed worldwide. Perhaps the true significance of tepary beans lies not within the context of "superior" nutritional quality, but rather in its ability to produce a seed crop under conditions which cause more commonly grown legumes to fail.

In an agriculturally rich and well developed country such as the USA, where a reliance upon local food production is unnecessary for survival, the nutritional significance of a decline in tepary use may be difficult to assess accurately. However, if teparies were to be introduced into lesser developed areas of the world suitable to their culture, their nutritional significance may possibly be measured by the difference between adequate legume procurement or crop failure.

Introduction of Tepary Beans to Other Arid/Semi-arid Environments

Arid lands such as those of the Sonoran desert of North America are well suited to the production of tepary beans. The main adaptive advantage of this legume is that of drought avoidance through early maturation of a seed crop (60-70 days). This physiological phenomenon together with traditional Indian floodwater farming techniques allowed indigenous peoples to produce tepary crops most seasons without the aid of ground-water or conventional irrigation.

What then can be said about the suitability of teparies for use in other arid lands where subsistence agricultural systems may be vital to the survival of the resident populations? The National Academy of Sciences (1979) recommends the species' introduction to areas in Africa, South America, Asia, the Middle East and arid Pacific and Caribbean islands. In addition to use as a subsistence crop, teparies may also hold promise as a valuable commodity produced in arid areas of well developed nations such as Australia and the United States.

Little published information is available concerning attempts to introduce teparies to other areas potentially suited to their culture. However, these beans have been introduced in several areas on the African continent.
either tepary beans or the traditional pulse (cowpeas or broad beans), they either preferred the food product containing teparies or had no preference for foods containing either pulse source.

As stated earlier, introduction of tepary beans into fuel-poor areas may precipitate potential nutritional hazards as these beans require a somewhat lengthy cooking time to counteract several antinutritional factors. Detailed experimentation to quantify protease inhibitors and lectins in raw and cooked tepary food samples and to explore the relationship between cooking time and the destruction of these nutritional antagonists are currently underway.

If the nutritional significance of this species lies in its ability to provide a needed food source where growth of similar legumes might fail, then the decline in tepary production and use by southwestern Indian groups may be potentially detrimental to the nutritional status of many arid land dwellers. Tepary introduction to cultures which are more dependent upon subsistence techniques might be greatly facilitated by the availability of diverse germ plasm sources. However, the decline or abandonment of floodwater agriculture in the Southwest has resulted in the loss of familial seed stocks through decreased seed viability [Nabhan et al., 1980], and thus, a loss of potential adaptability to areas where this species might serve as a major source of nutrition.

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Gene Transfer
Between Tepary and
Common Beans

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Introduction
Successful crop production in desert regions requires adequate supplies of irrigation water. Vast amounts of capital, energy, and labor must be committed to fulfill the water requirements of most crops. Whereas technological advances have better enabled water conservation during its conveyance and application, limited success has been achieved in improving plant drought tolerance. Improved drought tolerance of crop plants could result in a diminished consumptive demand for irrigation water. Many of the putative individual traits thought to be capable of imparting drought tolerance to crop plants have not been proven to be causally related to improved field performance. Possibly, by first investigating the regulation of water usage by related species that are indigenous to desert environments, one can ascertain the characters necessary for the survival of cultivated plants under low moisture conditions. It may then be possible to transfer beneficial characters from the xerophytic species to the commercial crop species which are not now adapted to arid environments.

The desert adapted tepary bean (P. acutifolius) and the drought susceptible common bean (P. vulgaris) offer a prospective system with which to make such a transfer. Common beans are an important dietary constituent of many people, and they have long been the subject of considerable research by plant scientists. Their adaptation to desert regions is quite poor however (Freeman, 1918; Thomas et al., 1983). Though not cultivated extensively today, tepary beans offer great potential for the improvement of P. vulgaris (Thomas et al., 1983). If tepary and common beans were easily cross-compatible, a combination of characters might be brought together capable of completely transforming the biological efficiency of common beans in arid regions. Unfortunately, a substantial degree of reproductive affinity does not exist among the species within the genus Phaseolus (Smartt, 1979). Rather, great effort must be expended to overcome the reproductive barriers that restrict gene-flow between them (Smartt, 1979; 1981). This situation is in contrast with the cereals, wherein several major crop species have been improved by the use of their extensive secondary gene pools (Harlan and de Wet, 1971; Feldman and Sears, 1981).

