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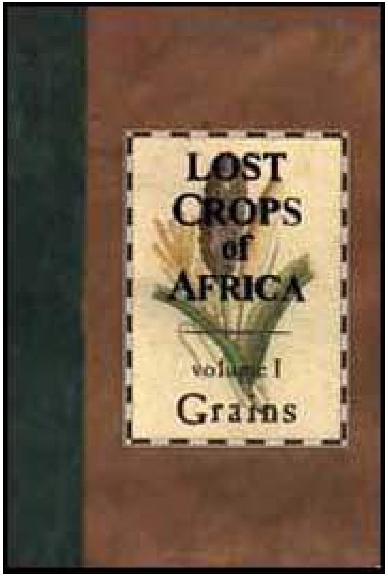

LOST
CROPS
of
AFRICA
volume I
Grains

11. Sorghum: Fuel and Utility Types

Few people heretofore have paid much attention to the idea of growing sorghum to burn. Cereal scientists, quite naturally, have regarded the plant exclusively as a food. But these days, feeding the fire can be as hard as feeding the people. Certain sorghums might help, and they warrant research.

Moreover, fuel is fundamental to many other parts of modern living. Indeed, most of the human race is so hooked on flammable liquids for running factories and powering trains, trucks, cars, and buses - not to mention providing electricity - that life would be impossible, or at least intolerable, without them.

For all that, however, the prime liquid fuel, crude petroleum oil, is in jeopardy. Perhaps the greatest challenge of the coming century will be the development of sustainable alternatives.

Surprisingly, sorghum might be one of them. Indeed, sorghum could well bring many countries a giant step toward the renewable-energy future everyone is hoping will eventuate to keep life livable in the post-petroleum era.

This chapter highlights sorghum's potential to produce both solid fuels and liquid fuels, to yield industrial products, and to help maintain the overall sustainability of agricultural production.

FIREWOOD

Although food is fundamental, fuel is almost as basic to the modern diet. Without it food cannot be cooked, and today's main grains, pulses, roots, and tubers, as well as many vegetables, must be cooked to be edible.

These days, millions cook over open fires. Indeed, for more than a third of the world's people, the real energy crisis is a frantic scramble for firewood. In the poorest countries, up to

90 percent of the population depend on wood to cook their meals. In parts of Africa and

Southeast Asia, an average user may burn well over a ton a year.

Although the search for food soaks up a major part of the daily lives of billions, the search for fuel to cook it with is becoming equally time consuming. Firewood is more and more difficult to find. In increasing number of places, gathering fuel now takes more time than growing food. There is a saying in Africa that it costs more to heat the pot than to fill it.

Although in recent years much effort has been expended on developing firewood crops, few advisers or administrators have ever thought of developing sorghum for the fire. It is a fact, however, that certain types have woody stems that put out surprising amounts of heat. They could well become part of the mix of the firewood crops of the future.

Although these solid-stemmed sorghums have received almost no study as fuel resources, one type has been tested in a preliminary way. It comes from Egypt, where its stalks are more valued than its grains. Egyptians use them as fuel. Called Giza 114, it has solid lignified stalks that burn at an especially high temperature for the stem of a grass.

Little is known about Giza sorghum but, based on results from preliminary trials, it could have a glowing future. It has shown promise in Peru, for example, where it was produced to fuel cookstoves and brick kilns. It is now being tested in Haiti, where it also seems to have good potential as fuel.

It is not inconceivable that sorghums like this could become a standard part of farming in fuel-short nations. Their annual biomass yield is likely to equal or better that from trees. The yield of sorghum stalks has been measured in China as 75 tons per hectare, probably representing more than 10 tons per hectare of dry biomass. This would be a respectable annual production for even the fastest growing trees. The overall yield in fuel-calories per hectare may also be comparable, although even the densest sorghum stem will not equal the caloric output of a wood sample of equal volume. Perhaps, too, a modest harvest of: grain can also be achieved.

Compared with trees, sorghums have the advantage in that they produce fuel within months - even weeks, Several crops a year may be possible in appropriate locations. This may help relieve not only the frenzied foraging for firewood that goes on today, but also the destruction of woodlands and forests that seems to end only when desert or degraded soils remain. People who can find fuel in fields close at hand will not hike to far-off forests and haul bulky wood all the way back. Their need is not for large-diameter tree trunks but for small stems that can be easily cut, carried, and fed into the space beneath a pot perched on rocks. For such a purpose, solid-stalked sorghums could become vital resources of the future.

LIQUID FUELS

For the economic stability and expansion of nations, liquid petroleum fuels - kerosene, gasoline, and diesel, for instance - have become essential. As noted, these liquids not only power factories, trains, trucks, and buses, they also generate electricity and produce thousands of items from machines to medicines. Moreover, maintaining mobility is critical to the public welfare: police, fire fighters, ambulances, mass transit, and construction fleets all depend on liquids that will explode in the cylinders of internal combustion engines.

For these and other reasons, the growing dilemma over future petroleum supplies makes it imperative to investigate renewable fuels, especially those suited for use in existing engine types. Of all the nonpetroleum possibilities, ethanol is the only one now significantly used in motor transport.

Research Council, Washington, D.C. 1983. Research on another renewable-energy alternative. vegetable oils' is described in E. Griffin Shay. Diesel fuel from vegetable oils: status and opportunities. Biomass and Bioenergy. Vol. 4, No. 4, 1993. pp. 227242.

At present' ethanol is made from either sugarcane or maize. In the future, however, sorghum is likely to also be a prime supplier. The stalks of certain sorghums are just as packed with sugar as are sugarcane's. Their juice contains 13-20 percent total fermentable sugars. They can yield about 6 percent alcohol.

Sweet-stalk types are sparingly distributed across sorghum-growing areas of Africa and India, where people chew the green and tender stems like sugarcane or make syrups, molasses, sugar, or confections from them. They were once a major source of sweeteners in the southern United States. Now, however, they have a rising potential as sources of fuel.

All in all, sweet sorghums are important for future ethanol production because they have:

· High biomass yield;
· High percentage of fermentable sugars;
· High percentage of combustible materials (for fueling the processing);
· Comparatively short growth period;
· Tolerance to drought stress; and
· Relatively low fertilizer requirement.

Moreover, sweet sorghums may produce some grain for food or feed. Indeed? as sorghum is one of the most efficient plants, and as it produces fermentable sugars as well as grain, it seems almost ideal for producing both energy and food. Technologies used in the sugarcane industry can be applied virtually without modification.

Sweet sorghum has a number of potential advantages over sugarcane. For example, it is adapted to many growing conditions, unlike sugarcane, which is restricted to tropical climates. It requires less water and fertilizer. It can be planted more easily (from seeds not stems). And it also has a potential for low unit costs because it can be fully mechanized and the fields need not be burned (unlike sugarcane fields).

Sorghum's advantage over maize (in which the grain is converted to alcohol) is that it produces sugar rather than starch. As a result, sorghum juice can be directly fermented without the expense or delay of an initial hydrolysis.

Recently, researchers in at least three countries have begun to appreciate the potential of sorghum as a fuel as the following examples show.

India

In southern India, the potential of sorghum varieties that yield both grain and sugar-filled stems is being explored.

Engineers at the Nimbkar Agricultural Research Institute (NARI) have found that these dual- purpose varieties solve three problems: they yield food, the fuel to cook it with, and the fodder to feed the farm animals that help produce it. From the top of the plant comes grain for food; from the stalk comes sugar (and hence alcohol) for fuel; and from the pulp remaining after the sugar is extracted comes animal fodder.

In the past, multipurpose sorghums were dismissed or at least overlooked, probably in the expectation that the individual yields of the various products would be low. But the NARI researchers are showing that this may not be the case. Indeed, they claim that I hectare of their sorghums can annually yield 2-4 tons of grain, 2,000-4,000 liters of alcohol, and enough crushed stalk to feed from three to five cattle year-round.

The idea of "growing" fuel alcohol is of course not new. However, most other programs have faltered because the cost of the fuel needed to distill the alcohol rendered them economically unattractive. NARI engineers circumvented this by designing a solar-powered still, incorporating a solar collector and a distillation column that can run at 50-70°C temperatures that the solar collector can easily provide.

Also, they have developed pressurized and unpressurized lanterns as well as a wickless stove that will run on aqueous alcohol taken directly from the still.

NARI suggests that this combination of multipurpose sorghum and appropriate technology could, in theory, meet all the automotive fuel requirements in India by the year 2000, completely replace the kerosene now used in Maharashtra, and supply 80 percent of the fodder for all the cattle in Maharashtra. Although such levels will never be approached in practice and it seems axiomatic that grain yields will tumble when sugar is also produced, the NARI concept is a powerful one that could be a big breakthrough that boosts sorghum into an energy resource worldwide. And perhaps, after all, it is not too far-fetched to envisage sorghum producing both high contents of sugar in the stem and high yields of grain.

United States

A large sorghum-for-alcohol project was carried out across the

United States between 1978 and 1984. As part of this project' the University of Nebraska developed a demonstration farm based entirely on renewable fuels. Sweet sorghum was the principal crop for alcohol production. Hybrids that grew rapidly and produced large amounts of sugar were created.

A major constraint of sweet sorghum in the temperate zone is the harvest period. Wherever the potential of a freeze exists, the harvest period is greatly reduced because the crop must be gathered before any freezing weather. Sugar in the damaged stalks begins to ferment.

Brazil

Of all the nations in the world, Brazil is the ethanol-fuel pioneer. It already has fuel alcohol in large-scale nationwide use. So far, however, this has come almost entirely from sugarcane.

Now, Brazil's scientists are exploring the use of sweet sorghum. The two crops, it has been found, supplement one another: sorghum can provide alcohol during the season in which sugarcane is unavailable. Therefore, using the two together increases the period of production, decreases the unit cost, and increases the total amount of alcohol that a distillery can produce each year. The same equipment is used to process both sugarcane stalks and sweet-sorghum stalks.

The Brazilian scientists are also extending their studies to incorporate sorghum into an integrated system in which the by-products are used as food, feed, fertilizer, and fiber.

Further, they are adapting this technology to a microscale to allow the economical production of fuel in a decentralized industry. This reduces transportation costs and may perhaps allow the farmers to generate their own energy.

Will Brazil's Cars Run on Sorghum?

Brazil leads the world in the use of fuel alcohol. In 1993, about 4.3 million vehicles-one-third of the country's total fleet and about 40 percent of its car population - operate on ethanol.

Almost all that alcohol now comes from sugarcane, but in the future it may come from sorghum as well.

Brazilian researchers have shown that sweet sorghum can yield from 22 to 45 tons of raw biomass per hectare in 110 days. Fermentable solids (80 percent sugars and 20 percent starch) in the stalks amount to 2.5-5 tons per hectare. To optimize the output, enzymes are added so that the starch in the stems is also converted to alcohol. Research has shown that in this way 1 ton of sweet-sorghum stalks has the potential to yield 74 liters of 200-proof alcohol.

Such discoveries have implications for countries everywhere. In that distant but inevitable day when the world's petroleum runs out, maybe people will turn to sorghum to keep civilization humming. Brazil is showing us yet another way this remarkable plant will be important in our future.

SORGHUM IN SUPPORTING ROLES

Around the world, sorghum is mostly grown for food or feed and (as just mentioned) a little is being grown for fuel. However, there are several interesting uses in which sorghum is grown not for its own sake but for the benefit of other crops. Below are three examples.

Soil Reclamation

Saline Soils It has recently been found that crosses between sorghum and sudangrass (a special race of sorghum), have the capacity to repair saline soils made crusty by sodium compounds. David L. Carter, director of soil and water management research at the U.S.

Department of Agriculture station in Kimberly, Idaho, predicts that "they are going to produce some good forage on these marginal lands and at the same time will reclaim some of these soils for crops for human consumption."

Acids released by the sordan roots dissolve calcium carbonate or lime, and in so doing they release calcium. The calcium then displaces sodium in the soil. The newly released sodium reacts with carbon dioxide to form sodium bicarbonate, a soluble salt that is less injurious to plants and mostly washes away in the rain.

After growing sordan on sodic lands for about 2 years, farmers can often re-use the soil for conventional crops.

Reclaiming Toxic Soils U.S. Department of Agriculture scientists in Lincoln, Nebraska, have found that sorghum has an exceptional ability to absorb pollutants out of soil. According to their research, sorghum strips excess nitrogen out of soils with such efficiency that it may solve waste disposal problems for cities and livestock operations (such as feedlots) that generate nitrogen-laden wastes. "We've been able to capitalize on sorghum's natural ability to act as a scavenger," says Kenneth J. Moore. "Sorghum thrives in toxic soils that kill less resilient plants and its penetrating roots can capture the nitrogen in a vast volume of soil."

Moore, an agronomist, and his colleague Jeffrey F. Pedersen, a plant geneticist, are now developing a system in which nitrogen is not only removed but is returned to use safely and economically. They plant sorghum in highly contaminated soils, cut the crop several times through the growing season, and feed the foliage to livestock. The key to the process is sorghum's robust growth and extensive root system.

Such an environmental tool could be very valuable these days. In Nebraska, for instance, municipal and livestock wastes are commonly disposed of by applying them to fallow cropland. An excessive buildup of nitrogen is one of the resulting hazards. "By planting forage sorghum in well-managed cropping system, producers can safely recycle that nitrogen," says Moore.

Two years ago, Moore and Pedersen began their project at a sewage sludge disposal site by planting several types of sorghum: grain types, forage types, tropical types, sweet sorghums, and sorghum-sudangrass hybrids. Soils there contained 400 kg per hectare of nitrogen. The tropical sorghums and hybrids absorbed the most nitrogen from the soil, removing an average of 200 kg and yielding more than 20 metric tons of dry matter per hectare in one season.

"We hoped for more, but the first year's growing season proved to be short and cool," says Moore. "Under normal conditions, some tropical sorghums absorb as much as 300 kg of nitrogen and yield 25 tons of dry matter per hectare."

Sorghum is so efficient a scavenger that nitrogen levels in the foliage can actually build up to levels harmful to livestock. To address this possibility of nitrate toxicity, the researchers rated their sorghums for nitrate content. Most were at or near toxic levels, but the ensiling process (a lactic-acid fermentation; see Appendix C) removes any threat to the animals.

With further refinement, this process could prove to be a method for continuously stripping nitrogen (and perhaps other pollutants, both useful and hazardous) out of the wastes from cities and industries. "Sorghum-sudangrass hybrids are very popular now in Nebraska and other Central Plains and Midwest states," says Pedersen. "They could be put immediately to work consuming organic wastes."

New Life for Salty Soil

Over the last few decades, irrigation has saved the world's food supply from catastrophe. But irrigation has a fundamental flaw: in the drylands where it is most used, evaporation leaves the site with a surplus of soda and salt. In their worst forms such "sodic" soils become self- sealing: their internal structure collapses so that water just sits uselessly on the surface.

Sorghum, it turns out, can help.

Sorghum roots ooze large amounts of sugars. Ordinarily, soil microbes gobble these up, but sodic soils tend to be anaerobic and lack the right organisms. Instead, chemical processes break down the sugars in a way that releases carbon dioxide.

A weak natural acid carbon dioxide reacts with the soluble alkalis (sodium carbonate and sodium bicarbonate) to form acetic acid and a little formic acid. These stronger acids, in turn, react with the insoluble alkalis such as calcium carbonate. Sorghum's overall effect is therefore to reduce the alkalinity and convert minerals into more soluble forms. When those wash away, the soil's natural porosity is reopened.

This process occurs with amazing efficiency. Researchers at the U.S. Department of Agriculture have reclaimed marginal sodium-affected soils using sorghum (mainly the forage types called sordan and sudangrass) after just one season. In fields so toxic that crops would not grow, they get respectable stands of barley and alfalfa after just one season of sorghum. Beans, a highly salt-sensitive plant, can be grown after two or three seasons of sorghum. Within one season it not uncommon for the alkalinity to drop a full pH unit and the calcium solubility to increase tenfold.

At first, however, the plants come up scraggly, stunted, and yellow. This has been traced to iron deficiency, to which sorghums are very sensitive. But when the'´acidification mechanism" kicks in, the iron concentration in the plant shoots up, they turn green and grow rapidly.

The process is much more than a way to reclaim soils. The researchers are also getting some of the highest dry-matter production recorded in feed-sorghum, especially during the hottest of the summer months. Dry weight up to 67 tons per hectare.

WIND EROSION

Researchers the world over are working hard to keep sorghum alive, but James D. Bilbro. Jr., is more interested in sorghum dead. He wants to foil the winter winds that pick up soil from Texas farmland and whirl it away across the American landscape. Dead sorghum, it seems' is an answer.

Bilbro, a U.S. Department of Agriculture agronomist in Big Spring, Texas, is exploring ways to protect farmland during a long, cold, blustery winter when the crops have been harvested and the land is bare. Today, farmers in his part of the country normally put in a special crop to cover the land and keep the soil pinned down. The plants survive under the snow, and to get the land back for planting the main crops again, the farmers must eventually kill them with herbicides.

Bilbro asks: Why spend money on herbicides and risk the environment when nature could do the work? In late summer or fall he plants warm-weather crops and finds that they serve very well. Although dead by December, they cover at least 60 percent of the ground, thereby eliminating wind erosion.

Of the 16 crops Bilbro has tested, forage sorghum is the most promising. He thinks that farmers will soon start using it to protect soil because it will save them money, help the environment, and (because the sorghum plants live such a short time before the frost arrives) leave more moisture behind for the subsequent crops.

The technique is being developed in the Texas High Plains, but it may prove useful wherever wind erosion is a problem in the coldweather zones.

This may seem like a minor use for a major food crop, but the potential is actually vast. Wind damaged 1.74 million hectares of cropland and rangeland in the 10-state Great Plains area during the last wind-erosion season (November 1991 to May 1992). And more than 6 million hectares were reported to be vulnerable to losing their topsoil to the wind. And that was just in the United States.

Weed Control

In previous times, farmers used many plants in crop rotations to control weeds. With the advent of modern herbicides, this practice was dropped in favor of continuous cultivation of the most profitable cash crop. Science is now documenting what these farmers knew - and perhaps too often have forgotten. One example from the United States involves sorghum.

Despite the fact that U.S. farmers apply nearly 200 million kg of herbicides every year, they lose $10 billion worth of crops to weeds. But one Nebraska farmer, Gary Young, doesn't buy any herbicides and his 100 hectares of crops are doing just fine. About 10 years ago, Young noticed that his fields produced fewer than normal weeds the year after he grew sorghum.

Since then he has relied on sorghum, not chemicals.

Now there is increasing proof that sorghum is a weed killer that works. Frank Einhellig, a biologist at the University of South Dakota, and James Rasmussen, an ecologist at Mount Marty College of Yankton, South Dakota, recently completed 3 years of field trials on Young's farm. On test plots covering 6 hectares, they had Young plant strips of sorghum, maize, and soybeans, and they measured the number of weeds that came up in the following year's crop. The strips that had been planted with sorghum produced only one-third as many weed seedlings at crop-planting time. Even in midsummer - without herbicides or cultivation - the total weed biomass was still 40 percent less than that on the plots that had been planted to maize and soybeans the previous year.

The surprise is that sorghum suppressed broad-leaved weeds without affecting grasses. It is a selective "herbicide" and thus has special importance for cereal farmers. (It is also well known that broad-leafed crops following sorghum are likely to give poor yields.)

The active ingredients are thought to be phenolic acids and cyanogenic glycosides given off by sorghum's roots. Phenolic acids affect plant-cell membranes and thus reduce a plant's ability to absorb water. They also disturb cell division and hormonal activity, and seem to inhibit seed germination as well as the seedling's early growth and development. Cyanogenic glycosides are known to break down into secondary substances that include cyanide. "Cyanide," Einhellig notes, "is a pretty strong inhibitor of any growth system."

In his latest technique, Gary Young plants sorghum in the fall and allows it to freeze during the winter. The dead sorghum almost completely suppressed weeds, particularly broad-leaved weeds, throughout the year. Snap beans and other crops planted in the residue the following season required almost no weed control.

Now, many of Young's neighbors also plant sorghum and are finding reasonable weed control without herbicides. In Africa, these effects may be especially important. Today, weeding is perhaps the greatest of all drudgeries in African farming. Most is done by hand - some of it on hands and knees.

Returning to the old ways might just solve the problem. With the new findings in mind, it is possible that the ongoing switch from sorghum to maize may be exacerbating Africa's weed problems. In the future, though, sorghum may become the maize farmer's best friend. Rotations of the two may benefit both.

Sorghum Saves the Season

As this book shows, sorghum is a remarkable crop, but even we were surprised to learn of the following recent experience.

In the area around Lubbock, Texas, cotton has long been king. The rains there fall in the spring (as well as fall) and the cotton thrives in the hot, dry months that follow. But in the spring of 1992, the rains and record low temperatures came during the planting season.

Throughout the region, more than 800,000 hectares were lost because of the unusual conditions. The cool and damp released the soil diseases and pests that had built up over the years and the cotton seedlings quickly succumbed.

The Federal government declared the crop a total loss and authorized disaster payments for the farmers. The farmers, however, faced an unexpected problem: their land was bare and could blow away in the summer winds or wash away in later rains. They needed a ground cover. In desperation they decided to sow nearly 600,000 hectares to sorghum.

Even in this seemingly simple task there was a difficulty. The cotton fields had been treated with a weed killer that is both persistent and designed to kill grasses. Sorghum obviously could not survive. Then someone suggested that an old-fashioned farm implement called a

"Ester-planter" might work. Fifty years before, farmers used these double-moldboard plows but had since given them up as too old fashioned and too energy consuming.

Now, however, in the 1992 emergency, the countryside was scoured for any of the old plows that were still Iying about. Some were found quietly rusting away behind various barns.

Instead of planting sorghum seed in the normal way on the ridges left by the lister, the farmers planted it in the furrows.

There, the roots had better access to the soil moisture, but more importantly the toxic topsoil had been scraped aside.

Nothing more was done. The sandy land had already been treated with nitrogen for the cotton crop and - although most observers believed that the rains had probably already leached the fertilizer below root depth - everyone hoped that the combination of furrow- planting and sorghum's deep roots would ensure at least a solid stand to cover the land. A few went beyond that and hoped for a modest harvest of sorghum grain.

The crop was harvested in the fall of 1992. Even with the late planting, minimum preparation, and no inputs, it was a record for that parched area. The figure - 4,500 kg per hectare - actually matched the national average for sorghum. Elevators overflowed with the unexpected bounty and grain had to be mounded in huge piles in the city streets.

Some of the piles were half a kilometer long. Coming on top of their disaster payments, the farmers made more money than ever!

Is it any wonder, therefore, that the cotton farmers of Texas now look on sorghum with new respect? Years before they had used it as a rotation crop, and now they would like to use it that way again. Planting sorghum one year in four, they think, should break the buildup of cotton pests and diseases in the soil and help avoid future failures of the cotton crop. It might also improve soil filth, decrease erosion, and diversify the local agriculture.

Crop Support

West African farmers use sorghum for supporting yam plants. They employ a special kind that has stalks like ramrods. The yam plants are extremely heavy so the fact that sorghum can hold them up is graphic evidence of its strength.

Actually, it is even more remarkable than it appears at first. The sorghums support the crushing weight of yams even 8 months after their grain has matured and they have died.

Farmers bend the sorghum stalks over to create an intertwined "trellis" about 1.2 m high.

The yams are grown on this woven wall of dead stalks from the previous season's sorghum crop.

Few plants could withstand such treatment. The tentlike canopy of clambering yam plants entraps heat and moisture and fosters molds, mildews, and rots of many kinds. These sorghums, therefore must be very fungus-resistant, even when dead.

Little attention has ever been given to yam-staking sorghums.

Latin America's traditional use of maize plants to hold up climbing beans has been extolled, but Africa's even more remarkable counterpart is little known.

These strong-stalk sorghums might be excellent for use with many climbing annuals, including, for example:

· Macroptilium - an extremely promising tropical forage legume whose yields rise dramatically if it can be kept off the ground, where it becomes affected by mildew.
· Winged bean - a climbing bean that could become a major crop of the tropics if cheap ways to support it can be found.
· The viny types of lima beans, common beans, common peas, and runner beans that tend to be the highest yielding varieties but are seldom grown because of the expense of staking them or the lack of poles.
· Beans, squash, or other climbing plants traditionally grown on maize. Switching to sorghum might extend this useful

practice to locations too dry for maize.

SORGHUM IN INDUSTRIAL PRODUCTS

Strictly speaking, this book is about plants that produce food, but we cannot resist rounding out the sorghum story with a glimpse at this plant's actual and potential utility as a source of everyday items for industry and for people in their homes.

Fiber Resources

In the rural regions of Africa and Asia, people have devised many uses for sorghum stems.

These include:

· Roof thatching;
· Sleeping mats and baskets (made from the peeled stems); and

· Strings in traditional musical instruments (in Nigeria, for example, the peeled bark is used this way).

In China, a particularly strong type has been developed for its pliable, dense stalks. Usually known as galiang sorghum, it is used for constructing fences, walls, and many household items, including grain bins bigger than the beds of pick-up trucks.

Brooms

Broomcorn belongs to this special galiang group of sorghums. It is a special sorghum that is grown not for food, forage, or fuel but for the bristles that rise from its flower head (inflorescence). These stiff, very strong, strawlike projections can be up to 60 cm long. For several centuries, people have used them to make brooms and brushes.

Broomcorn was apparently developed in the Mediterranean region during the Middle Ages. (The original sorghums are thought to have come from Africa or India.) It was growing in Italy before the year 1596, and soon thereafter it was being cultivated in Spain, France, Austria, and southern Germany.

Before this sorghum's arrival, Europe's houses, warehouses, front steps' streets, and other places that accumulate dust, dirt, leaves, and horse manure were swept with loose bundles of straw. These not only fell apart quickly, they lacked the strength and springiness to properly flick dust and dirt out of cracks and crevices. Broomcorn, therefore, may well have been one of the most beneficial advances in European public health.

In the United States broomcorn became, if anything, even more important than in Europe. Benjamin Franklin is credited with introducing this strange sorghum. He apparently brought the seed from England in 1725 (when he was only 19) and grew the first broomcorn in North America. It took hold, however. In 1781, Thomas Jefferson listed broomcorn among six important agricultural crops of Virginia. It has been the basis for billions of long-lasting brushes and brooms ever since.

In the competition with man-made fibers and the vacuum cleaner - both of which should in theory have swept it aside - broomcorn is holding its own in the United States. Today, products made of this sorghum are used in millions of American households, warehouses, stores, factories, steel mills' smelters, cotton mills' and barns. They range from whisk brooms to yard brooms for rough sweeping and special purposes.

Considerable development of broomcorn subsequently took place in the United States, but apparently few (if any) other countries have given the crop much attention. This is certainly surprising and should be investigated. Dozens of countries - from Rwanda to Russia - still sweep with bundles of straw. For them, too, this sorghum with the wiry flowers might be a boon.

