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Essays

Underexploited Tropical Plants with Promising Economic Value: The Last 30 Years

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Based on a keynote address at the conference *Underutilized Plants: Their Role in Preventive Medicine, Nutrition, and Sustainability* May 2, 2006 at the Center for a Livable Future, Johns Hopkins Bloomberg School of Public Health, Johns Hopkins University, Baltimore, Maryland, USA

When considering how to cast this talk, I first settled on giving an overview of the plant kingdom's species and highlighting how few are actually used intensively. This seemed most appropriate for a lecture at this great university. Then I had a second thought: To hell with all that! I'll merely relate some stories about my life as a "Crop Champion."

This being the School of Public Health, I'm supposing many of you will eventually find yourself working in faraway regions. And there you're going to notice strange plants and weird-looking foods like the ones I spent my career getting to know and love. So I thought that if I provided some personal insights maybe one particular snippet might remain in your memory. And then at that future time in some far-flung market, maybe you too will get inspired to become a Crop Champion.

As background, you ought to know that the plant kingdom has many jewels, and most have yet to be polished and put to proper use. A Crop Champion is the person who gives them enough gloss to attract professional attention and spark their march into the fullness of their promise.

Also, you ought to know that there is no school for Crop Champions. The development of underexploited crops is not a scientific discipline and thus by default remains open to amateurs. I was an amateur, having been trained as an organic chemist; the people who will speak after me are also basically amateurs. So you have as much chance to advance a forgotten crop as any of us. Don't feel intimidated by the task: specific details about a plant can be picked up quite easily. And what its advancement requires is mostly a matter of common sense. Championing a species, however, takes drive, vision, and guts. Anyone attempting it must be prepared to face setbacks and sometimes take a beating from critics and worry warts. But in the long run, a successful Crop Champion makes the future more livable.

Solutions where the problems are

Thomas Jefferson once declared that the greatest thing a person can do for their country is to provide one new crop. In this era of globalization we can expand his vision and say that the greatest thing a person can do FOR THE WORLD is to provide one new crop.

You see, new-crop development will become increasingly significant in the years just ahead. Even now we can barely feed the current six billion people equitably; so what will happen when several billion more are added during the lifetime of most of the students in this room?

Adding to my fervor is the fact that the most urgent public health problems exist where the greatest diversity of plants happens to occur. There is thus a natural connection between the nations needing the most help and the plants that have the most to offer. Despite their obscurity and often funny names, these under-producing plants can carry great promise. That's why more Crop Champions are needed. By drawing attention to the species' untapped powers they help solve humanitarian or environmental problems in a novel and natural manner. They add, moreover, a dimension conventional thinkers will never come up with.

Crop Champions might be scientists, economists, ethnographers, public health specialists, Peace Corps volunteers, geographers or none of the above. Essentially they are publicists, guidance counselors, lobbyists and nags for the world's downtrodden plants—species that are useful but underused.

Discovering jojoba

I got into this strange business entirely by coincidence. At the time I was a well-behaved organic chemist doing graduate research at the University of California with

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the aim of making a career as a chemistry professor. Then one day in 1965 I took a passing interest in the components in different pine resins. My professor mentioned that the geography department had a specialist who knew a lot about pines, so I made an appointment and went to see N. T. Mirov.

That afternoon we spent perhaps an hour talking, and Dr. Mirov offered me resin samples from the 90 pine species he had growing near Placerville. At five o'clock I thanked him for his help and was literally halfway out the door when he said, "Oh, just a minute." Then from his desk he pulled an old-fashioned aspirin bottle full of yellowish liquid. And beside it on the desk he placed a piece of white solid as well as a few seeds that looked like olives far past their "use by" date. Finally, he proceeded to introduce me to the plant called jojoba (pronounced ho-HO-bah) and to the oil and wax its seeds supply.

During this brief overtime discussion, maybe 10 minutes, he provided a copy of a paper he'd written in 1953. Although it laid out the plant's untapped potential, nothing much had happened in the twelve intervening years. He also told me that when the paper first appeared, he'd received a telephone call from a Shell Oil scientist who said, "Send me a tank car of that oil. Doesn't matter what it costs. Just send enough to fill a tank car." Well, I doubt Dr. Mirov had ever seen much more jojoba oil than was in his aspirin bottle. Thus there'd been a fault line between what a learned academic could provide and what big business needed for formulating new products. Understandably, nothing eventuated.

A whale of an oil

The next Saturday I tracked down the biology library and spent a memorable weekend reading about jojoba (*Simmondsia chinensis*). I learned that this shrub was native to the Sonoran Desert of northern Mexico and southern Arizona. It had long contributed to Native-American life and could be found growing on some tribal lands.

The seeds were rich in an oil that had no triglycerides, no diglycerides, no monoglycerides—no glycerin whatsoever. Instead, this very unusual lipid is made up of long chain acids esterified to long chain alcohols. Chemists call that a liquid wax and jojoba is the only plant to produce it, at least in quantity.

I learned also that one species in the animal kingdom produced it in quantity. That was the sperm whale, and at that time, the mid-sixties, whalers were killing one every 29 minutes. The meat being inedible, whalers sought only the oil, which was such a great lubricant that most vehicles on earth had a little in the mix making up the transmission fluid. The U.S. had actually designated sperm oil a strategic commodity, and future supplies were in doubt because the anti-whaling movement was getting underway. In 1965 this was of acute concern because spacecraft depended on sperm oil, and the great national cause was to land men on the moon by 1970.

Imagine me at that moment: a young graduate student, one whose formal studies were so esoteric as to be of little value to anyone, stumbling over a plant that might save the deserts, save the Indians, AND save the whales? That was why the weekend proved memorable. Subsequently, I wrote searching letters to botanists and others working in the Southwestern deserts, but was unable to find anyone actively developing or even studying the plant.