The classification of Harland and de Wet (1971) assigns related races or species to either the primary, secondary or tertiary gene pools of a crop species on the basis of reproductive affinity. Races or "species" which hybridize freely with the domesticated race belong to its primary gene pool. Species within the secondary gene pool are those which will cross with the crop species, but only after sometimes formidable interspecific barriers are overcome. Hybrids produced from such crosses are generally weak or sterile and the recovery of desirable types in advanced generations may be difficult (Harlan and de Wet, 1971). The tertiary gene pool involves even greater barriers to hybridization. Species contained within a tertiary gene pool often display either lethal or completely sterile hybrids when crossed with the cultivated species. More drastic measures such as embryo culture, grafting, doubling of the chromosomes, or the use of "bridging" species [species with greater affinity to the parents than they have with each other] to secure an interspecific hybrid are required (Harlan and de Wet, 1971).

Whereas a partial examination of the gene pools of P. vulgaris has been made (Smartt, 1981), a comprehensive description is not yet available. This is understandable since there are many related species within the genus Phaseolus (Marechal, 1978). However, it is clear that of the other domesticated species in that genus, P. cocineus (runner bean), P. lunatus (lima bean) and P. acutifolius (tepary bean), only P. cocineus is clearly a member of the secondary gene pool of P. vulgaris (Al Yasiri and Coyne, 1966; Smartt, 1981).

Although tepary beans, both domesticated and wild, are in the same subgeneric group as the common bean (Buhrow, 1983), difficulties in hybridizing the tepary bean with the common bean suggest that these species rarely fulfill any criteria warranting their inclusion in the secondary gene pool. As data presented below will indicate, P. acutifolius should be assigned to the tertiary gene pool of P. vulgaris.

The desirability of transferring certain characters of tepary bean to the common bean, such as drought tolerance, high temperature toler-

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Figure 1. An interspecific hybrid ['Masterpiece' x P. 440 x P. acutifolius 'MBAC'] showing the phenotype similar to that of the 'cripple' disorder. The initial cross was performed on March 13, 1931. Three embryos were excised and cultured 21 days after pollination and only one produced a viable plant. This hybrid flowered poorly and after 23 attempts to backcross it, during a five month period, it remained completely sterile.

ance, and pest and disease resistance, have been discussed by several authors (Mok et al., 1978; Waines, 1978; CIAT, 1979; Thomas and Waines, 1980; Prendota et al., 1982; Thomas et al., 1983). However, since tepary bean belongs to the tertiary gene pool, conveyance of such traits to P. vulgaris is indeed a tenuous proposition. In addition, the heritability of such traits as heat and drought tolerance is not known. It is likely that these traits are controlled by the interaction of many genes. The recent reports of fertile backcross lines, derived from P. vulgaris x P. acutifolius (and reciprocal) hybrids, are certainly encouraging (Thomas and Waines, 1982; Pratt et al., 1983). The recovery, however, of fertile backcross lines (P. vulgaris as recurrent parent) displaying desirable tepary characters as well, remains to be demonstrated convincingly.

As stated by Smartt (1979a), interspecific hybridization "is an enterprise beset with pitfalls." To help avoid these pitfalls, a review of research findings from many investigators, a discussion of how reproductive isolating barriers are essential to speciation, and how certain of these barriers prevent gene transfer between tepary and common beans are presented here. Strategies for successful gene transfer between tepary and common beans will be presented which hopefully will provide greater insight toward the achievement of an ultimate goal, that goal being the combination of desirable characters from an important world crop [the common bean], with those of the tepary bean, which is remarkably adapted to desert environments (Freeman, 1918; Nabhan and Feiger, 1978).