The broomcorn plant is unlike other sorghums. The stem is dry and hard. The kernels are small and are often enclosed in long ellipsoid husklike coverings (glumes).

The plant has been typecast as a source of brooms and brushes, but it could very well have other equally important uses. For instance, broomcorn stalks are used for paper in France. Reportedly, excellent yields of fiber are obtained by planting the crop very densely. The pulp is used to manufacture kraft paper, newsprint, and fiberboard.

Danish scientists have also made a good paneling using the chips from internodes. Similar products are beginning to be explored in Zimbabwe as well. However, insufficient work has been done to really know the possibilities.

Chinese researchers are using tall sorghums for making plywood. The process apparently works well and gives a product stronger than wood.

Dyes

Moroccan leather is said to get its color from red dye extracted from special sorghums. These red-seeded varieties were raised in sub-Saharan Africa and in the old days were sent across the Sahara to Fez or elsewhere by caravan. Natural dyes (especially red ones) are increasingly in demand these days, so perhaps these types could be commercially produced once more.

Resins

There is a black-grain sorghum from Africa called "shawya" that shows promise in producing industrial resins.

ANIMAL FEED

The United States probably leads the world in developing sorghum as a feedstuff. The plant is now a vital animal feed throughout the nation's warmer regions.

Although it has been in the United States since the earliest day, grain sorghum first became a major American crop in the 1930s, when dwarf cultivars were bred. These lent themselves to large-scale operations and combine harvesting, and the acreage began increasing. The grains were used exclusively for feeding livestock and became so valuable for this purpose that by shortly after World War Il. sorghum had become the most important cash crop in Texas and was a valuable resource in several other states as well.

Then in the late 1950s male sterility was discovered in sorghum. This made hybrids possible. Sorghums that had originated in South Africa, Ethiopia, and the Sudan were bred together to create hybrids, and yields jumped as much as 40 percent. This led, in turn, to vastly more plantings and even more American animals were soon living off sorghum grain.

Today, the country produces about 19 million tons of sorghum grain each year, and millions of American cattle, pigs, chickens, and turkeys are fattened on it. Production is centered in the Great Plains, and extends over a vast area from the Gulf of Mexico to the Dakotas.

But the crop is a more important feedstuff even than that. Only about two-thirds of America's sorghum plants are harvested for grains, and most of the rest also goes for animal feed.

They, however, are turned into forage or silage or are left in the fields for grazing. This use of foliage rather than grain developed after sudangrass was introduced in about 1909. This grass sorghum has since been hybridized with grain sorghums to yield the "sorghum-sudan" hybrids. These crossbreeds are now widely used in the dry regions of the Plains states as well as in the Southeast, where other forages are sometimes hit hard by midsummer droughts and pests.

Although sorghum has advanced rapidly during the last 50 years, the fact that Americans developed it mainly as a livestock feed is in some ways unfortunate: the varieties typically had brown or red seed coats and are only peripherally relevant to food production. Moreover, in the public mind the crop became stigmatized as "animal food." Only now is there a nationwide glimmering of appreciation for sorghum as something people can eat. Today,

American farmers are growing more and more of these food-grain sorghums, abandoning the brown and red types and switching to those with yellow or white seeds.

Red Sorghum Rising

In parts of West Africa people grow a form of sorghum that is inedible (and may even be poisonous). The plant provides a windbreak around huts and along the edges of fields, but more importantly it provides masses of leaf sheaths. These rustycolored, parchment-like wrappings, which surround the leaf stems, provide pigments that are traditionally used to color leather goods. Millions of suitcases, shoes, hats, baskets, book covers, and other products get their brilliant red hues this way. The scarlet flame of the famous "Moroccan leather" and of the fez have their origins in this particular sorghum plant (race caudatum).

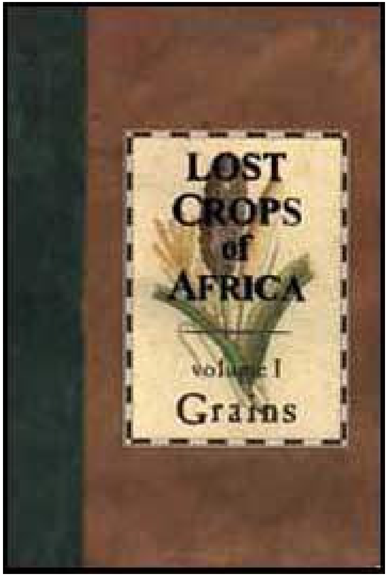
Traditionally, bundles of leaf sheaths were extracted in a difficult and laborious cottage- industry process. Now, however, this time consuming and uncertain technique is being updated. In Burkina Faso, Mouhoussine Nacro, head of the Organic Chemistry Laboratory at Ouagadougou University, has been developing a new and more versatile version since 1989.

Indeed, he is opening up the potential for producing sorghum dyes on a massive scale. Nacro's dye-extraction process uses simple techniques but modern materials. Basically, he and his colleagues crush the sorghum sheaths, add a solvent, separate the liquid emulsion, and centrifuge the result. This produces the pure pigment as a burgundy-red powder that is ready for use and can be safely stored.

The pigment, Professor Nacro has discovered, is a mixture of anthocyanins. The main component, apigenin, is the same natural coloring used by food industries in many parts of the world. Moreover, it is increasingly sought these days because synthetic food dyes are suspected of causing harm.

Red-sorghum leaf sheaths contain over 20 percent of the apigenin and are said to be the only known source of such large concentrations. They contain more than four times the amount in the skin of the red grape, currently the most common source.

Burkina Faso's new process can easily be reproduced on an industrial scale, and commercial production of dyes could result in a new and valuable use for sorghum - one that has widespread application throughout the developing world, but especially in West Africa.


LOST
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volume I
Grains

Notice

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competence and with regard for appropriate balance.

The report was reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

This report was prepared by an ad hoc advisory panel of the Board on Science and Technology for International Development, Office of International Affairs, National Research Council. Staff support was funded by the Bureau for Africa, Bureau for Research and Development, Office of Nutrition, and Office of Research, Agency for International Development, under Grant No. DPE-5545-A-00-8068-00.

A Note from the Sponsors

For two decades, the U.S. Agency for International Development (AID) has supported various reports from BOSTID's Innovation Program. This current one, on the underexploited cereals of Africa, is particularly timely. Africa's nutrition situation is deteriorating, and this is a serious concern. Much of the population is more vulnerable to malnutrition and starvation than ever before. Clearly, the problem needs tangible and sustained support from the international community, but it also needs a host of fresh ideas.

This book offers many such ideas and is part of a commitment

AID made at the International Conference on Nutrition (ICN) in December 1992. There, member countries, nongovernmental organizations, and the international community pledged to eliminate or substantially reduce starvation, widespread undernutrition, and micronutrient malnutrition within this decade.

By highlighting the broad potential for Africa's own native boidiversity to reduce the vulnerability of seriously at-risk people to food shortages, the book could become a major contributor to the ICN objectives. The so-called "lost crops" obviously can help provide food security in their native areas, which include many parts of Africa threatened with hunger. At the same time, however, maintaining the diversity of these ancient crops will protect options for the rest of the world to use.

For these and other reasons, we are pleased to have been this project's major sponsors. We hope the wealth of information in the following pages will stimulate much interest and many subsequent activities. If that occurs, the now largely overlooked resources described herein should contribute substantially toward achieving the goal of eliminating hunger and malnutrition by decade's end.

David A. Oot
Office of Health and Nutrition

John Hicks
Bureau for Africa

Nan Borton
Office of Foreign Disaster Assistance

The National Academy of Sciences is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. Upon the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

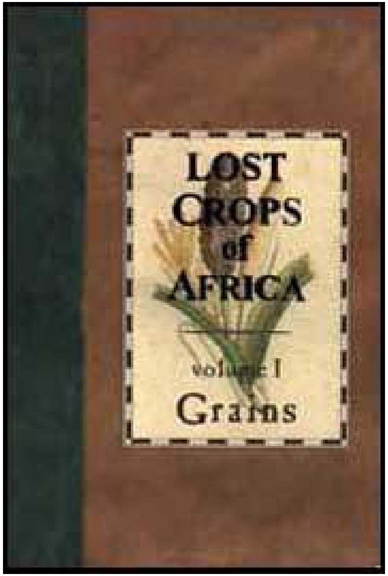
The National Academy of Engineering was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. Harold Liebowitz is president of the National Academy of Engineering.

The Institute of Medicine was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, upon its own initiative, to identify issues of medical care, research, and education. Dr. Kenneth I. Shine is president of the Institute of Medicine.

The National Research Council was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. Harold Liebowitz are chairman and vice chairman, respectively, of the National Research Council.

The Board on Science and Technology for International Development (BOSTID) of the Office of International Affairs addresses a range of issues arising from the ways in which science and technology in developing countries can stimulate and complement the complex processes of social and economic development. It oversees a broad program of bilateral workshops with scientific organizations in developing countries and conducts special studies. BOSTID's Advisory Committee on

Technology Innovation publishes topical reviews of technical processes and biological resources of potential importance to developing countries.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Grains

12. Tef

Tef (Eragrostis tef) is a significant crop in only one country in the world - Ethiopia. There, however, its production exceeds that of most other cereals. Each year, Ethiopian farmers plant almost 1.4 million hectares of tef, and they produce 0.9 million tons of grain, or about a quarter of the country's total cereals.

The grain is especially popular in the western provinces, where people prefer it to all other cereals and eat it once or twice (occasionally three times) every day. In that area, tef contributes about two-thirds of the protein to a typical diet.

Most tef is made into injera, a flat, spongy, and slightly sour bread that looks like a giant bubbly pancake the size of a serving tray. People tear off pieces and use them to scoop up spicy stews that constitute the main meals. For the middle and upper classes it is the preferred staple; for the poor it is a luxury they generally cannot afford.

Unlike many of the species in this book, tef is not in decline. Indeed, farmers have steadily increased their plantings in recent years. The area cultivated rose from less than 40 percent of Ethiopia's total cereal area in 1960 to more than 50 percent in 1980.

Tef is so overwhelmingly important in Ethiopia that its absence elsewhere is a mystery. The plant can certainly be grown in many countries. Some has long been produced for food in Yemen, Kenya (near Marsabit), Malawi, and India, for example. Also, the plant is widely grown as a forage for grazing animals in South Africa and Australia.

Now, however, the use of tef as a cereal for humans is transcending the boundaries of Ethiopia. Commercial production has begun in both the United States and South Africa, and international markets are opening up. This is because Ethiopian restaurants have recently become popular in both Europe and North America. Many cities (including Washington, New

York, Chicago, San Francisco, London, Rome, and Frankfurt, not to mention Tel Aviv) now have restaurants that rely on injera, as well as the convivial communal dining it fosters. And only tef can make authentic injera.

The new appreciation of tef is also extending into the research community. These days scientists in Ethiopia and a few other countries are beginning to seriously study the plant and its products.

This is all to the good. Tef has much more promise than has been previously thought. It provides a quality food. It grows well under difficult conditions, many of them poorly suited to other cereals. Even in its current state it gives fairly good yields - about the same as wheat under traditional farming in Ethiopia. And it usually produces grain in bad seasons as well as good - an invaluable attribute for poor farmers and of special benefit to locations beset by changeable conditions.

However, along with its advantages tef has serious drawbacks, mainly stemming from its tiny seeds, high demands for labor, lack of development, and difficult cultural practices. All in all, at this stage at least, it is neither easy to grow nor easy to handle.

PROSPECTS

To chart tef's future - both its course and final destination among world cereals - cannot now be done with confidence.

This will become clearer as the current research efforts begin producing more results. Nonetheless, there are good reasons for optimism that tef's technical limitations can be overcome and that it can rise to be a specialty crop in a number of nations. It could happen quickly. Indeed, injera is such a fascinating food (half pancake, half pasta) that it has the potential to eventually become well-known worldwide.

Central America. which is being sold in supermarkets throughout the United States and is also showing up ever more frequently in other parts of the world.

Africa

In Ethiopia, the plant's stable yield under varying conditions, as well as the grain's good storage properties, palatability, and premium prices, will likely make tef ever more attractive. However, although prospects for raising its production seem good, substantial increases will probably occur only after its labor requirements are reduced.

Tef may also come to benefit other African countries, notably some that today face food- production problems. The plant's resistance to diseases, pests, and heavy soils give it special appeal.

Several of tef's relatives are valued forages in the world's arid zones, and tef itself might also have a future as a fodder.

Indeed, in southern Africa it is already used extensively, having originally fed the horses and oxen of the Boer War almost a century ago. Tef hay is of such quality that South African farmers prefer it over all others for feeding, their dairy cattle, sheep, and horses.

Moreover, this grass is exciting South Africans as a “quick fix" for holding down bare soil and thereby baffling erosion while more permanent ground covers establish themselves.

Humid Areas Prospects probably low. For Africa's humid areas, tef's prospects are unknown because trials have not been conducted (or at least not reported). However, the crop comes from a relatively dry environment and probably has little or no potential in a hot and steamy one.

Dry Areas Good prospects. Tef is a reliable cereal for unreliable climates, especially those with dry seasons of unpredictable occurrence and length.

Upland Areas Good prospects. Most of Ethiopia's tef is produced at moderate elevations, but it has long been common on the high plateau and is being slowly introduced to higher and higher locations. Its future contribution to the rural economy of these and other African highlands appears to be substantial.

INJERA

Perhaps the most intriguing of all the world's staples, injera is a bread like no other. Moist, chewy, and almost elastic, it has a unique look and feel. A very correct British gentleman visiting Ethiopia in the mid-1800s tried to explain the experience of eating injera: "fancy yourself chewing a piece of sour sponge," he said, "and you will have a good idea of what is considered the best bread in Abyssinia." But these days people are not so closed minded.

Indeed, the search for new tastes and new culinary sensations is becoming a force that is opening up the food industries of affluent nations. Injera is now winning converts all over the world. It is served in fine restaurants in Europe, North America, and Israel and is receiving an enthusiastic welcome.

Other Regions

Tef holds promise for many countries beyond Africa. Mexico, Bolivia, Peru, Ecuador, India, Pakistan, Nepal, and Australia might well adopt it. In addition, this plant's rapid maturity and inherent cold tolerance may open new areas of grain cultivation for high latitudes where growing seasons are short - Canada, Alaska, the Soviet Union, and northern China, for instance. It might also become important to Israel, which has a rising Ethiopian population.

Some observers see tef as a promising new grain for the United States as well. They point out that it is nutritious enough to be a "health" food and tasty enough to be a gourmet food.

A company in Idaho already produces it on a commercial scale and supplies markets nationwide (see box). Tef is also being produced on farms in Oklahoma, where it is harvested by machine and sold under contracts from food companies eager to buy it.

These experiences, limited as they are, are probably laying the groundwork for a mass- produced specialty grain that will remain a part of the American food system.

USES

Tef grain comes in a range of colors from milky white to almost black, but its most popular colors are white, red, and brown. By and large, the darker the color, the richer the flavor.

Although blander in taste, the white seeds command the highest prices. However, the red and brown seeds come from plants that are hardier, faster maturing, and easier to grow. In addition, tef aficionados prefer their more robust flavor.

Tef contains no gluten - at least none of the type found in wheat. For this reason, Americans with severe allergies to wheat gluten are among those buying tef these days. Despite the seeming lack of this "rising,' protein, injera is a puffy product, somewhere between a fiat bread and a raised one.

In Ethiopia, tef hour goes into more than just injera. Some is made into a gruel (muk), some is baked into cakes and a sweet dry unleavened bread (kita), and some is used to prepare homemade beverages. In the United States, it is recommended as a good thickener for soups, stews, and gravies, and, at least according to one promotional pamphlet, "its mild, slightly molasses-like sweetness makes tef easy to include in porridge, pancakes, muffins and biscuits, cookies, cakes, stir fry dishes, casseroles, soups, stews, and puddings."

As fodder, the tef plant is cheap to raise and quick to produce. Its straw is soft and fast drying. It is both nutritious and extremely palatable to livestock. Its leaf:stem ratio (average 73:27) is high, its digestibility (65 percent) relatively high, and its protein content (1.95.2 percent) low but nonetheless valuable. Ethiopian farmers rely on it to strengthen their oxen at the end of winter, a time when fresh grass is unavailable but the plowing season is coming on.

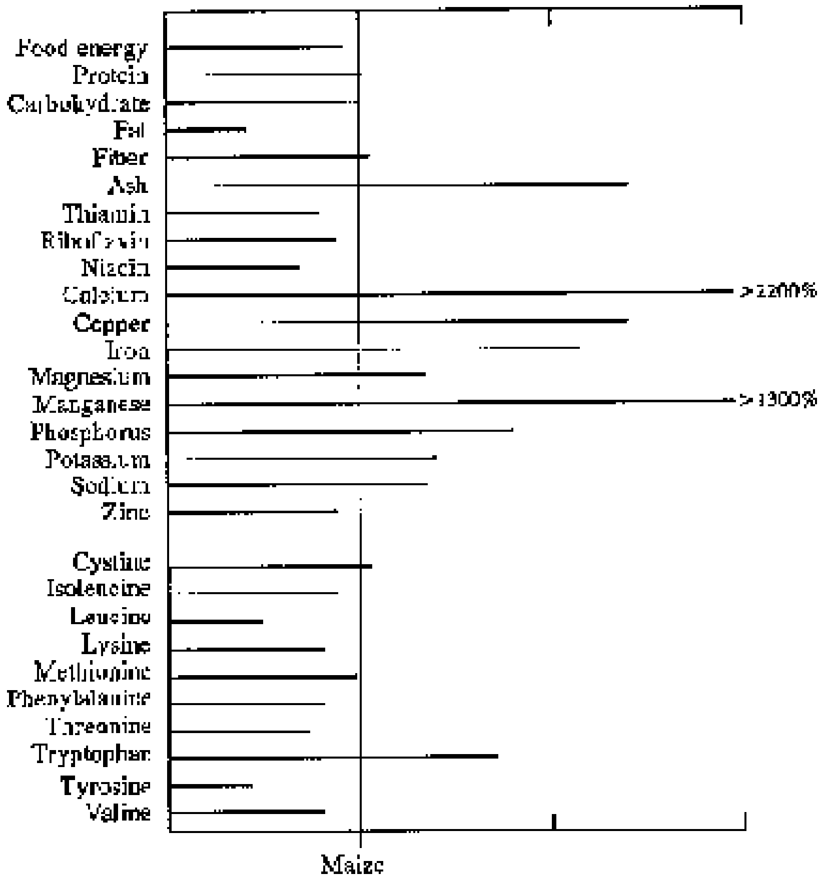
In Ethiopia, tef straw is the preferred binding material for walls, bricks, and household containers made of clay.

NUTRITIONAL PROMISE

Main Components		**Essential Amino Acids**	
Moisture (g)	11	Cystine	1.9
Food energy (Kc)	336	Isoleucine	3.2
Protein (g)	9.6	Leucine	6.0

Protein (g)	[illegible]	Leucine	[illegible]
Carbohydrate (g)	73	Lysine	2.3
Fat (g)	2.0	Methionine	2.1
Fiber (g)	3.0	Phenylalanine	4.0
Ash (g)	2.9	Threonine	2.8
Vitamin A (RE)	8	Tryptophan	1.2
Thiamin (mg)	0.30	Tyrosine	1.7
Riboflavin (mg)	0.18	Valine	4.1
Niacin (mg)	2.5		
Vitamin C (mg)	88		
Calcium (mg)	159		
Chloride (mg)	13		
Chromium (µg)	250		
Copper (mg)	0.7		
Iron (mg)	5.8		

Magnesium (mg)	170		
Manganese (mg)	6.4		
Phosphorus (mg)	378		
Potassium (mg)	401		
Sodium (mg)	47		
Zinc (mg)	2		


Food energy
Protein
Carbohydrate
Fat
Fiber
Ash
Thiamin
Riboflavin
Niacin
Calcium
Copper
Iron
Magnesium
Manganese
Phosphorus
Potassium
Sodium
Zinc
Cystine
Isoleucine
Leucine
Lysine
Methionine
Phenylalanine
Threonine
Tryptophan
Tyrosine
Valine
>2200%
>1300%
Maize

FIGURE

Tef has as much, or even more, food value than the major grains: wheat, barley, and maize, for instance. However, this is probably because it is always eaten in the whole-grain form: the germ and bran are consumed along with the endosperm.

Tef grains are reported to contain 9-11 percent protein, an amount slightly higher than in normal sorghum, maize, or oats. However, samples tested in the United States have consistently shown even higher protein levels: 14-15 percent.

The protein's digestibility is probably high because the main protein fractions - albumin, glutelin, and globulin - are the most digestible types. The albumin fraction is particularly rich in lysine. Judging by the response from Americans allergic to wheat, tef is essentially free of gluten, the protein that causes bread to rise. Nonetheless, tef used in injera does "rise".

The level of minerals is also good. The average ash content is

3 percent. Tef is reported rich in iron, calcium, potassium, and phosphorus. The iron and calcium contents (11-33 mg and 100-150 mg, respectively) are higher than those of wheat, barley, or sorghum. In Ethiopia, an absence of anemia seems to correlate with the levels of tef consumption and is presumed to be due to the grain's high content of iron.

However, some samples of tef have failed to show the extraordinary levels of iron. Part of the iron may well come from dust and dirt that clings almost uncannily to these tiny grains.

Washed seeds have shown a level of iron of about 6 mg, much less than the reported figures but still a remarkable amount.

NUTRITION

Tef seeds appear similar to wheat in food value; however, they are actually more nutritious.

There are two reasons for this: (1) the seeds are so tiny that they have a greater proportion of bran and germ (the outer portions where nutrients are concentrated); and (2) because the seeds are so small, tef is almost always produced as a whole-grain noun.

For a grain, tef is rich in energy (353-367 kcal per 100 g). Its fat content averages about 2.6 percent.

In most samples, the protein content is as good as, or better than, that of other cereals. It ranges from 8 to 15 percent, averaging 11 percent. The protein. as in most cereals, is limited by its Iysine level. Otherwise, however, it has an excellent balance of essential amino acids.

Indeed, two nutritionists, having surveyed all the common foods of Ethiopia, commented:

"[W]e want to draw attention to the high values for methionine and cystine found in tef ....

The protein from a mixture of tef and a pulse will give a near optimal amino acid mixture with regard to both Iysine and to the sulfur-containing amino acids."

The vitamin content seems to be about average for a cereal, but making injera involves a short fermentation process, and the yeasts generate additional vitamins. The value of the grain is thus enhanced.

The mineral content is also good (average ash content 3 percent). The iron and calcium contents (0.011-0.033 percent and 0.1-0.15 percent) are especially notable. In Ethiopia, an absence of anemia seems to correlate with the areas of tef consumption, presumably due to the grain's good iron content.

AGRONOMY

Ethiopian farmers grow tef either as a staple or as a standby. As a staple, they plant it like other cereals, but they normally sow it late and harvest it well into the dry season. As a standby, they wait until their main crop - maize, sorghum, or maybe wheat - shows signs of failing. Then they sow a fast-maturing tef as a backup source of sustenance in case of disaster.

Even where other cereals offer reasonable reliability and substantially higher yields,

Ethiopian farmers still include a field or two of tef. Not only does it bring them high prices, its late sowing date allows them to grow and harvest both crops.

In Yemen, tef is known as a lazy man's crop: the farmers merely toss seed onto moist soil following Hash floods and then return after about 45 days to collect the grain.

No matter how it is grown, tef requires little care once it is established. Its rapid growth stifles most weeds; few diseases and pests attack it; and it is said to produce well without added nutrients. However, in most places tef will respond to fertilizers.

HARVESTING AND HANDLING

Tef threshes well with standard methods and equipment. Very earlymaturing types are ready to harvest in 45-60 days; early types in 60120 days; and late types in 120-160 days.

Yields range from 300 to 3,000 kg per hectare, or even more. Although the national average in Ethiopia is 910 kg per hectare, yields of 2,000-2,200 kg per hectare are considered routinely attainable if good agronomic practices are carefully followed. Yields of 2,000 kg per hectare have been achieved on South African farms also, although storms have sometimes leveled the fields, resulting in large losses.

The grain is easy to store and will survive for many years in traditional storehouses without damage by insects. This makes it a valuable safeguard against famine.

LIMITATIONS

The seeds are so small that this alone makes the crop hard to deal with. The fields are tedious to prepare, and it is difficult to get an even stand. Also, wind or rain can bury the minute seedling before it can establish itself. Threshing, winnowing, and grinding such tiny seeds by hand is very laborious. Handling and transporting them is also a problem because they tend to fall through any crack.

NEXT STEPS

Tef seems poised on the brink of becoming a resource for everyday foods, gluten-free specialty items, animal feeds, and erosion control. Ethiopian farmers, therefore, have much to teach nations the world over. The problem is that at this point few people have recognized tef's qualities. Activities are needed to spark interest and raise overall awareness of tef's status, potential, problems, and requirements. These could begin, for example, with conferences, monographs, newsletters, and publicity materials.

Although people in tef's homeland know more about the crop than anyone else, it is unrealistic to expect that Ethiopia can spearhead such activities, at least at present. An international global effort is called for. Luckily, tef is not a weed. Trials can be conducted in different parts of the world with little hazard. Although many countries could participate, the United States, South Africa, and Australia especially could help pioneer the selection of types for trials and eventual use worldwide.

Tef is also a challenge to the world's cereal scientists, agronomists, and food chemists. It is an interesting new cereal that few people know of at present. It seems to offer many possible benefits, but what its limits and potentials are in practice is still very uncertain.

Germplasm Collection and Evaluation The germplasm in Ethiopia is potentially of worldwide importance. Since Ethiopia is the center of origin and the center of diversity for this crop, preserving its diversity is a prerequisite for all tef improvement. Actually, several thousand samples have already been collected. Although more undoubtedly remain, perhaps the most urgent task is to characterize the tef lines already available.

Plant Breeding Until very recently, crossing tef was tedious. It was constrained to a few minutes at about dawn, and required supremely skillful personnel. Now, however, techniques have been developed that make the process quite straightforward and routine.

A program of tef improvement by plant breeding - combining the desirable qualities of several parents in a planned way - might well bring big advances. Objectives include early maturity, short and stiff straw, disease resistance, and higher harvest index.

One variety created in Ethiopia has yielded 3,560 kg per hectare. Other targets for improving the crop, especially for large-scale commercial production, include larger grain size, less shattering of seeds, and quicker drying seeds.

Agronomy In Ethiopia, large yield improvements can be achieved by applying techniques that are already known: careful land preparation, use of selected seeds, fertilization, sowing and weeding at the optimum time, and disease and pest control, for example. Yields can also be increased by mechanization.

Sowing methods require special attention.

Ornamentals There is now an explosion of interest in ornamental grasses in Europe, the United States. and Japan. With its upright, compact habit, its often brilliantly colored leaves (many color combinations are possible), and open feathery panicles, tef is exceptionally attractive. The development of selected strains might create a small but profitable market niche as an ornamental.

Forages In South Africa various productive races have been selected for hay production.