Late in 1968, when I moved to Stanford as a post-doctoral student, I mentioned jojoba to my new professor. Carl Djerassi was a great chemist who created the compound in the modern birth control pill as well as many more materials that remain in common use. As much of his research had been done in Mexico, he'd acquired a lively interest in Latin America, not to mention Africa and Asia. Through that extracurricular interest, he'd been appointed to a National Academy of Sciences board that was attempting to raise the quality of science in developing countries. Because of my interest in jojoba, he suggested I go to Washington DC and work for this board, which was just getting established and was hiring staff. To shorten a very long story, I took up his suggestion in 1970 and, along with my family, left the Golden State and headed east.

The NAS group's formal title was Board on Science and Technology for International Development (BOSTID). Its chairman, Roger Revelle, was the sage to whom Al Gore later attributed his awakening to the importance of the environment. Roger was a farsighted polymath whose interests stretched even to the consequences of the rising levels of atmospheric carbon dioxide, the significance of which the public in those days had no clue.

More to the point, though, Roger possessed the strange belief that although developing countries faced many problems, somewhere in the sciences or the world many solutions could be found. What was missing was the means to bring those solutions to the problems. I was hired to be that means.

The fact that no one knew how to define my task proved most fortunate, because the lack of a formal job description allowed me to work on anything, so long as it might solve a developing country problem and was innovative and underappreciated. In other words, I could go searching across the sciences and across the globe for fascinating far-out possibilities that were languishing for lack of leadership.

Jojoba gets going

During my first weeks on the job I happened to mention my jojoba story to a colleague. He suggested I talk to a Cherokee friend who worked in the Office of Economic Opportunity. This was President Johnson's so-called "Great Society Program" and even in the Nixon era it remained great.

The Cherokee, Bill Miller, was a stunner. He'd won the Silver Medal in the javelin throw in the Olympic Games in 1952 in Helsinki. I'm told he was the second Native American to medal at the Olympics. And like Jim Thorpe before him, he was a man of spirit. When I explained that a plant growing on southern Arizona reservations might provide the local tribes an economic base he was elated.

That enthusiasm was somewhat scary because all I knew about jojoba was what I'd gleaned from Dr. Mirov and the meager literature. I explained my fear that

deep down there must be some problem, because this was the great United States that annually spent billions on research. How could so potentially valuable a resource, one capable of providing a strategic material, exist within our own borders and remain ignored?

Bill seemed unfazed, and he and I spent a few days in Arizona checking things out. At a small botanic gardens in the hills north of Phoenix, we met with a dozen or so locals representing almost the entirety of individuals who sensed jojoba's possibilities. We pressed them about potential problems: "What's wrong? What's wrong?" we asked over and over. There were no obvious indictments, no major technical barriers that would doom any future for jojoba as a crop.

None of this was part of my formal career, just a *pro bono* contribution. Bill's program, however, had a pot of federal dollars to help Native Americans and he was anxious to move ahead. Still and all, I feared there must be a flaw hiding itself from the amateurs; surely a corporation or an entrepreneur would have otherwise led the way long before.

To resolve all doubts, Bill sponsored a jojoba conference. I believe it was 1972 by this time, and at that large gathering on the Tucson campus of the University of Arizona a raft of uncertainties arose: How do you plant the crop? How do you manage a plantation for the best production? Although some specimens are more productive than others, how should they be propagated? And how could the seeds be harvested?

Managing the sexes was a special concern. Half of jojoba's seeds grow into male plants, which produce no oil and are essentially worthless. Was it possible to separate those seeds so the planting could be made overwhelmingly female from the get-go?

As it turned out, no one had definitive answers to these questions. Thus we were faced with basically domesticating a wild species from scratch. On the other hand, the array of practical, technical and economic problems were ones that had been solved for many other crops. Why not jojoba?

A few days after our return to Washington, Bill called and asked if he could come by. He plunked himself down on a chair in my tiny office on Pennsylvania Avenue and blurted out, "Well, what the hell do we do now?" I hadn't given that question any thought, but there came a flash of insight, and I said, "Let's get a tank car of oil!"

In the upshot, Great Society funds were used for the next several years to pay Arizona tribes to harvest the jojoba growing wild on their lands. Primarily, this involved the San Carlos Apache, whose reservation is just north of Phoenix. After a huge heap of jojoba seeds were on hand, the U.S. Department of Agriculture stepped in and offered help. Members of the tribe drove truckloads of seed to Berkeley, California, where USDA researchers provided them equipment to separate the oil and clean it up.

In this manner, Bill Miller, the San Carlos Apaches and the USDA obtained what amounted to a tank car of jojoba oil. Then all the drums containing the unique liquid were trucked to Tucson and made available without charge to anyone who could make a case for it. To get a sample you wrote to the Office of Arid Land Studies at the University of Arizona, and, if you were convincing, they'd send anything from a little bottle to a full 55 gallon drum.

This may perhaps seem wasteful, but we were aiming to ascertain the demand end, figuring that if the oil proved useful the production end would take care of itself. Also, I still wasn't entirely convinced we wouldn't suddenly stumble into that damnable fatal flaw.

I needn't have worried. As a result of the oil giveaway, all sorts of scientists, entrepreneurs and corporations discovered valuable uses. To mention just one: Mobil found the oil such a high grade lubricant that the company didn't wait for the plantations and created its own synthetic copy. At least, that's what one of its engineers told me a few years back. This top-of-the-line engine oil, Mobil One, remains on the market to this very day.