Speciation and Genetic Isolation
The process of speciation occurs as populations follow separate lines of descent from a common ancestral population. In a given environment, new characters of adaptive value gradually become fixed. During this evolutionary process, divergent populations wherein such genetic changes are being incorporated may eventually achieve subspecies status. Genetic continuity among such subspecies, and with the original population from which they have been derived, remains unsevered. However, when sympatric populations become so distinct from one another that reproductive barriers between them come into effect, they are then deemed to have achieved separate species ranking.

Effective reproductive isolating mechanisms include both prezygotic and post-zygotic phenomena. Many prezygotic barriers are of greater importance in nature and can be overcome by the plant breeder (Hadley and Openshaw, 1980). Artificial cross-pollination and fertilization between P. vulgaris and P. acutifolius is performed readily by conventional methods in the greenhouse, as described by Buishand (1956), hence pre-zygotic barriers do not pose a problem. However, there are post-zygotic mechanisms which prevent successful recovery of interspecific common bean x tepary hybrids (Rabakoraihanta et al., 1979; Alvarez et al., 1981).

Post-zygotic isolation barriers can be manifested at any point in the life cycle of the hybrid sporophytic generation from the first mitotic cleavage of the zygote through the generation of functional gametes, and even later on in subsequent generations (Stebbins, 1958).

Of all the barriers to interspecific hybridization, perhaps the most common form of incompatibility is incongruity existing between the genes and chromosomes of the parents, resulting in developmental abnormalities (Stebbins, 1977). The genes within interspecific embryo or endosperm tissue, which are not fully compatible, must direct the complex molecular events responsible for normal development and
functioning of the hybrid embryo. Embryos which are the result of *P. vulgaris* x *P. acutifolius* crosses develop abnormally, due partially perhaps to the insufficient production of cytokinins [Nesling and Morris, 1975].

### Interspecific Hybridization between Common and Tepary Beans

The breakdown and subsequent abortion of ovules in this cross generally occurs between 5 to 26 days after pollination [Al Yasiri and Coyne, 1964; Mok et al., 1978]. The greatest degree of abortion is evident approximately 14 to 20 days after pollination [Al Yasiri and Coyne, 1964]. While the production of mature seed in situ from this cross is possible [Smartt, 1970; Prendota et al., 1982], investigators usually resort to embryo rescue techniques since a much higher frequency of mature hybrids can be obtained.

Embryos are generally excised 14 to 24 days after pollination and cultured on a medium containing 30 to 40 g/l sucrose along with minerals, salts and vitamins [Honma, 1955; Mok et al., 1978; Alvarez et al., 1981; Pratt et al., 1983]. Numerous studies have indicated that the frequency of mature hybrids can be obtained.

The interspecific hybrids from this cross display substantial phenotypic variability, based on morphological and growth characteristics. The first reported interspecific hybrids [Honma, 1955; 1956] were described as being intermediate between the parents in morphological characters, the plants becoming more like the *P. vulgaris* parent with time. Floral morphology was described as being similar to *P. vulgaris*. Subsequent reports of interspecific hybrids have indicated the morphological characters to be either abnormal or intermediate [Smartt, 1970; Alvarez et al., 1981; Prendota et al., 1982; Pratt et al., 1983]. Investigators also have described the floral characters as resembling more nearly the tepary parent [Smartt, 1970; Prendota et al., 1982; Pratt et al., 1983].