These deserve to be exploited elsewhere. Also, it seems likely that a wealth of new types, adapted to many different conditions, can be created from Ethiopia's broad germplasm base.

Erosion Control It seems likely that demand will increase worldwide for non-weedy annual grasses that can serve as temporary ground covers. South Africans are now using tef as a “nurse crop" that quickly covers the ground and fosters the establishment of perennial grasses sown along with it. This should be tested elsewhere, too. In South Africa it is already used in mixtures to protect road cuts, open-cast mine workings, stream banks, and other erodible sites.

Black Cotton Soils Tef has evolved on the Ethiopian highlands on vertisol (black cotton) soils that frequently get waterlogged. Few other cereals can be grown there. In fact, tef is able to withstand wet conditions perhaps better than any cereal other than rice. It even grows in partly waterlogged plots, as well as on acidic soils.

Vertisols are a problem in many parts of the tropics. They are cracking clays that regularly heave and sag and split. Few crop plants can withstand such soil abuse. Tef might be a savior for such sites. India, in particular, has vast areas of these "impossible" soils.

Tef Pioneers

Until recently, Ethiopia's official commitment to tef research has been small compared with its investment in wheat, maize, and sorghum. However, several organizations have devoted their own efforts to boost the crop.

Both the Debre Zeit Agricultural Research Centre of Alemaya University of Agriculture and the Institute of Agricultural Research at Holleta Research Station near Addis Ababa have produced high-yield strains. Some of these get so heavy with grain that the stalk collapses.

Research is now under way to develop varieties with short, stiff straw to create high-yielding tefs that can benefit from heavy fertilizer use and irrigation without collapsing.

The Institute for Agricultural Research has also done research on tef with encouraging results at Debre Zeit. It has developed a variety, DZ 01-946, which has given yields of 1.78 tons per hectare.

There has also been increasing international interest. In England, London University's Wye College is doing systematic breeding. In Israel, the Volcani Centre is carrying out tef research trials. And in the United States, Wayne and Elizabeth Carlson of Caldwell, Idaho, have been developing cultivars and processing techniques for farmers both domestic and foreign (see box, opposite).

Tef in the United States

Wayne and Elizabeth Carlson are among the handful of non-Ethiopians who have begun growing tef for food. The crop is thriving on their farm near Caldwell, Idaho. In the harsh, dry valley on the Idaho-Oregon border, their fields are now producing Ethiopia's favorite food grain.

Wayne became aware of tef while working as a biologist in Ethiopia. On returning to the United States, he planted some. Within 5 years the Carlsons had progressed from growing a few varieties in their backyard to harvesting 200 acres of four selected strains, as well as threshing, milling, and packaging thousands of kilos of tef seed each year.

The Carlsons' tef flour now goes to natural-food markets nationwide as well as to the numerous Ethiopian restaurants that have been springing up in major cities to serve Americans as well as an estimated 50,000 Ethiopian immigrants and students. Their long- range goal is to make tef a new option among America's cereal crops.

Tef's homeland has not been overlooked. Each year the Carlsons return a portion of the grains they have bred to Ethiopia for trials and for farmers. Last year, they donated 16,000 kg of seed to a relief agency for planting in Ethiopia.

Wayne Carlson says that the Western world should pay more attention to tef. For centuries the plant's adaptability and nutritional value have helped Ethiopian highlanders maintain their independence in the harsh surroundings in which they live, he notes.

Tef in Transvaal

In 1886, the Royal Botanic Gardens at Kew, England, obtained tef seed from Abyssinia and distributed it to various botanic gardens and other institutions in India and the colonies. In its first issue (1887), Kew's Bulletin of Miscellaneous Information advocated introducing the crop "to certain hill stations in India, to elevated portions of our colonial empire, and indeed to all places where maize and wheat cannot be successfully cultivated."

These efforts stimulated tef trials in various parts of Africa, Asia, and Australia. As a result, many reports on the plant's performance were received.

Perhaps the most effective introduction was to the Transvaal (which was not then under direct British control). Growers there found that "it makes very rapid growth, maturing in seven or eight weeks from the time of sowing, and if cut before the seed develops, a second crop can be obtained from the same stand; it makes an excellent catch-crop for hay, two successive cuttings being obtainable during the summer on unirrigated land. The plants seed heavily, our yield of seed from a small plot has been at the rate of about three-fourths ton per acre [1.875 tons per hectare]; the seedlings are not readily scorched by the intense heat of summer. On account of the soft, thin straw, it dries and cures very quickly."

But despite the good results, tef took off only by a fluke. As is usually the case with new farm crops, it did not sell well when first offered. The story goes that a farmer, having more tef hay than he required, sent the surplus to the Johannesburg market. It sold poorly - none of the buyers knowing the stuff - and it finally went for animal bedding. It is softer than the ordinary bedding (normally cut from sedges and Arundinellal eckloni), and a bayer selected one lot for a racing stable. Rumor has it that the stable owner found his racers eating their bedding in preference to their feed! To his surprise they also began to put on condition. Then he bought up all the tef on the market and called for more. Others soon got wind of this and the price rose. Tef was accepted and became a fodder of notable importance to the Transvaal in the early twentieth century. (For instance, during the Boer War it probably fed the horses on both sides.)

"Tef has raised scores of small Transvaal farmers from poverty to comparative comfort, and has been largely instrumental in putting the dairy industry of the Witwatersrand on its feet," wrote Joseph Burtt Davy in the Kew Bulletin of 1913. "The opinion has been expressed by our farmers that 'if the Division of Botany of the Department of Agriculture had done nothing else, the introduction and establishment of tef as a farm-crop would have more than paid South Africa the whole cost of the Division for the ten years of its existence.”

In the Transvaal, as well as in other parts of South Africa, tef is often sown with its relative, weeping lovegrass (Eragrostis curvula). This perennial has been developed in South Africa into an almost incredible array of types for land protection and reclamation purposes. It is providing outstanding erosion control on toxic, dry, degraded, and infertile slag heaps and other problem sites where nothing previously would grow. As an erosion-fighting plant, weeping lovegrass is better than tef because it is a perennial whose natural staying power keeps the land covered as the seasons go by. But while tef may not be good at such a "longdistance event," it is very good as a "sprinter." Thus tef is used to produce a fast cover that protects the site while its slower cousin is finding its legs.

SPECIES INFORMATION

Botanical Name Eragrostis tef (Zucc.) Trotter

Synonyms Poa abyssinica Jacq.; Eragrostis abyssinica (Jacq.) Link

Common Names

Afrikaans: tef, gewone bruin tef (ou bruin)
Arabic: tahf
English: tef, teff, Williams lovegrass
Ethiopia: tafi (Oromo/Afar/Sodo), safe-e (Had); tef, teff, taf (Amarinya, Tigrinya languages)
French: mil ethiopien
Malawi: chimanganga, ndzungula (Ch), chidzanjala (Lo)

Description

Tef is an annual tufted grass, 30-120 cm high, with slender culms and long, narrow, smooth leaves. It is shallow-rooted.

Its inflorescence is a loose or compact panicle. The extremely small grains are 1-1.5 mm long, and there are 2,500-3,000 seeds to the gram.
The plant employs the C4 photosynthetic pathway, using light efficiently while having low moisture demands. It is a tetraploid with a chromosome number of 2n=40.

Distribution

Tef was grown in Ethiopia before recorded history and its domestication and early use is lost in antiquity. Its most likely ancestor is Eragrostis pilosa, a wild species that looks very similar and has the same chromosome number. Samples claimed to be tef have been found in the tombs of the Egyptian pharaohs. The plant is still harvested in the wild - and wild tef is eaten, sometimes on a considerable scale, in mixtures with other wild grains (see wild grains chapter).

Cultivated Varieties

There are many different types of tef. The narrow panicled "muri" (rat-tailed) types and the dwarf, semi-prostrate and short-lived "dabi,' types, for example. Both of these differ strikingly from the tall, loosepanicled varieties that are most commonly grown.

As noted, three main color types are recognized in Ethiopia:

· White tef (thaf hagaiz). This slow-maturing form is grown in the cool season. It is superior for grain. However, it makes higher demands on the soil and can be grown only below 2,500 m altitude. In South Africa this type is being developed as an export grain.

· Red and brown tefs. These are quick maturing and superior for fodder. In Ethiopia they are usually grown above 2,500 m. Elevation seems irrelevant, however, because this is the type being used in South Africa as a fodder crop.

Environmental Requirements

Daylength The exact requirements are unknown. In South Africa the plant seeds freely between 22 and 35°S latitude (average daylength, 12 hours). In Ethiopia, the latitude is between 5°N and 10°N (daylength, 11-13 hours).

Rainfall The average annual rainfall in tef-growing areas is 1,000 mm, but the range is from 300 to 2,500 mm. Tef resists moderate drought, but most cultivars require at least three good rains during their early growth and a total of 200 to 300 mm of water. Some rapidmaturing cultivars can obtain the 150 mm they need from water retained in soils at the end of the normal growing season. Most tef in South Africa is planted in the 500-800 mm summer rainfall zone.

Altitude Tef can be grown from near sea level to altitudes over 3,000 m. It is particularly valued for areas too cold for sorghum or maize. It has a wider aptitudinal range than any other cereal in Ethiopia. Most is cultivated between 1,100 and 2,950 m.

Low Temperature While tef has some frost tolerance, it will not survive a prolonged freeze.

High Temperature Tef tolerates temperatures (at its lower altitudinal range) well above 35°C.

Ogaden where the temperature reaches 50C.

Soil Type Tef's tolerance of soil types seems to be very wide. As noted, it performs well even on the black cotton soils that are notoriously hostile to crops and farmers. In fact in South Africa it is already very popular on such soil.

Soil acidities below pH 5 are apparently no problem for tef.

Bringing the Dead to Life. . .
. . . Just Add Water

Although the seeds of many flowering plants can survive complete dehydration, all other plant parts die when they dry. Certain plants, however, have the seemingly miraculous ability to recover from desiccation. Within hours of being watered, their leaves, stems, and sometimes even flowers spring back to life. Tissues that were brown and seemingly irreparably damaged take up a healthy green color and resume active growth once again.

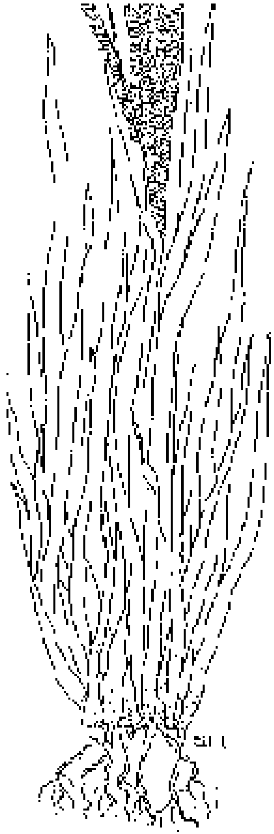
No one knows how many species can defy drought in this way, but it is a small number, and at least four of them are African grasses related to tef. This suggests that crossbreeding them with tef might yield hybrids combining the qualities of a good cereal with the ability to withstand the ultimate drought.

This fascinating possibility of a fail-safe crop that can bounce back from complete desiccation is being studied by Australian plant physiologist Don Gaff.

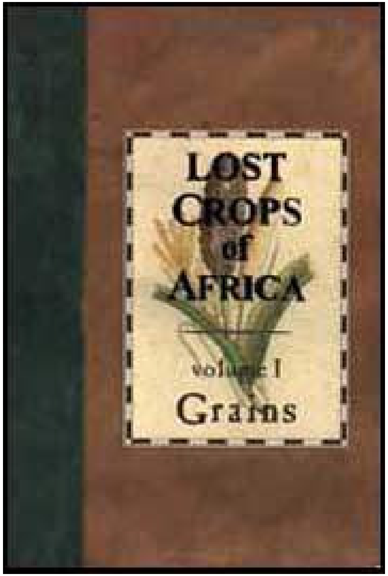
So far, his biggest problem (other than getting funds for such far-out research) has been to get tef to breed with its "resurrection relatives." Fertility barriers between the species are too high for natural pollination, so Gaff has adopted a process known as "somatic hybridization." Using electrical pulses, he induces cells from the leaves to fuse as if they were normal pollen and egg cells. To accomplish this, he must first strip the cells of their cellulose walls. The fused cells resulting from this forced marriage can be regenerated into whole plants using the techniques of tissue culture.

Although only at the beginning of this challenging work, Gaff has already found four eligible partners for tef. These are:

· Eragrostis paradoxa. A rare species collected in Zimbabwe, this relatively low-growing grass with very fine leaves has remarkable resilience and has survived growing on soils only 1 cm deep.
· Eragrostis hispida. This species, too, was from Zimbabwe and is taller and has broad, hair-covered leaves.
· Eragrostis nindensis. A vigorous grower, widely distributed in Namibia and other arid areas of southern Africa, this wild tef is locally valued as sheep fodder.
· Eragrostis invalida. Gaff's sample of this perennial was collected in the Tingi Mountains near the Niger River's source in Sierra Leone. Tallest of the four, it is still only 60 cm high; short rhizomes assist its clumps to spread.



FIGURE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13. Other Cultivated Grains

Some of the neglected cereals described previously - sorghum, finger millet, and pearl millet, for example - are not, strictly speaking, “lost." But there are a number of African food grains that are indeed truly overlooked by all of modern science. Most of these come from wild grasses (see next chapter), but some are from plants cultivated by farmers on at least a small scale. These last, Africa's least known grain crops, are discussed here.

GUINEA MILLET

Guinea millet (Brachiaria deflexa) is perhaps the world's most obscure cereal crop. It is cultivated by farmers only in the Fouta Djallon plateau, a rather remote region of northwestern Guinea. Little, if anything, has been done to improve this crop, yet where it is grown the people value it highly. They grind its soft seeds into a flour, which is used for cakes and fritters.

Although this domesticated plant is grown only in this one area of the Guinea highlands, the wild form is spread throughout the Sahelian zone from Senegal to the Horn of Africa as well as in coastal savannas from Ivory Coast to Cameroon. This wild form is also harvested for food.

The main difference between the two is that the cultivated type has much larger grains and is nonshattering (holds its seeds).

This plant grows to about I m tall, and looks so much like fonio (see Chapter 3) that for decades it was classified as just a special fonio variety.

However, it has botanical differences and bears larger grains.

Although unstudied by agronomists, guinea millet appears to have useful characteristics. For instance, some types mature so quickly they take only 70-75 days from planting to harvest (most, however, require 90-130 days).

Commonly, farmers use these fast-maturing guinea millets to fill in any gaps in their fields of sorghum, maize, or other grains. This allows them to get a full harvest from those fields.

To achieve truly quick growth, however, a rich and well-drained soil is required.

Guinea millet deserves recognition and attention from scientists and others interested in helping food production and agriculture across West Africa. Despite its current obscurity, it just might have a big future both there and in other regions.

ELMER

Emmer (Triticum dicoccum) is not strictly African; it is a wheat that originated in the Near East. Indeed, it was one of the first cereals ever domesticated and was part of the early agriculture of the Fertile Crescent.

Farmers had it in fields perhaps as far back as 10,000 years ago. For several thousand years it remained a major cereal throughout the Middle East and North Africa. Then people switched to durum wheat - the type now used worldwide to make spaghetti, macaroni, and other pastas. In fact, durum wheat (Triticum turgidum var. durum) probably originated from emmer by mutation. Farmers preferred it because its grain was free-threshing (the seed fell out of its husk quite easily), and during the past 2,000 years or so the older form, emmer, became an abandoned waif.

Despite its Middle Eastern origin, emmer nonetheless has an ancient African heritage. It reached Ethiopia probably 5,000 years ago, perhaps more, and it survives there to this day. Whereas it virtually disappeared elsewhere, emmer comprises almost 7 percent of Ethiopia's entire wheat production. Even in what is a major, modern, wheat-growing region, it remains important. Indeed, far from abandoning it, farmers in Ethiopia's highlands have over the last 40 years increased the percentage of emmer that they grow.

Emmer, locally known as aja, is used in various ways. Some is ground into a flour and baked into a special bread (kita). Some is crushed and cooked with milk or water to make a porridge (genfo). And some is mixed with boiling water and butter to produce a gruel. With emmer's high protein content and smooth, easily digested starch, the gruel is especially favored by invalids and nursing mothers.

This "cereal that refuses to die" deserves better treatment from science and commerce. Its economic importance in Ethiopia alone makes it worthy of research attention. However, there might also be worldwide interest. Already, small projects to restore it to widespread modern use are under way in the United States and France (see box). The plant grows in a wide range of environments and can be produced in many parts of the world. The fact that it is the wheat family's "living fossil," little changed from wheat eaten in the times of the Bible and the Koran could give it special consumer appeal. But it can also stand on its own culinary merits. Pliny the Elder (AD 23-79) wrote that emmer wheat makes the "sweetest bread," and even today its virtues are hailed with similar plaudits.

On the face of it, emmer might also benefit the world's wheatbreeding programs. Already, its genes have conferred on the American wheat crop resistance to rust, a virulent fungal disease that in earlier times periodically devastated the nation's food supply.

1935 and 1953, each time sowing fear and high prices. In

1918, the harvest was so bad that the U.S. government had to declare "wheatless days," on which no wheat products could be sold. Its other desirable characteristics include early maturity, drought resistance, and a high protein content.

Resurrecting Biblical Wheats

Emmer (see above) is just one of several ancient wheats that could help the modern world. Two others are being rescued in Europe. The efforts summarized below could be the spur for similar endeavors to bring emmer back as a major crop as well.

Einkorn

Until recently everyone thought that einkorn, perhaps the earliest of all cultivated wheats, was essentially extinct. But in 1989, botanist Jacques Barrau reported the following experience in the south of France.

"In 1971, I decided to look at all the food plants in the mountains of Vaucluse, where my father's family had its origin. From childhood memories, I knew that a kind of porridge was a popular peasant dish there in winter. I started looking for the cereal used for that purpose and found to my surprise that it was the neolithic [Stone Age] einkorn, Triticum monococcum. The crop was still being grown there, as well as in some localities in the Southern Alps, as a subsistence cereal of which the unground grain was used to prepare this special porridge. This was unknown to my learned friends in French agricultural research.

"Today, this relict prehistoric wheat is beginning to find markets as a 'natural health-food,' and it sells at a price rather satisfying for the stubborn traditional growers who, through generations, had kept it in cultivation, just to satisfy their lasting taste for this porridge."

Spelt

For the Stone Age inhabitants of what is now south Germany, spelt (Triticum spelta) was the main food source. Later, however, this primitive winter cereal was abandoned - not because of inferiority but because farmers found other wheats easier to grow. For one thing, spelt's grain had a close-fitting husk that made it harder to thresh, and its very long straw meant that summer winds could blow the plants down.

Now, spelt (or dinkel as it is usually called in Germany) is coming back as a crop. In this case, the driving forces behind its return are modern consumer preferences - notably the rising appreciation for good nutrition and for protecting the environment.

Nutritionally speaking, spelt is very exciting. Breadmaking wheats in northern Europe generally contain around 11 percent protein. Spelt averages between 14 and 15 percent; some types have even exceeded 17 percent. The grain also has greater concentrations of minerals and vitamins. Even with its lower yield, spelt can produce more protein per hectare than modern breadwheat.

And a growing number of consumers are acclaiming the "nutty" taste of products baked from spelt flour.

Spelt's environmental advantages are proving even more important. "The kernel is protected against fungi or insects by the close-fitting husk," explains Christof Kling, head of wheat breeding at Hohenheim University in Stuttgart. "This means the crop is very appropriate for use in environmentally sensitive areas or where farmers want to use less pesticide, or even none at all."

In the old days, when people had to thresh grain by hand, the very attribute that helps to protect the grain against pests and diseases - the close-fitting husk - was an overwhelming disadvantage. But in our mechanized era it is inconsequential.

Like einkorn and emmer, spelt never disappeared entirely, but until recently it was grown in only a few isolated pockets in Germany, Belgium, Switzerland, and Austria. Now all that has changed. In fact, enthusiasm for this long-lost grain is so high that spelt in the early 1990s is being cultivated on over 6,000 hectares in Germany alone. Indeed, a special organization (the Dinkelacker Foundation) has been established to help foster this prodigal son's return from the Stone Age.

Emmer

Recently, researchers in Syria have become excited over emmer. Samples gathered from different parts of the country grew surprisingly well when planted at two ecologically different locations (Tel Hadya and Breda). A wealth of qualities soon became apparent. The researchers concluded that their samples were: "an important genetic reservoir of variability for useful characters such as earliness, short stem, high number of fertile tillers [see picture overpage], long spikes, dense spikes, high number of seeds per spike' weight of kernels per spike, and protein content."

They also noted that most of the emmers exhibited traits suitable for cultivation in the arid areas. "Tolerance to drought is also one of [the] traits, which could be used in breeding wheat for the dry areas," they said.

Ethiopian Barley in New Mexico

Although Ethiopia's barley is all but unknown elsewhere, at least one overseas group has attempted to grow It, and with considerable success. In the dry southwestern quarter of the United States, the Ghost Ranch, a facility sponsored by the Presbyterian church, has been growing it as one of its main cereal crops since 1983. Following are comments by the farm's manager. The photograph was taken after the 1991 harvest.

We grow Ethiopian barley at our experimental farm in the northern mountains of New Mexico. We grow it for three main reasons: it matures quickly (about 110 days); it is hull- less; and it is the most drought-tolerant grain we've ever had. In addition, it has been almost trouble free. We've never experienced a problem with lodging. The plant tillers very well and produces good yields in most years. We haven't had any problems with disease, which might be only because our farm is isolated and the nearest barley grower is about 50 km away.

We thresh the dry grain in a small homemade threshing machine or an old combine employed as a stationary thresher.

It threshes easily. The seed is then cleaned in a seed- cleaning machine. (Both the threshing machine and the seed cleaner run off our solar electric system.) The grain mills nicely and produces a flour that has good baking and eating qualities.

Lynda S. Prim

BARLEY

Although barley (Hordeum vulgare) is probably not a native of Africa either, it also has been used in Ethiopia for at least 5,000 years. Indeed, Ethiopian barleys have been isolated so long that two of them, irregular barley and deficient barley, were for a time considered distinct species.

Among these two genotypes, as well as among the rest of the diversity of barley forms, can be found a wealth of promising types in addition to genes for use in the world's barley crop.

In fact, Ethiopia's assorted barleys are said to be a vital part of its cultural heritage. Under normal circumstances each family sticks tenaciously to its own seed stock. Thus, over thousands of years, each family's stocks have evolved along separate and divergent lines and a vast diversity has resulted. Today, the fields are amazingly rich in different types. In fact, each farmer usually cultivates complex mixtures or even separate plots of quite distinct barleys.

Barley ranks third in terms of area (after tef and sorghum) in Ethiopia. However, its value goes far beyond just economics and nutrition. It is, in fact, deeply rooted in the cultural life.

The Oromo people, for instance, consider it the holiest of crops. Their songs and sayings often feature this "king of grains." Everyone in the highlands encourages children to consume lots of barley. It makes them brave and courageous, they say.

Ethiopians turn barley into bread, porridge, soup, beer, and many other foods. A favorite snack is roasted unripe barley seed. Several types are made into various barley-water drinks, most of them nonalcoholic.

These beverages (made of water infusions of roasted and ground grains) are highly valued. Also, some intoxicating liquors (areuie) are home brewed from barley grains. Ethiopians draw clear associations between each grain type and its use. The white large- grained forms are preferred for porridges. The white, black, or purple large-grained types are made into bread and other baked foods. Partially naked grains are usually roasted or fried.

Small-grained types (mainly black and purple) are used for beverages. Barley is also important to the country's livestock. The grain itself is sometimes fed. (Wealthy farmers, for instance, use it to fatten horses and mules before and after long journeys or to strengthen cattle before the plowing season or going to market.) But more commonly, the animals end up eating the straw. Finely broken barley straw is also employed in constructing mud walls.

For all its importance, however, Ethiopia's barley production can be strengthened. A vast store of indigenous germplasm has yet to be tapped. Indeed, some of it is being lost. (This genetic erosion is happening mainly as farmers switch to crops such a bread wheat, tef, and recently, oats.)

Some of Ethiopia's barley could be made more useful by genes of the barleys developed elsewhere in the world. But the multitude of local types offer great opportunities on their own accounts. Many are unique. Even the number of rows of grains on the seedhead (spike) can be unique. Everywhere else in the world, barleys have exactly two rows or six rows.

However, Ethiopia's irregular barley has two full rows as well as parts of other rows. And its deficient barley has two full rows, but the lateral spikelets are greatly reduced or are wanting entirely.

Although essentially unknown elsewhere, irregular barley ranks fourth among Ethiopia's crops, both in quantity produced and area planted. At altitudes above 2,500 m it is usually the only cereal that can be cultivated satisfactorily. It is very important throughout most of the upper highlands, for example, where it accounts for about 60 percent of the population's total plant food.

Farmers in that area rely on fast-maturing types to save their families from starving during food shortages.

This is just one example of the genetic wealth to be found among Ethiopia's barleys. Other traits include:

· High yields. Some Ethiopian barleys have big and heavy kernels, some plants tiller (send up multiple shoots and seedheads) very well, and others mature quickly.
· High nutrition. Some have high levels of protein and a few are high in Iysine and are thus exceptionally nutritious. They are the only known source of quality-protein barley.

They have been called "Hi-proly" by the Danish food scientists who have studied them most.

· Disease resistance. Several have resistance to diseases such as powdery mildew, leaf rust, net blotch, Septoria, scald, spot blotch, loose smut, barley yellow dwarf virus, and barley stripe mosaic virus.
· Drought resistance. Many have the ability to grow under dry conditions - a feature apparently related to deep and efficient root types.
· Tolerance to marginal soils.

· Resistance to barley shoot fly and aphids.
· Vigorous seedling establishment.

On the other hand, Ethiopia's barleys tend to blow down easily due to weak straw and tall, spindly growth. Some specimens suffer from the condition known as "fragile rachis," in which the seed spike breaks apart and spills the seeds on the ground.

The outside world's barley breeders have not neglected Ethiopia's materials. For example, they employ the accession called Jet (jetblack seeds) to obtain resistance to loose smut, a severe fungal disease. In the United States and several other countries they have employed the genes for resistance to the extremely damaging barley yellow dwarf virus, leading to great savings in grain yields. But many more useful types remain to be employed both at home and abroad.

Thoroughly Modern Millets

Whereas today's most reliable approach to advancing littleknown grains is conventional plant breeding, biotechnology might soon be able to leapfrog much of the tedious and time- consuming toil traditionally involved in creating new varieties. Here we identify a few possibilities.

Because they are well known in scientifically advanced countries, wheat, rice, maize, and (to a lesser extent) sorghum have benefited from high-tech research. Millets, however, remain almost exclusively resources of countries with little or no basic research capacity. Millets have therefore barely benefited from the latest instruments and techniques. Given such attention, it seems likely that they can be leapfrogged into the twenty-first century using biotechnology.