More typically, the scientists, entrepreneurs and companies wrote back saying that the oil was very desirable. Most said they'd use it as long as the supply was guaranteed and the price reasonable. Given these assurances, they said, they'd reformulate their products. One company, Shiseido of Japan, began incorporating jojoba into its cosmetics even without such assurances.

The backdoor approach featuring a tank car of oil did indeed open the front door to production. It worked so well, in fact, that we soon had to endure the go-go era when jojoba turned into a "wonder plant." All sorts of speculators, from the committed to the crooked, pushed the crop. Many bought cheap desert land in Arizona and California, planted jojoba seed, and sold shares to investors. The outcome was unhappy, because the technical uncertainties remained unresolved and there were no reliable ways to get rid of the male plants, manage the plantations and harvest the seeds. Most of those premature plantings fell on hard times and, sadly, many innocents lost their investment.

But an industry had begun. And around that time horticulturists took up the production problems and, in time, solved them. A few made absolutely brilliant advances. Israeli scientists, for instance, made major advances in taming this wild desert dweller and creating a crop for the Negev Desert. An American, Ron Kadish, and horticulture professors in California and Arizona also made advances by selecting stellar lines that had hundreds of seeds lined up side-by-side along branches that on typical plants carried only a handful.

Today, the jojoba industry is established in Arizona, Mexico, Israel and Australia. And the plantations are increasing in productivity. Almost certainly people in this room are wearing cosmetics containing jojoba oil. Shampoos with it are likely to be the choice of certain audience members too.

This first experience with an underexploited plant taught me a basic lesson: it really was possible that no one had cottoned on to the potential of a prospective crop that was, so to speak, right under their noses. Despite annual expenditures of billions of research dollars, this potent resource was going nowhere without a Crop Champion.

I'll end this opening section with four pictures:

Figure 1: Jojoba samples much like those Dr. Mirov placed on his desk in 1965. Here you see the seeds that seem to have passed their "use-by" date. Here also is the oil in an aspirin bottle. Here, too, is the white solid, which in reality is the hydrogenated product. (Jojoba oil is mono-unsaturated, but when hydrogenated, it forms this crystalline wax rather than the margarine-like spreads produced by standard vegetable oils.)

Figure 2: Bill Miller, the Cherokee who really was *the* financial force behind this crop's development. I doubt anybody in the jojoba business today remembers him or knows anything of his contribution, but he was the pivotal character who got the money that paid for the tank car of oil that in turn kicked off all that eventuated.

Figure 3: One of the first jojoba plantations. This one was near Yuma, Arizona, and I recall our excitement at seeing it. Previously, we'd been dealing in abstract visions, hopes, and dreams; now here was plantation production in hard reality.

Figure 4: Just one of the stellar advances that arose once horticulturists began investigating jojoba. This branch with seeds every inch illustrates the tremendous productivity of the rare specimens that horticulturists ultimately discovered and propagated.

Promising plants of the tropics

I've already noted that this jojoba work wasn't part of my formal mandate; the National Academy of Sciences was paying me to help truly needy nations. However, as the jojoba developments started taking root, I began wondering whether my mandated countries in Africa, Asia and Latin America might also have promising natural resources that were being ignored. Among those tropical continents' myriad plant species could there be botanical jewels with jojoba-like potential?

Following this line of questioning, I wrote to perhaps a dozen economic botanists. I hardly expected a response, but, wow, you should have seen the flood of mail that poured back in. Those dozen or so specialists collectively nominated more than 100 species they thought were latent resources of the future.

Thus, in 1974 the NAS appointed a panel to identify the very best candidates for helping developing countries. The 20-member panel was co-chaired by Richard Evans Schultes, head of the botanic museum at Harvard, and Eddie Ayensu, head of botany at the Smithsonian Institution. We all met together for several days in the Virginia countryside and whittled the nominated species down to 36 that seemed to hold the highest potential. These winners were made public in *Underexploited Tropical Plants with Promising Economic Value*, a 188-page compendium in which the promise and development needs of each species was sketched out in just four or five pages. Those illustrated vignettes may have been short on specifics, but they proved long on inspiration. Perhaps you'll

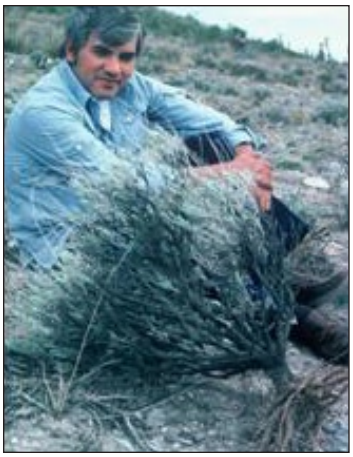

Figure 5: Guayule (*Parthenium argentatum*), a source of natural rubber

hear more about some of the fallout from the later speakers, but here I'll mention a couple of follow-ups I was involved in: guayule and winged bean.

Guayule: natural rubber from our own backyard

Like jojoba, guayule (*Parthenium argentatum*) happens to be an arid-land species from the Southwest. It is, however, native to the Chihuahuan Desert of Mexico and extends up into a smidgen of west Texas. Figure 5 shows the plant. A nondescript shrub, this one looks vaguely like scraggly sagebrush. But it contains a surprising raw material: natural rubber.

Guayule (usually pronounced why-OO-lee), was also part of the Native American culture. The Aztecs used its rubber to make balls for a game remarkably like modern basketball.

A desert plant that produced rubber had seemed so far-out that once the underexploited-plants compendium was published, I'd paid guayule little heed. But my attitude changed when, a couple of years later, an Israeli who'd been on the panel dropped by my office. "I've just come from Mexico," Joel Schechter said, "and I found that a group of young engineers have worked out how to process guayule and get the rubber out on an industrial scale."