Interspecific hybrids from this wide cross display substantial differences in growth. Smartt (1970) reported that *P. vulgaris* x *P. acutifolius* hybrids were more vigorous and persisted longer than the plants from the reciprocal cross. However, the opposite results have been observed [Prendota et al., 1982]. Mok et al. (1978) reported that hybrids, which were obtained through embryo culture, grew vigorously at first but then essentially ceased growing. Honma (1955) described the opposite, stating that the hybrids were weak at first, but that "they appeared to be entirely normal" by the time they were 15 inches high. Prendota et al. (1982) observed two predominant types of hybrids. One was characterized by a "severely unbalanced" and stunted phenotype whereas the second included plants which are much more vigorous and well-balanced, but with the presence of viral like symptoms. The presence of such symptoms as leaf curling and sectoral chlorotic patterns have been frequently reported [Smartt, 1970; Mok et al., 1978; Alvarez et al., 1981; Pratt et al., 1983]. The abnormal plants may resemble those of the "cripple" phenotype derived from certain intraspecific *P. vulgaris* crosses [Coyne, 1965] (Figure 1).

A "limited number of seed" was reported to have been produced by each of the first four putative hybrids between these species [Honma, 1956]. More recent investigations indicate that from a total of scores of putative interspecific hybrids, not one has yielded viable diploid seed. However, the interesting observation has been made that one sterile hybrid produced one seed per pod after an exogenous application of gibberellic acid [Nelson, 1982]. I have observed hybrids which produced a few ovules suitable for in vitro culture; however, the seedlings collapsed not long after transfer to soil [Pratt et al., 1983]. In light of the fact that essentially all putative hybrids from this cross are highly self-sterile, any reports of fertile hybrids should carry with them strong evidence of authenticity.

What accounts for the strong degree of sterility in these interspecific hybrids? If there is little homology between some or many of the chromosomes of the two parental species, successful pairing between all of the chromosomes may occur only very rarely. In the pollen mother cell [PMC] squashes [at metaphase II] thus far examined a mean of 6 to 8.7 bivalents [out of a possible eleven] have been reported [Hwang, 1979; Rabakoarihanta et al., 1980; Prendota et al., 1982]. As many as 10 and even 11 bivalents have been detected, though their frequency is extremely low [less than 6% of the cells examined] [Rabakoarihanta et al., 1980; Prendota et al., 1982]. The substantial variability in effective pairing between the chromosomes could suggest the involvement of genic factors in addition to some degree of chromosomal differentiation between the species. Meiotic phenomena which result in the formation of laggards and uneven chromosomal migration to the poles, observed in common bean x tepary (and reciprocal) hybrids [Rabakoarihanta et al., 1980; Prendota et al., 1982] can result in the development of abnormal daughter cells, and hence inviable gametes (Figure 2). Combined with the poor survival of dividing embryos [Rabakoarihanta et al., 1980; Prendota et al., 1982], these factors could result in the high degree of sterility displayed by the hybrids. This sterility presents a serious obstacle to the prospective transfer of useful characters from *P. acutifolius* to *P. vulgaris*.
Figure 2. A PMC squash at late anaphase I obtained from the interspecific hybrid [Masterpiece' × F2 (P.1.440 -790 x P. a. var. acutifolius 'MBAC')]. Note the presence of several laggards which are unlikely to reach the poles.

**Strategies for Successful Gene Transfer**

If a greater number of hybrids could be produced more readily, then the probability of obtaining more fertile genotypes would be enhanced. Sufficient research has now been performed with the common bean x tepary (and reciprocal) cross, that breeders can at least utilize parental accessions with the demonstrated ability to yield viable interspecific hybrids (see Table 1).

It is thought that the wild relatives of the tepary and common bean P. acutifolius var. latifolius and P. vulgaris (var. aborigineus), respectively, were the ancestral progenitors of the present cultivated varieties [Kaplan, 1965; Evans, 1976; Nabhan, 1978]. If these species diverged from common ancestral populations in Central America, then, according to the concept of biological speciation, it may be valid to assume that the reproductive barriers between these wild species are less severe than those existing between their more diverged domesticated counterparts.