This is especially important to Africa, where the needs are so vast and diverse, the resources so few, the time so pressing, the conditions so changeable, and the priorities so uncertain that conventional plant breeding, which can take 10-12 years to perfect a new variety, may not be up to the task. Certainly, its ability to breed for genetically complex attributes such as drought tolerance is limited. Moreover, in environments such as the Sahel, where climatic variables far outweigh genetic ones, plant breeding is all but impossible to do in the normal way in field trials.

When it comes to Africa, then, biotechnology could have a huge impact. For example, breeding can be done more quickly, it can be done indoors in controlled environments, and it can be done with greater precision. Increasingly, biotechnology can deal with genetically complex traits. In sum, technologies such as tissue culture, anther culture, embryo rescue, protoplast fusion, and genetic markers are likely to bring undreamed of breakthroughs that will transform Africa's native grains.

The key to this gene revolution is to develop tissue-culture techniques for each of Africa's grains. If scientists can grow mature, fertile plants from tissues of pearl millet, finger millet, fonio, irregular barley, and tef, they will open doors to the more rapid development of these cereals. Grasses are difficult to culture so difficult, in fact, that not long ago they were considered impossible - but rice, maize, sorghum, and vetiver have already succumbed and can be grown routinely in tissue culture. Now it seems likely that the right conditions can be discovered for the others.

Once tissue culture has been established, a major challenge will be to "map" the chromosomes using genetic "markers." Knowing the physical location of particular genes will result in many shortcuts to improved strains. This is particularly because thousands of young seedlings can be tested for the presence of specific genes, rather than waiting for the genes to express themselves in the mature plant. It will also allow desirable genes to be more easily transferred, and undesirable ones to be eliminated. The markers could be provided by the restriction-fragment length polymorphism (RFLP) technique, a process already being applied to maize, barley, and rice.

Following are examples of the gains to be achieved:

Drought Resistance. Breeding drought-resistant varieties has always been difficult because researchers had no way to determine genetic influences on the basic mechanisms of drought injury and tolerance. In basic studies, biotechnology is now helping to show how water stress affects the physiological, biochemical, and molecular organization of plants during their various life stages.

In future, the new techniques could target the genes that govern rooting depth, water extraction, and root penetration of compacted soil layers. Once identified and mapped, the genes for these characteristics (which are extremely difficult to evaluate in the field) could be readily tracked in breeding programs. This would lead to crops with much higher drought tolerance.

Striga. An ability to manipulate the genes that attract or repel the striga parasite could boost cereal yields continent-wide.

Hybrids. Biotechnology would make it much easier to make hybrids within and between species. This might be brought about through chemical hybridizing agents, through clonally propagating sterile seed, or through embryo rescue.

As work progresses on the major crops in the world's most sophisticated laboratories, millets should not be overlooked. Pioneers pushing the frontiers of gene manipulation in wheat, maize, and rice, for example, should not leave the millets trailing so far behind that they will be abandoned willy-nilly. Actually, the hightech equipment and powerful genetic tools could likely help make major advances in millets and thereby bring more humanitarian benefits than in all the rest of the work.

ETHIOPIAN OATS

Ethiopia also has a native oats, Avena abyssinica. Partially domesticated in the distant past, this species is largely nonshattering - that is, it retains most of its grain so farmers can harvest them conveniently.

It has long been used in Ethiopia and is well adapted to the high elevations and other conditions there. It is, however, unknown elsewhere. With a rising international interest in oats this little-known species deserves research attention.

Unlike common oats (Avena saliva), which is a hexaploid, Ethiopian oats is a tetraploid. It is seldom grown as a solitary crop; it is almost always sown in a mixture with barley.

Agriculturists may classify it as a weak-stemmed "weed," but not the farmers. They harvest the two grains together and use them mainly in mixtures. These mixtures generally end up in injera (the flat national bread; see last chapter), local beer (tala), and other products. Some are roasted and eaten as snacks.

However, some people don't appreciate Ethiopian oats because the plant is not fully domesticated and does shatter somewhat. It is also fully fertile with the weed Avena vaviloviana, which creates swarms of weedy hybrids that shatter a lot.

Nonetheless, Ethiopian native oats deserves research attention and a chance to prove itself.

KODO MILLET

Although wild forms of kodo millet (Paspalum scrobiculatum) occur in Africa, the plant is not grown as a crop there. However, domesticated forms have been developed in southern India, where they are planted quite widely. This is therefore a plant in the very process of domestication, and the cultivated forms could have an important future in Africa as well.

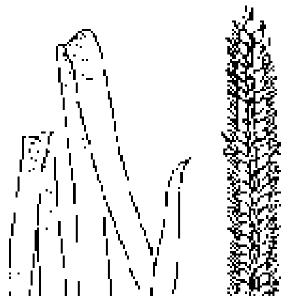
The wild form is common across tropical Africa (as well as across wetter parts of the Asian tropics from Indonesia to Japan). It is often abundant along paths, ditches, and low spots, especially where the ground is disturbed (which accounts for the reason it is sometimes called ditch millet).

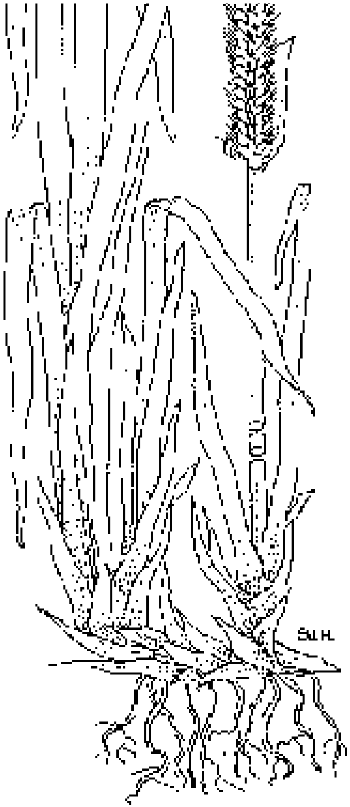
Although kodo millet frequently infests rice fields in West Africa, it is tolerated even there.

Many farmers actually take pleasure in seeing it in their plots. Should the rice crop fail or do poorly, they will not have lost everything . . . the field will likely end up choked with kodo millet, which can then be harvested for food. In this sense, the weed becomes a lifesaver for a subsistence-farming family.

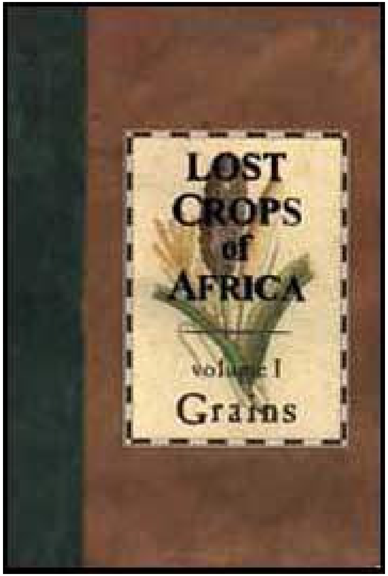
All in all, this is another obscure cereal deserving greater modern research and recognition.

Two technical problems to evaluate are an ergotlike fungal disease and the probable presence of antinutritional compounds.





FIGURE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14. Wild Grains

Over large areas of Africa people once obtained their basic subsistence from wild grasses.

In certain places the practice still continues - especially in drought years. One survey records more than 60 grass species known to be sources of food grains.

Despite their widespread use and notable value for saving lives during times of distress, these wild cereals have been largely overlooked by both food scientists and plant scientists.

They have been written off as "obsolete" - doomed since hunting and gathering started giving way to agriculture thousands of years ago. Certainly there has been little or no thought of developing wild grains as modern foods.

This deserves reconsideration, however. Gathering grains from grasslands is among the most sustainable organized food production systems in the world. It was common in the

Stone Age and has been important almost ever since, especially in Africa's drylands. For millennia people living in and about the Sahara, for instance, gathered grass seeds on a grand scale. And they continued to do so until quite recently. Early this century they were still harvesting not insignificant amounts of their food from native grasslands.

However, in previous centuries the grains of the deserts and savannas were harvested in enormous quantities. In the Sahel and Sahara, for example, a single household might collect a thousand kilos during the harvest season.

The seeds were piled in warehouses by the ton and shipped out of the region by the caravan-load. It was a major enterprise and a substantial export from an area that now has no equivalent and is often destitute.

But in modern times these wild grains have been neglected and even much maligned. Various writers repeatedly refer to them as "famine foods." This is obviously wrong. Where the grains were gathered, surplus was often the rule. Wild grains were eaten even when pearl millet was in oversupply, for instance.

Modern writings also imply that the wild-grass grains were eaten only in desperation when nothing else was available. This, too, is apparently false. The harvest was large scale, sophisticated, and commercial: it must have been founded upon a keen and constant demand. Indeed, all evidence suggests that the grains were a delicacy that even the wealthier classes considered a luxury.

Remnants of this once vast and highly organized production still linger. One observer pointed out that harvests of wild grains were still being carried out in 1968, at least 60 years after they had last been major contributors to the local diet. However, despite its former prestige and ancient heritage, the wild-grain harvest has been declining for a century or more.

A major reason for the decline is that the once vast stands of grasses are much reduced. Partly this results from the demise of the nomads. Sedentary life encourages continuous and localized grazing so that the plants never get a chance to form grains. Partly, too, the decline results from the breakdown of traditional authority. Formerly, chieftains banned grazing animals from certain areas while the wild grains were filling out. If camels were caught there during that time, the chieftain could slaughter one of them in recompense; if goats were caught, he could kill as many as 10.

Just because wild grasses no longer contribute greatly to Africa's food does not mean they should be disregarded. Even preliminary study is likely to turn up many fascinating possibilities and perhaps much future potential. Many come from locations where burning temperatures, scant rains, and ravenous insects make the better-known grains impossible to produce. Some can populate and stabilize sand dunes - perhaps even the juggernaut dunes that threaten to bury oases, farms, villages, roads, and towns. Forged upon the unforgiving anvil of survival, these wild grasses are clearly suited to the worst of conditions.

In fact, plants like these - inured to harshness and constantly pressured by pathogens, pests, severe weather, and harsh soils - are just the sort of resources the world needs for overcoming some of its most intractable environmental problems. For example, some of Africa's wild cereals might be especially good weapons for combating desertification. Indeed, resurrecting the ancient grain-gathering industry could well be a way to defeat land degradation across the worst afflicted areas of the Sahel and its neighboring regions. A vast and vigorous grain-gathering enterprise, for instance, would ensure that once again the grass cover is kept in place and that overgrazing is controlled once more.

Such a possibility is not inconceivable. Wild cereals might be made into an everyday food source, a famine reserve, and perhaps even a specialty export crop. This last may seem unlikely, but it should at least be considered. Today, the overall situation is different from that of a century ago. Railroads and airfreight mean that grains can now be shipped from the Sahara with much greater ease than on the backs of camels. Moreover, consumers in affluent nations are increasingly interested in buying and trying "exotic" cuisines. And many people of goodwill are highly motivated and eager to help avoid the horrendous tragedies of Sahelian drought and famine they have witnessed on their television screens in recent decades.

A similar concept is being attempted as a way to combat the destruction of tropical rainforests. In the last few years, for instance, an international trade in special tropical-forest products has begun. The object is to foster an economy based on resources of the rainforest itself. If successful, it will generate powerful local disincentives for destroying the natural environment.

In the case of the rainforest, the products are such things as wild rubber, fruits, nuts, and vegetable-ivory buttons. In the case of Africa's decertifying areas, the product might be kreb.

Kreb is perhaps the most famous food of the Sahara. A complex of a dozen or more different wild grains, it was harvested from natural meadows. Its composition varied from place to place and probably from year to year, depending on the mix of grasses that grew.

These days, given some clever marketing, "kreb from the Sahara" might sell at premium prices in Europe, North Africa, and North America, for example. It would be seen as a gourmet food that provides income to nomads and protects the earth's most fragile lands from further destruction by keeping a cover of wild native grasses on them.

Although this idea is highly speculative, subject to many limitations and uncertainties, it is not beyond reason. Mixed-grain products are not uncommon in Western supermarkets these days. For instance, in the United States a popular breakfast cereal is a grain mixture that people boil in water like rice. (It is made from conventional grains but goes by the trade name "Kashi," another word for kreb.)

And some expensive breads are made from as many as 11 different grains. Resurrecting the production of kreb could provide food, income, and perhaps a protection against famine. It might bring substantial environmental benefits as well. Many of the wild

African grains come from perennial grasses that continuously cover the soil and protect it from water and wind erosion. In addition, these plants facilitate the infiltration of rainfall and prevent rapid runoff from desert downpours early in the season, a time when annuals are still getting started and much of the soil around them is exposed and hard. Moreover, perennial crops have long growing seasons and the extra solar energy they collect normally produces good grain yields. (This is why some hybrids, including maize hybrids, have been so productive.)

Native perennials might prove to have economic benefits as well. Perennials save the vast amount of energy and labor that farmers must put in each year to move soil for planting and tilling annual cereals. Also, they save on the often large amount of grains that must be put aside each year for planting - with a perennial, those can be eaten.

Beyond their direct use as cereals, Africa's wild grasses may also have international value as genetic resources. Some are related to species used elsewhere for food or fodder and are likely to have genes of international importance - particularly because many of them have outstanding tolerance and resistance to heat, drought, drifting sand, and disease. On the other hand, some might prove weedy when taken out of the desert and introduced to more salubrious situations.

The nutritional value of wild-grass seeds has seldom been studied in detail, but those analyses that have been made indicate that protein contents are usually considerably higher than that of cultivated cereals. Several Saharan grains, for instance, have protein contents of 17-21 percent, roughly twice that of today's main cultivated cereals.

All cereals are low in vitamins A, D, C, B12, and the amino acids Iysine and tryptophan. Wild grass seeds are no exception. However, some may be unusually high in food energy. Certain kram-kram seeds' for instance, apparently have about 9 percent fat and are perhaps higher in energy than any other cereal grain.

Africa's promising wild cereals include those described below. All of these deserve the attention of food and agricultural scientists, as well as of the people involved in battling Sahelian desertification. Even the most basic studies could be extremely valuable. These include the following:

· Tests to determine how best to plant and establish each species (seed treatments, sowing depths, planting times, and so on);
· Direct seeding trials using rain as the sole source of moisture;
· Searches for elite specimens (those that, for instance, hold onto the ripe seed, that have bigger seed, and that best

survive harsh conditions);

· Trials on various sites (from the most favorable locations to moving sand dunes);

· Analyses of food value (physical, chemical, and nutritional) as well as of the foods prepared from them; and

· Multiplication of seeds or other planting materials for distribution to nomads, farmers, governments, and researchers.

Harvesting Wild Grasses

To most people, it probably seems inconceivable that in this age of intensive agriculture, wild grasses are still being gathered. The following (adapted from a recent FAO report) gives a sense of the ongoing importance of wild grains in different parts of Africa.

Niger

On their way from the wet- to the dry-season pastures, the Tuareg of Niger regularly harvest wild cereals. The grains, collectively known as ishiban, include desert panic (Panicum laetum) and shame millet (Echinochloa corona). Women do most of the gathering, and around harvest time groups of five or six women often go off for a week or so to gather wild grains (as well as fruits, gum arable, and other wild products).

They collect the grains in different ways:

· If the seed is ripe and ready to fall, they harvest early in the morning when dew tends to hold the seed in the inflorescence. They swing a deep, cone-shaped basket through the tops of the plants to gather the grain.
· If the seed is not ripe enough to fall, they first cut the grass and then dry, thresh, and winnow the grain as if it were a domesticated cereal.
· If the seed has already ripened and fallen, they cut or burn

the stands, and later sweep the seeds up off the ground. (This spoils the taste and adds soil and pebbles, but the harvesters often have no choice.)

· Sometimes the women search for seeds in ant nests and termite mounds. In desperate times, such as the terrible drought of the 1970s, they even dig down to the ants' subterranean storehouses.

Sudan

The Zaghawa of the Sudan and Chad harvest many annual grasses for food and beer. These include Egyptian grass (Dactyloctenium aegyptium), desert panic, shame millet, wild tef Eragrostis pilosa), and wild rice (Oryza breviligulata). Kram-kram (Cenchrus biflorus) and Tribulus terrestris seeds are used only during famine. The women generally use the grains for their own families, but they sell some as well. The Zaghawa spend a month or two in the areas where the wild cereals grow, often returning with three or four camel loads of grain. The various sites are visited several times, at intervals of 15-30 days. The earliest harvests usually yield the most. There is much communal cooperation. The women mentally mark off areas for themselves, cut the grass, and pile it up to dry. To foil any goats or wildlife, they cover their piles with thorny branches, and to guard against theft, they leave a symbolic stone representing each woman's clan. Livestock are barred from these areas until after the grain harvest, and herders are fined if any animals get in. It appears that the gathering actually helps maintain a good stand of wild cereals, because less useful plants (especially kram- kram) are taking over the areas where gathering is no longer practiced.

Zambia

The Tonga of Zambia routinely harvest the grains of wild sorghum and Egyptian grass, and during famines they also harvest species of Brachiaria, Panicum, Echinochloa, Rottboellia, and Urochloa. They supplement these wild cereals with relishes made from leaves, most of which they also usually find in the wild. These two together provide them with sources of starch, proteins, fats, vitamins, and minerals. They also use wild native plants for brooms, building material, fiber, salt, medicine, poisons, and so on.

South Africa

When in the 1930s the Chamber of Mines began asking about edible wild plants, its labor- recruitment offices across South Africa became overwhelmed. "We were inundated with parcels from many parts of the country containing plants or parts of plants," wrote one of the participants recently. "It became clear that a nutritionally significant part of the people's diet was being obtained from the veldt"

Among the grains sent in were those from

· Sporobolus fimbriatus (matolo-a-maholo)
· Brachiaria brizantha (bread grass, long-seed millet)
· Echinochloa stagnina (bourgou)
· Panicum subalbidum (manna grass)
· Stenotaphrum dimidiatum (dogtooth grass)

DRINN

The grass known in Arabic as drinn (Aristida punges) once provided by far the most important wild grain of the northern Sahara. It was extremely abundant, often growing on sand dunes but especially on bottomlands watered by runoff from higher ground. It is a tall (to 1.5 m), tufted perennial with deep roots and long leaves. Its grains are black.

Travelers crossing the Sahara in the past often wrote about drinn's value, both as a food and as forage. Duveyrier (1864) commented: "its grain is often the only food for people." Cortier (1908) referred several times to the abundance of drinn: "The hillocks of sand in all the plain," he wrote, "are embossed by enormous tufts of drinn, whose black grains at the tips of long stems swing and sweep the soil."

Even as recently as 1969, drinn was still a significant part of the diet in the Sahara oases.

In earlier times it was an important food from the desert's edge almost to the Ahaggar (southern Algeria). It was, for instance, vital to people living a tenuous existence in the very heart of this fearsome region; the Toubou of Tibesti (northern Chad) are just one example.

Kram-Kram is now harvested only when other crops fail, but given some attention it might once again become a universal food for the peoples of the northern Sahel. Also, this wild plant might be converted to a useful crop.

Domestication could come about quickly, particularly if its grain were enlarged by selection or cross-breeding with other Cenchrus species. The plant grows well on sandy soils. It is a reliable source of forage, since it persists in a dry but palatable state until the next rainy period.

On the other hand, kram-kram is vicious. It is a sandbur whose grains are enclosed in clusters (fascicles) surrounded with many sharp spines. These grab onto the fur of animals and the clothing of people. Indeed, they easily penetrate flesh and have literally been thorns in people's sides for millennia. Travelers have long complained of the plant's "troublesome nature" and "constant inconvenience," but they did admit that it was also very useful. "Many of the Tawarek, from Bornu as far as Timbuktu," wrote Heinrich Barth in the mid-1800s, "subsist more or less upon its seed."

When mature' the burs fall to the sand in great quantities, often clinging together in giant masses that roll along with the wind, growing as they go. People sweep them up with bunches of straw or with giant "combs." They throw them into a wooden mortar and pound and winnow away the troublesome spines leaving behind the white, flavorful seeds.

Livestock cannot abide the prickly spikelets, but they like grazing on kram-kram both in its juvenile state and after the spiky burs have fallen off. The plant grows vigorously, and during the rainy period it can be cut several times for hay or silage. The hay must be made at times when the burs are absent, but silage can be made at any time because the fermentation softens the bristles, so that animals digest them without difficulty.

Not all forms of this plant are spiky nuisances. At least one has blunt inner spines and no outer spines at all. It has been called Cenchrus leptacanthus. If this type breeds true and if it could be developed as a crop, it would make kram-kram easier to handle and perhaps very valuable as a forage for many dry areas.

A related species, also used as a wild cereal, is Cenchrus prieurii. It is spread throughout the Sahara from Senegal to Ethiopia (as well as India). People eat the crushed grain, mainly as porridge.

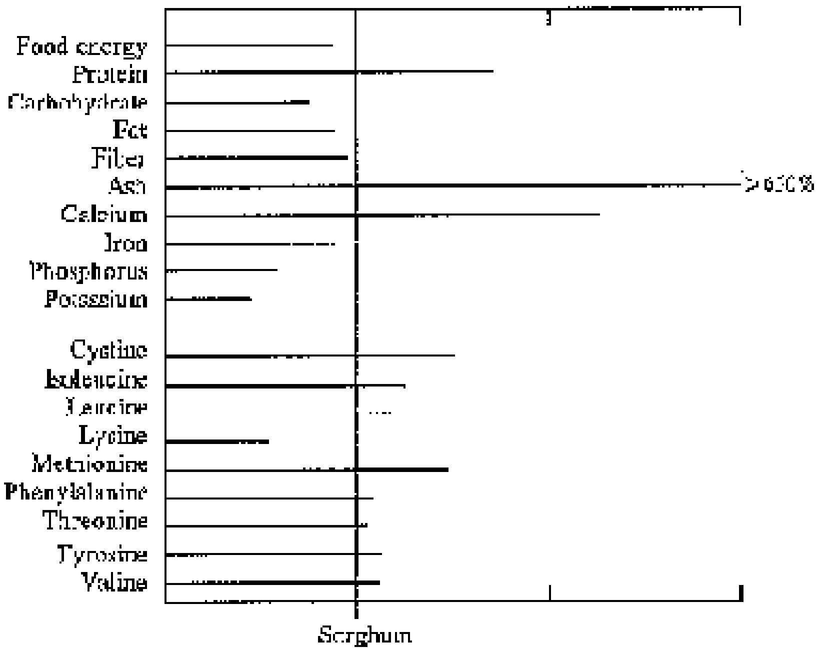
KRAM-KRAM

Main Components(a)		**Essential Amino Acids**	
Food energy (Kc)	325	Cystine	1.7
Protein (g)	19.2	Isoleucine	4.8
Carbohydrate (g)	56	Leucine	15.5

Carbohydrate (g)	56	Leucine	15.5
Fat (g)	2.9	Lysine	1.1
Fiber (g)	2.3	Methionine	2.2
Ash (g)	10.2	Phenylalanine	5.2
Calcium (mg)	63	Threonine	3.2
Copper (mg)	0.5	Tyrosine	3.2
Iron (mg)	6.4	Valine	5.5
Magnesium (mg)	63		
Manganese (mg)	2.0		
Phosphorus (mg)	162		
Potassium (mg)	153		
Zinc (mg)	5		

(a)Assuming 10 percent moisture.

COMPARATIVE QUALITY



FIGURE

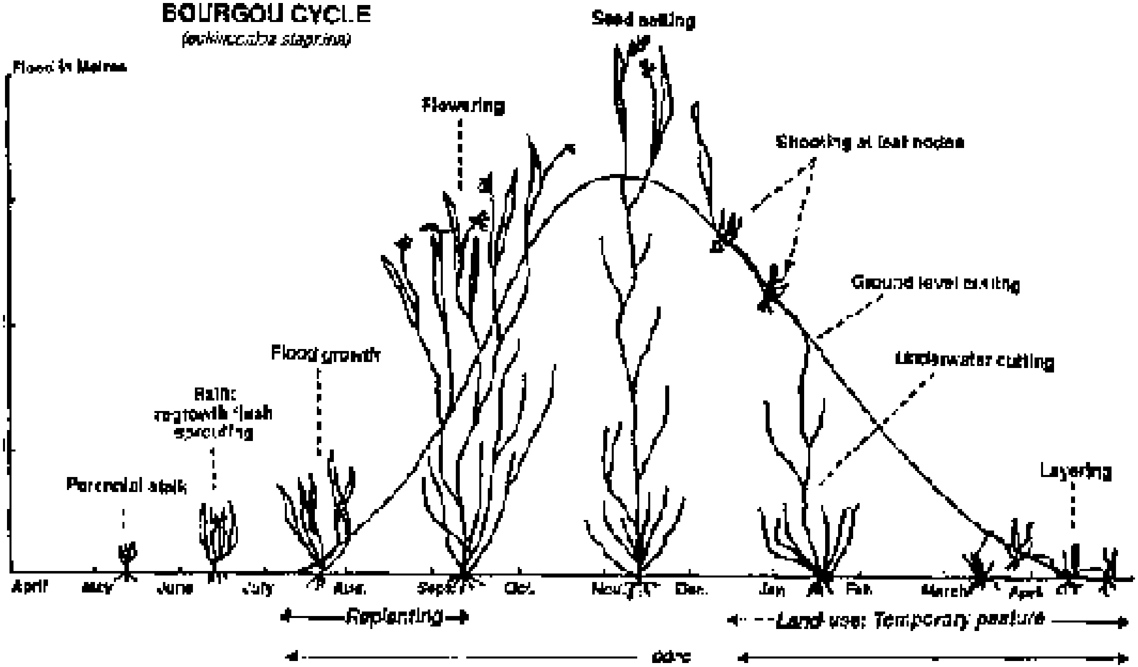
Lakes of Grass

The following, taken from a 1990 report from the United Nations Sudano-Sahelian Office (UNSO), shows how a farsighted project is restoring one of the formerly important West African wild grasses. Although it emphasizes animal feed, it gives a glimpse of what could be done by developing wild grasses for food.

To farmers and pastoralists in the Inner Delta of Mali, the bourgou floodplains supply a crucial source of fodder. Without these bourgoutieres, the livestock would die during the dry season. Only bourgou can survive in these bottomlands that go underwater each year for months at a time.

Bourgou is unique in its adaptation to these amazing conditions. As the waters rise around it, the grass grows taller and taller until (after about 3 months) its stems can reach lengths of more than 3 m. At this point bourgou is like an aquatic plant with only its flowers and seedheads sticking above the surface. Once the water level drops, cattle are given access, and as they walk through the shallows, they trample the seeds and runners into the soft ground. This ensures that the crop will survive and grow again. However, when everything has dried out, there remains on the surface a dense mat of grass, half-a-meter thick.

This mat is what is used for fodder. If well managed, bourgou produces nearly 30 tons of dry matter per hectare - a sizable yield even for much more productive locations. When cut and sold in the market, the grass fetches good prices: between 25 and 100 CFA francs per bundle (1-3 kg) in the early 1990s.