Joel's excitement was contagious and in time I got to launch a formal guayule investigation. The funds came in part through Bill Miller, who was still in Washington but had transferred to the Bureau of Indian Affairs. In this case, our mission was not unprecedented. Back in the 1940s a huge federal program had all but domesticated guayule. During those war years, America was cut off from the rubber-producing nations in Southeast Asia and faced a crisis. After 1942 rubber was withdrawn from sale to consumers. New tires went only to the military, and a 30-mph nationwide speed limit was imposed primarily to help people conserve their old tires.

Given those strictures, guayule was seen as vital to vanquishing the Axis Powers, and 30,000 acres eventually got planted in Central California. The campaign happened to be filled with high drama, and one day Bill and I went to the Federal Archives in Suitland, Maryland to see what we could find about it. I distinctly remember the archivist trundling out a trolley laden with boxes of WWII-era documents. Amid that mountain of reports lay a parcel whose paper wrapping was falling apart. Inside was a big black block of rubber that had been isolated in 1944. The parcel must have weighed 50lbs and the 30-year-old rubber was going a little gooey round the edges. Bill later had it sent to Akron, Ohio. There, researchers at the Goodyear Tire and Rubber Company took a coring from the center and put it through the most rigorous modern analysis. Guayule proved to be excellent rubber.

As part of our research I visited Saltillo, the Mexican city where the modern processing was under study. Getting the rubber out is harder than you might think. The liquid latex is held in separate cells and, unlike the rubber tree, cannot be drained by tapping the trunk. Instead, Enrique Campos-Lopez (the young man featured in Figure 5) and his engineer friends had designed and built a facility that mashed the stems and used vats of water to float the rubber away from the sodden vegetable matter. Figure 6 shows the resulting rubber. The operation was impressive to see, and the engineers had scaled everything up to the point where they would soon have enough to make test tires.

Our 80-page book *Guayule: An Alternative Source of Natural Rubber* was published in 1977. It generated considerable follow-up in Texas, Arizona and California. For years the U.S. Department of Agriculture and others continued exploring the plant and its products. In the end, however, the programs petered out.

Although guayule did not rise to become a modern crop, I'm perfectly happy. The rubber tree anchors a super-sustainable production system—one that absorbs atmospheric CO2 and turns it into wood that ultimately becomes furniture and other quality products likely to lock up carbon

Figure 6: Rubber extracted from guayule

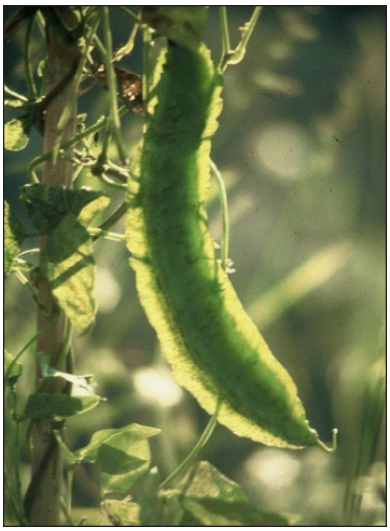

Figure 7: Winged bean (*Psophocarpus tetragonolobus*)

Figure 8: Winged bean pods being sold in a Bangkok market

for decades or perhaps centuries. The rubber tree, however, is vulnerable to collapse because its native area in the Amazon basin hosts a devastating leaf blight. Should that disease-causing fungus ever cross the Pacific and infect the main production areas in Southeast Asia, the world's rubber production would plummet.

This would not be good. When you think about it, civilization runs on natural rubber. Small tires can be entirely synthetic, but the rest rely on natural rubber, which runs cool and keeps tire walls from failing. Even a small cutback would foreshadow a global catastrophe. Guayule produced in dry-land areas with machine agriculture—the way cotton or corn are grown—could then seemingly burst out of nowhere to keep civilization rolling. The basic research we helped stimulate would, under such a scary scenario, prove invaluable.

The supermarket on a stalk

There were four legumes among the 36 species in *Underexploited Tropical Plants with Promising Economic Value*, one of which got me started on a lifetime of interest in these nitrogen-fixing species. Legumes are nature's pioneers, and they not only revegetate barren land but also leave sites better than they found them. By building soil and depositing nitrogen and vegetable matter legumes benefit all later comers, whether plant, animal, microbe or human. Because of this capacity for what is nowadays fashionable to call "sustainability," I spent 15 years touting the legume family in print and in popular lectures.

This binge was stimulated by the winged bean (*Psophocarpus tetragonolobus*). This is of course not a bean that flies; its common name refers to the pod, which, as Figure 7 shows, has "wings" running along its length.

At the time of my involvement, only one brief paper said anything about the species' agronomy or uses. There were taxonomic reports and such, but none even touched on its humanitarian potential. This nitrogen-fixer is, however, a village food source *par excellence*. Something like Jack's beanstalk, it grows huge and offers six edible parts:

Pods: Figure 8 shows the pods being sold in a Bangkok market. Beyond being nice to eat, they are nutritious.

Seeds: Figure 9 shows the seeds you find inside the pods. In composition, these are essentially identical to soybeans. They are rich in oil and food energy, and they're also rich in quality protein.

Flowers: Boiled or steamed, the prolific blossoms turn black and chewy, and look and taste like mushrooms. They also go into the pot.

Leaves: Masses of leaves enshroud a winged bean plant. They too are edible. In taste, texture, table presentation and nutritive quality they are akin to spinach.

