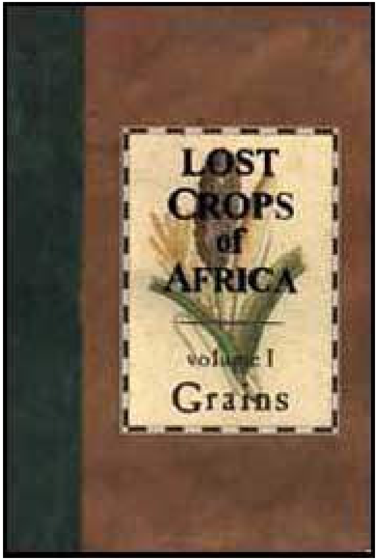

Lost Crops of Africa: Volume 1 - Grains (BOSTID, 1996, 372 p.)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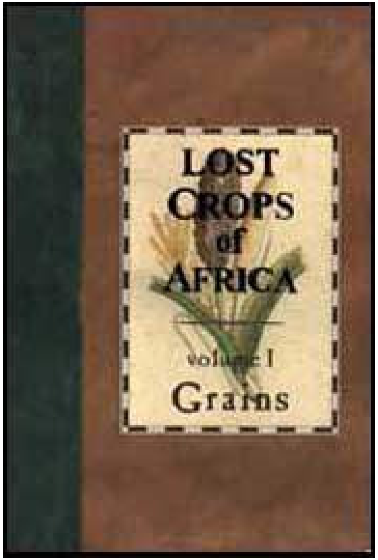

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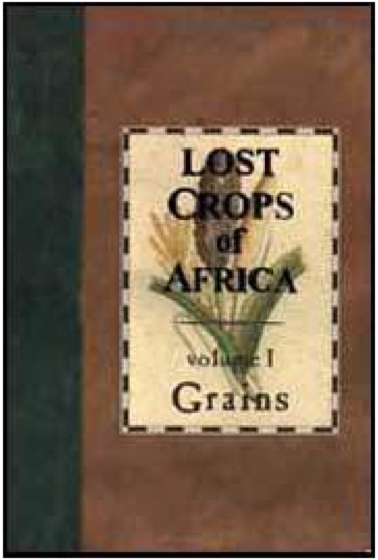


2. Finger Millet

Finger millet (Eleusine coracana) is hardly "lost." Indeed, it is one of the few special species that currently support the world's food supplies. This African native probably originated in the highlands of Uganda and Ethiopia, where farmers have been growing it for thousands of years. In parts of eastern and southern Africa as well as in India, it became a staple upon which millions depend. And its annual world production is at least 4.5 million tons of grain, of which Africa produces perhaps 2 million tons.

For all its importance, however, finger millet is grossly neglected both scientifically and internationally. Compared to the research lavished on wheat, rice, and maize, for instance, it receives almost none. Most of the world has never heard of it, and even many countries that grow it have left it to languish in the limbo of a "poor person's crop," a "famine food," or, even worse, a "birdseed."

Further, in recent years this neglected crop has started an ominous slide that could propel it to oblivion even in Africa. In fact, it has declined so rapidly in southern Africa, Burundi, Rwanda, and Zaire, for instance, that some people predict that in a few years it will be hard to find - even where until recently it was the predominant cereal. In those areas it clings to existence only in plots that are grown for use on feast days and other occasions demanding prestige fare.

The world's attitude towards finger millet must be reversed. Of all major cereals, this crop is one of the most nutritious. Indeed, some varieties appear to have high levels of methionine, an amino acid lacking in the diets of hundreds of millions of the poor who live on starchy foods such as cassava and plantain. Outsiders have long marveled at how people in Uganda and southern Sudan could develop such strapping physiques and work as hard as they do on just one meal a day. Finger millet seems to be the main reason.

This crop has many other advantages as well. Its grain tastes better than most; Africans who know it usually prefer finger millet over all others. The plant is also productive and thrives in a variety of environments and conditions. Moreover, its seeds can be stored for years without insect damage, which makes them lifesavers for famineprone areas.

Given all these qualities, it is perhaps hard to understand why finger millet is being rejected.

But the reason is simple. People are giving it up in favor of maize, sorghum, and especially cassava because producing finger millet takes a lot of work.

The truth is that finger millet, as produced at present, demands a dedication to drudgery that, given a choice, few people are willing to invest. Part of the terrible toil is in weeding the fields, part in handling the harvest, and part in processing the grain.

PROSPECTS

Even though finger millet is declining in the heartland where 30 years ago it was the major crop of the land, all is not lost. Indeed, if immediate attention is given, the impediments causing the decline will probably be eliminated. In fact, there are already signs that the slide may be bottoming out. Prices paid for finger millet have risen dramatically in some places, and the crop is enjoying something of a resurgence - and a highly profitable one at that. In

Kenya, for instance, the grain currently sells at more than twice the price of sorghum and maize. In Zimbabwe, too, the government offers an attractive producer price, which has tended to slow the decline. And Uganda's most recent statistics indicate that finger millet still occupies 50 percent of its cereal area.

Africa

If this crop is given proper attention, it has the following possibilities within Africa.

Humid Areas Excellent prospects. Certain varieties are adapted to heat, humidity, and tropical conditions. (Finger millet was once the principal staple for people in southern Sudan and northern Uganda, for instance.) Given research, recognition, and sympathetic policies, production could expand dramatically.

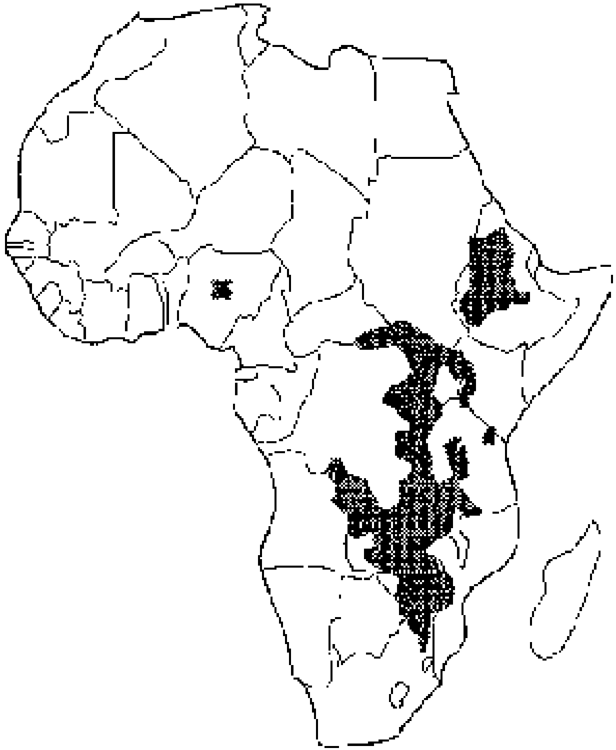


FIGURE: Finger millet is grown throughout eastern and southern Africa, but especially in the subhumid uplands of Uganda, Kenya, Tanzania, Malawi, Zaire, Zambia, and Zimbabwe. The crop originated somewhere in the area that today is Uganda.

Dry Areas Fair prospects. Finger millet is not as drought tolerant as pearl millet or even sorghum, but it could play a much greater role in savanna areas that get at least moderate rainfall.

Upland Areas Excellent prospects. Certain finger millet landraces are fully adapted to highland conditions. In Africa the crop is usually grown at altitudes between 1,000 and 2,000 m and in Nepal it is grown at altitudes up to at least 2,400 m.

Other Regions

Finger millet is certainly not being abandoned in Asia. Indeed, India's national yields have increased 50 percent since 1955.4 Moreover,

Most of the increase occurred between 1955 and 1975 and resulted from genetic improvement of India's traditional landraces. Subsequent increases were due to crosses between those and new strains introduced from Africa. in Nepal, the finger millet area is expanding at the rate of 8 percent per year.

This high-methionine grain might also be beneficial for use in weaning foods and in many other cereal products in parts of the world (Latin America and North America, for instance) where it is now largely ignored.

USES

This is a versatile grain that can probably be used in dozens of types of foods, including many that are quite unlike its traditional ones. Its several major uses include the following:

· Porridge. The small grains - which are usually brown but occasionally white - are commonly boiled into a thick porridge.
· Bread. Some finger millet is ground into flour and used for bread and various other baked products. All are relished for

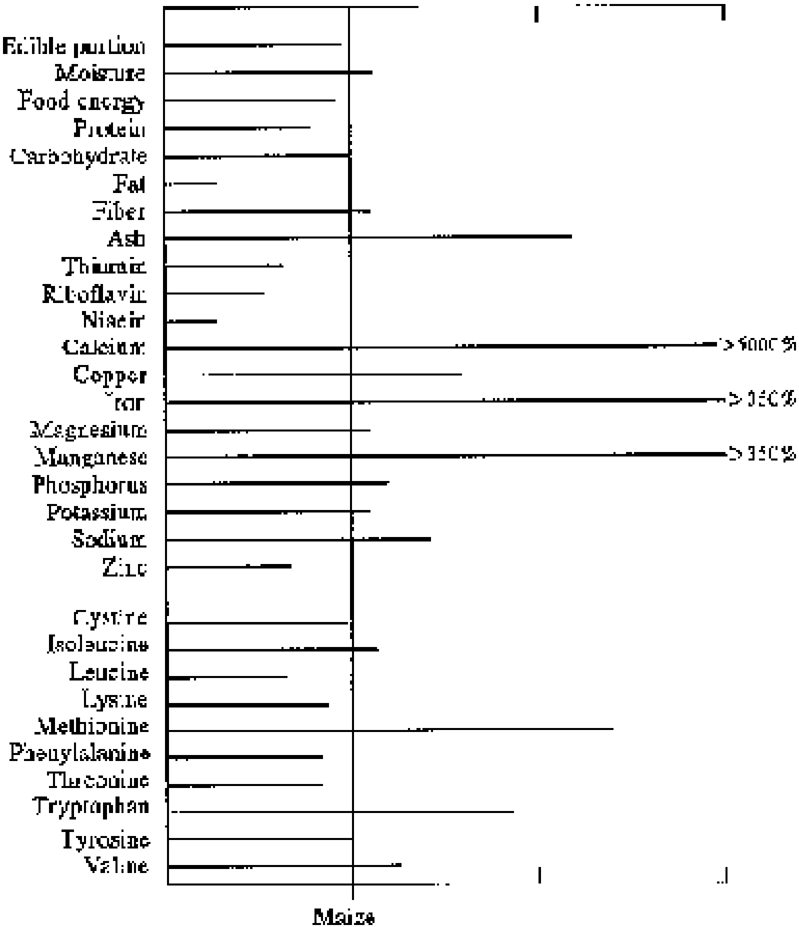
their flavor and aroma.
· Malt. Malted finger millet (the sprouted seeds) is produced as a food in a few places. It is nutritious, easily digested, and is recommended particularly for infants and the elderly.
· Beverages. Much finger millet in Africa is used to make beer. Its amylase enzymes readily convert starch to sugar. Indeed, finger millet has much more of this "saccharifying" power than does sorghum or maize; only barley, the world's premier beer grain, surpasses it. In Ethiopia, finger millet is also used to make arake, a powerful distilled liquor.
· Fodder. Finger millet straw makes good fodder - better than that from pearl millet, wheat, or sorghum. It contains up to 61 percent total digestible nutrients.
· Popped Products. Finger millet can be popped. It is widely enjoyed in this tasty form in India.

NUTRITIONAL PROMISE

Main Components	**Essential Amino Acids**

Edible portion (g)	95	Cystine	1.7
Moisture (g)	12	Isoleucine	4.0
Food energy (Kc)	334	Leucine	7.8
Protein (g)	7.3	Lysine	2.5
Carbohydrates (g)	74	Methionine	5.0
Fats (g)	1.3	Phenylalanine	4.1
Fiber (g)	3.2	Threonine	3.1
Ash (g)	2.6	Tryptophan	1.3
Vitamin A (RE)	6	Tyrosine	4.1
Thiamin (mg)	0.24	Valine	6.4
Riboflavin (mg)	0.11		
Niacin (mg)	1.0		
Vitamin C (mg)	1		
Calcium (mg)	358		

Chloride (mg)	84		
Copper (mg)	0.5		
Iodine (fig)	10		
Iron (mg)	9.9		
Magnesium (mg)	140		
Manganese (mg)	1.9		
Molybdenum (fig)	2		
Phosphorus (mg)	250		
Potassium (mg)	314		
Sodium (mg)	49		
Zinc (mg)	1.5		


Edible portion
Moisture
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
Maize

FIGURE

No single set of numbers can adequately convey the nutritional promise of a grain as variable as finger millet. The numbers in these pages should be taken with caution. The dozen or so measurements that have been reported generally agree on most of the different nutrients. However, protein contents ranging from 6 to 14 percent have been claimed. The levels of fat (1-1.4 percent) and food energy (323-350 Kc) that are normally given are fairly consistent and are about the same as in maize. However, in some samples they seem to be much higher. The situation regarding iron is somewhat similar. Most analyses give the figure as about 5 mg per 100 g. But there have been two reports of iron exceeding 17 ma.