FIGURE

The problem, however, is that the period of intense drought, from 1968 to 1985, destroyed many bourgoutieres. So, in 1982 UNSO and the Malian government began a project to learn how to regenerate bourgou grasslands.

So far, the most effective technique has been to plant rootlings: small, rooted cuttings collected either from existing bourgoutieres or from nurseries specifically set up for the purpose. The planting (at an average rate of 10,000 plants per hectare) is done by hand. This takes a lot of work, but it has been so successful that this grass has now been re-established on more than 4,000 hectares. And, as bourgou is a perennial, it should continue in those floodplains for decades.

Already, regenerated bourgoutieres have had a great impact locally. Farmers use the grass both for direct grazing and for making silage and hay. Many have been able to increase their incomes through selling both fodder and milk. Local milk supplies have increased so much that thousands of families have benefited from better nutrition.

UNSO feels that areas all along the Niger River could also be planted with bourgou. It is possible that the grass might even thrive in other river valleys, such as that of the Senegal, where annual floods make better known crops difficult to grow.

BOURGOU

Of all the grasses of the central delta of the Niger, bourgou (Echinochloa stagnina) was once the most prevalent. At one time it covered an estimated 250,000 hectares. (Much of that land, which is flooded for part of each year, is now under cultivated rice, see Chapter 1.) The Fulani people, for example, harvested large amounts of bourgou seed for food. They also got sugar from the plant. Some of the sugar produced by photosynthesis is not converted to starch and accumulates in the stems. People used it in beverages, both alcoholic and nonalcoholic. Even today, some sugar is still extracted from bourgou and is utilized especially for making sweetmeats and a liqueur.

This grass is found typically along river banks and other moist areas, especially those of Central Africa and on the central delta of the Niger. Recently, a farsighted UN-sponsored project has begun to restore some of the old bourgou stands in the area.

Although its seeds are harvested for food, bourgou today is mainly used for fodder. For this purpose, it is notably important at the beginning of the dry season. As the annual floodwaters recede, it provides the vital forage needed to fatten livestock before the dry season sets in and their drastic weight losses begin.

The genus Echinochloa is one of the larger ones in the grass family. Two more species used for food in Africa are the following.

Antelope grass (Echinochloa pyramidalis) This native of tropical Africa, southern Africa, and Madagascar is primarily used for fodder, but is also used locally as flour.

Shama millet (Echinochloa corona) This plant probably originated in Asia, but it has been in Africa a very long time. Today people eat its grain only in dry years, although Egyptians possibly once grew it as a cereal on farms. The plant thrives in wet, clay soils where few grasses do well (in some African languages it is called "waters/raw"). Beyond its use as a food, the plant is suitable for making hay and silage and is relished by livestock.

CROWFOOT GRASSES

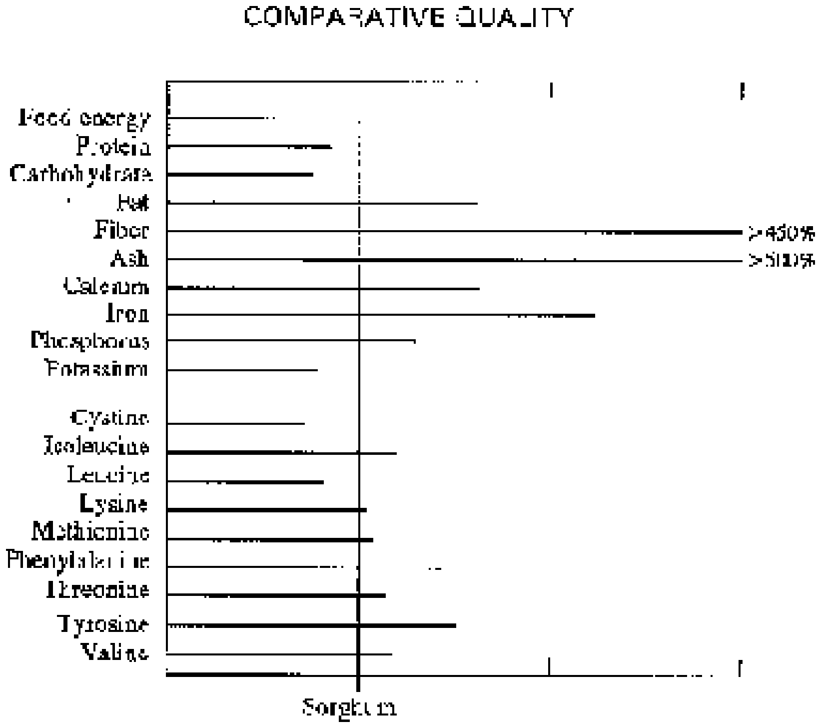
At least one Daclyloctenium species is eaten in Africa. It is the socalled Egyptian grass (Dactyloctenium aegyptium). This annual of the Sahara and the Sudan is now widely naturalized in different parts of the tropics and subtropics, including North America. It has never been considered as a possible cultivated crop, but nomads and others in its homeland (as well as Australian aborigines) gather the grains for food. The plant mostly grows in heavy soils at damp sites below 1,500 m. Livestock enjoy it, and it is also suitable for making hay and silage.

SHAMA MILLET

Main Components(a)		**Essential Amino Acids**	
Food energy (Kc)	311	Cystine	0.8
Protein (g)	9.5	Isoleucine	4.6
Carbohydrate (g)	56	Leucine	10.8
Fat (g)	5.3	Lysine	2.1
Fiber (g)	11.1	Methionine	1.6
Ash (g)	7.8	Phenylalanine	6.9

Ash (g)	7.8	Phenylalanine	6.9
Calcium (mg)	45	Threonine	3.5
Copper (mg)	0.4	Tyrosine	4.3
Iron (mg)	9.7	Valine	5.8
Magnesium (mg)	198		
Manganese (mg)	2.5		
Phosphorus (mg)	369		
Potassium (mg)	270		
Sodium (mg)	9		

(a)Assuming 10 percent moisture.



FIGURE

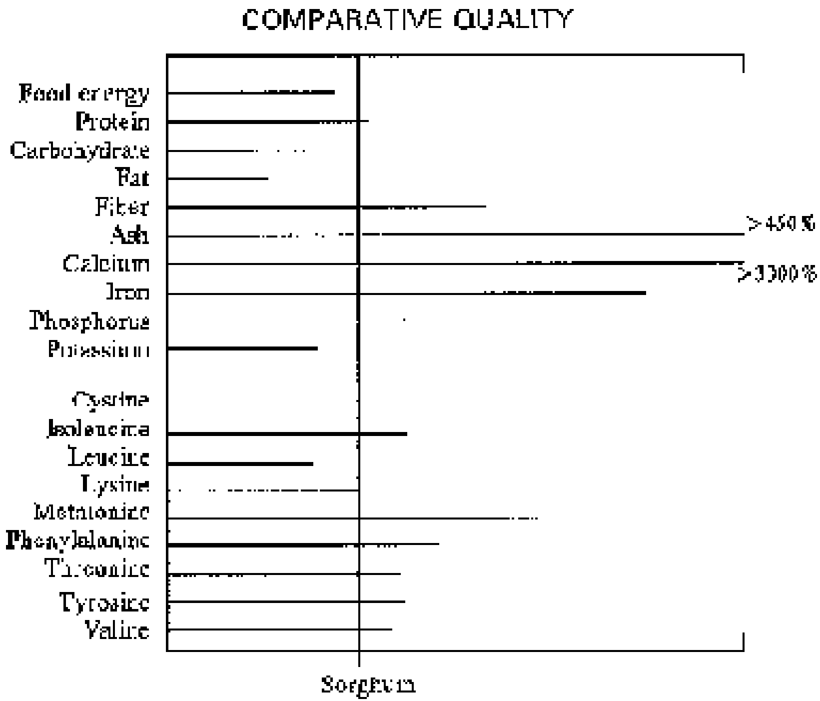
EGYPTIAN GRASS

Main Components(a)	Essential Amino Acids

Main Components(a)		Essential Amino Acids	
Food energy (Kc)	323	Cystine	1.5
Protein(g)	11.8	Isoleucine	4.8
Carbohydrate (g)	65	Leucine	9.9
Fat (g)	1.7	Lysine	2.0
Fiber (g)	4.0	Methionine	3.2
Ash (g)	7.5	Phenylalanine	6.8
Calcium (mg)	963	Threonine	3.5
Copper (mg)	0.6	Tyrosine	3.7
Iron (mg)	10.9	Valine	5.8
Magnesium (mg)	198		
Manganese (mg)	38.3		
Phosphorus (mg)	351		
Potassium (mg)	270		
Zinc (mg)	6		

Zinc (mg)	6		

(a)Assuming 10 percent moisture.



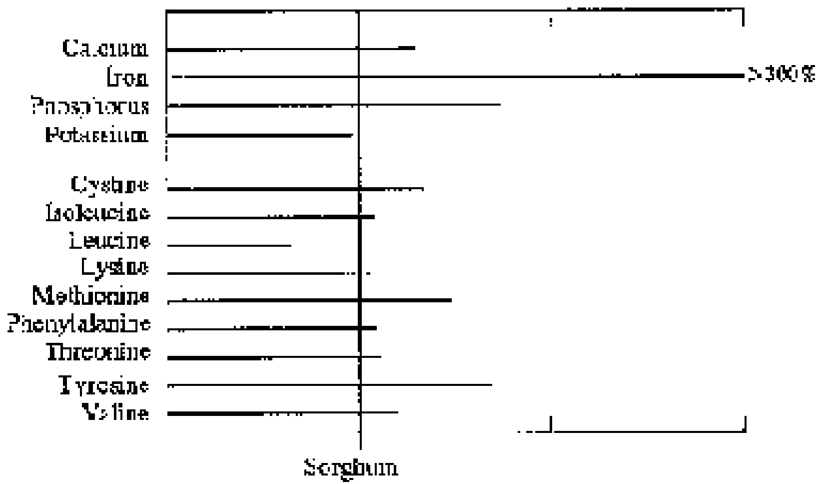
FIGURE

WADI RICE

Main Components(a)		**Essential Amino Acids**	
Calcium (mg)	36	Cystine	1.5
Copper (mg)	0.6	Isoleucine	4.1
Iron (mg)	15.1	Leucine	8.6
Magnesium (mg)	243	Lysine	3.6
Manganese (mg)	4.4	Methionine	2.2
Phosphorus (mg)	495	Phenylalanine	5.2
Potassium (mg)	333	Threonine	3.4
Sodium (mg)	9	Tyrosine	4.8
Zinc (mg)	4	Valine	5.9

(a)Assuming 10 percent moisture.

COMPARATIVE QUALITY



FIGURE

This chapter's tables and graphs show that Africa's faminefood grains can be quite nutritious. They are notably rich in those amino acids that are essential for human health but that are normally deficient in sorghum and the other common staples. Kram-kram, Egyptian grass, and wadi rice, for example, have more of the sulfur-containing amino acids than the FAO reference protein requirement. Egyptian grass and shame millet proteins are also significantly higher in threonine than those usually reported for sorghum protein. Wadi-rice protein (see above) is notably better than sorghum, but it closely resembles that of common cultivated rice in its amino-acid composition.

WILD RICES

Cereals of the West and Central African savannas include two wild rices. One, Oryza barthii, is the wild progenitor of the African domesticated rice (see African rice chapter and especially the map). An annual, it tends to grow in shallow depressions that fill with water during the rains but later dry up. It produces abundant seed and is still harvested on a considerable scale.

The second species, Oryza longistaminata, is perennial and thus requires a more continuous supply of moisture. It is a relatively shy seeder, but its grain is sometimes harvested in sufficient quantities to reach the local markets.

A third wild rice (Oryza punctata) is indigenous to eastern Africa. This so-called "wadi rice" is a freely tillering annual that grows up to 1.5 m tall, and it, too, commonly occurs in rain-flooded depressions. Its seeds are relatively large and resemble those of cultivated rice except that they have a reddish husk. In Central Sudan, where wadi rice is widespread, the grains are boiled with water or milk and eaten as a staple.

OTHER WILD GRAINS

Among other wild African grasses that are, at least on a few occasions, used as food are the following. Little or nothing is known about these or their food uses, but certain botanical tomes contain the following cryptic comments.

Urochloa mosambicensis. Central and East Africa. Grains boiled.

Urochloa trichopus. Tropical Africa. Grains sometimes eaten.

Themeda triandra. Tropical and southern Africa. Perennial grass. Grain eaten during times of famine. Forms principal cover in fireclimax savanna areas. Used as fodder for livestock. Possibly of use in papermaking. Used a lot for thatching; bundles are sold in Ethiopian markets for the purpose.

Latipes senegalensis. Tropical Africa. Annual grass. Seeds are eaten by desert tribes.

Eragrostis ciliaris. Widespread in tropics. Grains used as famine food.

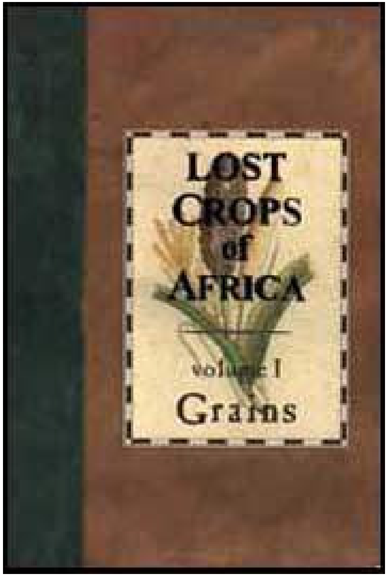
Eragrostis gangetica. Tropical Africa and Asia. Grains used as famine food.

Eragrostis pilosa. Grains harvested regularly in East Africa.

Eragrostis tremula. Tropical Africa and South Asia. Grains used as famine food.

Setaria sphacelata. Eastern South Africa, South Cape, Botswana, Namibia. Perennial, robust, usually tufted grass. Of much economic importance. Different varieties or ecotypes have various uses: for hay and silage; for silage only; or just for grazing. Seeds eaten as famine food.

initiative, mastered by Software Developer Alex Weir and hosted by GNUveau_Networks (From globally distributed organizations, to supercomputers, to a small home server, if it's Linux, we know it.)ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



Appendix A

Potential Breakthroughs for Grain Farmers

This book was intended to be solely a survey of Africa's promising grains. However, in drafting it the staff became aware of certain nonbotanical developments that could bring enormous benefit to the use and productivity of Africa's indigenous grains. Some of these promising developments that deal with farming methods are presented here; others dealing with food preparation are given in Appendixes B. C, and D. It should be understood that the innovations described are not the only ones. Indeed, there may be dozens of alternatives for helping to solve the problems described. Nor is it our intention to suggest that these are panaceas. It should be understood further that the novel subjects described here are largely unproved or even undeveloped. Each incorporates a sound and seemingly powerful concept, but whether any will become truly practical in the harsh reality of rural practice and poverty is uncertain. We present them to encourage scientists and administrators to explore these unappreciated topics that just might become vital to Africa's future.

CONQUERING QUELEA

A tiny bird is perhaps the greatest biological limit to African cereal production. The most numerous and most destructive bird on earth, the seed-eating quelea (Quelea quelea) can descend on a farm in such numbers as to consume the entire grain crop in a matter of hours.

Quelea occurs only in Africa, but there its population is estimated to be at least 1.5 billion. Although it holds much of the continent's agriculture hostage, its worst outbreaks are in parts of the eastern and southern regions, where its plagues are worse than those of any locust.

The fields of ripe grain Iying in the path of quelea migrations are essentially doomed. And it is unlikely that the consequences will diminish. Indeed, marginal lands are increasingly employed to grow grains, and future destruction is likely to be even greater.

The quelea's influence is insidious. This bird not only eats enough farm grain to feed millions of people, it destroys the farmers' morale and drains all interest in planting more land.

Where quelea occurs, family members must patrol the ripening fields for weeks, disrupting their lives and restricting all outside activities such as jobs or schooling. Its preferences even dictate what is planted - millions of families now grow dark-seeded, tannin-rich, poorly digestible sorghums, at least in part because the birds, quite naturally, dislike them (see Chapter 10).

Trying to scare away hordes of ravenous birds is clearly futile in all but the smallest plots.

Efforts to control quelea with poisons, napalm, dynamite, pathogens, and electronic devices have failed. Dynamiting the densest concentrations can achieve temporary local control, but a single flock may contain more than two million pairs and spread over an area far too wide for an explosion to have much effect. However, one line of research is now showing some promise.

At sunset each day queleas congregate in patches of tall grasses or trees. As the sky darkens they crowd together, until thousands are packed side by side in a small space.

Researchers at the Zimbabwe Department of National Parks and Wildlife Management have observed that (provided the night is dark and the roost is isolated and fairly homogeneous, such as a patch of bulrushes) the birds are loath to leave. When disturbed, the chattering flock flutters forward a meter or two and only reluctantly decamps into the soundless darkness beyond. Indeed the scientists found that, once the flock had settled in' they could "herd" it around in the roost on moonless nights. By blowing whistles, beating on metal, or making some other disturbance, they could hustle the birds from one end to the other at will.

This was the key. If a barrier (a sheet of glass or transparent plastic, for example) was placed across the middle of the roost, thousands of queleas could be forced to fly into it each night (at least, for three consecutive nights, after which the birds became more cautious). If a holding cage was placed beneath the barrier, at least some of the halfstunned birds tumbled in. They could then be dispatched humanely, or, even better, could be trucked directly to a slaughtering facility and processed like poultry.

In a second step, the Zimbabwe researchers tested tailor-made roosts. In isolated locations (and on sites quelea should find irresistible), they planted plots of napier grass and shaped them with slightly narrowed waists where the barriers and traps could be easily erected.

This seemed like an excellent way to turn a pest into profit, or at least into food, but it proved to have operational difficulties. The biggest problem was that only a few birds ended up in the cages. Those coming in from the fields flew fast enough to stun themselves on the glass, but most of those herded within the roost recovered too fast to fall.

Actually, because of such disappointing results the Zimbabwean authorities dropped the whole idea. They do, however, still use trap roosts to concentrate the birds so that workers with backpack sprayers can get to them with avicides (bird-killing chemicals).

This is much cheaper than using aircraft.

For most parts of rural Africa, killing birds with chemicals is unlikely to be nearly as practical or as appealing as capturing them for food. Thus, even though not yet perfected, the trap-roost concept seems to have promise. Indeed, it might in the end prove ideal for much of rural Africa because it offers the hungry poor both food and source of income. In principle, the operation is simple, cheap, and easy to understand and replicate. Given a new burst of innovation, today's limitations might well be overcome. Nets might be devised or the cages raised so that the chattering flocks would fly right in during the dark of the night and not have to stun themselves at all. Certainly, there seems to be much scope for improvement.

Of course, at this early stage there are many uncertainties even if the method can be made operational. Will it work in locations where the birds normally roost in trees? Could it be modified for use in trees'? Are there grasses better than napier? Will the birds learn, over time, to avoid the seductive patches of grass?

These issues are of course unresolved. However, if this approach can be made to succeed even partially, its effects could be far-reaching. And if it can be brought to perfection, it might transform the production of cereals throughout the quelea combat zone. Relieved of this feathered scourge, farmers could grow the best-adapted, best-tasting, and most nutritious grains. They could plant more land, their children could stay in school during bird season, and they themselves could keep their outside jobs.

Although the trap-roost technique will never be a panacea, it appears to have advantages over other approaches on several grounds:

· Environmental. The method requires no bird-killing chemicals.
· Economic. Trap roosts need no imported materials and farmers can build them with their own labor and materials so the technique could be employed by subsistence farmers, who

have no cash to spare for bird control.
· Conservation. Although the fact that other species roost with quelea is a concern that needs to be evaluated, techniques such as use of chemicals and explosions, for instance - are as indiscriminate or more so.
· Logistical. The method is independent of supplies, government, consultants, or high-level training.
· Adaptability. Catching birds in trap roosts seems infinitely adaptable to various locations and to the differing needs of users from subsistence farmers to large-property owners. For instance, a village farmer might install a small trap roost to get a little "poultry" for a party or a corporate farmer may establish many large ones to maximize a crop worth millions.

EXORCISING WITCHWEED

A small plant is the second largest biological constraint on Africa's cereal production.

Usually called striga or witchweed, it is a parasite that lives off other plants during its first few weeks of life. Its roots bore into neighboring roots and suck out the fluids, leaving the victims dried out and drained of life. (thus the drying-out effect) and to increase its production of roots (at the expense of its leaf growth). Obviously both are processes that greatly reduce grain yields. Information from J.L. Riopel.

Unfortunately, striga (there are two main species, Striga indica and Striga hermonthica) loves maize, sorghum, millet, cowpeas, and other crops. Millions of hectares of African farmland are continually threatened; hundreds of thousands are annually infested. The traditional defense was long, idle fallow - now impossible because of population pressure.

And today when striga breaks out severely, nothing can be done. Farmers usually abandon their land. Some of the most productive sites now lie idle - victims of this abominable sapsucker.

And the problem is worsening. Striga is most damaging when crops are stressed by drought or lack of nutrients - phenomena that are increasingly common. Changes in farming practices are also helping striga to conquer ever more countryside. The continuous cropping of cereals, for example, contributes more and more striga seed to the soil.

At present, the only way to keep this weed in check is by carefully crafted farming practices: crop rotations, fertilization, and skillful use of herbicides, for instance. But this is impractical for the millions of subsistence farmers who have no surplus land for crop rotations and can afford neither fertilizer nor herbicides. Also, it would be nearly impossible to train millions of farmers to modify their farming practices, especially in the impoverished zones where striga is most threatening.

A "technological fix" to take care of the problem easily, universally, and permanently has never been found, but there is a possibility that it might be just around the corner. A crack in the plant's biological armor has been discovered, and through it researchers see exciting new prospects.

The excitement is based on the recognition that striga relies heavily on "chemical signals" to locate its victims. The mechanisms of this signaling have now been defined. In addition, approaches have been designed to cut striga's "lines of communication" or to provide misinformation. And control methods are proving successful in laboratory trials and even early field experiments.

Striga seeds refuse to germinate until they receive a chemical signal from the root of a potential host. The signal telegraphs the fact that a victim is nearby and that moisture is adequate for successful germination. The seed may lie dormant for decades awaiting this chemical confirmation that it is safe to come out.

But striga's elegant adaptation provides a window of opportunity. Farmers could, at least in theory, block the signals. Better still, they could supply false signals and trigger striga seeds into suicidal germination. Striga depends so much on the lifeblood of other plants that unless its seedlings can latch onto a root within four days, they die. Each striga plant produces millions of tiny seeds, but a chemical trigger could perhaps fool all of them into germinating. If the land had been newly plowed, the parasite would find no victims and four days later farmers could safely plant their crops.

Recently, scientists have identified chemical signals that trigger striga's germination as well as others that inhibit it. Apparently, the balance between stimulation and inhibition is what determines whether the seed will germinate. Both chemical types are extremely active. The stimulants, for instance, can be diluted 10,000-fold or more and still cause striga seed to germinate. If compounds like these can be synthesized, mimicked, or economically extracted from plant roots, they could be (at least in humanitarian terms) among the most valuable of all organic chemicals. For example, it may be possible to produce striga-suicide sprays, perhaps even in the regions that require the most help. This approach has been exploited by Robert Eplee of the U.S. Department of Agriculture to dramatically reduce striga attachment in greenhouse tests.

Also, another striga signal has been identified. This compound (2,6-dimethoxybenzoquinone) "tells" the germinating striga seedling to form the organ (haustorium) that pierces the victim's root. This, too, may offer a way to overcome striga. For instance, an antagonist chemical might blunt striga's underground weapon. If the pest can find no host' it never develops a growing shoot (apical meristem), it never becomes photosynthetic, and it dies.

Recently, scientists have found that nature is ahead of them. At least one strain of sorghum can already foil striga by producing watersoluble compounds that are striga inhibitors. This sorghum, SAN-39, both resists the parasite and has desirable agronomic characteristics and good-quality grain. Its striga resistance appears to be simply inherited (only one or two genes). Crosses with other cultivars have already been made and promising progeny obtained. Moreover, an assay has been developed to screen breeding material for this resistant characteristic. These results suggest that sorghum breeders may soon be able to breed for striga resistance rapidly and efficiently. Similar progress has been achieved in maize.

It has also been found that some leguminous plants -

Crotolaria species are examples - excrete their own striga-stimulating signals but do not serve as hosts. Although the striga germinates, it immediately dies. Thus, plants like these could be employed to deplete the striga seed bank in the soil. They may prove extremely valuable species for fallow crops or alley crops. Crotolaria species (rattleboxes) are legumes, so they not only knock out the parasitic pest, they also enrich the soil with nitrogen and organic matter.

All these approaches to the striga problem should be top research priorities, and not only in Africa. This parasite already affects India and has broken out in a small part of the United States. It could easily come to infect much of the world's farmland. Solving the problem now would lift from African agriculture a burden so big that the result might compare with a "Green Revolution." It would also help insulate the rest of the world from the heartbreak of this herbaceous horror. All countries have a stake in the outcome of this challenging research.

LIQUIDATING LOCUSTS

Numerous African countries, but especially those in the Sahel, are victimized by the desert locust (Schistocerca gregaria). Controlling this one pest soaks up vast amounts of money, time, and insecticides - 700,000 liters of concentrate were sprayed over 14.5 million hectares in 1988, for instance. It has generally been effective, but in recent years some of the locust's relatives have risen up to become equally menacing. In 1989, for example, grasshoppers - in particular the Senegal grasshopper (Oedalus senegalesis)-arrived just at harvest time, causing 10 times more damage than the locusts had the previous year.

For nearly 30 years Dieldrin was the pesticide of choice. Applied in strips across the desert terrain where locust larvae hatch, it seemed an ideal way to stop the insects before they reached their damaging migratory stage. It worked, it needed no repeated spraying, it was cheap, and it could be stored without degrading even in the scorching heat of the Sahara.

But in the late 1980s, even while locust swarms were swelling to worrisome levels, people began protesting because of Dieldrin's potential toxicity to humans and animals.

On environmental grounds, organophosphorus chemicals and pyrethroids seemed preferable but they remain effective for a few days only and must be reapplied over and over.

This means higher costs, more work, and the destruction of all insect life - even beneficial species.

Now, a new approach to chemical control seems to offer some hope. Research in Germany has shown that oil from the seed of the neem tree (Azadirachta i' indica stops locust nymphs from clustering.

After exposure to even tiny doses, the juvenile locusts fail to form the massive' moving plagues. They remain alive but solitary and lethargic; they sit on the ground, almost motionless, and are thus very susceptible to insectivorous birds. Grasshopper nymphs are affected in the same way.

This is very different from the earlier applications of neem against locusts. Those first attempts used alcoholic extracts of the seed kernel, and were aimed at disrupting metamorphosis or at stopping the adults from feeding on crops. Although highly promising in experiments, they proved less successful in practice.