Gentry (1969) has posed the question whether or not the use of such wild, related species and varieties would enhance the probability of success for interspecific hybridization within the genus *Phaseolus*. Several independent groups have already utilized the wild species in such a manner, with considerable success [Thomas and Waines, 1980; Prendota et al., 1982; Pratt et al., 1983]. The utilization of parents with enhanced "gametic diversity" (heterozygous and/or heterogeneous plants) also is a method of proven value in species crosses in the genus *Phaseolus* [Wall and York, 1959; Remis and Kedar, 1961; Thomas and Waines, 1980; Nelson, 1982; Pratt et al., 1983]. By crossing cultivars and land race accessions with related wild species one can obtain parents with a very high degree of "gametic diversity."

The use of such agents as colchicine to double the chromosome number of interspecific hybrids with the hope of improving fertility in subsequent backcross generations is also under investigation [Prendota et al., 1982; Thomas et al., 1983]. Prendota et al. (1982) have doubled the chromosome complements of eight P. acutifolius x P. vulgaris hybrids. From the completely sterile hybrids, colchicine induced tetraploids were obtained which set several mature seeds. While the potential for obtaining useful lines directly from such plants is doubtful, multivalent pairing in the allotetraploid has been observed [Prendota et al., 1982]. The formation of such multivalents indicates that some degree of heterogenic exchanges may have occurred. This implies that as backcrossing is initiated with *P. vulgaris* (as the recurrent parent) the sterile triploid will contain some tepary genes. The crossover events, due to the previous intergenomal pairing within an individual allotetraploid, are unlikely to produce sufficient variability for the recovery of desirable multigenic tepary characters in the subsequent backcross progeny. However, such restricted crossing over may increase the probability of transferring 1 or 2 gene traits without the problem of "hybrid breakdown" due to a substantial amount of intergenomic crossing over (Stephens, 1961; Wall, 1970).

Attempts to obtain viable, fertile backcross plants have met with variable success. Smartt (1970) was unable to obtain backcross individuals and Mok et al. [1978], Thomas and Waines [1980] and Pratt et al. [1983] found it expedient to utilize embryo rescue to obtain backcross plants. Rabakoaranta et al. [1980] encountered less difficulty when using the tepary as the backcross parent, whereas Thomas and Waines [1980] and Pratt et al. [1983] were successful in obtaining backcross seed utilizing the common bean as the recurrent (backcross) parent. Backcross individuals display great variability with respect to both vegetative phenotype and degree of fertility [Thomas and Waines, 1982; Pratt et al., 1983].

In addition to the desirable genes contributed by the tepary and its wild relatives, deleterious genes undoubtedly will be present in interspecific hybrids as well. The only possible method to eliminate them is by repeated backcrossing to a recurrent parent followed by selection. While the greatest strength of a backcross program is its ability to transfer one or several specific genes to a recurrent parent, it is possible to transfer quantitatively inherited traits also. Methods for such an
Transfer of multigenic traits between related species using a simple recurrent backcrossing system may be significantly restricted, however (Stephens, 1961). It appears that with interspecific Phaseolus crosses, reduced chiasmata formation (Matecha, 1971) and subsequent crossing over, due to structural or molecular differences between apparently homologous chromosomes will prevent the separation of linked genes. This result would be analogous to the consequences of a reduction in effective chromosome map length as discussed by Hanson (1958). This may make it extremely difficult to transfer all of the desired genes of a complex multigenic character in teparies to common beans without the transfer of undesirable ones (e.g., small seed size) which may be closely linked.

In common bean x tepary crosses (and reciprocal) as many as 3-5 of a total complement of 11 chromosomes in F1 PMC squash preparations frequently have been observed to not pair (Hwang, 1979; Rabakoarihanta et al., 1980; Prendota et al., 1982). Many of the genes conferring desirable agronomic traits may be located on the more non-homologous (homeologous) chromosomes of such crosses, between which crossing-over occurs at a very low frequency, if at all. Hence, the recovery of individuals which have acquired complex multigenic traits from P. acutifolius likely will occur at a very low frequency.