Figures reported for the essential amino acids are generally consistent, but 3 percent methionine is commonly referred to in the literature. Possibly, this was based on degerminated flour. Even that figure is outstanding for a cereal grain.

In this chart, we have compared whole-grain finger millet with the standard figures for maize. These are perhaps not fair comparisons, but they do accurately reflect the differences between the forms in which each food is normally eaten.

NUTRITION

The grain's protein content (7.4 percent) is comparable to that of rice (7.5 percent). However, it shows considerable variation, and at least one Indian cultivar contains as much as 14 percent protein.

The main protein fraction (eleusinin) has high biological value, with good amounts of tryptophan, cystine, methionine, and total aromatic amino acids. All of these are crucial to human health and growth and are deficient in most cereals. For this reason alone, finger millet is an important preventative against malnutrition. The methionine level - ranging around 5 percent of protein - is of special benefit, notably for those who depend on plant foods for their protein.

Finger millet is also a rich source of minerals. Some samples contain 0.33 percent calcium, 5-30 times more than in most cereals. The phosphorus and iron content can also be high.

AGRONOMY

In Asia, finger millet is planted in rows and managed much like other cereals. But in Africa it is usually handled differently. Unlike maize, sorghum, or pearl millet - all of which are planted at individual stands in a rough seedbed - finger millet is traditionally planted in Africa by broadcasting its tiny seeds. This demands a very fine seedbed and means that the farmers must work hard and long, both to prepare the land and to weed the young plants.
Two crops a year are possible with early-maturing types.

HARVESTING AND HANDLING

In most of Africa the crop is harvested by hand. Individual heads are cut off with a knife, leaving a few centimeters of stalk attached. These are piled in heaps for a few days, which fosters a fermentation whose heat and hydrolysis makes the seeds easier to thresh.

Finger millet seeds are so small that weevils cannot squeeze inside. In fact, its unthreshed heads resist storage pests so well they can be stored for 10 years or more without insect damage. (It is said that if kept dry the seed may remain in good condition for up to 50 years!)

Yields are variable but (compared to those of other grains in the area) are generally good. In Uganda, for example, a threshed yield of 1,800 kg per hectare is regarded as average. In India, on reasonable dryland sites, yields may run to about 1,000 kg per hectare, and on irrigated sites a normal average is more than 2,000 kg per hectare. Yields of 5,000-6,000 kg per hectare have been obtained under ideal irrigated conditions. Similar yields have been obtained in Nepal even under rainfed conditions.

LIMITATIONS

As has been noted, the small size of the seeds is a serious drawback. It makes the crop difficult to handle at all stages. Weeding is a particular problem. In Africa the dominant weed, a wild relative of the crop, looks so much like finger millet in its early stages that only skilled observers and close scrutiny can tell them apart. The problem is compounded by the practice of broadcasting seed. To weed the resulting jumbled stands, people must inspect every plant, even going through on hands and knees.

Finger millet is subject to bird predators - notably to the notorious quelea (see Appendix A).

By and large' the plant suffers little from diseases and insects, but a ferocious fungal disease called "blast" can devastate whole fields.

Finger millet is almost entirely self-pollinating and crosses between different strains can be made only with difficulty. Until recently, genetic improvement was limited to pedigree-based selection. However, in Uganda a few plants with male sterility have now been discovered. These should ease the way to breeding methods in which different lines can be crossed without trouble.

Because the seeds are so small, it takes skill and much effort to convert finger millet into flour - particularly by hand. Even hammer mills have difficulty. They must be fitted with very fine screens and run at high speed. Recently, however, a special mill for millet has been devised.

NEXT STEPS

If finger millet is ever to be rescued, now is the time. The key is to find ways to present its plight and promise to the public and politicians and to develop its markets. A few motivated individuals could do much here. Among helpful actions might be a pan-African finger millet conference, where researchers and others could compare methods used to grow it, prepare it, and sell it in the various nations. This meeting would provide the opportunity to exchange experiences and to begin the process of preparing papers, pamphlets, recipes, and perhaps a monograph. Another might be the establishment of a "fingermillet action program" to share seeds and research results in the future. There might even be established a pan-African finger millet "SWAT" team to provide advice and stimulus to the countries where finger millet is now declining toward economic extinction.

Rescuing this crop may be easier than now seems probable. Lifestyles and eating habits may have changed, but in much of Africa people still appreciate finger millet. Subsistence farmers like finger millet also. Every seed sown can return between 200 and 500 seeds (other grain crops seldom go above 100 even under ideal conditions). And this crop has many uses. To those whose very lives and livelihoods depend on what they grow, its flexibility is vital.

Beyond Africa, finger millet should also be given a higher research priority. It is a good way to help the rural poor in parts of Asia. Much of the spectacular rise of wheat occurred in areas where irrigation could be used. Overcoming finger millet's yield constraints would, more importantly, benefit rainfed agriculture.

Processing Finger Millet

Milling

Mechanical milling is of course well known; for wheat, rice, and maize, it is a major industry. But for finger millet, this primary step in the commercial processing of a food grain is essentially unknown. Machinery for rubbing the bran (embryo) off finger millet has never been available, perhaps through a lack of interest but mainly because the grain is exceptionally difficult to mill by machine. Finger millet, therefore, is usually eaten as a whole-grain flour, and the presence of oil in the embryo means that its shelf life is short and its commercial use limited.

Finger millet seed is a challenge to mill because it is very small and because its seed coat is bound tightly to the edible part (endosperm) inside. Moreover, the grain is so soft and friable that conventional milling equipment cannot remove the outside without crushing the inside. However, farmers have long known that moistening finger millet (for about 30 minutes) toughens the bran and reduces its grip enough that it can be mechanically separated without crushing the rest.

A machine for doing this has now been developed in India. This so-called "mini millet mill" consists of a water mixer, a plate grinder, and various sifter attachments. It is a versatile device in which debranning and sizing the endosperm (into either flour or semolina) take place in a single operation. It yields fairly white products. It can also be used to process wheat, maize, sorghum, and pearl millet and will even remove the outer husk from finger millet seeds if the clearance between the grinder plates is reduced.

This machine, and others like it, could initiate a new era for finger millet as a processed grain of commerce. The flour would then have a good shelf life and could be trucked to the cities and sold in stores as are wheat, rice, and maize. Commercial horizons would open up that have never before been contemplated.

Malting

Finger millet could be the key to providing cheap and nutritious foods for solving, at last, the malnutrition that each year kills millions of babies throughout the warmer parts of the world.
As is described elsewhere (notably in appendixes C and D), the process of germinating finger millet activates enzymes that break down the complex structures of starches into sugars and other simple carbohydrates that are easy to digest. The enzymes are of course there to benefit the seeds in which they occur - to mobilize food for the growing seedling; but long ago people found that they could use them also to break up starches from other sources. This process (usually called malting) became the

first step in making beer and liquor out of starchy foods such as potatoes, maize, rice, or sorghum.

What has been overlooked to a large extent is that malting can be used for more than just brewing. Indeed, it is probably the key to making cheap, digestible, liquid foods with little effort and no extra cooking fuel. These foods are particularly promising for children facing the life-threatening dietary switch from mother's milk to solid foods.

Adding a tiny amount of malted grain turns a bowl of hot starchy porridge into a watery liquid. The resulting food matches the viscosity of a bottled baby food, such as those sold in American supermarkets. A child who is too small or too weak to get down solids can then get a full meal - and get it out of the food its mother is preparing for the rest of the family.

The germinated grain acts as a catalyst to liquefy any of the world's major starchy foods: wheat, rice, maize, sorghum, millet, potatoes, cassava (manioc), yams, and the rest. Moreover, it does more than turn those staples into liquid form: it predigests the starches, making the food easy for a body to absorb, and (by releasing sugars) it renders even the blandest staples palatable.

The malted grain is readily available, cheap, and safe to eat. It should develop healthy bodies and fully functioning brains in the millions of children whose health and happiness is now jeopardized by malnutrition.

Of all the world's cereal grains, finger millet is second only to barley in its ability to hydrolyze starches ("malting power"). And it has the inestimable value of growing in the latitudes where malnutrition is rife. (Barley is strictly a temperate-zone resource.)

But for all its potential to benefit the malnourished, not much attention has been paid to malting internationally. Only in India and Nepal have malt-based children's foods been intensively studied. In both countries, food scientists have created malted-grain products that can overcome malnutrition. And in almost every product, malted finger millet was the prime ingredient.

The fact that malting is a cheap and widely understood process that can be easily accomplished in the home or village and requires no fuel or special equipment is a major benefit. This means that top-quality weaning foods can be made by the poor, who cannot afford to buy commercial baby-food concoctions.

Research Needs

Research is needed on all aspects of this plant, which now is little known to scientists in general. ICRISAT is conducting research on it, but more effort is needed. Research operations might include those discussed below.

Trials in New Areas Entrepreneurs in the United States as well as in Australia and other countries that specialize in cereal breeding could probably do much to benefit this crop. It is already grown in a small way in the United States. It grows well, but so far is used only for birdseed. Nonetheless, it might support a small specialty grain industry for local and national food uses. And enlisting the country's outstanding cereal-science capabilities could perhaps transform this crop's potential worldwide.

Farming Methods As far as Africa is concerned, finger millet's greatest immediate needs lie not so much in plant breeding as in farming practices. Reducing the current drudgery involved with its production would bring the biggest and quickest benefits.

Surprisingly, techniques for making finger-millet production less laborious can probably be employed rapidly and widely. For instance, planting the seed in rows would dramatically slash the need for weeding. One or two hoeings (or perhaps a layer of mulch) would eliminate most of the weeds with little further effort. To make this practical, however, a device is needed that can deliver small seed with precision. It would have to be easy to make and simple to use. Such devices do indeed exist (see Appendix A) but have not yet been introduced to finger millet farmers.

Examples of other types of farming practices worth exploring are the following:

· Minimum tillage seeding.
· Wide rows for water capture.
· Control of birds.
· Intercropping or undersowing with legumes. (The foliage from leguminous shrubs or ground cover may be especially helpful by supplying nitrogen to the crop.)
· Sowing or transplanting with other crops. (In Nepal, for instance, it is often planted with maize.)
· Weeding using animal power and other labor-saving techniques.
· Developing ox-drawn implements for planting, cultivating,

harvesting, and threshing finger millet.

Erosion Control In some parts of southern and eastern Africa finger millet has been abandoned because it "causes" severe soil erosion. In these areas, farmers typically clear forest from a hillside, burn it, and sow finger millet in the ashes. The tiny plants hold soil poorly, and it easily washes away. For such sites there is a need for alternative methods of erosion control. One example might be vetiver (see Appendix A). Another is mulching with stubble from the previous crop.

On the other hand, other parts of Africa actually employ finger millet for erosion control. In fact, when broadcast - or even line sown - across the slope it is good for reducing erosion.

Data from Zambia, for example, show that the plant prevents erosion more effectively than legumes do. Farmers in Nepal also report that finger millet "holds the soil."

Plant Breeding In its genetic development as a crop, finger millet is about where wheat was in the 1890s. Many landrace types are known but have not been systematically evaluated, codified, or analyzed, Thus it is likely that the best-yielding, best-tasting, and best-handling types have not been isolated or created out of the massive gene pool. Since the 1890s, average yields of wheat have risen from about 500 kg per hectare to more than 4,000 kg per hectare; finger millet's could rise similarly and much more quickly.

Various finger-millet landraces possess genes for blast resistance, robust growth, early vigor, large panicle size, high finger number and branching, and high-density grain. Similarly, there are water-efficient types with high carbon dioxide fixation and low leaf area that could be outstanding new crops for semiarid conditions. Long-glume types with high seed weight are especially promising for increasing seed size. All of these, and more, are genetic raw materials that could transform this crop.

The grain is already nutritious, but it might be improved even more. As noted, types containing up to 14 percent protein are known. Also, it is a high-methionine protein and, of all the essential amino acids, is the most difficult to find in grain-based foods. Thus these finger millets could be a "super cereal" in nutritional terms.