The new approach uses neem oil rather than neem-kernel extracts. Experiments have shown that at very low concentrations (2.5 liters per hectare) this oil, like Dieldrin, prevents locusts from developing into their migratory swarms. It doesn't kill them but it keeps them in the harmless, solitary (green) form. It apparently disrupts the formation of hormones necessary for the transformation into the yellow-and-black gregarious stage whose plagues are the bane of arid Africa and Arabia.

The neem tree grows throughout West Africa, and thus the locustcontrol agent could, in principle, be locally produced. To press the oil out of the neem kernels and to spray it over the areas where locusts breed and gather requires neither particularly high-technology equipment nor unexpected expense. The oil itself is neither toxic to mammals nor to birds and is biodegradable.

Another approach that may have some localized merit is to provide nesting sites for insectivorous birds. In western China, where another plague locust occurs, farmers have reportedly met with success by protecting, and even building, nesting sites for the feathered locust eaters of the area.

EASING EROSION

The effects of soil erosion are well known: it devastates farms and forests: worsens the effects of flooding; shortens the useful lifetimes of dams, canals, harbors, and irrigation projects; and pollutes wetlands and coral reefs where myriad valuable organisms breed. But there could now be a way to slow or even stop it.

Hedges of a strong, coarse grass called vetiver have restrained erodible soils for decades in Fiji and several other tropical locations. The hedges are only one plant wide and the land between them is left free for farming, forestry, or other purposes. This persistent grass has neither spread nor become a nuisance. If current experience is applicable elsewhere, vetiver offers a practical and inexpensive solution to the problem of soil losses in many locations. It could become an exceptionally important component of land use, at least in the hot parts of the world.

This deeply rooted perennial can already be found throughout Africa, but in most places the idea of using it as a vegetative barrier to erosion is new and untested. However, it is not farfetched. Strips of vetiver certainly are able to catch and hold back soil. The stiff lower stems act as a filter that slows the movement of water enough that it drops its load of soil.

Equally important, the dense, narrow bands of grass cause the runoff water to spread out and slow down so that much of it can soak into the soil before it can rush down the slopes.

This captured moisture allows crops to flourish when those in unprotected neighboring fields are lost to desiccation.

So far, all the international attention has focused on an Indian vetiver (Vetiveria zizanioides).

This is already widespread in Africa and has shown promise for controlling erosion in Nigeria, Ethiopia, Tanzania, Malawi, and South Africa, and appears to be a blessing for many countries. However, Africa has its own native Vetiveria species. These are entirely untested, but they may confer similar benefits. One (Vetiveria nigritana) has long been used to mark out boundaries of properties in northern Nigeria, for instance, and it has been employed for the same purpose in Malawi and Zambia as well.

Vetiver has many interesting and unexpected uses. Tobacco farmers in Zimbabwe report that putting a vetiver hedge around their fields keeps out creeping-grass weeds, such as kikuyu and couch. It even seems to be a good barrier to ground fires.

In the Sahel? vetiver hedges may prove extremely useful as sand barriers. Winds off the Sahara often blow sand with such power that it scythes across the landscape at ankle level, cutting off young crops before they are barely beyond the seedling stage. Rows of vetiver planted on the windward side of fields could be an answer. The stiff stalks would doubtless halt the scurrying sand, providing both a windbreak and a sand trap.

Rows of vetiver planted across wadis may also make excellent waterharvesting barriers.

Once planted, the barriers would be essentially permanent. The deep-rooted grass is likely to find enough soil moisture to survive even the driest seasons in most arable locations.

Although the upper foliage may die back, the stiff, strong lower stalks that block the sand, soil, and water will remain. These are so coarse that not. even goats will graze them to the ground.

HANDLING SMALL SEEDS

As has been noted several times, a major problem with many of Africa's grains - finger millet, fonio, and tef, for example - is that they have tiny seeds. Size alone is holding these crops back. Small seeds create many difficulties. They are hard to store and hard to handle because they pour uncontrollably through even the smallest holes. They also make the crop difficult to plant because the soil must be very finely textured (clods or clumps can overwhelm the seeds' puny energy reserves), and the seeds must be placed precisely at just the right depth. Moreover, because the emerging seedlings are small and weak, they are easily smothered by weeds.

Many innovations could probably be devised to overcome these problems; here we present several examples of seeding devices newly developed in four Third World countries. These are undoubtedly not the only innovations for planting small-seeded crops, but we present them here as guides to those who wish to help Africa's lost crops.

Cameroon In the late 1980s, the Cameroonian Agricultural Tools Manufacturing Industry (CATMI) in Bamenda produced a seeder that, compared to traditional planting by hand, reduces planting time by 60 percent and seed requirements by 33 percent. It is not specifically for small-seeded crops but includes a simple distributer mechanism that can be adjusted to accept seeds of different sizes. It is said to reliably plant the desired number of seeds at the right depth and distance apart.

It is simple to handle, suitable for planting both on ridges and on flat land, durable, easy to maintain, and cheap. In 1988, 30 prototypes were distributed to farmers and research stations for field testing.

After further improvements, 300 more were produced and sent out. Various agricultural services ran information and demonstration campaigns to promote the planter. A line of credit was set up in the Northwest Province to enable small farmers to purchase one. In addition, other provinces were contacted and provided with demonstrators and seed planters.

A survey after the first planting season (1989) indicated that 97 percent of the farmers who tried the implement bought it. Not only did it make the work easier (no back pain) and speeded up planting, but it also reduced the need for hired labor and helped increase both the area farmed and the yields achieved.

Peru Cultivos Andinos, Universidad Nacional Tecnica del

Altiplano, Avenida de la Infancia N° 440, Huanchac, Cuzco, Peru. In the Andean city of Cuzco, Luis Sumar Kalinowski has created a seeder capable of handling kiwicha, whose seeds are as small as sand grains. It is a simple, almost cost-free device that can sow large areas evenly and in uniform rows. It may also work well with Africa's small seeds.

One version of the Sumar seeder uses a scrap piece of plastic pipe with a foam-plastic cup taped to the end. A nail is pushed gently through the bottom of the cup to leave a hole of known diameter.

Another version employs a commercially available plastic end piece, which is drilled to provide the hole. In either case, seed placed in the pipe trickles out at a constant rate, and the farmer can vary the seeding density by walking faster or slower.

Indeed, by measuring the flow of seed through the hole, it is easy to calculate how fast to walk (in paces per minute, for example) to sow the desired density of seed. With a little practice, the farmer can attain an accuracy rivaling that of mechanical drills. For the method to work, however it is important that the seeds be clean and free of straw, small stones, or other debris that could block the hole. Engineers at Morogoro have designed and developed a low-cost, hand-operated device known as the Magulu hand planter. It includes an attachment that can be fastened to a hand hoe and can be used to plant both maize and beans in a straight row. It is said that to plant a hectare of land using the Magulu hand planter takes between 18 and 27 man-hours as compared with 80 man-hours using the conventional method of planting by hand hoe.

Thailand The Asian Institute of Technology (AIT), which is located near Bangkok, has developed a mechanical seeder that is now being popularized in many Asian countries. In one stroke, this so-called "jab seeder" makes a hole, drops a seed, and covers the site, without the operator ever having to bend over.

The seeder weighs only about 1.5 kg and costs about US$10.00 (including labor, materials, and mark-up). In Thailand, a farmer can recover the cost. in terms of labor saved, in only 5 days and on an area as little as one-fifth of a hectare. Mass production is expected to reduce the cost even further.

In Thailand's northern province of Chiang Mai, the idea has already caught on: a number of local manufacturers are producing mechanical seeders based on the AIT model.

At present, this machine is not intended specifically for small seeds. It is used mainly with soybean, rice, maize, and mungbean. But even with these crops, it brings big advantages in labor saving and yield.

In Nepal, field tests have found that - at wages of 25 rupees (US$1) a day - a farmer can recover the cost of a jab seeder by planting maize or soybean in just I hectare of land. Fifty seeders made locally by the Agricultural Tools Factory in Birganj cost US$13.50 each.

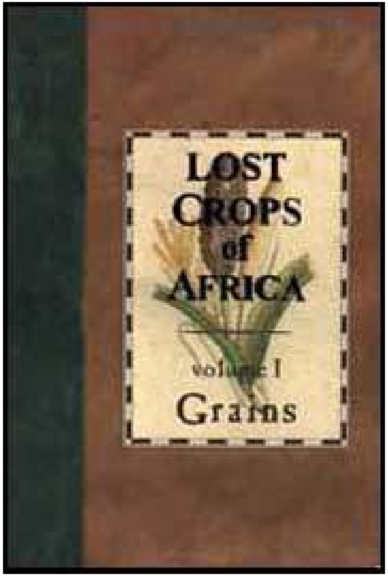
By making a less onerous and more systematic operation, the jab seeder could well increase grain-crop productivity and thereby benefit millions of Africa's grain farmers.

OTHER INNOVATIONS

Seed planters are probably the main need for small-seeded crops, but they are not the only need. Various appropriate technologies are required also for harvesting, storing, shipping, and handling tiny cereal grains. Some of these might come from techniques devised to produce ornamentals, forages, and vegetable crops, many of which also have minute seeds.

Southern Great Plains with precision for half a century. I worked with native grass seeds myself for 25 years. Some of the seeds are smaller than tef, fonio, or finger millet. We had equipment that would mete out seed at low seeding rates very accurately and plant them with precision. Our planters, processors, and cleaners are, perhaps, too sophisticated for subsistence farmers. but modified versions are well within the capabilities of most village mechanics and blacksmiths. The technology has been available for a long time. Suggest you contact Chet Dewald, Southern Great Plains Range Research Station, 2000 18th Street' Woodward, Oklahoma 73801."

Also, it is not impossible that the size of the seeds could be increased through selection and breeding. Luis Sumar has already created a simple machine for doing this in the case of kiwicha. The Sumar sorter uses a small blower and a sloping plastic pipe. The seeds are blown up the pipe and drop into different containers, depending on their weight. With it, Sumar has increased the grain size in kiwicha. He keeps only the heaviest for planting, so that over the years the crops produce seeds that are ever larger, on average. The use of such a simple, inexpensive device in Africa might dramatically benefit fonio, finger millet, and tef, to mention just three cereals.



Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)

Appendix B

Potential Breakthroughs in Grain Handling

Appendix A identified technological advances that might boost the production of indigenous African grains. Here we identify other advances that might similarly influence the methods of milling and storing those grains. These, too, are innovations that, in principle, could bring outstanding benefits continent-wide. Again, however, it should be realized that they are just a smattering of examples that caught our attention as the book was being prepared. Other cuttingedge technologies may be as good, or better.

NO MORE POUNDING

Every day of the year, perhaps 50 million Africans - most of them women and children - spend hours preparing the grain that their families will eat that day. They usually soak the grain in water, pound it with the butt end of a heavy wooden pole (pestle) to knock off the outer seed coat, winnow the beaten mixture to separate the bran, moisten the grain a second time, and finally pound it yet again to break it up into flour.

This is always a hot and disagreeable task. It limits both cereal use and life itself.

Decorticating enough pearl millet for a family meal (about 2.5 kg) takes two women about 1.5 hours; converting the product into flour with a mortar and pestle requires an additional 2 hours, sometimes more. Moreover, because the flour spoils quickly and cannot be put aside for later use, it has to be done day after day, in fair weather and foul, and regardless of sickness or other indisposition.

Probably no single development could help rural Africa more than relief from this never- ending drudgery. It would recover millions of "lost" hours every year, it would improve health and family welfare, and it would make the whole continent more productive. Perhaps most important in the long run, it would secure the future of the local grains. At present, the burden of the terrible toil is causing a silent rebellion against sorghum, millet, and the other indigenous cereals.

Now an option is emerging. Small power mills can, in just a few minutes, perform the task that now absorbs so much human energy and time. Some of the most successful consist of a series of 8 or 12 grinding stones of the type used for sharpening tools. The essential component, the dehuller, was originally designed at the Prairie Regional Laboratory in Saskatoon, Canada. A small version specially sized for rural Africa has been built, field- tested, and improved at The Rural Industries Innovation Centre in Kanye, Botswana. It is powered by a small diesel engine.

Reportedly, the machines waste no more grain than hand pounding does. (Recovery rates of 85 percent have been achieved, which is 10 percent better than is normal in the village.) Also the machine-dehulled grains apparently make no detectable changes in local foods. Since they use dry grain, the dehullers are more flexible than traditional methods, and the resulting flour can be stored.

The dehuller does only half of what African women do: it takes off the seed's outer layer, leaving white, ricelike grain. A further grinding is needed to make flour or grits. To do this mechanically, a hammer mill is employed. In some cases, the dehuller and hammer mill are combined into a single unit.

Although these mechanical systems were designed primarily for processing sorghum and pearl millet, they have also proved satisfactory for fonio and food legumes such as cowpeas and pigeon peas. One of the main attractions is their capacity to handle (without major adjustment) grains of widely different size.

Under a Canadian-sponsored program, different models are currently being developed or distributed for use in Senegal, the Gambia, and Zimbabwe. Mali and Niger, following Botswana's lead, are creating designs suitable for local toolmakers to build.

Mechanized processing probably has its most immediate use in cities and towns. In rural areas, people must carry their grain to the mill and then carry home their flour and bran. For them, the chore of carrying several kilograms several kilometers may be just as onerous as staying home and pounding the grain with a pole. However, there are ways to circumvent this. In Botswana, for instance, a donkey cart is being made available without charge to carry the grain and flour back and forth. (The donkey is fed on the customer's bran waste.) Also, the milling unit could conceivably be mounted on a cart and wheeled to the customers. Thus, for example, a mobile mill might stop at various villages once a week and process the grain on the consumer's own doorsteps. A hammer mill perhaps might not work on such a system, but the dehuller alone would relieve the major and most unpleasant part of the drudgery.

All of this opens the possibility of substantially lessening the burdens that at present fall so heavily on millions of people. It will probably widen the mix of crops they grow. It could increase lifestyle options and employment opportunities by freeing women from the daily morning and evening chore of pounding grain. It may contribute dramatically to better health among women and children, provide time for more productive pursuits, create better markets for farmers, and lead to a more stable food situation for many countries.

Despite the fact that people must pay to have their cereal mechanically milled, this mini- milling industry is already starting to take hold in parts of Africa. Several nations have introduced the Canadian-type mills, and support for their maintenance has quickly spread, even into remote areas. Moreover, merchants and consumers throughout Africa are showing increasing interest in buying and using flours instead of unprocessed grain. A grain revolution seems to be arising, bringing new options for farmers and consumers, as well as new possibilities for a better life in the rural areas.

Sorghum and Women

Sorghum is a women's crop in Africa. To a large extent they are its planters, cultivators, and harvesters. Through the accumulated wisdom of centuries, women have amassed information about the crop and its handling. Many are expert in distinguishing closely related varieties . . . a knowledge which men - even professional scientists - seldom attain. Only now, however, are researchers beginning to pay attention to this knowledge.

Joyce Kanyangwa is one of those. Working under the auspices of Texas Tech University, she traveled to three sorghum-growing areas of Lesotho, visiting selected households to gain a perspective on attitudes about the use of sorghum. "I was interested in finding out what might be done to expand the use of sorghum in the diet to give women more income for their labor, as well as a cheaper staple for their tables," she explains.

Her research indicates that improving sorghum use can do much to help Africa's women.

"Sorghum is a woman's crop, but the market for the product is limited primarily to brewing beer for men," she notes.

Better processing methods are particularly needed. The processing and cooking of sorghum and millet takes more time than rice. Women going to work, either in the fields or in the community, have less and less time available for processing and cooking. Small-scale rural sorghum and millet processing mills, like the rice mills already available in India, could help promote the consumption of sorghum and millet.

"When sorghum is processed using a special machine, people like it," Kanyangwa says.

"I'm optimistic that the crop has the potential for helping female-headed households feed their families better and for helping women make more money."

The introduction of suitable dehullers and flour mills will:

· Reduce the drudgery of women in the sorghum eating areas.
· Convert sorghum into a much more convenient grain.
· Improve the quality of sorghum products.
· Check the tendency of shifting from sorghum to other grains.
· Help develop composite flours and commercialize sorghum products.

GRAIN DRAIN

To worry only about grain production is not enough; what counts is the amount and quality of the food that gets into people's bodies. Today, unfortunately, much of Africa's cereal crop never gets that far - it spoils or is lost sometime after the harvest. Estimates suggest perhaps 25 percent of each year's food production is either lost or rendered unfit. Others say that it is less than 10 percent. Certain types of traditional stores are very effective, but a 25-percent loss is very common in government stores (partly because farmers often contribute only their poorest materials). And the losses on the farm can rise dramatically if a new variety of grain is produced.

The reasons are clear. During handling and storage, heat and humidity foster molds and rots that ruin much grain. Insects, rodents, and birds steal enormous amounts. Most subsistence farmers store their harvest in small granaries (capacity 1.5 tons or so) and 10-20 percent usually deteriorates or disappears before it can be eaten.

An obvious answer is better storage, and these days pest-proof silos built of several materials are showing much promise. Examples follow.

Brick

A Zimbabwean engineer, Campbell D. Kagoro, has for years been developing a granary built of local brick. Zimbabwe. The design was developed by the Institute of Agricultural Engineering (IAE) and Agritex. ENDA-Zimbabwe (Environment, Development, Activities) has joined with Agritex to undertake a major study of the subject, with financial assistance from IDRC. His structures - known as ENDA granaries - have been installed in dry, poverty-prone areas of Zimbabwe. People there (as elsewhere in Africa) know how to manufacture baked-clay bricks. To build the silos, they lay the bricks directly on gravel-covered soil or on rock. (In some instances, wooden joists and masonry footings are used.) They cover the final structure with a waterproof thatch roof. The silos have a capacity of about 2.5 tons and may include up to five compartments for storing different products. They are equipped with air vents and are said to offer excellent protection against dampness, insects, and rodents.

Ferrocement

A form of reinforced concrete, ferrocement utilizes materials that are normally readily available - wire mesh, sand, water, and cement. It does not corrode easily and can last a lifetime.

Experience in Thailand and Ethiopia has demonstrated that ferrocement silos can be built on site relatively inexpensively, using unskilled labor and only one supervisor. In such silos, losses are less than I percent per year. Rodents, birds, insects, and dampness cannot get in. If the bin is well constructed and its lid tightly sealed (tubing from a bicycle tire makes a useful gasket), even air cannot get in. Inside an airtight silo, the respiring grain quickly uses up the oxygen. Insects (eggs, larvae, pupae, or adults), as well as any other air-breathing organisms introduced with the grain, are then destroyed.

The possibility of putting ferrocement silos on every farm is demonstrated by a remarkable program in Thailand. There, where the concern is storing pure water rather than grain, the government has provided three ferrocement jars (each two cubic meters in size) for every family of six in rural areas. The project involved three million families and nine million jars.

Each jar costs $20, but the per-capita cost - because a revolving fund of $13 million is recoverable - can be as low as 42 cents.

Heat is a basic problem with ferrocement (and most other) silos. Bins in the burning sun can warm up so much that moisture evaporates from the grain, collects at the top, and fosters molds or sprouting. For this reason, silos should always be located in the shade of trees or houses, sunk in the ground, or surrounded with some rough-and-ready sun shield (thatch or scraps of foamed plastic comes to mind).

Although much of the promise is for small bins for household use, ferrocement can also be used to construct large storage facilities for town or regional use. One of the most intriguing is the horizontal "sleeping silo" pioneered in Argentina (where they are used mostly for storing potatoes). These large structures are shaped like the hull of an upside-down ship half buried in the ground. Bulkheads give strength and also create separate compartments in which different products or different owners' products can be stored. Compared to the towering grain elevators now used in much of the world, the horizontal counterparts lie on the ground and require little in the way of engineering, footings, or structural reinforcing.

Mud

Recently, an airtight grain store made from clay and straw has been introduced to Sierra Leone. The silo, demonstrated by Chinese instructors brought by the UN's Food and Agriculture Organization (FAO), is simple in construction, low in cost, and has potential to significantly decrease postharvest grain losses.

The raw materials in this case consist of mud and straw, and the finished silo is roofed with boards, straw, reeds, or other waterproof materials. Its inventors are the peasants of northeast China who, from time immemorial, have built tiny mud turrets to store their household food reserves. In recent years, a national campaign to decentralize grain storage has led to this very simple and economical technique being used throughout the Chinese countryside. In fact, mud silos are now being built as large as 8 m in height and diameter, to hold

200 tons.

Ghana, too, has been testing improved mud silos. Instead of ordinary mud, however, sun-dried molded mud bricks, from a locally made mold, are used for the circular wall. The top is a separately molded mud slab. The whole unit is sealed with a mixture of mud and clay, and the wall is whitewashed to maintain coolness.

Neither of these two silos requires any great expertise to construct or use.

Plastic

Researchers in Australia and the Philippines in recent years have jointly developed sealed plastic enclosures for storing grain in ware- houses located in the humid tropics. In 1992, a new project was begun to design a counterpart suited to the smaller-scale and outdoor needs of cooperatives, small millers, and merchants. The scientists have developed a plastic container that is rodent- and insect-proof and protects grain against the extremes of the tropical environment. It is also simple to fumigate and suitable for storing damp grain before drying. The plastic silos have been designed using the general principles already employed for storing bulk grains in Australia.

Although conducted in and for the Philippines. this work seems suitable for application throughout the humid tropics. Research (ACIAR), G.P.O. Box 1571, Canberra, A.C.T. 2601, Australia.

Rubber

Israel's agricultural research organization, familiarly known as the Volcani Institute, has pioneered development of simple, cheap, and easily movable grain stores with capacities up to 1,000 tons. These collapsible, tentlike structures can be taken down, trucked to a new site, and quickly reassembled - a novel feature that makes them especially useful for handling emergency food supplies and for storing excess grain from unexpectedly bountiful crops. The walls are constructed of rolls of strong wire mesh (actually weldmesh fencing material), but the grain is held within UV-resistant plastic liners. These silos are sufficiently airtight to control insect infestation without requiring pesticides. They are primarily for use in drier areas.

DRYING GRAIN

Insects and rodents are not the only grain despoilers. Insufficient drying also leads to vast amounts of damage. Dampness fosters molding, sprouting, and decay that renders grain inedible. Drying the grains before storing them is therefore vital. Techniques for doing this under Third World conditions are being devised in several parts of the world.

Sierra Leone

Farmers in six districts of Sierra Leone are replacing traditional mud floors, used for drying freshly harvested rice, with improved drying yards. This cheap and simple change keeps the grain clean, lessens the drying time, and reduces postharvest losses by more than half.

United States

The Food and Feed Grains Institute of Kansas State University has designed a new kind of dryer for developing country use. It has no fan or other moving parts and uses heat generated by burning weeds, rice husks, agricultural by-products, or other wastes.

This natural-convection, hot-air drying could open up new options in many areas of Africa where today the only cereals that can be grown are those that mature after the rains have ceased (when grains can be dried in the sun). In 1990, Kansas State tested its dryers under conditions of very high rainfall in Peru and Belize. Sun-drying was impractical, even impossible, but the new dryer proved very effective: rough rice was reduced from a level of 20 percent moisture to 14 percent in only about an hour. While this is too fast for everyday practice with rice, it clearly demonstrated that the dryer would perform well in the dampness of the tropical rainy season.

Thailand

The Asian Institute of Technology (AIT), near Bangkok, has developed a simple solar dryer, constructed of bamboo poles and clear plastic sheeting Centre of Canada. It can process up to one ton of rice at a time and even in the wet season can reduce the moisture content from 22 percent down to 14 percent in about 2 days. It is said to cost only around US$150 to build.

In this device, sunlight passes through a clear plastic sheet and strikes a layer of black ash (burnt rice husk) or black plastic sheet. This absorbs the solar energy, converting it into warm air. The heated air rises by natural convection through the slatted floor of the rice box, up through the grain (contained in fine wire mesh), and out a tall chimney (again fabricated from bamboo and plastic sheet).

Korea

In the early 1980s rice farmers in South Korea faced postharvest losses of about 10 percent.

But now those losses have been halved, thanks to a new technology. Korea Advanced Institute of Science and

Technology (KAIST). Funds for the program were provided by the Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH. The system has been so successful that just 8 years after the project was launched, 70,000 dryers had been purchased. By 1995, half a million are expected to have been built.

With this method, the grain is dried using a low-temperature process that mainly exploits the drying potential of ambient air. Basically, a fan blows air through grain in a silo. The process is cheap, requires little capital investment, and the silo can subsequently be used for storage purposes. To enable drying in humid weather and during the night, a small electric heater is used to heat the ambient air a few degrees.

In practice, the dryer is a room-sized brick structure, with a false floor to prevent soil moisture from seeping up. The air is uniformly distributed using wood or sheet metal air ducts, laid on this false floor. The air is pushed through the piled-up grain by a small 400- watt electric fan.

KILLING STORAGE INSECTS

The need to protect Africa's stored food from insects is particularly important these days. The larger grain borer, a Central American beetle introduced accidentally into Tanzania and West Africa, is relentlessly spreading through maize-growing areas. This voracious pest feeds on stored maize, cassava, wheat, sorghum, sweet potato, peanuts, and other foods. The destruction it causes can be devastating; in tests in Tanzania up to 34 percent of cob maize in a crib has been destroyed after only 3 months, and up to 70 percent of dried cassava after only 4 months.

Insects get into even the best silos when the grain is added. Previously, there were no cheap and effective controls for subsistence farmers to use. However, some innovations follow that might help overcome the problem.

Sunshine

Researchers in India have found that farm produce can be disinfested by "roasting" the bugs in the sun. They first wrap a square sheet of black polyethylene around two slats of wood, leaving a "mouth" at either end. After filling the resulting pouch with produce to a depth of 3 or 4 cm, they seal the ends by weighing them down with slats of wood or bags of earth.

Finally, they add a covering of transparent polyethylene. This transmits sunlight through to the black inner pouch and traps the heat inside.

The inventors, T.S. Krishnamurthy and colleagues, report that insects, at all stages of the life cycle, die when kept at 60°C for 10 minutes. They tested pouches of varying sizes containing several kinds of produce, including wheat, rice, pulses, and semolina. A pouch containing 40 kg of peanuts, for example, reached an internal temperature of 67°C in just 4 hours. Wheat took 6 hours to reach 61°C. No insects survived.

Neem Products

Neem (see Appendix A) is an Indian tree that has been introduced widely in Africa and now can be found from Mauritania to Mauritius. People in neem's homeland have long known that ingredients in its leaves and seeds can disrupt the lives of storage insects. For thousands of years, Indians, for example, have placed neem leaves in their grain bins to keep away troublesome bugs. Now, scientists are finding that there is technical justification for this process and commercial neem-based pesticides are already being employed in the United States. With all the neems in Africa (not to mention the new ones being planted because of the rising international enthusiasm for this tree), neem-based methods for controlling insects in grain stores are soon likely to be widely available.