Figure 9: Winged bean seeds

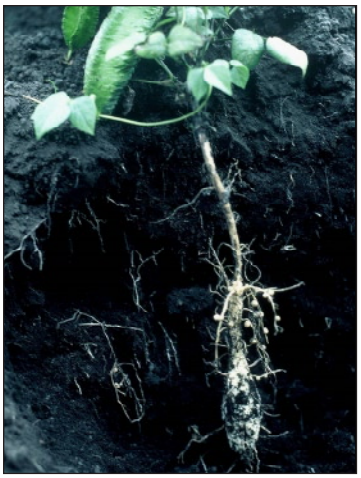

Figure 10: Winged bean tuber (young stage) and root nodules

Tendrils: The tendrils the plant uses to clamber up a pole are also pleasant to dine on. They're vaguely like very thin asparagus, at least in appearance.

Tubers: You might think that delivering the equivalent of green beans, soybeans, spinach, mushrooms, and asparagus would be enough for any plant. But that's just what winged bean provides above ground; below ground it grows a tuber. Figure 10 shows one at a young stage. Notice also the prominent root nodules that host the plant's plentiful bacterial partners that busily download nitrogen from the atmosphere. Those tubers are not only delicious when cooked in a fire (as were the samples shown in Figure 11), but they also add nutrition into the bargain. Nitrogen is the key atom making up protein, and this powerhouse nitrogen-fixer provides tubers with 10-12% protein (measured on a dry weight basis). They are among a handful of starchy root vegetables that are protein-rich.

Now perhaps you can grasp why I dubbed winged bean the "supermarket on a stalk." At first, I was baffled why Thais and others hadn't advanced this crop themselves. Then I learned that the better-off classes dismissed winged bean as merely "a poor person's vegetable." The upper crust in the Philippines, for example, relegated the so-called "seguidillas" to the servants' quarters. But association with poor people is no reason to reject a crop…quite the opposite, in fact. Poor people's plants are likely to be robust, productive, self-reliant and useful. Once upon a time, many of today's food crops were foolishly dismissed as "poor people's plants." Examples include peanut (slave food), soybean (coolie food), potato (Irish food), corn (Southern food) and pasta (Italian immigrant food).

Soon after our 40 page book appeared in 1975, Southeast Asia's discrimination began fading and around the world a clamor arose. Though *The Winged Bean: A High-Protein Crop for the Tropics* was very slim, it sparked its own go-go era. The crop came in for frenzied research in Thailand and other nations whose authorities had forever studiously ignored it. And in a few nations that had never heard of it, the winged bean rose to become a new crop.

Yet despite all the enthusiasm, the supermarket on a stalk has still not reached its potential. I'm tempted to write it up all over again. Part of the problem is that it is a pole bean, and needs support to grow well. That complicates production compared to, say, soybean. However, soybean only became self-standing thanks to modern selection and breeding.

The winged bean still needs stakes, fences or a back wall of the house. Nonetheless, when provided such supports it produces vast amounts of food—far more per square meter than soybean. That's when it most closely impersonates Jack's beanstalk. And its six separate foodstuffs target the main malnutrition monsters: the disastrous deficiencies of food energy, protein, vitamins and minerals that annually kill millions of children.

Leucaena: soil improvement and forage

To this point in my career, I'd never dreamed of dealing with forestry species. But in 1976 Don Plucknett, a farsighted and intellectually courageous agronomist on the USAID staff, called. "If you'd like to write a book on leucaena," he said, "I'll fund it." Actually, the last thing I wanted to do was write a book on leucaena (pronounced loo-SEE-nah), which quite literally had a seedy and weedy reputation. But I thought to myself, if Don thinks enough of it to put up the dough, maybe I ought to say yes.

Figure 11: Winged bean tubers

Leucaena, like many plants I've dealt with, has a name that is difficult to spell, pronounce or remember. I wish I'd had the smarts to select simpler names. For instance, "lucena" and "wing bean" would probably have speeded those crops' progress. However, I represented a prestigious scientific organization and was working with botanists worldwide, so it was impossible to make changes so heretical. A gawky name can hinder anyone trying to make a little-known plant succeed in the wider world. That's what happened with a fruit I grew up with. In New Zealand during my youth we called it "Chinese Gooseberry," a name that proved political poison when the first samples arrived in the U.S. in the 1960s. "Red China" was then the evil enemy, and the fruit bombed until someone came up with "kiwifruit."

The resulting study focused on the newly developed giant leucaena (*Leucaena leucocephala*), which to my surprise proved neither seedy nor weedy. This species rises more than 80 feet with a trunk more than 3 feet in diameter. Although far from a forester's dream, it produces quality wood. Its protein-rich foliage also makes good feed for certain animals. More basically, while producing those useful products it rebuilds the soil and fosters the return of fertility and further types of vegetation.

Despite its sustainable land uses and appeal as a resource, this species' greatest feature is its tremendous speed of growth. This aspect is best illustrated visually:

Figure 12: This giant leucaena growing in terrible soil near Bangkok is merely three months old.

Figure 13: These giant leucaenas grown on the coast of the Philippines about 100 miles north of Manila, are just one year old. I spent an hour walking around under them. A year earlier, the site had been barren and festooned by a coarse, weedy, cutting grass called imperata. Now the grass was gone and the soil was black and bedecked by worm castings. Moreover, the original rainforest vegetation was beginning to regenerate in the shade, shelter and moist conditions beneath the canopy of greenery.

Figure 14: These giant leucaenas—growing close to the city of Pune on India's Deccan Plateau—are four-and-a-half years old. They made a memorable sight because all around this plantation the land was totally treeless. This mini-forest seemed akin to a separate 3-dimensional ecosystem that continuously supplied firewood, forage, furniture and building materials.