White-seeded forms that make good unleavened bread and bakery products are also known, and they too are undeveloped. Today's crop in Africa is overwhelmingly the coarse, rusty-red form that is mainly useful for porridge and brewing beer.

Hybrids between Indian and African varieties seem promising as well. These high-yielding "Indaf" types are popular in India. Similar hybridization and selection for improved Indaf varieties for African conditions is now being started.

Hybridization, however, is difficult and mutation breeding is another approach worth exploring.

Some of finger millet's relatives have interesting traits that might be transferable. Among wild Eleusine species are perennials that might lend some of their enduring characteristics to finger millet. Others have genes for tolerance of heat, cold, drought, and waterlogging, as well as resistance to salinity and an ability to mobilize phosphorus and utilize nitrogen efficiently. Less dramatic but more immediately practical plant-breeding needs are the fine-tuning of today's varieties. The most important objectives are resistance to blast, helminthosporium (another fungus), striga (parasitic witchweed), lodging, stressful soil and moisture conditions, and grain that can be more easily dehulled and ground.

Other objectives might include fast seedling growth to compete better with weeds, shade- tolerant types for relay and intercropping, and types with anthocyanin pigmentation in the leaves (possibly obtainable through induced mutation), which could be spotted easily in the fields and would make weeding a much easier task. Post Production Research Reducing the labor to dehull and to grind grain is obviously a vital need. Less urgent needs include: (1) improvement of malting quality (important both for brewing and for making high-methionine weaning foods); and (2) new methods of processing, such as parboiling, milling, and puffing (see Appendix B).

Ragi

Finger millet crossed the Indian Ocean more than 1,000 years ago and since then has become extremely important in South Asia. In India, where it is generally called "ragi," this native African grain is now grown on more than 2 million hectares.

In its new home, scientists and farmers have created numerous ragi races. There are, for instance, plants that are purple; seedheads that are short, long, "open," "curved," or "fisty"; seeds that range from almost black to orange-red; and there is also a popular type whose seeds are pure white. Some ragi varieties are dwarfs (less than 50 cm), some tiller profusely, some are slow to mature and are grown mainly under irrigation, while others mature quickly and lend themselves to dryland production.

Ragi is considered one of India's best dryland crops, and most of it is produced without supplemental water. The plant is both adaptable and resilient: it survives on lateritic soils, it withstands some salinity, and it has few serious diseases or pests. Ragi also yields well at elevations above those suitable for most other tropical cereals. In the Himalaya foothills, for example, it is cultivated up to slightly over 2,000 m above sea level.

Despite its importance in the Himalayas, about 75 percent of the ragi area lies in South India, particularly in Karnataka, Tamil Nadu, and Andhra Pradesh. In parts of this vast region farmers can get two crops a year; in Tamil Nadu and Andhra Pradesh three are not unknown. Wherever the rains at sowing time are uncertain, the farmers often transplant ragi like rice. In fact, the two crops are commonly grown in a "relay" that is good for both. For instance, in May a farmer may start out by sowing ragi seeds in the nursery; in June, he (or she) transplants the seedlings to the field and replants the nursery with rice seeds; in August, the ragi crop is harvested and the rice seedlings are put out into the just vacated fields. This process is efficient, highly productive, and a good insurance against the vagaries of the weather.

Ragi yields as much as 5,000 kg of grain per hectare. Because the seed can be stored for decades (some say 50 years), it is highly valued as a reserve against famines.

However, ragi is much more than just a famine food. In certain regions it is an everyday staple. It is, for instance, a principal cereal of the farming classes in Karnataka, Tamil Nadu, and Andhra Pradesh, as well as in the Himalaya hill tracts (including those of Nepal). The grain is mainly processed into flour, from which is made a variety of cakes, puddings, porridges, and other tasty foods. Some, however, is malted and turned into beer as well as into easily digested foods for infants and invalids.

As in its African homeland' ragi enjoys a reputation for being both nutritious and sustaining, and Indian studies lend scientific support to this view. Certain grain types, particularly the white ones, can match the most nutritious local cereals, at least in protein content.

SPECIES INFORMATION

Botanical Name Eleusine coracana (L.) Gaertner

Common Names

Afrikaans (and Dutch): vogel gierst
Arabic: tailabon
Bantu: bule
English: finger millet, African millet; koracan

French: petit mil, eleusine cultivee, coracan, koracan
German: Fingerhirse
Swahili: wimbi, ulezi
Ethiopia: dagussa (Amharic/Sodo), tokuso (Amharic), barankiya (Oromo)
India: ragi
Kenya: wimbi (kiswahili), mugimbi (Kikuyu)
Malawi: mawere, lipoko, usanje, khakwe, mulimbi, lupodo, males), mawe
Nepal: koddo
The Sudan: tailabon (Arabic), ceyut (Bari) Tanzania: mwimbi, mbege
Uganda: bulo
Zambia: kambale, lupoko, mawele, majolothi, amale, bule
Zimbabwe: rapoko, zviyo, njera, rukweza, mazhovole, uphoko, poho

Description

Finger millet is a tufted annual growing 40-130 cm tall, taking between 2.5 and 6 months to mature. It has narrow, grasslike leaves and many tillers and branches. The head consists of a group of digitately arranged spikes.

It is a tetraploid.

Distribution

Finger millet derives from the wild diploid Eleusine africana. There is archaeological evidence that before maize was introduced it was a staple crop of the southern Africa region. Today it is found throughout eastern and southern Africa and is the principal cereal grain in Uganda, where it is planted on more than 0.4 million hectares (especially in northern and western regions), as well as in northeastern Zambia. It is also an important backup "famine food" as far south as Mozambique.

Finger millet does not appear to have been adopted in ancient

Egypt, and it is said to have reached Europe only about the beginning of the Christian era. However, it arrived in India much earlier, probably more than 3,000 years ago, and now it is an important staple food in some places, particularly in the hill country in the north and the south.

Cultivated Varieties

Numerous cultivars have been recognized in India and Africa, consisting of highland and lowland forms, dryland and irrigation types, grain and beer types, and early- and late- maturing cultivars. By and large, there are highland races and lowland races - each adapted to its own climate.

Environmental Requirements

Daylength Finger millet is a short-day plant, a 12-hour photoperiod being optimum for the best-known types. It has been successfully grown in the United States as far north as

Davis, California (with considerable problems of photoperiod sensitivity), and it is widely grown in the Himalayas (30°N latitude); however, it is mainly produced within 20°N and 20°S latitude. Daylength-neutral types probably exist.

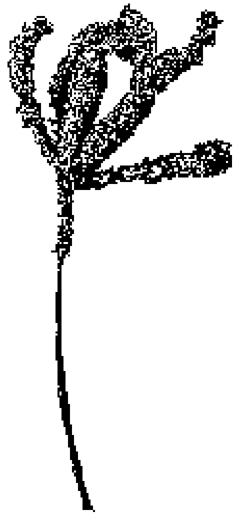
Rainfall It requires a moderate rainfall (500-1,000 mm), well distributed during the growing season with an absence of prolonged droughts. Dry weather is required for drying the grain at harvest. In drier areas with unreliable rainfall' sorghum and pearl millet are better suited. In wetter climates, rice or maize is preferable.

Altitude Most of the world's finger millet is grown at intermediate elevations, between 500 and 2,400 m. Its actual altitude limits are unknown.

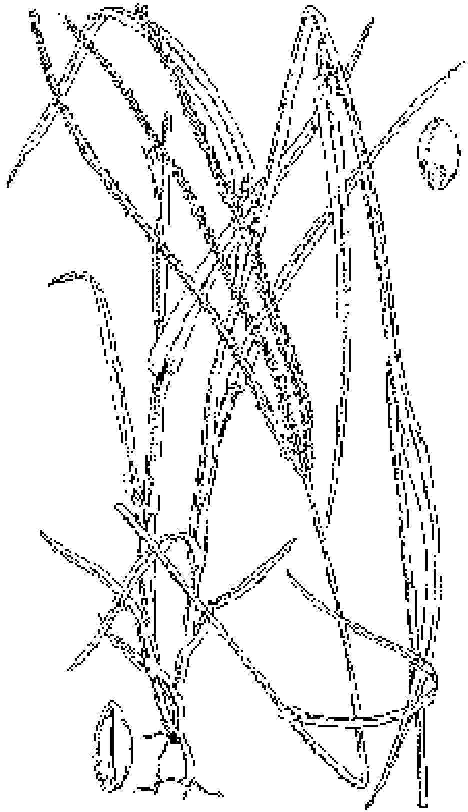
Low Temperature The crop tolerates a cooler climate than other millets. For an African native, this crop is surprisingly well adapted to the temperate zones.

High Temperature Finger millet thrives under hot conditions. It can grow where temperatures are as high as 35°C. In Uganda, the crop grows best where the average maximum temperature exceeds 27°C and the average minimum does not fall below 18°C.

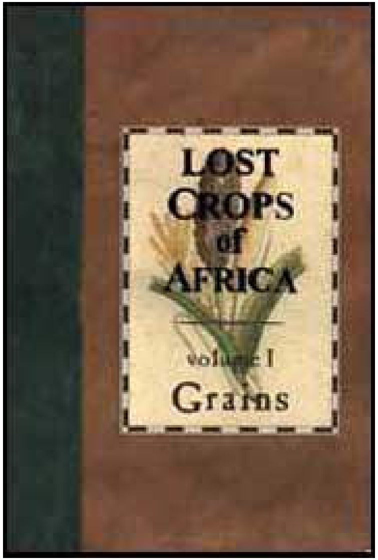
Soil Type The crop is grown on a variety of soils. It is frequently produced on reddish-brown lateritic soils with good drainage but reasonable water-holding capacity. It can tolerate some waterlogging. It seems to have more ability to utilize rock phosphate than other cereals do.



FIGURE



FIGURE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3. Fonio (Acha)

Fonio (Digitaria exilis and Digitaria iburua) is probably the oldest African cereal. For thousands of years West Africans have cultivated it across the dry savannas. Indeed, it was once their major food. Even though few other people have ever heard of it, this crop still remains important in areas scattered from Cape Verde to Lake Chad. In certain regions of Mali, Burkina Faso, Guinea, and Nigeria, for instance, it is either the staple or a major part of the diet. Each year West African farmers devote approximately 300,000 hectares to cultivating fonio, and the crop supplies food to 3 -4 million people.

Despite its ancient heritage and widespread importance, knowledge of fonio's evolution, origin, distribution, and genetic diversity remains scant even within West Africa itself. The crop has received but a fraction of the attention accorded to sorghum, pearl millet, and maize, and a mere trifle considering its importance in the rural economy and its potential for increasing the food supply. (In fact, despite its value to millions only 19 brief scientific articles have been published on fonio over the past 20 years.)

Part of the reason for this neglect is that the plant has been misunderstood by scientists and other decision makers. In English, it has usually been referred to as "hungry rice," a misleading term originated by Europeans who knew little of the crop or the lives of those who used it.(1) (1) Information from J. Harlan. In Nigeria it is usually called "acha."

Unbeknownst to these outsiders, the locals were harvesting fonio not because they were hungry, but because they liked the taste. Indeed, they considered the grain exotic, and in some places they reserved it particularly for chiefs, royalty, and special occasions. It also formed part of the traditional bride price. Moreover, it is still held in such esteem that some communities continue to use it in ancestor worship.

Not only does this crop deserve much greater recognition, it could have a big future. It is one of the world's best-tasting cereals. In recent times, some people have made side-by-side comparisons of dishes made with fonio and common rice and have greatly preferred the fonio.

Fonio is also one of the most nutritious of all grains. Its seed is rich in methionine and cystine, amino acids vital to human health and deficient in today's major cereals: wheat, rice, maize, sorghum, barley, and rye. This combination of nutrition and taste could be of outstanding future importance. Most valuable of all, however, is fonio's potential for reducing human misery during "hungry times."

Certain fonio varieties mature so quickly that they are ready to harvest long before all other grains. For a few critical months of most years these become a "grain of life." They are perhaps the world's fastest maturing cereal, producing grain just 6 or 8 weeks after they are planted. Without these special fonio types, the annual hungry season would be much more severe for West Africa. They provide food early in the growing season, when the main crops are still too immature to harvest and the previous year's production has been eaten.

Other fonio varieties mature more slowly - typically in 165-180 days. By planting a range of quick and slow types farmers can have grain available almost continually. They can also increase their chances of getting enough food to live on under even the most changeable and unreliable growing conditions.

Of the two species' white fonio (Digitaria exilis) is the most widely used. It can be found in farmers' fields from Senegal to Chad. It is grown particularly on the upland plateau of central Nigeria (where it is generally known as "acha") as well as in neighboring regions.