Some German-sponsored research has already pioneered one approach that employs the oil extracted from neem seeds. In this project, neem oil has proved effective against bruchid beetles - the prime pest of Africa's stored products. Amounts as small as 2-3 ml per kg of stored food will protect grains and legume seeds up to 6 months - long enough to overcome the critical period when bruchids and other storage insect pests are active.

In Togo, a program for teaching farmers how to protect seeds with neem has been under way for the past 15 years.

Now Niger, Senegal, and other nations are following suit. Neem oil imparts no bitterness to the food. In trials, people could not distinguish the seeds protected by it.

Probably in the long run, however, it will be neem leaves that are used most. This is the simple technique employed since ancient times in India. The leaves are merely added to the grain at various levels in the bin. The leaves eventually dry out, turn to powder, and (for all intents and purposes) disappear. The important thing is that bruchids, weevils, and flour beetles disappear also.

Mineral Dusts

For some time researchers have known that certain powdery minerals can kill insects. The sharp-edged dust particles "spear" through the thin joints between the horny plates of the animal's exoskeleton. This was first recognized with diatomaceous earth, a widely available, completely safe powder that kills cockroaches almost on contact. Now scientists in Nigeria have found that a common local mineral called "bona" also works in the same way - at least on certain storage pests.

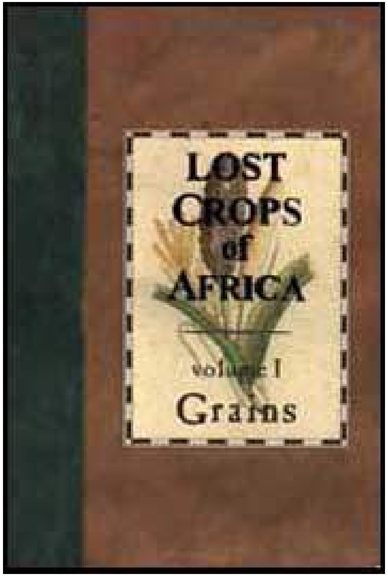
In experiments, powdered bona proved lethal to the maize weevil (Sitophilus zeamais), causing almost 100 percent mortality after 15 days of exposure. It also reduced the maize weevil's fecundity in grains treated with the dust. Ecosystems and Environment 32:69-7S. (L.C. Emebiri and M.I. Nwufo, Department of Crop Production, S.A.A.T., Federal University of Technology, Owerri, P.M.B. 1526, Nigeria.)

Trona, Na,CO3·NaHCO3·2H2O,is a crystalline carbonate/bicarbonate that occurs naturally in several parts of Africa. It is apparently not toxic to humans and livestock. Indeed, in most

African countries, rural people use it as a food additive. For example, they commonly drop it into okra soups to increase the mucilaginous quality or into boiling cowpeas to reduce the cooking time. In northern Nigeria, farmers add bona to their cattle's drinking water.

Mixing bona dust with maize grains (at 1.5 percent by weight or more) killed or inhibited the biological activities of the most ubiquitous pest of stored maize, the maize weevil; but another noxious pest, the red flour beetle (Tribolium castaneum), was unaffected. Carlson and H.J. Ball. 1962. Mode of action and insecticidal value of a diatomaceous earth as a grain protectant. Journal of Economic Entomology 55:964-970.

Mineral dusts may never be fully reliable in grain-store insect control, but their permanence, low toxicity, and ready availability make them attractive possibilities for a simple, cheap, and ubiquitous answer to at least part of the massive and widespread storage losses.


LOST CROPS of AFRICA
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Grains

Appendix C

Potential Breakthroughs in Convenience Foods

Most people have never considered (or perhaps have abandoned) the idea of sorghum, millet, and the other African grains becoming prestigious foods for up-scale mass consumption. Everyone accepts that wheat is sold as bread, pastries, and baked goods; rice comes in all sorts of precooked forms; and maize is routinely available in convenient flour or grits. However, almost no one thinks of sorghum and millets in the same light. These African cereals are relegated to the limbo of foods suited only for personal use in rural regions by individual families who have to prepare their own food from raw grain.

But possible ways to upgrade Africa's own grains are on the horizon, and these deserve thorough investigation and development. Such processing breakthroughs can break the malicious mind-set, diversify the uses, improve the nutritive value, and boost the acceptability among consumers. Their success will create convenient-to-use foods, open vast new markets for Africa's farmers, and improve both rural economies and the balance of payments of many nations. In this particular sense, food technologists hold the key to the future of the lost grains of Africa.

This topic is far too broad to be covered adequately here. ('It actually deserves a major international research endeavor.) Nonetheless, a few possible innovations - encountered while compiling this report - are mentioned below, just to provide perspective on some opportunities that are now languishing through lack of initiative.

POPPING

Popping is a simple technique that produces light, attractive, ready-to-eat products. It improves taste and flavor and it yields a crunchy, convenient food. Most people think of it as a process only for maize, and no wonder: popcorn is wildly popular among Americans and others who know it well. What has hardly been appreciated, however, is that most of Africa's grains also pop. While less spectacular than popcorn, they do expand dramatically and they, too, take on an agreeable toasty flavor. In the future, popped forms of sorghum, pearl millet, finger millet, fonio, and perhaps other grains could find extensive usage.

As has been mentioned previously, people in India already pop sorghum and finger millet on a large, and sometimes commercial, scale. They often mix together milk, brown sugar (jaggery), and popped finger millet to create a very pleasant dessert. Popped finger millet is also used in brewing.

For finger millet, as well as for Africa's other cereals, popping seems to offer many benefits.

It is a promising way to increase the grain size, create ready-to-eat foods, and add flavor to what are often bland dishes. Something similar is happening in the United States with amaranth. This former staple of the Aztecs and Incas is making a comeback, largely as a popped snack food. Recently, a continuous popper designed to handle amaranth's extremely small seeds was patented. Minnesota. Such a device may well be the key to commercially popping Africa's small-grain cereals as well.

Once the popped grains are available, many new foods are likely to be created. Indian food scientists have blended popped finger millet with legumes such as puffed chick pea or toasted green gram to form nutritious and very tasty new foods. In Africa, something similar might be done using legumes such as peanut, cowpea, or bambara groundout.

PUFFING

The process of puffing, a variant on popping, was discovered almost a century ago. Since then, cereals made from puffed rice and puffed wheat have been breakfast staples worldwide. Puffed oats and maize are now also produced.

In the puffing process the grain is placed in a sealed chamber and heated until the pressure rises. Then the chamber, or puffing "gun," is suddenly opened. Relieved of the pressure, the water vapor expands, blowing up the grains to many times their original size (for wheat, 816 times: for rice, 6-8 times). Finally, they are toasted and dried until crisp.

Puffing has probably never been attempted with African rice, fonio, tef, or the other African grains, but it is another possible way to boost the size of these small grains, add flavor, and produce quality convenience foods with high consumer demand.

MALTING

Germination also upgrades the quality and taste of cereals. The sprouting process, known as malting, releases amylase enzymes that break starches down into more digestible forms including sugars. The result is to liquefy, sweeten, and raise the nutritional value.

Malting is particularly good for children because they can better assimilate the partially digested nutrients. During World War II, government authorities in Great Britain (to mention just one country) seized on malting as a way to prevent childhood malnutrition brought on by wartime food shortages. Malt extract was produced in large amounts and distributed for daily use by children. This thick, dark, pasty material may have looked awful, but children loved its sweet and pleasant taste. It is in fact still sold in parts of the world, not so much as a nutritional supplement but as an everyday food that people buy for its flavor. It is also the key flavoring ingredient in famous foods such as malted milk and Ovaltine.

Why malting is not more widely used in these days of mass malnutrition is a puzzlement.

Perhaps the process is so associated with barley that the two have become almost synonymous, and, because barley will not grow where malnutrition mostly occurs, it is never considered. What has been overlooked, however, is that finger millet and some sorghums are almost as good at malting as barley. Their amylase activity is also high. And they will grow where the malnutrition is rife.

It is perhaps the ultimate irony that malting is practiced every day in many African homes, but the fact that malted grains make fine foods is overlooked. Finger millet malt, for example, is great tasting, easily digested, rich in both calcium and sulfur-containing amino acids, and an ideal base for foods for everyone, from the very young to the very old. But most of what is made these days is used in fermentations that produce beer.

FERMENTING

Lactic acid fermentations are used worldwide to produce foods such as sour cream, yogurt, sauerkraut, kimchee, soy sauce, and pickled vegetables of all kinds. Except for making sourdough bread, it is so far not used widely to "sour" cereal products. But in Africa it is traditionally used to flavor and preserve porridges and to produce popular foods such as bogobe (sour sorghum porridge) in Botswana, nasha (sour sorghum and millet porridge) in the Sudan, and obusera (sour millet porridge) in Uganda. People in many parts of the continent prefer the sharp flavor of these fermented porridges.

Despite its almost complete neglect by cereal science, acid fermentation is yet another process for upgrading a grain's taste and nutritive value. For the food supply of Africa, it is particularly promising. The lactic acid fermentation process is well known. It is generally inexpensive and requires little or no heating, making it fuel efficient. It yields highly acceptable and diversified flavors. And it usually improves nutritive value.

It is commonly used in households (at least throughout eastern and southern Africa) and remains one of the most practical ways to preserve food for hundreds of millions of hungry people who cannot obtain or afford canned or frozen foods.

Lactic acid fermentations make foods resistant to spoilage, thereby performing an essential role in preserving wholesomeness. The bacteria rapidly acidify the food to a pH so low that dangerous organisms are no longer able to grow.

They also produce hydrogen peroxide, which kills organisms that cause food spoilage (the lactobacilli themselves are relatively resistant to hydrogen peroxide). Certain lactic bacteria (notably, Streptococcus lactis) produce the antibiotic nisin, active against gram-positive organisms. Others produce carbon dioxide, which also helps preserve foods, notably by displacing oxygen (if the substrate is properly protected).

The course of the fermentation can be controlled by adding salt. Salting limits the amount of pectinolytic and proteolytic hydrolysis that occurs, thereby controlling softening (as well as preventing putrefaction).

Although fermented porridges were once extremely popular in rural Africa and are still widely consumed, their popularity appears to be declining. Some consumers are turning to alien alternatives that are widely advertised, such as tea or carbonated drinks. In many districts, farmers (as we have noted earlier) are giving up sorghum and millet and are growing maize.

And in others, people are said "to lack the will and the interest" to prepare traditional fermented porridges.

But for all that, fermentations have a future and deserve recognition and attention. For one thing, they are very promising for creating weaning foods that may overcome mass malnutrition (see next appendix). For another, lactic acid fermentations are promising as commercial methods of processing and preserving food as well as for creating business enterprises.

PRECOOKING

To help meet the demands of an ever hungrier Africa (not to mention the world), the partial cooking of grains looks particularly promising. When dropped into boiling water, most (perhaps all) of the grains described in the earlier chapters soften within 5 or 10 minutes.

The hot water partially gelatinizes the starch so that the dough sticks together and can be rolled into sheets or squeezed into noodles.

Some food technologists have already begun applying such processes to sorghum and pearl millet. Institute (CFTRI), Mysore, Karnataka 570 013, India. There, N.G. Malleshi and his colleagues, although thousands of kilometers from Africa, have been doing work of great possible significance to the future of African grains. In the future, precooking might be applied to most of Africa's native cereals to produce top-quality, ready-to-cook foods that are stable, more nutritious, and easy to store. Below we highlight three techniques - parboiling, flaking, and extruding.

Parboiling

Parboiling is basically the process of partially cooking grain while it is still in the husk (that is, before any milling). The raw grain is briefly boiled or steamed. (Generally, it is merely soaked in water, drained, and then heated.) Only after the resulting product is dried is it dehusked and decorticated.

What results is very different from the normal milled grain. Sorghum kernels, for instance, come out looking like rice: light-colored, translucent, firm, and intact - attractive in both appearance and aroma and much less sticky than normal. Of course, they still must be cooked to become edible.

Parboiling not only gelatinizes the starch in the grains, it also does the following:

· Makes the milling process more efficient. (In a recent trial with soft-kernel sorghum, parboiling more than doubled the yield of decorticated grain.)

· Inactivates enzymes and thereby greatly extends shelf life. (It even improves the storability of pearl-millet flour, a material notorious for turning smelly during storage.)

· Kills insects and their eggs so that it reduces storage losses.

· Improves the grain's cooking characteristics. (Boiling parboiled sorghum, for instance, doesn't produce mush; instead, the kernels remain separate, whole, and very much like pilaf or rice.)

· Improves nutritional values. (This is notably because it helps retain water-soluble constituents - such as the B-vitamins and certain minerals - that otherwise are thrown out with the cooking water.)

· Upgrades certain grains that have poor processing characteristics (the soft endosperm in finger millet, for example).

Given its now widespread use in the rice industry, parboiling is a surprisingly recent newcomer to commerce. Until the 1930s, it was hardly known outside South Asia where it was a village technology employed by poor people in their cottages. In the last 60 years, however, parboiled rice has rocketed into extensive worldwide use, and parboiling is now done on a giant commercial scale in countries such as the United States.

Parboiling is still good for village-level use, however. For example, field trials in Mali, using local sorghum and pearl millet, showed that it was practical, satisfactory, and boosted the yields from milling. Malian families tested the parboiled grains in local dishes and condiments (such as peanut sauce) and rated them very acceptable. (covered) and heated in tap water over an open fire until the boiling point was reached. The pots were then taken from the fire and allowed to cool overnight. The next morning they were heated again and drained immediately after once more reaching the boil. The moist grain was next spread out in the shade to dry (24 hours for pearl millet and 48 hours for sorghum).

The final product was decorticated with a mechanical mill.

At first sight, the extra energy and effort needed to parboil grains would seem to be a major disadvantage. However, the increases in yield and quality provide both the processor and consumer with substantial benefits. Rice is already parboiled in the villages of some parts of Mali (not to mention half of India), which certainly suggests that the product is good enough so that people will find the fuel and put in the extra effort to prepare it.

Flaking

In this process, decorticated (pearled) grains are soaked, heated, partially dried (to about 18 percent moisture), pressed between rollers, and, finally, completely dried into flakes. What resulted was the famous Kellogg's Corn Flakes.

The resulting product is a convenience food of many potential uses. The flakes store well and hydrate quickly when dropped into warm water or milk. They can be used in many types of sweet or savory dishes. When deep fried, they burst into light and crispy products.

African grains are particularly suitable for flaking because they are small and soak up water quickly. But although the process is simple, it is seldom used today. The holdup seems to be purely technological: grain-flaking machines are large, expensive, and inappropriate for Third

World use. Now, however, a simple, inexpensive machine capable of flaking cereals in villages has been developed in India A unit has been installed in a village near Bhopal, and the people took to it and were able to operate it without supervision.

This type of invention could open up a new world for sorghum, millet, fonio, and other grains.

More than 30 years ago, South African researchers mixed sorghum flour with water, then passed the slurry through a hot roller that both cooked and dried it. The resulting ready-to-eat flour proved very palatable and would keep for at least 3 months without deteriorating. Whole milk or skim milk (used in place of the water) produced a similar flour that was not only tasty but rich in protein, calcium, and phosphorus. Processing costs were reportedly low.

Extruding

Extruding is a variant of the flaking process. The moistened and half-cooked grains are squeezed out through small holes. It is how noodles and pastas of all kinds are prepared. It, too, improves water absorption and cooking quality. Noodlelike products can probably be made from all the grains highlighted in this report. The pearled grains are first soaked for a day or two, then drained, mashed, cooked, extruded, and dried.

Noodles prepared from blends of finger millet and legume flours are already being used in India to form nutritionally balanced foods that can be used as supplementary foods for malnourished children. When deep fried, they make excellent crispy products - said to equal those prepared from rice. Noodles from finger millet and other African grains could probably be economically produced in small-scale industries, as the equipment needed is not overly complicated and the capital investment is modest.

Success Brewing in South Africa

Mohale Mahanyele's story exemplifies the immense business opportunities to be found in commercializing the traditional foods made from African grains.

In the late 1980s South Africa's government set out to privatize the sorghum-beer industry.

For at least 20 years, sales had been dropping, as workers migrated to the cities and left the rural villages where the low-alcohol, high-protein drink is embedded in the culture. The government hired a management consultant, Mohale Mahanyele, to advise it on how to get rid of the business. His task seemed like a thankless one; the sales decline seemed inexorable. One analyst said the authorities were merely unloading "an old Third World product doomed to die."

Mahanyele did not agree. "There were a lot of leaders in the African community who thought we were being set up to fail," he says. "But I thought differently. Here was a drink that had always been associated with our festive occasions, and it had been taken away from us and tainted. It was humiliating, degrading. I wanted to restore the dignity of sorghum."

Armed with that vision, Mahanyele himself set out to buy the business from the government- run monopoly in 1990. It seemed like a foolish notion. He had to raise $20 million to purchase the corporation and its 21 factories, but he had no access to white capital. So he did something never before attempted in his country: he sold shares to fellow Africans, building on the centuriesold custom of stokvels - small, informal savings societies - in traditional communities.

National Sorghum Breweries ended up with 10,000 shareholders, more than 90 percent of whom are black - a novel arrangement in a country where few blacks own the roof over their heads.

But Mahanyale's problems were far from over. In addition to the dropping sales, he had to overcome sorghum beer's political stigma, created during the 80 years when the white-minority government ran the business. To his own people, "Kaffir beer," as it was known, had become a symbol of white oppression.

But Mahanyele succeeded. Today, National Sorghum Breweries is by far South Africa's most successful black-owned business. It has nearly doubled its volume in the past three years, while paying annual dividends of 20 percent or better. "We understand the product," he says. "We have a color fit and a culture fit with our customers."

Through the development of the sorghum-brewing business, Mohale Mahanyele has become South Africa's foremost apostle of black economic empowerment. The company's board and management team, once all white, is now nearly all black.

Most of its contractors are black, including 500,000 small businessmen who distribute the beer to stores throughout the country. It employs a quarter of South Africa's black accountants, and is putting more than 100 of its executives through an MBA program that it runs on the premises.

Today, National Sorghum Breweries is beginning to diversify into other products - food, soft drinks, computers and, most daunting of all, conventional beer, a market in which a giant whiteowned brewery currently has a 98-percent share. Can more success be far behind?

Sorghum beer has a rather thick consistency with a refreshing acid flavor; the alcohol content is only 3-4 percent by volume, but large amounts are apt to be consumed on festive occasions. Women have brewed it in Africa's villages for centuries.

No one has ever written a definitive work on African beers and their nutritional or social roles.

This could be a major project for African scholars. These beers are more important than most people realize. A special quality is their safety. Because they are highly acidic (ranging between 3 and 4 on the pH level), they are free of bacterial contamination. So far, however, science has shied away from investigating such beers. Anthropologists and nutritionists refer to them, but that is about all. This is surprising because sorghum beers are an important part of life throughout most of Africa below the Sahara.

The Power of Processed Foods

Despite the reliance on sorghum and millet in some countries, and despite consumer preference for flour made from them, the industrial production and commercialization of local flour has barely been established in Africa. Sorghum and millet flours are still mainly produced by each individual household. On the other hand, the introduced grains - wheat, rice, and maize - are more commonly milled at commercial facilities.

This makes the foreign grains look superior and it holds back the local cereals. And the situation is worsening. Soon, the rural labor force could be insufficient. Thus, even if production is increased there won't be the people to process it. For example, in most regions it is the young women who process most of the grain, but increasingly they are going to school, getting jobs, or abandoning the countryside to seek opportunity in the cities.

In a sense, then, it is imperative to find and develop good profitable uses for millet, sorghum, and the others. And the time is ripe. With increasing urbanization and rising disposable incomes, the demand for preprocessed and convenience foods is accelerating. This is one reason why commercially milled wheat and maize flour are increasingly preferred. Sorghum and millet are much cheaper, but they are unprocessed and therefore less convenient to use. As a result, markets for locally grown sorghum and millet are diminishing, incentives for local production are deteriorating, and foreign exchange reserves are dwindling to meet ever- rising demands for preprocessed flours.

In dry regions, processing facilities are particularly vital to the future of local cereal farming.

There, sorghum and millet are essential for a viable agricultural community. Both crops are so drought tolerant they can grow where other cereals cannot. When imported flour crushes the demand for them, the farmers are left with no outlet for their grain in years of good rainfall when they have a surplus. And when market prices fall, farmers cannot afford the inputs, such as fertilizer, that can keep their yields up.

If, as has been noted, markets for local flour and processed foods are developed, a large and healthy trade between a country's own sorghum, millet, and fonio farmers and its cities could operate to everyone's benefit.

Success with processing would likely transform Africa's native cereals into big-time, high- value worldwide foods.

LEAVENING LOAVES

Raised bread has become what is perhaps the world's premier food. Wherever it is introduced people eagerly adopt it and clamor for more. Unfortunately, however, leavened breads can be made only from wheat or rye, neither of which grows well in the tropical zone where the neediest people are concentrated. When the dough is fermented, gluten's network of protein strands traps carbon dioxide released by the yeast. As the gas bubbles up, it raises the dough into the light open texture of leavened bread. Triticale. a man-made hybrid between wheat and rye, not unexpectedly. can also produce raised breads. (Triticale is described in a companion report, Triticale: A Promising Addition to the World's Cereal Grains.

For at least 30 years scientists worldwide have searched for ways to make raised bread without using wheat and rye. Such work could have profound implications for Africa but, despite the theoretical promise, nowhere has there been much practical success so far. Local staples tend to make unattractive, short-lasting, poorrising breads that the public shuns. Dough strengtheners and other modifiers (such as emulsifiers, pentosans, xanthan gum, and wheat gluten) can be added. They make acceptable breads, but usually they must be imported and are expensive.

Now, however, there is a possibility of a breakthrough: research has shown that it is possible to prepare loose-structured bread from local grains using a swelling and binding agent.

Different types have been tested. Dried pregelatinized cereal or tuber starches have shown some success. Glyceryl monostearate is said to be effective. Locust bean gum, egg white, and lard are also fairly good. These compounds act to bind the starch granules together, making it possible for the dough to hold carbon dioxide gas and thereby to rise. Baked products obtained this way have greater volume, softer crumb, and a more regular texture.

Avoiding the Wheat Trap

Researchers in several southern African nations have banded together to produce a white sorghum that can be locally grown to make flour for bread and mealies (cornmeal). They seem to be already on the verge of success. If so, they will have developed the first truly

African bread grain. The following is a recent announcement from PANOS, an international organization that specializes in disseminating Third World news.

Fifty scientists from Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, Swaziland, Tanzania, Zambia, and Zimbabwe, the 10 countries grouped in the Southern African

Development Coordination Conference (SADCC), are now being trained to breed and produce sorghum hybrids. Soon, that number of trainees is expected to double. Why all the excitement?

To help reduce the region's dependence on imported wheat, researchers in Zimbabwe have developed hybrid strains of sorghum and millet that are designed for use in making flour and bread. The work at the Matopos Research Station near Bulawayo forms part of a drive to reduce food shortages in the SADCC countries.

For most people in the region maize is the staple, but the crop does not grow well in the drier areas. Researchers are trying to develop substitutes that can be grown there and mixed with wheat for bread or maize for mealiest Any surplus could be sold to make high-quality malt.

In farm tests, the new hybrids have produced bigger yields than existing varieties. The researchers expect to have white-grained hybrid sorghum for milling very soon. It is hoped that the white sorghum will satisfy a popular preference for white maize meal. A local milling company is already working with a nongovernmental organization called Enda-Zimbabwe to set up pilot mills in rural areas to grind the hybrid grains for bread.

Before people in areas of low rainfall can be persuaded to abandon their often futile efforts to grow maize, good varieties of the new hybrids must be available in large quantities of the seed.

FAO Bread

Although none of the techniques has yet yielded light, high breads like those from wheat, there has been partial success. Perhaps the most advanced is a project operated by the Food and Agricultural Organization of the United Nations (FAO). The FAO method involves boiling part of the flour from a local cereal (or root) until it thickens into a gel strong enough to hold the gas released during breadmaking. When added to local flour, yeast, sugar, and salt, this starchy substitute for gluten produces a puffy bread of acceptable texture, taste, and color.

Reportedly, this new technology is simple, inexpensive, and uses nothing but local ingredients. It can, for example, produce leavened loaves using sorghum, millets, and other African grains.

The Wheat Trap

Africa is finding itself more and more caught up in what is being termed the "wheat trap."

During the past 20 or 30 years, certain governments as well as private companies have responded to consumer demand by establishing wheat mills. As a result, various countries now spend large amounts of foreign exchange importing wheat to feed those mills. The bulk of the flour produced is used to make bread for the working population, as well as for the small expatriate population living in the towns and cities.

Bread is a convenient food because it is ready to eat, easily carried around, and not messy like porridges and gruels. Its taste is highly acceptable, it gives a feeling of bulk and fullness, and it is relatively cheap. With large numbers of people migrating from rural areas to the cities, the demand for bread has increased.

However, the population is being fed on food the country does not grow, with scarce foreign exchange being used to import wheat to produce flour. More foreign exchange is also spent on spare parts and foreign managers to maintain and run the flour mills. The process not only damages the economy but the indigenous African cereals as well. They are being left in a state of underdevelopment and inadequate processing.

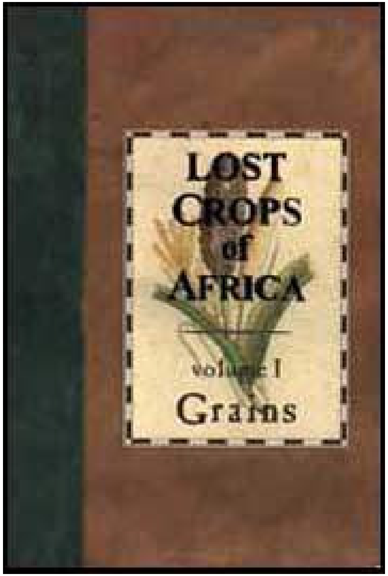
J. Maud Kordylas

Leavening with Fungus

Recently, food scientists in India have found that fermenting a mixture of grain and pulse (legume seed) can produce a gum thick enough to act like gluten. This special process, locally known as idli or dosai fermentation, involves the microorganisms Leuonostoc mesenteroides, which is used in other parts of the world for producing dextran gums from sucrose. Using this fermentation, a mixture of rice and dahl (made with black gram or other legume) can be turned into a dough that will produce breadlike products without employing any gluten. Either the legume, the microorganisms, or the combination produces a gum that holds the carbon dioxide gas, thereby leavening the products. It is a fermentation that enables raised breads to be made without any wheat or rye. Perhaps other fermentations or other substrates for this fermentation to do this job can also be found.

Biotechnology

With all the advances in biotechnology these days, it seems likely that the genes that cause gluten to form in wheat will soon be isolated. Inserting them into the chromosomes of Africa's native grains could bring profound changes. Suddenly, sorghum or pearl millet would (at least in theory) produce bread that rises without any extra help. This is not a far-fetched idea. Indeed, it will be surprising if it does not come about within the next decade or two.



Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)

Appendix D

Potential Breakthroughs in Child Nutrition

As in the three previous appendixes, we report here innovations relating only indirectly to Africa's cereals. Once again, these seem of notable significance to the continent as well as to the future of the traditional grains. In this case, the potential breakthroughs are of great humanitarian significance - no less than a means by which Africa may at last put behind it the horrors and heartbreak of childhood malnutrition.

WEANING FOODS

In most parts of the world, baby foods are commonplace. In North America, for example, supermarkets may carry whole aisles of liquefied and semisolid concoctions carefully created from cereals, vegetables, and fruits. Through these foods, a child gets a diet that is easily digested, rich in energy, and balanced in protein, vitamins, and minerals. Such foods help the child make the complex and otherwise life-threatening transition from mother's milk to adult fare.

The tragedy for Africa's millions of malnourished children is that comparable bridging foods are unavailable to, or at least far beyond, a family's financial reach. A child in Africa, therefore, faces a cataclysmic change from a balanced and hygienic liquid diet of mother's milk to an unbalanced solid adult food that is often very unwholesome. Although the young milk-fed bodies are basically unprepared for such a switch, they must start digesting foods of alien consistency and inferior quality. Moreover, they often must do this while battling new and numerous intestinal infections introduced through unclean hands and utensils as well as through inadequate cooking.

This situation constitutes the gravest emergency facing children today. As UNICEF's executive director, James P. Grant, has pointed out: "The period of weaning, during which a young child becomes accustomed to the change from a diet consisting solely of his or her mother's milk, to one totally devoid of it, may take a year or more, and in much of the world this is perhaps the most dangerous period of the child's life. Many will not survive it. Of those that do, too many will be stunted in body, and perhaps in mind, and never be able to attain the full promise of their birth."

Today this hazard falls heaviest on Africa's children. Perhaps in the future centrally processed weaning foods will, as in North America, serve the children's needs. However, at present the cost of such products and the inability to distribute them throughout the rural regions makes this impractical. The only answer for the moment, then, is weaning foods that can be prepared either in the home itself or at least in nearby locations in the rural districts.

Given the extent of present malnutrition, one could be forgiven for concluding that household weaning foods are an impossibility for rural Africa - that appropriate ingredients must be unavailable, or that the people cannot make foods appropriate for children. But a number of knowledgeable nutritionists and food technologists believe that bridging foods for the critical nutritional years of each new generation can indeed be produced locally and cheaply. And, in their view, it is the traditional native grains - sorghum and finger millet, in particular - that are the key to this vital and life-saving possibility.

The reason for this is unexpected but understandable.

Those who, in the past, blamed malnutrition exclusively on the lack of certain nutrients in the foods were largely wrong. The local cereal products are not as poor in nutrient quality as was (and is) generally claimed. Today's nutritionists increasingly blame the low quantity of solids (what they call the "nutrient density") in the foods used for feeding the very young.

Africa's traditional weaning foods are watery gruels based on boiled cereal. These may have the right consistency for a child whose sole diet has been milk, but they are just too dilute. A gruel whose consistency is acceptable to a one-year-old contains merely one-third the food energy of a typical Western weaning diet. A child simply cannot consume enough to meet its energy and other nutrient requirements. Even when stuffed with gruel to its limit, a small stomach contains too little solid to keep its owner fed for very long. And most of the children must get by on only two feedings a day because mothers who work in the fields have no time to boil batches of gruel throughout the day. The children therefore get fed only in the morning and evening when the rest of the family's food is prepared.

A tragic irony is thus becoming apparent. Although the gruels are too thin, the porridges the mothers are cooking for the rest of the family would be satisfactory except for one fact: they are too thick to be swallowed by an infant. A stiff porridge is useless to anyone who cannot eat solids.

What can be done? The answer, the nutritionists now say, is to take a small part of the adults' thick porridge and change its consistency so any child can "drink" it. How? By the age-old African methods of malting or fermenting (see Appendix C). Both procedures break up boiled starch so that it collapses into smaller saccharides, including sugars, and releases the water that keeps it thick.

For the rest of the world, malting and fermenting are not everyday household operations, but in Africa they are. Indeed, these two processes are probably better known at the household level in Africa than anywhere else in the world. Both techniques require only a minimum of equipment and appear to be good ways to turn stiff starchy porridges into liquid weaning foods.

MALTED FOODS

Given what is currently available in an African village, probably nothing can compare with malting as a means for carrying rural babies across the nutritional abyss between mother's milk and adult foods. The previous appendix discussed malted grains and the potential they offer in and of themselves. Here, however, we discuss another side of these versatile materials: their use as culinary catalysts for modifying starchy foodstuffs. This is a process all but unknown to most people' but it is by far the biggest use of malted grains and is conducted all over the world. It is, in short, the vital first step in making beer and whisky.

Perhaps because of this association, malting has been saddled with a somewhat seedy reputation. But it is a simple, safe process that produces no alcohol and should be more widely used and better known to cooks everywhere.

In Africa, malting has a special promise. Two of the native staples - finger millet and certain sorghums - are rich in the malting enzymes (amylases) that break down complex starches.

To liquefy even the thickest cereal porridges takes only a small quantity of flour from germinated sorghum or finger millet. When this flour and the porridge are heated slowly, the amylase enzymes hydrolyze the gel-like starch in the porridge so that it collapses and can no longer hold water.

In this way, sprouted sorghum and finger millet can turn a pasty porridge semiliquid in minutes.

Moreover, the food not only thins down, it becomes, to a certain extent, predigested so that it is easier for the body to absorb. In addition, the enzymes hydrolyze not only the starches but some of the proteins as well. They also reduce antinutritional and flatusproducing factors, improve the availability of minerals, and enhance some of the food's vitamin content. Further, the malting process imparts sweetness and flavor that makes for a tasty end product.

Considering the extent of malnutrition, it is more than ironic that individuals throughout Africa know more about this process than people anywhere else in the world. Indeed, throughout sub-Saharan Africa, millions of homes have a crock in the corner that contains malted grain.

A small sample of the contents would transform thick porridges into baby foods sufficiently liquid for children to consume and sufficiently nutrient-dense to keep them healthy. Tests have shown that adding a little germinated cereal while a porridge is being prepared doubles the amount of food energy and nutrients a child can ingest. However, at present the malt is used only to make beer, almost never to prepare weaning foods.

Experiences in Tanzania suggest that the concept of liquefying porridges for baby food is not an impractical dream. In the early 1980s, scientists at the Tanzania Food and Nutrition

Centre found that small quantities of flour from germinated sorghum or finger millet could be used to thin the traditional viscous porridges. They called their product "Power Flour." When a spoonful was added during cooking, porridges thick enough to hold up a spoon turned liquid within 10 minutes.

The researchers found that mothers in Tanzania's villages were only too willing to use Power Flour. Most of the mothers knew how to prepare germinated cereals for brewing but knew nothing about making foods for their children from them. However, because the procedure was already so well known, they quickly adopted it. Although it is ironic (even tragic) that malting is so well known across Africa, it is also an advantage. Using germinated cereal to improve weaning foods is simply a variation on an already widespread technology - not a strange foreign food or technique to be imposed by an outside authority.

Local, national, and international efforts to stimulate appreciation of this could see a new level of weaning foods sweep across Africa with little outside involvement. The key in many areas may be to educate village brewmasters to the potential of a second product from their ongoing malting operations.

Sorghum is the most widely available malting grain in Africa, and it has been used in most of the nutritional experiments so far. However, finger millet is a better choice: it has a higher amylase activity; it has no tannins; it develops no potentially toxic materials on germination; it is rich in calcium and methionine, both of which are needed for child growth; its malt has a pleasant aroma and taste; and, finally, it does not mold or deteriorate during germination.

Considering the fact that the technology and raw materials are common in most village situations, why has this immensely beneficial practice not been more widely used? For one thing, the process of germinating grain does take some time; mothers, already weighed down with burdensome work loads, tend to reject anything that takes up more of their day.

However, germinated flour need not be produced daily. Indeed, small portions can be set aside whenever a fresh batch of beer is begun. In addition, as in the case of Tanzania's

Power Flour, the malt could be made centrally and sold widely. Unlike the weaning foods themselves, it is a stable, concentrated material that is used only a pinch at a time.

FERMENTED FOODS

The fermentation of cereals by lactic-acid-producing bacteria has been discussed in the previous appendix. It, too, appears to be a way to prepare weaning foods. Like malting, fermentation is a householdlevel food technology that reduces the viscosity of stiff porridges (although not as much and not in minutes). It raises the levels and bioavailability of proteins, vitamins, and minerals. It enriches the foods through the synthesis of some B vitamins, and it adds flavor. On top of all that, it helps protect the foods from diarrhea-causing microorganisms.

As has been noted in Appendix C, lactic fermentation is practiced throughout the world to make pickles, sauerkraut, soy sauce, sourdough bread, and other popular foods, but it is especially well known in Africa. From Senegal to South Africa "sour" porridges are popular.

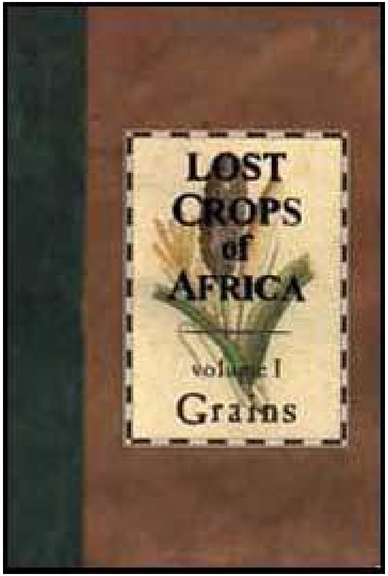
However, although still widely consumed, they are often overlooked as weaning foods.

But sour porridges seem to fulfill many of the characteristics required, and they also reduce the risk of pathogenic diarrhea - Africa's leading cause of infant death. They save time and energy as well, and might be very suitable for use during the day when a working mother has no time to cook.

A few fermented foods are already employed as weaning preparations. One example is ogi, a blancmange-like product that is one of Nigeria's most important foods. Ogi is created by fermenting a slurry of sorghum, millet, or maize. Adults eat it for breakfast, but some is kept aside and used as a weaning food.

There are possibilities, too, of combining fermentation and malting. Thus, fermented doughs, such as ogi or ugi (a similar product widely eaten in East Africa), might be liquefied with

Power Flour into forms that weanlings can "drink." In that way children could ingest more, and the double processing would likely produce highly digestible foods, easy for any young, old, or sick bodies to assimilate.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Appendix E

After Words

While compiling this book, we were in contact with several hundred researchers who specialize in the various crops described. Along with their technical advice, some sent in provocative quotes, valuable for their pith and perceptiveness. In addition, during the four years that have gone into this book, we came across a number of equally intriguing quotes in the published literature. All in all, there were too many to include in the body of the text, so a selection of them is appended here. Some contradict each other, a reflection of the contributors' different visions and of the complexity of the issues. Each, however, contains insights that complement the earlier parts this book, which perforce had to be focused exclusively on the plants and their promise.

Philosophical Overview

The negative trends in Africa are not solely due to lack of knowledge. We shall claim too much if we say "give us money, we will do research, and we will solve the African food problem."

A.H. Bunting

The resources of farmers are not confined, let us remind ourselves, to the classical factors of land, labor and capital' although by suitable definitions we can fit all resources into one or other of those omnibus packages. We have to think also of seed, equipment, knowledge, chemicals, credit and many other things, as well as of external encouragement, services and support, particularly from the policy of governments. Development in Africa might well take a different course if governments were able to be more effective. Many African governments and government services are inexperienced and some are unstable. Many of them have great difficulty in forming and executing development plans.

A.H. Bunting

Farmers are rightly suspicious of the counsel of anyone who does not himself have to live by the results.

John Kenneth Galbraith

African farmers are not a bunch of village idiots; far from it. They can squeeze more out of a hectare than you or I could, and under difficult circumstances.

Jack Harlan

At least eleven hundred million people do not have enough to eat. Many of them live in countries that cannot afford to import food and where per capita domestic food production has declined since 1980. Most of these countries are in Africa, where the gap between food production and demand is expected to quadruple by the year 2000.

Inji Islam

What Africa needs is more agricultural research conducted by welltrained scientists with good support. It should include - at the least - plant breeding, pathology, agronomy, biotechnology, entomology, and soil science.

Arthur Klatt

The right technology - be it genetic or agronomic - will be put to use. If it increases yields economically, Africa's farmers will adopt it.

Arthur Klatt

Unless we satisfy the basic needs of four billion poor, life for the rest of use will be extremely risky and uncomfortable. Struggling farmers . . . threaten environmental stability, while the growing masses of urban poor are a menace to political stability.

Klaus Lampe

These "old" plants are neglected mostly because both local and foreign "experts" are prejudiced against them, but also because of the experts' own preference for anything that is new!

James M. Lock

The promotion of any indigenous crop must be done within local constraints of labor availability, gender relations, cultural constructs, and environmental stress. If local constraints, practices, and beliefs are not realized, promotion of the crop will not succeed.

Clare Madge

Of the two billion persons living in our developing member countries, nearly two-thirds, or some 1.3 billion, are members of farm families, and of these are some 900 million whose annual incomes average less that $100 .... for hundreds of millions of these subsistence farmers life is neither satisfying nor decent. Hunger and malnutrition menace their families. Illiteracy forecloses their futures. Disease and death visit their villages too often, stay too long and return too soon.

The miracle of the Green Revolution may have arrived, but, for the most part, the poor farmer has not been able to participate in it. He cannot afford to pay for the irrigation, the pesticide, the fertiliser, or perhaps for the land itself, on which his title may be vulnerable and his tenancy uncertain.

Robert McNamara President, World Bank [1973]

The persistence of child malnutrition in Rwanda is attributed largely to a lack of time and money on the part of the mothers. In the northern parts of the country, women spend nearly 10 hours in the field and so can prepare the family food only once or twice each day; this food is usually high in bulk but low in nutritional value and is, therefore, inadequate for feeding young children.

M. Ramakavelo

One of the problems that makes the task of the prevention of famines and hunger particularly difficult is the general sense of pessimism and defeatism that characterizes so much of the discussion on poverty and hunger in the modern world. while pictures of misery and starvation arouse sympathy and pity across the world, it is often taken for granted that nothing much can be done to remedy these desperate situations, at least in the short run.

There is, in fact, little factual basis for such pessimism and no grounds at all for assuming the immutability of hunger and deprivation. Yet those unreasoned feelings dominate a good deal of public reaction to misery in the world today. In fact, pessimism is not new in this field, and has had a major role over the centuries in dampening hearts and in forestalling preventive public action.

Amartya Sen

Instead of running away from these traditional products, we should be encouraging their use as quality foods that are as good or maybe even better than some of the foods people are presently substituting for them.

S. Vogel and M. Graham

Cereals in General

There is no doubt that cereals selected and cultivated by man are the basis for a stationary human culture as in the cities and villages of the world. The apparent value of the cereals was high convenience in storage and in cooking quality as well as a pleasant smell and bland taste of the final product combined with a high level of satiety after consumption.

Lars Munck

One of the possible reasons of the lack of research on native grains is that many African postgraduates go abroad either to USA or Europe and do their higher university degrees on wheat or maize. When they return, it is quite natural for them to continue their studies. (I have seen this happening in the past here in Australia but this is now changing.) It would be a step in the right direction if these postgraduates work on the crops of their own country for these degrees. (As a bonus it might even broaden the thinking of their supervisors.)

Donald F. Beech

There is no doubt that the human body was designed mainly to get calories from carbohydrates - starches and sugars - and since most starchy foods are fairly bulky it can be actually quite difficult for children to consume enough carbohydrates in a day if they come entirely from starchy foods like bread and potatoes and root vegetables.

John Birkbeck

Some 80-85 percent of the population in many African countries subsists on farming, and this large segment needs to be helped in improving itself. As improvements occur in agriculture and as it becomes less marginal and less subsistence-oriented, opportunities will need to be created for people to move to other sectors of activity.

Norman E. Borlaug

Although starchy fruits, roots, and tubers will continue to be important in the diets of African people in many countries and regions, much of the extra food needed will consist of cereals.

A.H. Bunting

There are many weaknesses in the output delivery systems such as physical infrastructure, transport, markets, storage, processing, wholesaling and retailing, and prices. These components determine the extent to which farmers can sell off the farm, which is the essential nexus in the whole business of agricultural and rural development.

A.H. Bunting

These cereal grains supply man with 60 percent of his energy and 50 percent of his daily protein requirements . . . the volume of grain required each year to satisfy man's needs can be calculated to be a highway of grain 2 meters high by 23.5 meters wide, that circles the earth at the equator. Approximately 1000 meters of new highway must be added each year to satisfy population increases.

Vernon D. Burrows

In Africa in the 1970s, the total area under all three cereals [sorghum, maize, and millet] increased by 8 percent, while mean yield declined by 1.5 percent and the human population increased by 29 percent. Unless this trend can be reversed, there is real trouble ahead.

Hugh Doggett

Often, a new variety fails to enter the traditional agricultural setup because no one checked if it will make the preferred foods at an acceptable quality. In Ethiopia, for example, bread-wheat varieties have been identified, but the farmers only grow them for cash as they cannot make good bread or grits using the traditional food-making techniques.

Sue Edwards

An essential feature of African diet is that the staple food - either maize, sorghum, millet, rice. cassava or wheaten bread

- supplies about 80 percent of the people's calories, compared with approximately 30 percent eaten by Europeans in the form of bread. For Africans, the staple food is not merely the main source of carbohydrates' but also of proteins, minerals and vitamins.

M. Gelfand

Politics is probably the biggest "stumbling block" in Africa. In one country, they told me that the farmer could double the grain yield of pearl millet with existing agronomic practices but when the farmer did this, the government cut the price in half.

Wayne W. Hanna

The colonial literature is full of nonsense about "scarcity foods." They [the colonials] thought people harvested wild grass seeds because they were hungry and did not know that these were staples and gourmet foods.

Jack Harlan

A major widespread constraint to increased production that remains in Africa, in contrast to Southeast Asia, is that of unstable grain markets. In consequence, rural families grow sorghum and pearl millet by the most reliable methods to meet their own needs and produce relatively little surplus to market. When there is a good year, everyone has a surplus and the market price falls catastrophically. Very rationally, farmers invest their efforts into cash crops or some other enterprise where returns are more assured.

R.C. Hoseney, D.J. Andrews, Helen Clark

Since the most ancient of days, the destiny of humanity has been inseparable from grain.

Even today in the age of the microchip processor, humanity's affairs remain closely linked to the Fates attending cereal grains.

KUSA

African cereal production has two great weaknesses: there are no facilities for producing top-quality seed and there are no conduits for conditioning, storing and distributing it. Africa is full of entrepreneurs and there is a tremendous opportunity for them to start businesses selling quality seed. India started its own seed-trade that way: entrepreneurs began selling locally produced elite seed to their neighbors. Gradually, an entire distribution system developed.

A. Bruce Maunder

Nowhere in Africa are grains traditionally grown for "yield per hectare." Rather, they are grown for basic ingredients of specific foods such as ugali, injera, couscous, or beer.

J.F. Scheuring and M. Haidara

I suggest that researchers are now avoiding many of these traditional cereals because they consider it infra dig to use simple breeding and selection technology. The crops' status suffers from solely because there are no high tech (genetic engineering, etc.) papers in the literature.

Gerald E. Wickens

In cereal production, Africa's greatest weakness is that there is little local storage. At harvest time farmers must sell their grain, regardless of price. Even in the United States, the drop in grain prices can be startling at harvest time, but most American farmers have their own storage and any farmer can rent storage, either locally or near the markets (which may be thousands of miles away). This allows the farmers the chance to wait and benefit from price rises after the harvest. It also buffers price swings, which benefits everybody except the speculators.

In Africa, the situation will change when a large demand for sorghum and millet flour develops. That will create a need for year-round supplies, and storage capacity will have to be created to provide millers with grain during the off-season. This will serve to draw off grain stocks during flush seasons while maintaining grain stocks during periods of shortage. In turn, it will allow farmers to hold their grain until they're happy with the price. It will also give the farmers an incentive to use superior seedstock, especially because prices won't fall as much during good years.

John Yohe

Plant Breeding

New variety types have to complement a farmer's food security strategy. Farmers in southern Mali have related to me that pearl millet and maize have expected storage times of three years, sorghum up to seven years, and fonio of well over seven years.

D.J. Andrews

I am sure that breeding for multiple objectives is essential if we are to attain our objectives sufficiently rapidly to benefit hundreds of millions of farmers and consumers by the year 2000.

S.C. Harland transformed Tanguis, the main cotton of Peru, by what he named the mass pedigree system of selection. By setting standards for six characters which could be measured on single plants, rejecting plants or small bulks in which these characters were below the norm or the arithmetic mean' and by advancing the standards in successive years, he soon produced populations of improved quality which yielded very much more than before. Starting from preliminary observations in 1940, the first wave of about 500,000 kg of improved seed was issued in 1943; and by 1949 yields around I ton of lint per hectare were being harvested on a field scale by some farmers. In respect of characters other than those for which they had been selected, the new populations were genetically heterogeneous and further improvement in them was evidently feasible.

A.H. Bunting

There are still abundant examples of major plant breeding programs which do not take account of the real constraints faced by many farmers. This is equally applicable to national and to international programs. The importance of this is vividly highlighted by the fact that after forty years of breeding on sorghum and millet at internationally supported research stations in West Africa, less than five percent of the crop is planted to such material. The products simply do not meet most farmers' needs.

Stephen Carr

There has been a tendency to so under-rate the value of traditional cultivars that the extension staff ignore them. In so doing they miss the opportunity to provide a well- worthwhile service to their clients.

Stephen Carr

The germplasm story requires a whiff of skepticism. While the collections may not have everything (do they ever?), the real problem is to use what we have. We need more real breeders and fewer people pontificating about germplasm.

Geoffrey P. Chapman

Time has come when our breeding strategy has to change from the one where land is tailored to suit the requirements of a high-yielding cultivar, to where we tailor the cultivars to suit the harsh and ordinarily inhospitable habitats where the small farmers have to grow their crops.

T.N. Khoshoo

Above all, it is the imagination and ingenuity of the breeder that will be the decisive element in producing any new cereal crop in the future.

C.N. Law

Much progress has been made in the training of African scientists, such as by the Title 12, Sorghum-Millet Collaborative Support Research Program, INTSORMIL. Whereas vehicles and computers have been supplied to thier in-country projects, little or no input has been given to adequate seed storage. Therefore, the maintenance of lands races, varieties, and breeding lines requires frequent re-increases; inefficient activity with risks of losing the original genetic composition.

A. Bruce Maunder

Simple harvesting and processing machines could greatly increase the effectiveness of seed production, and at minimal cost. Even on research stations in Africa, it is common to see sorghum and millet being pounded with wooden clubs. This is just too inefficient: even working night and day, there's no way they can handle the quantities required.

In fact, many suitable small machines are Iying around the developed world, having been superseded by newer and more sophisticated models.

A. Bruce Maunder

Traditional grain varieties have been selected over the centuries to fit the constellation of agronomic adaptability in diverse environments, and at the same time have optimum milling, food quality, and storage properties. Most of the recent improved varieties from breeding programs in Africa yield grain that is poorly developed, headbug damaged, and chaffy when harvested from stressed environments. Such grain lends itself to high storage losses, low decortication yields, poor food quality, and poor seedling vigor. That the farmers don't adopt those varieties should not be a surprise. Cereal grain yield in Africa is the amount of nutrient per hectare that finally makes its way to the human stomach as food and to the animal stomach as feed. It is our challenge to start measuring that.

J.F. Scheuring and M. Hadara

Everybody wants to help the poorest of the poor. However, when it comes the reality of applying modern knowledge it is often logistically impossible. To create a new variety - even of a well-understood crop like wheat - can easily take a decade of dedication and perhaps a million dollars of support. It is therefore clearly impractical to reach, individually, the thousands of different subsistence regions, each with its likes and dislikes, needs and desires, climates and conditions.

Noel Vietmeyer

There is a need to strengthen the links between sorghum and millet breeders and the food scientists, home economists, and other scientists involved in postproduction systems and the commercialization of sorghum and millet end products.

S. Vogel and M. Graham

Agronomy

When the aim is to improve a crop, one has also to improve the cropping system and the management of the fields (in terms of plant population, plant protection, soil fertility, etc.).

The yield of any crop is very often related to the degree of intensification of the farming system. Therefore if we remain within the context of a traditional farming system or a slightly improved farming system, the agronomists and the breeders should not aim at achieving high dry-seeds yield; rather they should define the adaptive potentialities of the local varieties and try to utilize these to their maximum.

J.P. Baudoin

Despite the tremendous increases in food production in Asia, the Middle East, and parts of Latin America in recent years, agriculturalists today face even greater production challenges to feed future generations. New Green Revolutions must occur in the more marginal production areas of Asia, sub-Sahara Africa, and parts of Latin America. These areas are generally rain-fed environments that suffer from moisture and temperature stresses, soil fertility problems, diseases and pests, and other difficult production conditions.

Norman E. Borlaug

For arid and semiarid regions with their variable and unpredictable climate breeders should select cultivars that can yield moderately well over a wide climatic spectrum and low agricultural inputs. Maybe the local farmers growing a mixture of cultivars in a field have the right idea!

Gerald E. Wickens

Sorghum

Sorghum is an excellent example of a low-input grain crop that has tremendous potential to meet the needs of an increasing demand for lower input, sustainable solutions to the world's agricultural production problems. Its present adaptation to marginal production areas and its lack of research input to increase its response to external inputs guarantees its better fit into any future agricultural production systems. Its wide, untapped genetic variability found in landraces and its wild an weedy relatives lend tremendous genetic wealth to increase its productivity in these more sustainable systems.

Paula J. Bramel-Cox

Far more attention needs to be paid to sorghum as a human food. In temperate zones the staple grain is wheat, but many of the developing tropical countries cannot grow wheat, and the strain on their financial resources of importing this grain on any scale would be great.

They must, of necessity, grow most of their own food grains. Rice is a good grain type in areas where it can be grown. Maize is a valuable grain, but it shows a narrower range of variation in grain type than does sorghum, and cannot be grown everywhere. Of the tropical grains, the one most likely to repay research is sorghum, because it has so much variation in which to work. It should prove possible to develop sorghum grains of a better standard than any present-day tropical grains.

Hugh Doggett

Our responsibility is to develop even more stable and higher yielding [sorghum] cultivars from this wealth of diversity by making the appropriate collections from dissimilar climates and recombining them into more widely adapted improved types useful to the world's people.

Fred R. Miller

The profuse branching and wide distribution of the root system is one of the main reasons why the sorghums are so markedly drought resistant. Other factors are however of importance. In the first place the plant above ground grows slowly until the root system is well established. Secondly, the system has to supply a leaf area which is approximately half the leaf area of maize. Thirdly, the low transpiration rate must influence the water demands.

Finally, the plant can remain dormant during a prolonged drought and thereafter recontinue its development.

Hector (1936)