After our 115-page book *Leucaena: Promising Forage and Tree Crop* came out in 1977, giant leucaena took off. The late 1970s proved to be this tree's go-go era. Soon it was being planted throughout the Asian tropics. The locals were agog at the speed of growth and the value of the resulting wood.

Then a pest broke out. A species of psyllid, an insect from leucaena's homeland, El Salvador, had made its way to Asia. For a time I was under the gun because the trees looked dead and gone. Critics and even some colleagues blamed me for bringing on a disaster. But leucaena turned out to be irrepressible; though defoliated, it actually wasn't dead. Regardless of the ravaging insects, it kept struggling to push out leaves. Then, in a year or so, local predatory insects learned to thwart the foreign newcomer. It sure was a relief to see those lifeless-looking trees finally leafing out for good.

I don't know where leucaena stands today, but I'll bet it can be found in most tropical lands. It is, however, basically restricted to alkaline soil and shuns the red acid soils so prevalent in tropical latitudes. Nonetheless, this tree that absorbs so much CO2 so quickly and in such a small patch of earth could contribute to what might be called "global cooling." The furniture-grade wood could, like rubberwood, end up in upscale commodities that keep the carbon tied up almost in perpetuity.

Calliandra: an annual firewood crop

One leguminous tree that takes to those red acid soils is calliandra (*Calliandra calothyrsus*). In the 1979 compendium on tropical legumes I'd included a couple of pages on this strange species, and in 1981 I took a small panel to Indonesia to judge it up close and personal. Calliandra isn't much to look at. Its

stems are so small they're like rake handles and the tree itself is tiny. However, calliandra can top 20 feet in its first year. If you whack that stem off, the base will send out five or six new ones and they'll top 20 feet the next year. Should you cut those, there'll be eight or ten more the following year. You can literally go on cutting a crop of wood year after year for decades.

This rapid and never-ending rotation allows annual firewood harvests from the same spot of land. This is important because in many parts of the tropics firewood is as important as food. Corn, rice, yams, cassava and so forth are useless unless there's some way to cook them. Native forests in many rural parts of the tropics are being raped to provide the fuel poor people need. Calliandra can help change that. Though only like rake handles, the stems are ideal for people who lack axes and wedges and who cook over a typical three-rock open fire. They merely whack their trees with a machete and feed the bits between the rocks.

On the eastern end of Java, we visited ingenious villagers who'd built their own crop rotation around this species. First they grew corn for several years. Then, when sensing that the soil fertility was failing, they planted calliandra and kept it in place for 5 years, all the while harvesting wood for their fires and forage for their animals. Then they dug out the stumps (which were sold as charcoal) and replanted corn in the newly replenished soil. Figure 15 shows them using their inspired system.

Although this was the villagers' own innovation, Indonesia's calliandra Crop Champion was Sukiman Atmosudaryo. As director of the government tree-growing corporation, Perum Perhutani, this former professor planted calliandra over large areas easily accessible to the villagers. The resulting firewood and forage was theirs to use. In exchange, though, the locals had to pledge to never enter the government's teak plantings on the higher slopes.

When Dr. Sukiman took us to several of these sites he was greeted like a savior. The villagers had previously raped his teak plantings solely because they needed firewood and a place to feed their animals. Now, with calliandra, they had those things in abundance and close by.

Figure 15: Villagers in Java using calliandra (*Calliandra calothyrsus*) in crop rotation

Dr. Sukiman also exercised similar ingenuity in restoring a denuded and eroding watershed in eastern Java. The dearth of vegetation cover had meant that during the dry season the stream below the slopes got weaker and weaker until it ran dry, which precipitated ruin for the valley's inhabitants. On his orders, calliandra seeds were broadcast along the ridges that topped the stark canyon-like cliff faces. Seeds from those trees fell down the sheer slopes and spawned more calliandra trees, which then dropped more seed even farther down. The natural reseeding proceeded for several years until this impossibly steep canyon was tree-covered top to bottom. Figure 16 shows the outcome. The villagers living below these slopes told us that the stream was again reliably providing water year-round. Also, native vegetation was springing

Figure 16: Formerly denuded and dried-up watershed, now replanted in calliandra

up thanks to this shady fertilizer tree's "nursing care." Moreover, Dr. Sukiman had helped them organize communal beekeeping, which had led to a lively trade in calliandra-blossom honey. All in all, the people loved the little tree so much that many children in that valley were named "Kaliandra."

Following publication of our 52-page book *Calliandra: A Versatile Small Tree for the Humid Tropics* in 1983, no go-go era eventuated. Nonetheless, this tiny tree that produces annual harvests like a farm crop got taken up in many parts of the tropics. Still and all, calliandra deserves revisiting. Firewood shortages remain a major driving force behind the disappearance of tropical forests.

Mangium: a forester's dream

In 1980 the U.N.'s Food and Agriculture Organization published a brief item in which C.K. Tham described tests in Borneo using a tree called *Acacia mangium*. Thus, after inspecting Indonesia's calliandra, the 5 panelists and I visited a forest station in Sabah, a Malaysian state on Borneo's northern tip. Tham, who turned out to be barely out of college, had just a few mangiums. The species is native to the tropical rainforest of north Queensland, Australia and its seeds had been obtained just a few years before. Unlike calliandra, mangium is a forester's dream. Its trunk is straight, its wood can be very fine, and it soars to great heights with surprising speed.