The other species, black fonio (Digitaria iburua), is restricted to the Jos-Bauchi Plateau of Nigeria as well as to northern regions of Togo and Benin. Its restricted distribution should not be taken as a measure of relative inferiority: black fonio may eventually have as much or even greater potential than its now better-known relative.

PROSPECTS

Unlike finger millet, African rice, sorghum, and other native grains, fonio is not in serious decline. Indeed, it is well positioned for improved production. First, it is still widely cultivated and is well known. Second. it is highly esteemed. (In Nigeria's Plateau State, for example, the present 20,000-ton production is only a quarter of the projected state demand. Third, it tolerates remarkably poor soil and will grow where little else succeeds. These are good underpinnings for fonio's future advancement.

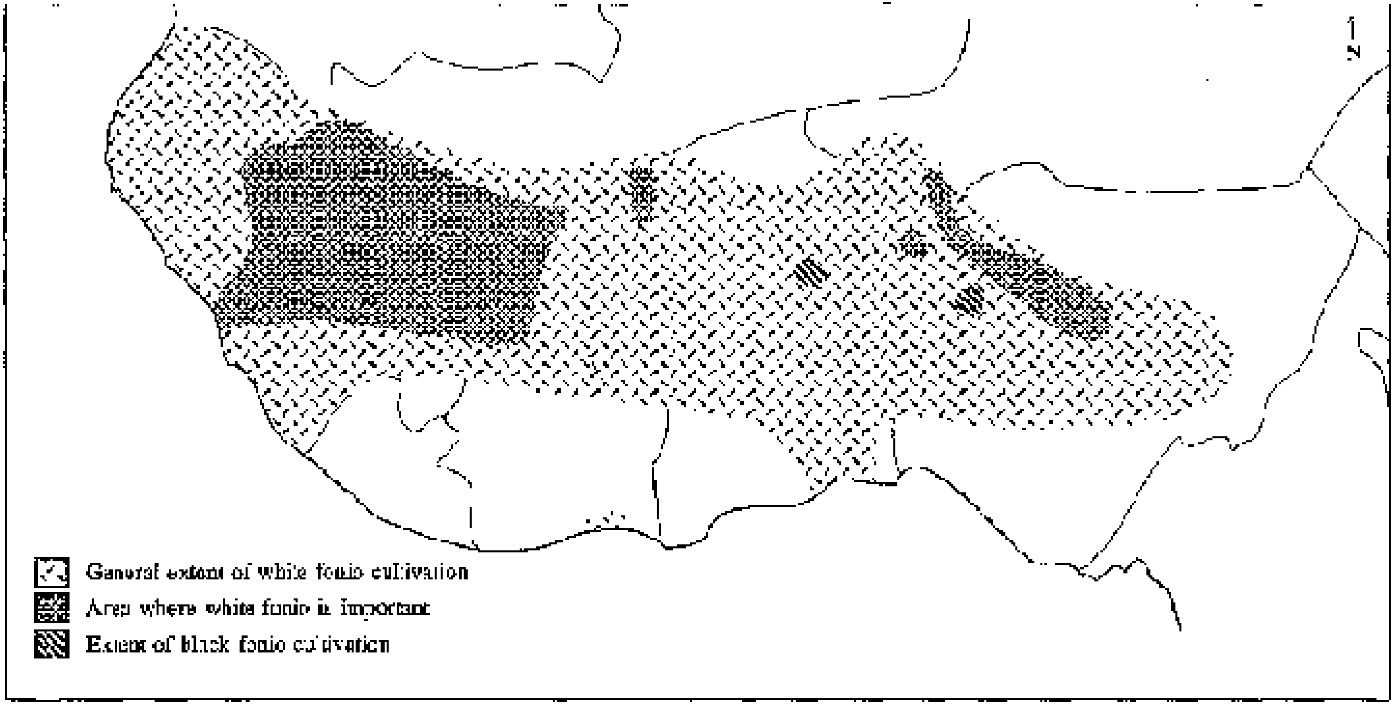


FIGURE: For a crop that is so little known to science, fonio is surprisingly widely grown. It is employed across a huge sweep of West Africa, from the Atlantic coast almost to the boundary with Central Africa.

Africa

Humid Areas Low prospects. Fonio is mainly a plant of the savannas and is probably ill adapted to lowland humid zones. It seems likely to succumb to various fungal and bacterial diseases. However, white fonio does grow around the Gola Forest in southeastern Sierra Leone, and black fonio is reportedly cultivated in Zaire and some other equatorial locations. These special varieties (occasionally misnamed as Digitaria nigeria) are possibly adapted to hot and humid conditions.

Dry Areas High prospects. People in many dry areas of West Africa like fonio. They know that it originated locally, and they have long-established traditions for cultivating, storing, processing, and preserving it. During thousands of years of selection and use, they have located types well adapted to their needs and conditions. Although the plant is not as drought resistant as pearl millet, the fast-maturing types are highly suited to areas where rains are brief and unreliable.

Upland Areas Excellent prospects. Fonio is the staple of many people in the Plateau State of Nigeria and the Fouta Djallon plateau of Guinea, both areas with altitudes of about 1,000 m.

Other Regions

This plant should not be moved out of its native zones. In more equable parts of the world it might become a serious weed.

USES

Fonio grain is used in a variety of ways. For instance, it is made into porridge and couscous, ground and mixed with other flours to make breads, popped, and brewed for beer. It has been described as a good substitute for semolina - the wheat product used to make spaghetti and other pastas.

In the Hausa region of Nigeria and Benin, people prepare a couscous (wusu-wusu) out of both types of fonio. In northern

Togo, the Lambas brew a famous beer (tchapalo) from white fonio. In southern Togo, the Akposso and Akebou peoples prepare fonio with beans in a dish that is reserved for special occasions.

Fonio grain is digested efficiently by cattle, sheep, goats, donkeys, and other ruminant livestock. It is a valuable feed for monogastric animals, notably pigs and poultry, because of its high methionine content.

The straw and chaff are also fed to animals. Both make excellent fodder and are often sold in markets for this purpose. Indeed, the crop is sometimes grown solely for hay.

The straw is commonly chopped and mixed with clay for building houses or walls. It is also burned to provide heat for cooking or ash for potash.

NUTRITION

In gross nutritional composition, fonio differs little from wheat. In one white fonio sample' the husked grain contained 8 percent protein and I percent fat. In a sample of black fonio, a protein content of 11.8 percent was recorded.

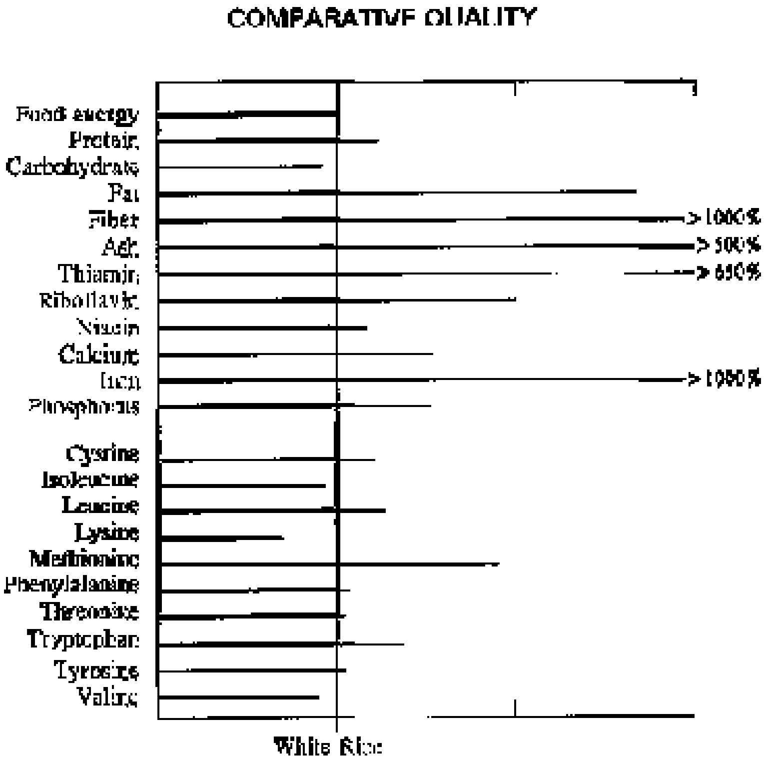
The difference lies in the amino acids it contains. In the white fonio analysis, for example, the protein contained 7.3 percent methionine plus cystine. The amino acid profile compared to that of whole-egg protein showed that except for the low score of 46 percent for lysine, the other scores were high: 72 for isoleucine; 90-100 for valine, tryptophan, threonine, and phenylalanine; 127 for leucine; 175 for total sulfur; and 189 percent for methionine.

This last figure means that fonio protein contains almost twice as much methionine as egg protein contains. Thus, fonio has important potential not only as survival food, but as a complement for standard diets.

NUTRITIONAL PROMISE

Main Components		**Essential Amino Acids**	
Moisture	10	Cystine	2.5
Food energy(Kc)	367	Isoleucine	4.0
Protein(g)	9.0	Leucine	10.5
Carbohydrate(g)	75	Lysine	2.5
Fat(g)	1.8	Methionine	4.5
Fiber(g)	3.3	Phenylalanine	5.7
Ash(g)	3.4	Threonine	3.7
Thiamin(mg)	0.47	Tryptophan	1.6
Riboflavin(mg)	0.10	Tyrosine	3.5
Niacin(mg)	1.9	Valine	5.5
Calcium (mg)	44		
Iron (mg)	8.5		
Phosphorus (mg)	[illegible]		

Phosphorus (mg)	177		



FIGURE

AGRONOMY

Fonio is usually grown on poor, sandy, or ironstone soils that are considered too infertile for pearl millet, sorghum, or other cereals. In Guinea's Fouta Djallon region, where fonio is common, the soils are acidic clays with high aluminum content - a combination toxic to most food crops. It is generally grown just like upland rice, and the two are frequently produced by the same farmers. Normally, the seed is broadcast and covered by a light hoeing. It germinates in 3-4 days and grows very rapidly. This quick establishment and the heavy seeding rate (usually 10-20 kg of seed per hectare) ensures that the fields seldom need weeding. In a few cases the crop is transplanted from seedbeds to give it an even better chance at surviving the harsh conditions.

In Sierra Leone, and probably elsewhere, fonio is often grown following, or even instead of, wetland rice. This is done particularly when the season proves too dry for good paddy production and the farmers decide to give up on the rice. Fonio thus serves as an insurance against total crop failure.

In certain areas, fonio may sometimes be planted together with sorghum or pearl millet. Indeed, it is frequently the staple, while the other two are considered reserves. Commonly, farmers in Guinea sow multiple varieties of fonio and then later fill in any gaps with fastmaturing varieties of guinea millet (Brachiaria deflexa).

HARVESTING AND HANDLING

Fonio grain is handled in traditional ways. The plants are usually cut with a knife or sickle, tied into sheaves, dried, and stored under cover. Good yields are normally 600-800 kg per hectare, but more than 1,000 kg per hectare has been recorded. In marginal areas, yields may drop to below 500 kg and on extremely poor soils may be merely 150-200 kg per hectare.

Traditionally, the grain is threshed by beating or trampling, and it is dehulled in a mortar. This is difficult and time-consuming.

The seed stores well.

LIMITATIONS

Because of the lack of attention, fonio is still agronomically primitive. It suffers from small seeds, low yields, and some seed shattering.

The plant responds to fertilizers, but most types are so spindly that fertilization makes them top-heavy and they may blow over (lodge).

Birds may badly damage the crop in some areas; bird-scaring is usually necessary in those locations. The plants are also susceptible to smut and other fungal diseases.

It has been reported that fonio causes soil deterioration, but this appears to be a misperception. It is often sown on worn-out soils, sometimes even after cassava (the ultimate crop for degraded lands elsewhere). It is this association with poor soils that has given rise to the rumor, but the soils were in fact impoverished long before the fonio was put in.

Some groups dislike black fonio because, compared with the white form, it is more difficult to dehusk with the traditional pestle.

The seed loses its viability after two years.

Because of its small seed size, the harvest is very difficult to winnow. Sand tends to remain with the seed and produces gritty foods. It is therefore necessary to thresh fonio on a hard surface rather than on bare ground. Also, just before cooking, the grains are usually washed to rid them of any remaining sand.