In addition to the problems encountered due to fewer cross-over events in a genome derived from two distinct species, apparently approach (with intraspecific hybrids) are discussed by Bliss (1980).
non-random cross-over events and differential gametic or zygotic elimination may occur which actively excludes the genes contributed by the other species from subsequent generations (Stephens, 1961; Wall, 1970). Recombination apparently has an optimal level in certain crosses. Wall (1970) concluded from studies with P. coccineus that gene transfer is facilitated by mating systems which achieve an optimum balance between enhanced heterospecific genome recombination and those deleterious effects (e.g., duplications and deficiencies) of recombination which result in "hybrid breakdown." To achieve this balance it was recommended that a backcross program include alternate cycles of sib-mating (Wall, 1970).

This author's attempts at sib-mating among BC1 (Back Cross) plants derived through the interspecific hybridization of P. vulgaris x P. acutifolius have not been encouraging. Only weak individuals have been obtained to date. Significant variability exists among the BC2 populations. It is with these populations (as large as possible) that sib-mating, followed by several generations of selfing, could perhaps result in the necessary diversity of phenotypes from which to select individuals with desirable metrical characteristics, e.g., drought tolerance, derived from the tepary parent. Crossing BC1 with BC2 plants also might aid in increasing the frequency of individuals with desirable genotypes if substantial elimination of P. acutifolius genes has occurred by the BC2 generation. The problem of restoring fertility without loss of sufficient tepary genes to produce individuals with desirable tepary characters will present a formidable challenge, though not an insurmountable one (Figures 3 and 4).

Authentication of Interspecific Hybrids

The utilization of diverse tepary and common bean parents presents various problems to the breeder. When grown in temperate environments, or at increasing latitudes, teparies may display irregularities in growth and development (Hendry, 1919) or flowering (Pratt and Erickson, 1982). The phenotype of tepary accessions may be highly variable due to environmental parameters or substantial heterogeneity within particular accessions. Hence, the use of morphological markers alone is insufficient evidence of hybridity. Smartt (1979a) discusses the difficulties involved when attempting to interpret primary leaf morphology as evidence of interspecific hybridization. The variable inheritance of this marker makes its use questionable (Figure 5). However, the lanceolate leaf character of wild P. acutifolius var. acutifolius has some potential for use as a marker in common bean x tepary crosses (Pratt et al., 1983). Other promising markers are those of flower bracteol size, shape and color, and flower size and color, but all require further investigation.

Of course sterility is a good indicator that a wide cross has been made, however it is not a foolproof one. "Apparent sterility" of selfs may be due to a strong photoperiod requirement, abnormalities such as the "cripple" disorder, or perhaps to the expression of recessive male sterility. Smartt (1979a) pointed out that it is essential to compare putative hybrids with parental progeny (especially when utilizing intraspecific hybrids), rather than with the actual parents themselves.

When putative hybrids appear to be partially fertile, a cytological or biochemical examination is recommended. The frequency of pollen

Figure 5. A BC3 plant showing truncate primary leaves (a tepary character) with a long petiole (a common bean character). Above that leaf, a primary leaf from the recurrent parent P. vulgaris 'Sanilac' which displays the cordate morphology. This phenotype was not observed in the BC1 or BC2 generations yet appeared in the BC3 generation.
mother cell displaying chromosomal abnormalities such as a lack of
pairing at metaphase I, the presence of laggards at anaphase I, and
the appearance of micronuclei in tetrads are far stronger evidence
of hybridity than are morphological characters or "intuition." A word
of caution is also necessary regarding the interpretation of cytological
preparations. Marechal [1971] showed very clearly that asynchronous
chromosomal migration during anaphase I and II in PMC figures can
be attributed to environmental causes. An examination of other cyto-
logical work performed with Phaseolus also demonstrates that the
presence of univalents in metaphase I and anaphase I and II PMC
figures can occur in the parental species, likely due to environmental
causes [Sarbhoy, 1978; Sinha and Roy, 1979]. Hence, as evidence of
hybridity, the examiner should provide data showing the frequency of
such meiotic abnormalities in comparison with those of the parental
species. Biochemical markers, such as Fraction I protein and isozyme
banding patterns have not yet been utilized in evaluating this cross
and should be invaluable to the breeder.