Figure 17: Four-and-a-half-year-old Mangium (*Acacia mangium*) sparking the regeneration of a rainforest

Figure 17 shows a mangium planting that is 50 feet tall, yet the trees had been in the ground just four-and-a-half years. What is more, this site had been most unpromising for anything other than the world's worst weed. You see, its red acid soil was held in the implacable clutches of imperata. This pestiferous cutting grass has a bad habit of catching fire—a feature that not only kills the competition but kicks the grass up a notch as well. Tham (who can be seen in the picture) had found that mangium seed could be planted directly into imperata-infested ground. As long as the planting was weeded once or twice the first year, the tree took off and conquered the grass shortly after that. With imperata's shackles broken and the trees contributing shade and nitrogen, a healthy ground cover arose spontaneously. As can be seen, the rainforest was returning like gang busters. To see an entire rainforest regenerating in less than five years was the most astounding sight of all.

Our 62-page *Mangium and Other Acacias of the Humid Tropics* came out in 1983, and since then this species has been widely planted. Indeed, I recall an Indonesian report way back in the early 1990s describing plantings covering tens of thousands of hectares. Like leucaena, this species could contribute to "global cooling" while turning barren expanses of the tropics back into their original rainforest. Millions of acres around the middle of the world are currently lost to imperata, so there's no shortage of space. And a tree that grows this fast takes a lot of greenhouse gas from the global heat shroud we all want to see reduced.

Bracatinga: a shade tree

Our large 1979 book on tropical legumes briefly mentioned *Mimosa scabrella*, a tree that once fueled southern Brazil's railroads. We featured it again in the 1980 book *Firewood Crops: Shrub and Tree Species for Energy Production*. Both insertions were quite daring because virtually nothing whatever had been written about bracatinga since modern fuels replaced wood on Brazil's railroads. However, I'd seen a 1930s brochure featuring this fast-growing hardwood that

Figure 18: Three-year-old bracatinga (*Mimosa scabrella*) near San José, Costa Rica

was then planted trackside for locomotive fuel.

Although inserting such a shadowy prospect was chancy, things worked out thanks to a young Costa Rican forestry student who caught a copy of *Firewood Crops* in the library at his university in Turrialba. He happened to have a Brazilian girlfriend and was searching for any excuse for a trip. He talked his professor into letting him investigate this tree, borrowed the airfare from his folks, had a good time with his sweetheart, and brought a new crop back to his country.

Figure 18 shows bracatinga's Crop Champion and the product of one of his seeds. As I recall, this tree is just 3 years old. The site is 50 miles west of San José, on a hillside near Heredia, and it is shading and sheltering sensitive coffee plants from the tropical sun's devastating heat and desiccation.

Where bracatinga stands today I know not, but surely a robust nitrogen-fixing tree that grows so big in just three years can contribute toward lessening several of our era's global problems.

Lost Crops of the Incas

Figure 19 shows the sort of scene graduates of this great institution [the Johns Hopkins Bloomberg School of Public Health] may find in the parts of the tropics where the public health problems exist. This picture was taken in the Andes and shows some of the strange-looking foods to be found throughout the South American highlands. What may look like offbeat potatoes are actually entirely different tubers, and what may look like offbeat chili peppers are lesser-known species as well. Indeed, few of the fruits and vegetables seen here have ever gotten out into the wider world. Even the locals tend to diss these ancient foods, writing them off as has-beens whose time has long since passed in this era of wheat, rice, corn and soybeans. The truth, though, is quite the opposite. These ancient resources portend a better future for the Andean nations and for the wider world. That's why we published the 400-page *Lost Crops of the Incas* in 1989. The next illustrations highlight just a few of the scores of potent prospects (see page 12).

Figure 19: Some strange-looking foods of the South American highlands

By the way, in Mexico, 4,000 miles northward of the Incas, the Aztecs had their own counterpart of kiwicha. Their species (*Amaranthus cruentus*) never disappeared, and it was one of the 36 "winners" in the first compendium volume. A decade later, we revisited it in *Amaranth: Modern Prospects for an Ancient Crop*. This 80-page highly illustrated summary helped spark modern attention. Rodale Press, however, was the real force that got this nutritious grain grown again. As a result of research inspired by the late Robert Rodale, amaranth breakfast flakes are staples in today's supermarkets and health food stores. Bob was a great Crop Champion. He was in the Soviet Union preparing to push new crops and new-age agriculture when a truck broadsided the car taking him to the airport for the flight home.

Lost Crops of Africa

In 1995 my prime sponsor, USAID, stopped funding the program, apparently on the basis that 25 years' support was enough, regardless of our many successes and meager needs. Sadly, I couldn't land a replacement sponsor. Thus the program abruptly ended.

The Academy let me keep my office, and I managed to persevere for over a year, toiling with essentially no pay, to complete the first volume of what had been projected as the program's master work. The 383-page *Lost Crops of Africa, Volume 1: Grains* describes more than a score of little-known but very promising cereal grains that are native to Africa's hunger zone yet remain poorly supported by science and produce at levels far below their potential. In essence, it touches almost all of Africa's needs: overcoming malnutrition, boosting food security, managing the land sustainably, fostering rural development and reducing poverty.

After that volume came out in 1996, sadly, I was forced to leave this line of endeavor and search for something that could pay the bills that had piled up.

Crop Champions: A field that welcomes amateurs

From my experience you can see that, though maybe not financially rewarding, being a Crop Champion is extraordinarily rewarding.

Figure 20: Yacon (*Polymnia sonchifolia*). This distant sunflower relative has tubers that are sweet but almost calorie-free. Because of their succulence, most are eaten raw for refreshment; many, however, are eaten cooked. A calorie-free sweet staple food sounds somewhat like modern civilization's holy grail. And yacon can grow in North America. Imagine!

Figure 21: Oca (*Oxalis tuberosa*). In the Andean highlands, it is second only to the potato, and remains a staple for Peruvian and Bolivian Indians living at high altitudes. Although the potato has gone forth and multiplied into a major food for mankind, oca has remained at home. New Zealand is about the only non-Andean nation that knows it. While growing up there, I enjoyed these red, wrinkled tubers which taste like potatoes that need no sour cream. The slight sourness makes them delectable. I predict these will be seen in supermarkets worldwide, perhaps quite soon.