Fonio: It's Not Just a Famine Food

Late in 1990, 1 interviewed a farmer with a largish plot of fonio. It was just a few kilometers from Bo town, in central Sierra Leone. What especially intrigued me was that this was not, as I at first supposed, a poverty-stricken woman's attempt to grow a little food for household subsistence. It was instead a commercial venture, aimed at the Bo market. There, fonio sells (cup for cup) at a better price than rice. By selling her crop she would be able to buy a larger amount of rice. To me, this was a striking confirmation of the commercial potential of this almost entirely neglected crop. To the people who know it, fonio is treasured more highly than rice!

Paul Richards

NEXT STEPS

Clearly, fonio is important, has many agronomic and nutritional virtues, and could have an impressive future. This crop deserves much greater attention. Modern knowledge of cereal-crop improvement and dedicated investigations are likely (at modest cost) to make large advances and improvements. Yields can almost certainly be raised dramatically, farming methods made less laborious, and markets developed - all without affecting the plant's resilience and reliability. These results, and more, are likely to come about quickly once fonio becomes as important to the world's scientists as it is to West Africa's farmers.

Promotion General activities to raise awareness of this crop's value and potential include a monograph, a newsletter, a "friends of fonio" society, a fonio cookbook, a series of fonio cook-offs, and fonio conferences. These could be complemented by publicity, seed distributions, and experiments to test fonio's farm qualities and cultivation limits.

It should not be too difficult to generate excitement for this "lost gourmet food of the great ancestors." It might prove a good basis for recreating traditional cuisines. Even export as a highly nutritious specialty grain is a possibility.

Scientific Underpinnings Despite its importance, fonio is a crop less than halfway to its potential. There have been few, if any, attempts to optimize, on a scientific basis, the process of growing it. Its taxonomy, cultivation, nutritional value, and time to harvest are only partially documented. Varieties have neither been compared, nor their seed even collected, on a systematic basis. Little or no research has been done on postharvest deterioration, storage, or preservation methods.

Germplasm Collection An early priority should be to collect germplasm. Varieties are particularly numerous in the Fouta Djallon Plateau in Guinea and around the upper basins of the Senegal and Niger Rivers. Among these will certainly be found some outstanding types. This alone seems likely to lead to better cultivars that will bring marked advances in fonio production. The collection should also be screened to determine if yield is limited by viruses. If so, the creation of virus-free seed might also boost yields dramatically.

Seed Size The smallness of the grain offers a special challenge to cereal scientists: can the seeds be enlarged - perhaps through selection, hybridization, or other genetic manipulation?

Yield The cause of the low yields needs investigation. Is it because of the sites, diseases and pests, poor plant architecture, inefficient root structure, lodging, poor tillering, bolting, or daylength restrictions? What are optimum conditions for maximum yields? Can fonio's productivity approach that of the better-known cereals?

Grain Quality Cereal chemists should analyze the grains. What kinds of proteins are present? What are the amino-acid profiles of the different proteins? Nutritionists should evaluate the biological effectiveness of both the grains and the products made from them. There are probably happy surprises waiting to be discovered. In particular, protein fractionation is likely to turn up fractions with methionine and cystine levels even greater than fonio's already amazingly high average.

The exceptional content of sulfur amino acids (methionine plus cystine) should make fonio an excellent complement to legumes. Feeding studies to verify this are in order. The combination could be nutritionally outstanding.

Cytogenetics As a challenge to geneticists, fonio has a special fascination. It has no obvious wild ancestor. That it appears to be a hexaploid (2n=6x=54) may help account for this. Does it, in fact, contain three diploid genomes of different origin? What are its likely ancestors, and might they be used to increase its seed size and yield?

Plant Architecture Lodging is a serious drawback, especially when the soil is fertile. This may be overcome by dwarfing the plant or endowing stronger stems by plant breeding. How "free-tillering" are the various types?

Other Uses Certain other Digitaria species are cultivated exclusively as fodder, whereas some are notable for their soil-binding properties and ability to produce an excellent turf. Is fonio also useful for such purposes? Could it, too, become a valuable all-purpose plant for many regions? Could improved fonio be "naturalized" in the northern Sahel to increase the availability of wild grain to nomadic groups'?

Sociocultural Factors How is the crop currently cultivated, distributed, and processed? What roles are played by social and cultural factors such as the division of labor, traditional beliefs, and people's expectations? (Fonio, after all, is seldom if ever grown under optimum conditions.) Its promotion will succeed best in West Africa if its development is placed within such local constraints.

Processing The processing and cooking of this crop is extremely arduous. Unless this can be relieved, fonio will probably never reach its potential.

SPECIES INFORMATION

Botanical Names Digitaria exilis Stapf and Digitaria iburua Stapf Black fonio has been known to science only since 1911, when a botanist recognized that what was growing in fields with pearl millet in the Zaria region of northern Nigeria was a species new to science.

Synonyms Paspalum exile Kippist; Panicum exile (Kippist) A. Chev.; Syntherisma exilis (Kippist) Newbold; Syntherisma iburua (Stapf) Newbold (for Digitaria iburua)

Common Names

English: hungry rice, hungry millet, hungry koos, fonio, fundi millet French: fonio, petit mil (a name also used for other crops)

Fulani: serm, foinye, fonyo, fundenyo
Bambara: fini
Nigeria: ache (Digitaria exilis, Hausa); iburu (Digitaria iburua, Hausa); aburo
Senegal: eboniaye, efoleb, findi, fundi The Gambia: findo (Mandinka)
Togo: (Digitaria iburua); afio-warun (Lamba); ipoga (Somba, Sampkarba); fonio ga (black fonio); ova (Akposso)
Mali: fani, fend, founde
Burkina Faso: fond
Guinea: pence, kpendo, founie, pounie Benin: podgi
Ivory Coast: pom, pohin

Description

As noted, there are actually two species of fonio. Both are erect, free-tillering annuals. White fonio (Digitaria exilis) is usually 3-75 cm tall. Its finger-shaped panicle has 2-5 slender racemes up to 15 cm long. Black fonio (Digitaria iburua) is taller and may reach 1.4 m. It has 2-11 subdigitate racemes up to 13 cm long.

Although both species belong to the same genus, crossbreeding them seems unlikely to yield fertile hybrids, as they come from different parts of the same genus.

The grains of both species range from "extraordinarily" white to fawn yellow or purplish. Black fonio's spikelets are reddish or dark brown. Both species are more-or-less nonshattering.

Fonio as Fast Food

As noted elsewhere (especially in Appendix C), a lack of processed products is holding back Africa's native grains. One grass-roots organization is doing something about this: it is turning fonio into a convenience food.

In southern Mali, fonio is mainly grown by women on their individual plots. Perhaps not unexpectedly, then, it is a women's group that has chosen to foster the grain's greater use. The group aims to raise fonio consumption by producing a precooked flour.

The project, backed by the Malian Association for the Promotion of the Young (AMPJ), is staffed and run entirely by women. Their goal is a fast-cooking fonio that will challenge parboiled rice and pre-packaged pasta (both of which are usually imported) in the Bamako markets.

The new "instant" fonio comes in 1-kg plastic bags and is ready for use. It requires no pounding or cleaning. It can be used to prepare all of the traditional fonio dishes. It is simple to store and handle. It is clean and free of hulls and dirt. And it requires less than 15 minutes to cook. For the user, then, it offers an enormous saving in both effort and time.

The project is currently a small one, designed to handle 6 tons of raw fonio per year. It uses local materials, traditional techniques, and household equipment: mortars, tubs, calabashes, steaming pots, sieves, matting, kitchen scales, and small utensils. The women sieve, crush, wash, and steam-cook the fonio; then they dry and seal the product in the airtight bags. The most delicate operation is a series of three washes to separate sand from the fine fonio grains.

The women have organized themselves into small working groups, formed for (1) the supply of raw materials, (2) production and packaging, and (3) marketing.

Fonio is considered a prestige food in local culinary customs. Yet, on the Bamako market this precooked product currently sells at a very competitive price: between 500 and 550 CFA Francs per kg. (By comparison, couscous sells at 650-750 CFA Francs.)

This small and homespun operation exemplifies what could and should be done with native grains throughout Africa. It is good for everyone: diversifying the diet of city folks, reducing food imports, and, above all, benefitting the local farmers by giving them a value-added product.

Distribution

Fonio is grown as a cereal throughout the savanna zone from Senegal to Cameroon. It is one of the chief foods in Guinea-Bissau, and it is also intensively cultivated and is the staple of many people in northern Nigeria. Fonio is not grown for food outside West Africa.

Cultivated Varieties

There are no formal cultivars as such, but there are a number of recognized landraces, mainly based on the speed of maturity.

Environmental Requirements

Daylength Flowering is apparently insensitive to daylength.

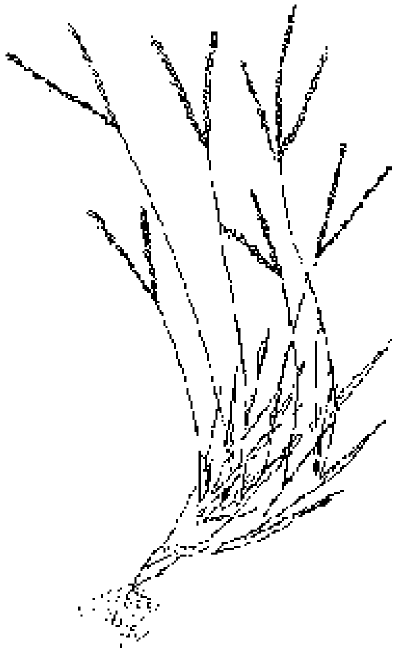
Rainfall Fonio is extremely tolerant of high rainfall, but not - on the whole - of excessive dryness. The limits of cultivation (depending on seasonal distribution of rainfall) are from about 250 mm up to at least 1,500 mm. The plant is mostly grown where rainfall exceeds 400 mm. By and large, the precocious varieties are cultivated in dry conditions and late varieties in wet conditions.

Altitude Although fonio is grown at sea level in, for instance, Sierra Leone, the Gambia, and Guinea-Bissau, its cultivation frequently is above 600 m elevation.

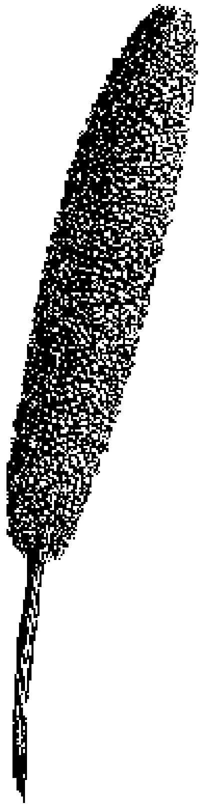
Low Temperature Unreported.

High Temperature Unreported.

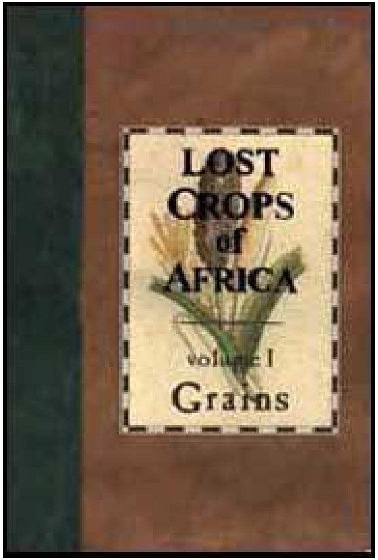
Soil Type It is grown mainly on sandy, infertile soils. It can, however, grow on many poor, shallow, and even rocky soils. Most varieties do poorly on heavy soils. However, by working with a range of varieties, one can generally adapt the crop to almost all terrains and exposures; for example, to fertile or unproductive conditions: sandy, limy, gravelly, or pebbly soils; slopes; plateaus; valleys; or riverbanks.



FIGURE



FIGURE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4. Pearl Millet

Of all the world's cereals, pearl millet (Pennisetum glaucum) is the sixth most important.

Descended from a wild West African grass, it was domesticated more than 4,000 years ago, probably in what is now the heart of the Sahara Desert. Long ago it spread from its homeland to East Africa and thence to India. Both places adopted it eagerly and it became a staple.

Today, pearl millet is so important that it is planted on some 14 million hectares in Africa and 14 million hectares in Asia. Global production of its grain probably exceeds 10 million tons a year, to which India contributes nearly half. At least 500 million people depend on pearl millet for their lives.

Despite its importance, however, pearl millet can be considered a "lost" crop because its untapped potential is still vast. Currently, this grain is an "orphan" among the significant cereals. It is poorly supported by both science and politics. In fact, few people outside of India and parts of Africa have ever heard of it. As a result, it lags behind sorghum and far behind the other major grains in its genetic development. For instance, its average yields are barely 600 kg per hectare and it is almost entirely a subsistence crop; perhaps for this last reason alone pearl millet has attracted little research or industrial support.