Conclusion
The barriers which once prevented successful interspecific hybridiz-
tion between P. vulgaris and P. acutifolius are no longer insur-
mountable. Gene transfer between these species has now reached a
second phase. The most productive avenue by which to fix desirable
tepary characters in an acceptable common bean background is now
being studied by several investigators. With the transfer of specific
tepary characters to the common bean accomplished, researchers may
then be able to ascertain the most valuable traits necessary for the
improved drought tolerance or water use efficiency of common beans
in desert environments. More heat tolerant, pest and disease resistant
lines may also be produced from tepary x common bean and reciproc-
call crosses. Then perhaps, as suggested by Gentry [1969], modern
plant scientists can start "returning the favor" to the native inhab-
tants of North America whose ancestors originally domesticated these
valuable food crops.

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Painting of a tepary bean field by Leonard Chana, a young Papago artist living at Sells, Arizona. In this scene of a traditional floodwater field, one can see the bean crop in front of maize, and weeds (canyon ragweed, grass). In the foreground are the family's seedstocks in various containers (white tepary beans in the jar; brown teparies in the devil's claw-decorated basket). To the left is a woman threshing beans on a tarp, and in the foreground round-tailed ground squirrels which the Papago call "desert prairie dogs." In the left background is a small wash or ditch with brush weirs diverting floodwaters toward the field.

Growing Teparies in the Desert. Tepary beans have been grown as a crop in the Sonoran Desert for as long as the indigenous O'odham people can remember. Indeed, the repeated discovery of tepary beans in prehistoric ruins and caves leaves little doubt that man's utilization of this food plant is of great antiquity. Teparies are not a mere cultivar of the common bean (Phaseolus vulgaris), but rather represent a distinct species adapted to hot desert conditions, Phaseolus acutifolius. Both wild and cultivated forms of the species are proper residents of the hot country of southern Arizona and adjacent Mexico.

Wild Phaseolus acutifolius is essentially a summer-ephemeral adapted to germinate only if and when heavy thunderstorms occur. As with other desert ephemerals, there has been selection in the wild for long-term seed viability to cope with the likelihood of a series of drought years. This attribute seems to carry over to the cultivated forms and has allowed the O'odham to store viable seed through long drought cycles. Another attribute of desert ephemerals is an extremely rapid life-cycle. Teparies must germinate, grow, photosynthesize and mature a crop of seeds in response to brief seasonal rain. They will be dead and dry within weeks of having germinated.

The thunderstorm agriculture of the O'odham carries the summer-ephemeral phenomenon to its logical extreme by enhancing, controlling and modifying it for production of food. It is indeed fascinating that a chief summer-ephemeral cultivar of the O'odham is a cultivated form of the endemic wild summer-ephemeral Phaseolus acutifolius!

Scientists are now beginning to catalog the physiologic and morphologic features of the tepary which make it such a successful crop in the desert. Like many other desert plants, the tepary has a root which extends to water at great depth. This allows it to survive while common beans (Phaseolus vulgaris, adapted to other ecological conditions) would die as the top layers of soil become desiccated soon after a rainfall. Modern-day farmers are fascinated by yet another desert adaptation of the tepary: extra irrigation produces extremely leafy plants often with few beans, but holding water back causes plants to set and mature a heavy crop of beans! With increasing costs of pumping water in central and southern Arizona, and with falling water-tables, a crop which reacts positively to the thunderstorm season and responds well when under-irrigated could seem like a dream come true. But a considerable amount of research and development lies ahead. The present issue of Desert Plants reports initial success with hybridizing tepary and common beans, but can only point to the possibility of producing a breakthrough in the form of a desert-adapted hybrid major commercial cultivar which, although grown in the desert, could find a market elsewhere. This Desert Plants issue also touches on the need for improving techniques for inoculating and enhancing nitrogen fixation in desert legumes, an approach which would improve production of not only teparies but other potential crops.