Figure 22: Quinoa (*Chenopodium quinoa*), which featured not only in *Lost Crops of the Incas* but also in the inaugural compendium, *Underexploited Tropical Plants with Promising Economic Value*. The grain is one of the vegetable kingdom's best protein sources. Quinoa (usually pronounced KEEN-wah) is already appearing in U.S. supermarkets. That's not necessarily because of our endeavors, but we are certainly glad to have helped nudge the crop along the path to its greater destiny.

Figure 23: Tamarillo (*Cyphomandra betacea*). Gardens high on the mountainsides from Colombia to Chile contain small trees that bear large crops of these egg-shaped "tomatoes." Tree tomatoes have bright, shiny, red or golden skins and can be eaten raw or cooked or added to cakes, fruit salads, sauces, or ice cream. Among the most popular local delights, their succulent flesh is tart and tangy and has a unique piquancy. Despite the tartness, these make good dessert treats. They are beginning to appear in the specialty sections of good supermarkets.

Figure 24: Kiwicha (*Amaranthus caudatus*). Until 400 years ago, this species was a major Andean crop, but it disappeared along with the Incas. After reading about our work, Luis Sumar Kalinowski, a professor in Cuzco, set out to rediscover it. Seemingly there was none anywhere. But finally, he located a few handfuls of seeds that some family had religiously grown for four centuries. This field results from their efforts and his. Today, kiwicha is cultivated again; the Incas would feel right at home here.

And this line of work needs more recruits because of all those jewels that exist in the plant kingdom and still await a polish. The majority of those exist in the unhealthy, hungry and deforested expanses of the tropical latitudes where public health also awaits more attention. Some audience members are therefore likely to find themselves face-to-face with a crop needing the publicity that can attract professional passion and inspire its march into the fullness of its promise.

The point here is that Earth holds at least 250,000 plant species, among which several thousand have edible fruits, leaves, roots, flowers, stems or some such part. Figure 25 is included to provide some sense of how few of those thousands currently feed humanity. You can see that basically 30 plants support all societies. Notice that mango, sunflower seed, and onion make the top 30, which is a telling indication of the smallness of the diversity behind the food that supports humankind.

Among those thousands of overlooked edibles, several hundred have the prospects for greater things in organized food production. Most are native to Africa, Asia and Latin America—the very places where food is in shortest supply and hardest to grow. Those uncut jewels are all out there, each awaiting its Crop Champion.

As you've seen, in the Crop Champion world, amateurs are welcome. Of all the people I've highlighted, none were trained crop developers. All were generalists who started out knowing nothing about their chosen plant and carried on by the seat of their pants. That can-do spirit, in fact, heightened their chances of success. There's no common blueprint to follow, and the challenges are too broad for specialist scientists. By itself, no scientific discipline can create a new crop. Only a sort of General Practitioner, prepared to wield an array of sciences and technologies together with inner wisdom and common sense, can do that. Completing this intellectual panorama also requires a hide tough enough to withstand setbacks, unforeseeable difficulties and all-too-common carping and criticisms.

If you've got what it takes, however, you too can become a Crop Champion. You can enjoy the ride of a lifetime. Engagement in such a venture helps make the future more livable for everyone, but especially for mankind's most needy—and for you.

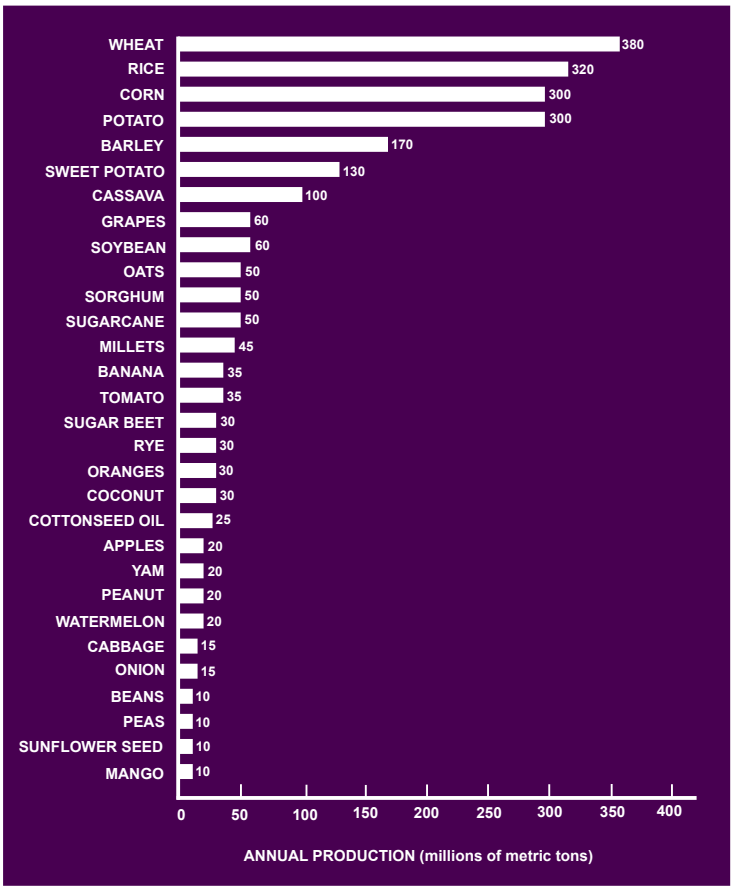

Figure 25: The top 30 plant foods that currently feed humanity