Indeed, largely due to neglect, pearl millet is actually slipping backwards. Production in West Africa during the last two decades has increased by only 0.7 percent a year - the lowest growth rate of any food crop in the region and far less than the population's growth rate. Furthermore, even this meager increase has been mainly due to expanding the area cultivated rather than to boosting yields. Elsewhere in Africa the decline has been even more dramatic. Just 50 years ago, pearl millet was of almost incalculable value to millions of rural people in eastern and southern Africa. But over the decades, more and more farmers - especially in southern Africa - have abandoned it and switched to maize.

There are several reasons for this. For one thing, international research efforts have made maize more productive than pearl millet; for another, government incentives have given maize an added financial advantage; and for a third, easier processing has made maize more convenient to use. The momentum for change has now gone so far that maize is often pushed into pearl millet areas to which it is poorly suited and where it cannot perform reliably.

Now, however, a new era may be dawning. Pearl millet is supremely adapted to heat and aridity and, for all its current decline, seems likely to spring back as the world gets hotter and drier. Perhaps the best of all "life-support" grains, pearl millet thrives where habitats are harsh. Of all the major cereals, it is the one most able to tolerate extremes of heat and drought. It yields reliably in regions too hot and too dry to consistently support good yields of maize (or even sorghum). These happen to be the regions most desperately in need of help.

It is there that the famines of recent decades have brought mass devastation and death. It is there that expanding deserts are destroying the productivity of perhaps 25 million hectares every year. And it is there that agricultural development could have its greatest humanitarian benefits.

These reasons alone should be sufficient to make pearl millet the target of a global initiative.

But this crop has even more promise. Rising climatic temperatures are starting to concern almost all countries. And water is shaping up as the most limiting resource for dozens of the world's nations - including some of the most advanced. Agriculture is usually a country's biggest user of water, so that crops that sip, rather than gulp, moisture are likely to be in ever greater demand. Thus, even for economies that until now never heard of it, pearl millet could quickly become a vital resource.

Agronomically, there is no reason why pearl millet could not (like sorghum) become used worldwide. Indeed, recent research in the United States is showing that its prospects are much higher than most people now think. Already, the crop is showing promise for the heartland of America. It might also become widely used in the hotter and drier parts of Latin America, Central Asia, and the Middle East. It could have a bright future in dry areas of Australia and other countries as well.

FIGURE: Pearl-millet-growing areas in Africa. There are an estimated 14 million hectares of millet in this zone, making it the third most widely grown crop in sub-Saharan Africa. The plant was probably domesticated some 4,000-5,000 years ago along the southern margins of the central highlands of the Sahara. It has since become widely distributed across the semiarid tropics of Africa and Asia. Today, approximately one-third of the world's millet is grown in Africa, about 70 percent of it in West Africa. Africa's major pearlmillet producing countries include Nigeria, Niger, Burkina Faso, Chad, Mali, Mauritania, and Senegal in the west; Sudan and Uganda in the east. In southern Africa, the commercialization of agriculture has resulted in maize partially or completely displacing this traditional food crop. (ICRISAT, 1987; each dot represents 20,000 hectares)

Pearl millet is easy to grow. It suffers less from diseases than sorghum, maize, or other grains. Also, it has fewer insect pests.

The widespread impression that pearl millet grain is essentially an animal feed, unpalatable to all but the desperately hungry, is wrong. The grain is actually a superior foodstuff, containing at least 9 percent protein and a good balance of amino acids. It has more oil than maize and is a "high-energy" cereal. It has neither the tannins nor the other compounds that reduce digestibility in sorghum.

Pearl millet is also a versatile foodstuff. It is used mainly as a whole, cracked, or ground flour; a dough; or a grain like rice. These are made into unfermented breads (roti), fermented foods (kisra and gallettes), thin and thick porridges (toh), steam-cooked dishes (couscous); nonalcoholic beverages, and snacks.

Grain from certain cultivars is roasted whole and consumed directly. The staple food of the mountainous regions in Niger is millet flour mixed with dried dates and dried goat cheese.

This nutritious mixture is taken on long journeys across the Sahara and eaten mixed with water - no cooking required.

Grain from other types is used to make traditional beer. In Nigeria, it is fermented, like maize or sorghum, to produce ogi - a traditional weaning food that is still common.

In future, pearl millet may be used in many more types of foods. The fact that it can be made into products resembling those normally produced from wheat or rice should make it acceptable to many more people.

With new technology, there seem to be possibilities of using it even to make raised breads (see Appendix C).

All this is not to say that pearl millet is perfect. Indeed, the crop has several serious problems. For one, the raw grain is difficult to process. Many consumers decorticate (dehull) the grain before grinding it into various particle sizes for use in different products. Dehulling by traditional hand pounding produces low yields of flour (around 75 percent) and the product has poor storage stability.

Despite these impediments, this plant's promise is so great that we have devoted the following two chapters to its various types. The next chapter highlights its promise for subsistence farmers -

the millions in Africa and Asia to whom pearl millet means life itself.

The subsequent chapter highlights commercial pearl millets - the types that are increasingly grown by farmers who produce a surplus to sell.

Bajra

About 3,000 years ago pearl millet crossed the Indian Ocean and became a vital contributor to South Asia's food supplies. Today it is India's fourth most important cereal, surpassed only by rice, wheat, and sorghum. Bajra, as it is called, is currently grown on almost 10 percent of India's food-grain area, and it yields about 5 percent of the country's cereal food.

Rajasthan, Maharashtra, Gujarat, and Uttar Pradesh account for nearly 80 percent of the 14 million hectares planted and 70 percent of the 5 million tons of pearl millet grain produced each year.

India's farmers grow some pearl millet under irrigation during the hot, dry months and routinely reap harvests as high as 3 or 4 tons per hectare. But most grow it in the arid areas, particularly where the rainfall is just insufficient for sorghum or maize. Here, the soils are usually depleted in fertility and there is no irrigation. Some plots receive as little as 150 mm of rainfall per year. But pearl millet survives and produces food.

FIGURE: Baira-growing areas in the Subcontinent. (ICRISAT, 1987; each dot represents 20,000 hectares)

Indians commonly grind pearl millet and make the flour into cakes or unleavened bread (chapati). Some goes into porridges, which may be thin or thick. Much is cooked like rice.

The grain is sometimes parched and eaten, the product (known as akohi, bhunja, lahi, or phula) being similar to popcorn. In some regions, the green ears are also roasted and eaten like a vegetable.

Although small quantities of the grains are used for feeding cattle and poultry, the plant is more often fed to animals as a green fodder. It is well suited for this purpose because it is quickgrowing, tillers very freely, lends itself to multiple cutting, and usually has thin and succulent stems.

All in all, pearl millet is not a neglected crop in India. Authorities realize that it stabilizes the nation's food basket. Improved strains, suited to various regions, have been created and released for cultivation. Indeed, its potential is being increasingly exploited, especially as the swelling population requires increased cultivation of marginal land.

Let Them Eat Millet Bread

Millet once played a greater role in the world of cereals for many rural people in eastern and southern Africa, but it has declined in importance over the last 30-50 years because of a preference for maize.

The decline has been compounded by increased research on maize leading to greater productivity of the crop and by the incentives given to maize production through government policies. Maize has been grown, as a result, in dry conditions to which it is not adapted and it has failed too often in these conditions. Governments have come to realize this as well as the farmers themselves.

So it is now necessary to reestablish the importance of millet and sorghum in these drier areas and to do so we must make the production of these crops attractive enough so that they can compete with maize, not only in the worst and most severe droughts but in at least a majority of years. Here is work for the scientists in millet.

But in the long run, even in Africa, maize is not the problem at all. The problem is wheat, or more correctly, bread. Politicians are going to give the people bread. They have been saying this for a long, long time, and they mean it. Technocrats may decry this trend, particularly in tropical areas where wheat cannot be grown satisfactorily, but I can assure you that the protestations will be to little avail. They may slow the process down but they will not stop it.

The people of the cities want bread, and the elected officials will ensure that they get it. The people are already exposed to bread and they will ask for it, they will insist upon it, and they will get it.

In many tropical countries it will be very expensive to satisfy this demand unless millet can become bread. And this, too, the politicians recognize and they will support this demand whether efforts can be made to decrease the cost of giving people the food that they demand. So here is something else for the millet scientists to do. Don't ask me how you do it. You know far better than I do. I am just telling you it's got to be done.

From an address by L.D. Swindale
Former Director-General, ICRISAT

NUTRITION

Pearl millet's average composition is given in the tables on the following pages. Some highlights are summarized below.

Carbohydrates usually make up about 70 percent of the dry grain, and they consist almost exclusively of starch. The starch itself is composed of about two-thirds amylopectin (the insoluble component that forms a paste in water at room temperature) and one-third amylose (the soluble component that forms a gel in aqueous solution).

Measurements made on several hundred types have shown that the protein ranges from 9 to 21 percent, with a mean of 16 percent. However, the varieties now used in farm practice have an average of about 11 or 12 percent. Of the different protein types, prolamine constitutes 40 percent and globulins 20 percent; the presence of an albumin has been also reported, but no gluten. The protein's biological value and digestibility coefficient have been measured as 83 percent and 89 percent, respectively. The protein efficiency ratio has been found to be 1.43, which is even better than that of wheat (1.2).

The grain has about 5 percent fat, roughly twice the amount found in the standard cereals. It is composed of about 75 percent unsaturated and 24 percent saturated fatty acids.

The vitamin values of pearl millet grain are generally somewhat lower than those of maize, although the level of vitamin A is quite good. The carotene value is also good - for a cereal.

Of the grain's edible portion, ash comprises about 3 percent, an amount somewhat higher than in wheat, rice, or maize. The various mineral constituents, accordingly, tend to occur in greater quantities as well. Compared with maize, phosphorus (average 339 ma) is half again as much, iron (average 9.8 ma) is more than three times, and calcium (average 37 ma) is more than five times as much. Traces of barium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, silver, strontium, tin, titanium, vanadium, zinc, and iodine have also been noted.

In feeding teals, pearl millet has proved nutritionally superior to rice and wheat. A review of research in India states that a diet based on pearl millet and pulses is somewhat better at promoting human growth than a similar diet based on wheat. In one trial, for instance, researchers made up vegetarian diets typical of those eaten by the poor. When pearl millet partially or completely replaced rice, the nutritive value increased appreciably.

Studies conducted on children showed that all the subjects fed diets based on pearl millet maintained positive balance with respect to nitrogen, calcium, and phosphorus. The protein's apparent digestibility was about 53 percent, an amount close to that for finger millet and sorghum proteins, but less than that of rice protein (65 percent). It was also found that pearl millet could replace 25 percent of the rice in a child's diet without reducing the amount of nitrogen, calcium, or phosphorus its body absorbed.

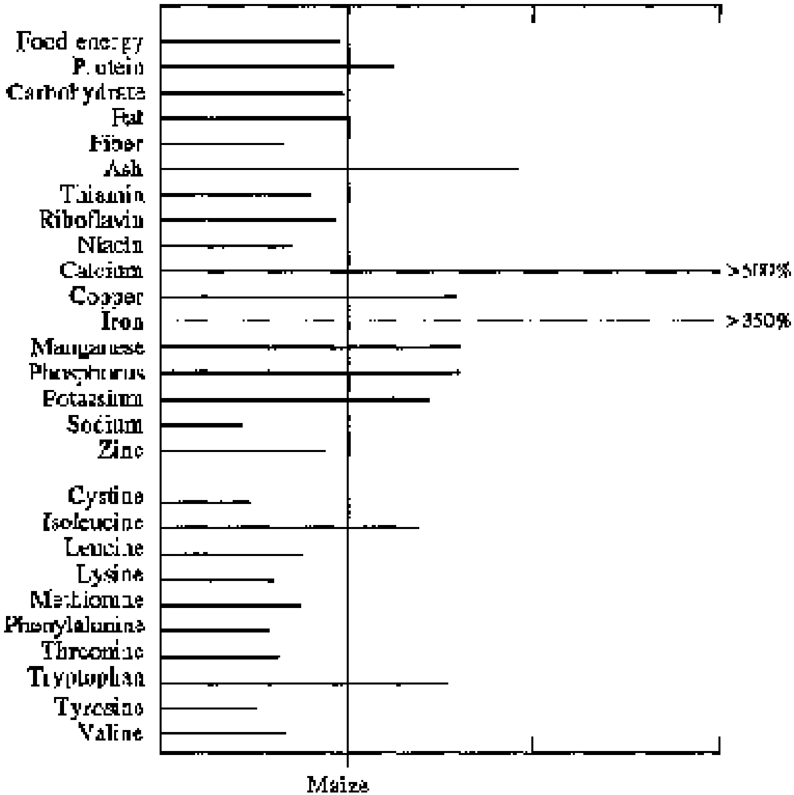
NUTRITIONAL PROMISE

Main Components		Essential Amino Acids	
Moisture (g)	10	Cystine	1.8
Food energy (Kc)	353	Isoleucine	3.9
Protein (g)	11.8	Leucine	9.5
Carbohydrate (g)	70	Lysine	3.2
Fat (g)	4.8	Methionine	1.8

Fiber (g)	1.9	Phenylalanine	4.1
Ash (g)	2.3	Threonine	3.3
Vitamin A (RE)	22	Tryptophan	1.4
Thiamin (mg)	0.31	Tyrosine	3.0
Riboflavin (mg)	0.19	Valine	4.9
Niacin (mg)	2.6		
Calcium (mg)	37		
Chloride (mg)	43		
Copper (mg)	0.5		
Iron (mg)(a)	9.8		
Magnesium (mg)	114		
Manganese (mg)	0.8		
Molybdenum (pa)	190		
Phosphorus (mg)	339		
Potassium (mg)	418		

Potassium (mg)	[illegible]		
Sodium (mg)	15		
Zinc (mg)	2.0		

(a)Values range from 1.0-20.7 ma.



FIGURE

The pearl millet grain is nutritious. It has no husk, no tannin, contains 5-7 percent oil' and has higher protein and energy levels than maize or sorghum. The unsaturated fatty acids making up the oil are oleic (20-31 percent), linoleic (40-52 percent), and linolenic (2-5 percent). The saturated fatty acids are palmitic (18-25 percent) and stearic (28 percent).

In general, pearl millet has a higher protein content than other cereals grown under similar conditions. In 180 pearl millet lines tested in 1972, protein contents ranged from 9 to 21 percent with a mean of 16 percent. It has an excellent amino acid profile and, depending on the variety and perhaps on the growing conditions, the levels of the various amino acids making up the protein can vary by as much as a factor of two. In general, however, the reported values show higher tryptophan, threonine, and valine and lower leucine, but otherwise similar essential amino acids in pearl millet compared with grain sorghum. What is uncertain, however, is the digestibility of pearl millet protein. It is possible that the actual amount of digestible protein is less than that of other major grains.

SPECIES INFORMATION

Botanical Name Pennisetum glaucum (L.) R. Br.

Synonyms Pennisetum typhoides (Burm.f.) Stapf and Hubbard, P. americanum (L.) Leeke, P. spicatum Roem and Schult.

Common Names

Angola: massango
Arabic: duhun, dukhon
English: pearl millet, bulrush millet, cattail millet, candle millet
Ethiopia: bultuk (Oromo), dagusa (Amharic)
French: mil du Soudan, petite mil, mil
India: bajra, bajri, cumbu, sajje
Kenya: mi/mawele, mwere (Kikuyu) Mali: sanyo, nyo, gawri
Malawi: machewere (Ngoni), muzundi (Yao), uchewere, nyauti

(Tumbuka)
Niger: hegni (Djerma), gaouri (Peul), hatch) (Haussa) Nigeria: gero (Hausa), dauro, maiwa, emeye (Yoruba Shona: mhunga, mhungu
Sotho: nyalothi Sudan: dukhon Swahili: uwele, mawele Swati: ntweka
Zambia: mawele, nyauti, uchewele (Nyanja), bubele, kapelembe, isansa, mpyoli (Bemba)
Zimbabwe: mhunga (Chewa), u/inyawuthi (Ndebele) Zulu: amabele, unyaluthi, unyawoti, unyawothi

Description

Pearl millet is an erect annual, usually between 50 cm and 4 m tall. Tillering and branching are not uncommon and are sometimes profuse. The straw is coarse and pithy.

The numerous flowers are tucked tightly around a cylindrical spike (rachis) that can range in length from 15 to 140 cm. This inflorescence is usually greenish yellow, and it may be cylindrical throughout its length or may taper at one or both ends.

The flowers can be either cross-pollinated or self-pollinated. The female part (stigma) emerges before the male part is ready to shed its pollen.

As a result, cross-pollination normally occurs. However, where the timing overlaps, some self-pollination can occur.

Grain begins developing as soon as fertilization occurs and is fully developed 20-30 days later. The whole process, from fertilization to ripening, takes only about 40 days.

The seeds range in color from white to brown, blue, or almost purple. Most are slate gray.

They are generally tear shaped and smaller than those of wheat.

The average weight is about 8 ma. Some thresh free from glumes, while others require husking.

The seeds are quick to germinate. If conditions are favorable, they sprout in about 5 days.

Freshly harvested seed may not germinate immediately; however, a dormancy of several weeks after harvesting has been reported.

Pearl millet is a diploid (2n=14).

Distribution

The two vast areas of West and East Africa where pearl millet is prominent have already been mentioned.

Soon after its domestication, the crop became widely distributed across the semiarid tropics of both Africa (15 million hectares) and Asia (14 million hectares). Pearl millet first became known in Europe about 1566 when plants were raised in Belgium from seed said to have been received from India. This form, sometimes known as Pennisetum spicatum, is still grown in Spain and North Africa. Pearl millet was introduced into the United States at least as long ago as the 1850s.

Double Dip

Pearl millet's extremely deep roots can reach down into soil layers untapped by other plants. Tests in the southeastern United States have revealed that it can pull up nutrients from residues that have accumulated below the root zones of the previous farm crops.

This finding, should it prove more widely true, has profound implications. Much of the fertilizer now put on crops leaches past their roots where it is not only lost but becomes a pollutant. Having an annual crop that can scavenge the lower layers gives farmers a second shot at the (expensive) fertilizer as well as a tool for cleaning the environment. They might even make a profit from it by selling the pearl millet.

Cultivated Varieties

There are vast numbers of types, differentiated by features such as the following:

· Quick maturity (about 80 days), medium maturity (100 days or so), or slow maturity (180 days or more)
· Height
· Amount of tillering
· Stem thickness and branching
· Leaf size and hairiness
· Seedhead size, shape, and "tightness"
· Number, length, rigidity, brittleness, and hairiness of bristles
· Size, shape, and color of grain
· The degree to which the glume adheres to the grain.

For pearl millet, the bulk of the systematic breeding has been done in India, but substantial contributions have also come from several African countries, France, and the United States.

Most yield improvements have resulted from incorporating genes from African varieties into

Indian breeder stocks. However, a breakthrough came in the late 1950s when plants carrying cytoplasmic male sterility were discovered. This genetic trait made hybrids a practical possibility. Today, singlecross pearl-millet hybrids, using male-sterile seed parents, are the basis of vigorous private and semi-public seed industries, especially in India.

Environmental Requirements

Daylength Pearl millet is usually a short-day plant (see next chapter), but some varieties are daylength neutral.

Rainfall Although the crop is grown where rainfall ranges from 200 to 1,500 mm, most occurs in areas receiving 250-700 mm. The lowest rainfall areas rely mainly on early- maturing cultivars. Although very drought resistant, pearl millet requires its rainfall to be evenly distributed during the growing season. (Unlike sorghum, it cannot retreat into dormancy during droughts.) On the other hand, too much rain at flowering can also cause a crop failure.

Altitude Pearl millet is seldom found above 1,200 m in Africa, but occurs at much higher altitudes elsewhere (for instance, in western North America).

Low Temperature The plant is generally sensitive to low temperatures at the seedling stage and at flowering.

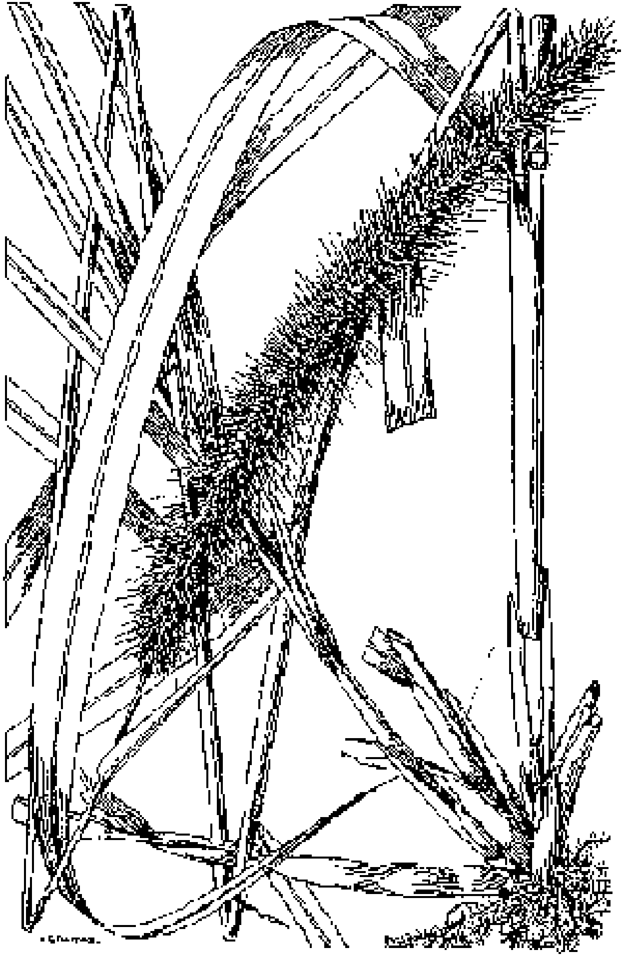
High Temperature High daytime temperatures are needed for the grain to mature. In Africa's pearl millet zone, temperatures are typically above 30°C.

Soil Type Like most plants, pearl millet does best in light, welldrained loams. It performs poorly in clay soils and cannot tolerate waterlogging. It is tolerant of subsoils that are acid (even those as low as pH 4-5) and high in aluminum content.

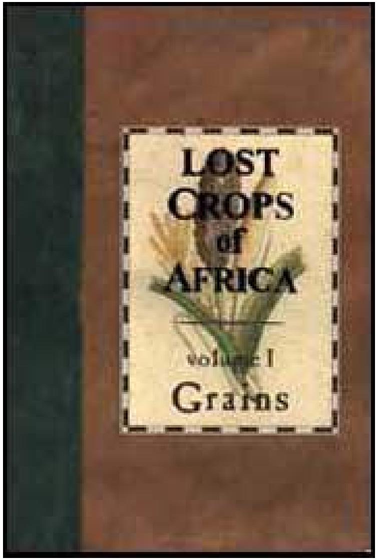
Related Species

Pearl millet has many relatives. A number are quite troublesome. In much of Africa, for instance, wild Pennisetum species manage to get their pollen in, and this cross-pollination quickly reduces the crop's productive capacity. The hybrid swarms of weedy "half-breeds" (called shibras in West Africa) are common contaminants in the farmer's crop. Whereas the cultivated races have broad-tipped persistent spikelets and large, mostly protruding grains, the wild species have narrower, pointed spikelets. Also, their grains are smaller, entirely enclosed by husks, and prone to fall out (shatter). Luckily, the weedy species did not accompany the crop to India.

Although hybridization and introgression between the crop plants and the wild relatives is a problem for farmers, it can be a blessing for plant breeders, giving rise to new forms both of the crop and of the weed.



FIGURE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5. Pearl Millet: Subsistence Types

Pearl millet is the staple of what is perhaps the harshest of the world's major farming areas: the arid and semiarid region stretching over 7,000 km from Senegal to Somalia (almost one-sixth of the way around the globe at that latitude). There, on the hot, dry, sandy soils, farmers produce some 40 percent of the world's pearl millet grain.

How to help these farmers - who live in the often drought-devastated zone on the edge of the world's biggest desert and who have no access to irrigation, fertilizer, pesticides, or other purchased inputs - is perhaps the greatest agricultural challenge facing the world. The answer may lie in their age-old staple, pearl millet.

Indeed, there is probably no better cereal to relieve the underlying threat of starvation in the

Sahel, the Sudan, Somalia, and the other dry lands surrounding the Sahara. Millions entrust their lives to this single species every day, and, of all the peoples on the planet, they are the ones most needing help. Yet, at the moment, pearl millet suffers from neglect and misunderstanding - in part because the crop grows in some of the poorest countries and regions and in some of the least hospitable habitats for humans (including research workers). People have thus unjustly stigmatized it as a poor crop, fit only for interim support while something better is located.

This chapter's purpose is to counter that misguided notion.

SUBSISTENCE MILLETS

Most pearl millets grown in Africa are necessarily oriented toward survival under harsh conditions rather than high yields.

For want of a better name, we have called them "subsistence types."

To any outsider used to the robust look of wheat, rice, or maize, subsistence pearl millets may seem puny, unproductive, and downright unworthy of consideration. To an agronomist or cereal breeder, they look particularly terrible. The plants perform poorly even when they are unstressed. They are tall and top-heavy; they are generally photosensitive; they exhibit low rates of fertilizer response; they have low harvest indexes; and they are localized in adaptation so that even the best of them cannot be easily moved around for use in other places. Above all, they are low yielding - averaging only around 500 kg per hectare.

In reality, though, subsistence pearl millets are some of the most remarkable food plants to be found anywhere. In the area of West Africa where pearl millet is paramount, the droughts can be fierce, the heat searing, and the rainstorms terrible. The sandstorms are even worse.

Early in the growing season, the ever-present winds increase in intensity and often swirl the soil so powerfully that it literally sandblasts the tender seedlings. Then, heated by the Sahara sun, the new-blown sand may "cook" the seedlings before they can grow tall enough to shade and cool the land around their roots. Finally, as the soil dries out, its surface often hardens into a crust so impenetrable that any surviving seeds cannot break through.

Because of conditions like these, crop failure is omnipresent and Sahelian farmers must repeat their sowings, often several times. But of all food crops, subsistence pearl millets tend to survive best - they sometimes survive even in bare Sahara sand dunes.

They are cereals for "base-line food security" and give the farmer the best chance of staying alive.

By and large, subsistence pearl millets can:

· Germinate at high soil temperatures;
· Germinate in crusted soil;
· Tolerate some sand blasting in the seedling stage;

· Yield grain at low levels of soil fertility;
· Resist downy mildew;
· Tolerate stem borer and head caterpillar; and
· Hold up reasonably well against the parasitic weed striga.

Few of the scientists' varieties could be relied upon to produce food under conditions of such uncompromising hostility.

Some of the "faults" perceived by outsiders are actually of great local importance, as the following examples show.

"The fact is, that after 40 years of [pearl] millet breeding. only one improved' line - CIVT - consistently surpasses (but not by much) local cultivars. Breeders' varieties routinely underperform local cultivars, even in on-station trials."

Farming on the Fringe

Pearl millet is the last cereal crop of arable farming on the edge of the desert - beyond it there is only pasturing and open grazing. There is not a more drought-tolerant cereal crop to relieve the threat of starvation. When it fails, nothing else can be substituted. Thus, millions are forced to entrust lives to this plant. It is not an easy bargain to make.

Most of Africa's pearl millet is grown where the danger of drought is ever present; where the landscape abruptly changes between the wet and dry seasons; where the rains are sometimes limited to only a month or two or three; and where utter aridity prevails the rest of the time.

It seems a cruel irony that the most destitute of people are forced to depend upon foods that they must produce for themselves in the harshest lands. But pearl millet has "rusticite," a

French term implying that it will produce something no matter what. Droughts, floods, locusts, diseases, and other hazards may hurt, but the plant produces food nonetheless. All other grains, on the other hand, are more vulnerable and more subject to complete collapse.

It is remarkable that any crop can cope with the sites where pearl millet is grown. Local cloudbursts can dump the year's precipitation in a few hours. On crusted and hard soils, such deluges result in massive rushing runoff, heavy erosion, and the nearly complete loss of desperately needed moisture. Earlyseason rains are preceded by severe dust storms that damage, bury, and desiccate tender emerging seedlings. Scorching heat can kill an entire crop before it becomes established.

Because of problems like these, the threat of crop failure is omnipresent. Farmers must repeat their sowings, often two or three times. Most sow more area - and in widely separated sites - than they anticipate getting a harvest from. During the planting period they may scatter seeds continually wherever their herds trample the soil, and thereby give the seeds a chance to survive. To farmers elsewhere, tossing a few seeds in cow tracks may seem futile, but to those of the Sahel it can mean life itself.

Late Maturation

Elsewhere in the world, plant breeders have tried to speed up their cereals - to make them mature quickly so that more than one crop can be grown per year; so that weeds, pests, and diseases have less chance of causing destruction; and so that food can be produced where growing seasons are short. This is one reason why subsistence pearl millets look bad: many tend to mature very slowly.

The long growing season certainly leads to problems. Since flowering generally takes place after the rains end, even a brief early drought can hit the plants before there is any chance of forming seed and thereby bringing on total crop failure.

However, to Sahelian farmers the delay is all important. They want the grains to ripen after the rains have ceased. Although agronomically inefficient, it eliminates many drying and storage problems. (The grains can be easily dried, and they do not grow molds.) It probably also reduces problems caused by grain diseases and insects, both of which need moisture to thrive.

For the same reason, some subsistence pearl millets are "openheaded." This, too, is inefficient, and plant breeders elsewhere try to replace loose seedheads with compact ones.

For the farmer in much of Africa, however, the open form eliminates many of the drying and storage problems encountered with tight-headed varieties.

The long vegetative growth phase is probably also a major adaptive advantage in this region where the soils are lacking in both moisture and fertility: it gives the roots a chance to explore larger soil volumes. For one thing, this probably contributes to the plant's drought tolerance. For another, it probably helps the plant amass the nutrients necessary to grow a good head of grain. This may take considerable time, because roots grow slowly and because in those depleted soils the release of any remaining mineral nutrients is itself often slow.

A related, subtle feature is that the traditional crop varieties usually mature at the same time.

This means that only one generation of birds, insects, and diseases gets a chance to attack the flowers and seeds. Adding a mixture of types that mature successively is a disaster: it provides a "rolling nursery" that builds up multiple generations of pests and diseases that then wipe out all late-maturing types.

Daylength Sensitivity

Many of the world's wild plants (as well as most traditional landraces) are sensitive to the length of day. Modern plant breeders try to eliminate this restrictive trait so the plants they produce can be grown in different latitudes and seasons. But, for the subsistence pearl millets of West Africa, daylength sensitivity is what ensures that grain will be ready to harvest just at the right time in the dry season. It is the length of day that triggers the plant to flower, not the age of the plants. The yield may be poor if the season has been difficult, but the plant will at least flower and mature whatever grain it can.

By-Products

Traditional rustic varieties tend to be big, tall, leafy plants that perform best when spaced far apart. While these varieties produce massive amounts of greenery (6-12 tons per hectare even under the prevailing circumstances), the harvest index is often less than 20 percent.

This means that less than 20 percent of the plant (above ground) is grain and more than 80 percent is stalk and leaves, as compared to 30 percent or more for improved high-yield-potential varieties.

But farmers who must produce almost every necessity right on their own land look at these cereals in totality. To them, there is no such thing as excessive stalk. For anyone who cannot buy fencing, roofing, or fuel, stalks are as valuable as grains. And for those who have a cow or some goats, the leaves are what keep the animals alive during the dry season.

Consumer Preferences

To a subsistence pearl-millet farmer, the kernel characteristics - shape, color, processing qualities, and endosperm texture - can be more important than the absolute yield. A grain is almost worthless if it doesn't have the right (and often very subtle) properties for the type of foods the family eats. Subsistence growers choose among the varieties mainly on grounds of suitability for preparing such dishes as:

· Toh. The principal food, served at least once a day in the northern Sahel, toh is a stiff porridge prepared by adding pearl millet to boiling water while stirring.
· Koko. This is prepared by mixing pearl millet flour with water into a fine paste, which is then put aside in a warm place for a day or two to ferment. The resulting sourdough is then dropped into boiling water to form a thin porridge of creamy consistency.
· Marsa. This favorite snack of Ghanaians is a deep-fried pancake, prepared from the leavened batter of pearl-millet flour.

Genetic Diversity

Pearl millets grown under truly marginal conditions are usually heterogeneous enough to ensure stable production over seasons with widely differing weather patterns. In a sense, the African farmers for centuries have been performing "population breeding," a technique that is only now becoming popular in science. With this technique, a cluster of genotypes acts as a "cohort" able (collectively) to make the best of varying conditions. The genetically different plants in the "swarm" help create a successful harvest, no matter what hazards the season may bring. Should one type be depressed by weather, pests, disease, or mismanagement, others carry the brunt.

Advancing the qualities of a plant along a broad genetic front helps ensure a reliable - although not maximum - yield. And when your life depends on what you can grow, reliability is the most fundamental need.

WHAT TO DO?

Supporting greater production of subsistence pearl millets is one of the world's most humane endeavors. But improving the plants in this case is probably of secondary importance. Given the already remarkable qualities of these time-tested survival crops, given the infertile soils and harsh climates, and given the resources at the farmer's disposal, it would be difficult to come up with a better plant than he has already.

More important is research to make the farming methods easier, more reliable, and more effective; research to make storing and handling the harvest better and safer; and research to ease the daily drudgery of processing the raw grain into edible forms.

This book is of course designed to highlight promising plants rather than farming, storage, or processing methods. However, during the course of this study we came across some innovative ideas that may help boost the performance and reliability of subsistence pearl millets. We mention them here briefly. In the appendixes can be found ideas on potential breakthroughs in pest control, grain storage, milling, and other pertinent aspects.

The Dual Track

In this report we have given equal weight to species for both subsistence and commercial production. This is certainly an uncommon approach: in recent years polarization and even rancor have prevailed between the proponents of each viewpoint. However, in a broad sense, subsistence and commercial farming, although separate, are parallel and equally worthy - a fact not widely recognized by the public and one that sometimes befuddles even the best-intentioned scientific minds.

Subsistence farming is vital to the lives of millions, of course, and strengthening it is perhaps the most humanitarian contribution that can be made to African agriculture. But it is often operationally impossible to reach the neediest in the way they want. To create a new variety - even of a well-understood crop such as wheat - can easily take a decade of dedication and perhaps a million in money. It is therefore clearly impractical to reach, individually, the thousands of subsistence regions, each with its likes and dislikes, needs and desires, climates and conditions.

Although technical farming is not inimical to traditional farming, it is often much criticized by those most motivated to helping the neediest farmers. Everybody wants to help the most poverty stricken, of course. However, there is probably not a single subsistence farmer who doesn't dream of producing a surplus for sale. And that surplus is much more than a way to pay for a daughter's dowry or a transistor radio; it is, after all, the way out of poverty.

For this reason, then, those who are developing modern cultivars and hybrids for use in even the poorest nations are not wrongheaded or misguided. Subsistence farmers may be in the overwhelming majority, but the other farmers are the ones who, producing more than they can eat, feed the nonfarming public - the city dwellers, businessmen, doctors, teachers, tourists, and, yes, even the visiting researchers. Nor is there any reason to deny subsistence farmers a route to prosperity by withholding from them the means for producing commercially desirable varieties. Any nation, to survive and prosper, must help its farmers feed more than themselves.

Commercial farming has different requirements and goals from subsistence farming, but it poses no threat. This can be seen in many parts of the world. Throughout the Middle East, for example, farmers grow rustic and advanced wheats side by side - one for family use, the other for market day. Also, in the highlands of Peru, Indians commonly grow traditional potatoes for themselves and modern potatoes for the cities.

Some have pointed out that the Green Revolution wheats in India and Pakistan were grown largely for sale. They conclude (rightly or wrongly) that commerce was the main motivation and that no quantum leap in food production can occur in Africa until similar commercial opportunities are available. Thus, despite the current polarized approaches, subsistence farming and commercial farming in the Third World are inextricably linked. Improvements in one can benefit the other.

Traditional Farmers Are Superb, But ...

Subsistence farmers are to be admired and even emulated. Their techniques have been honed in the uncompromising harshness of an unforgiving climate as well as in the ever- present knowledge that failure means hunger or even death. However, no one should get carried away with the romantic notion that peasants always know best.

In the 1860s, when the United States proposed putting an agricultural university in every state, there was much opposition and many claims that American farmers needed no technical help - that professors in universities could not possibly teach the people of the soil how to farm better. But it proved otherwise - the so-called "land grant colleges" provided the engine of basic knowledge that has driven U.S. agriculture to its current heights.

It was through those universities and similar research facilities that the life cycles of many farm pests were worked out, the effects of fertilizer demonstrated, crop genetics illuminated, soil types and soil micronutrients identified, and myriad other basic facts underlying any farming operation brought to light. With this knowledge, even the most stubborn traditionalists were able to coax more from their land, with less effort and more consistency.

All in all, there are many ways in which a basic biological understanding can benefit the subsistence farmers of the hungry nations. Even the best of those farmers can, in this way, be helped to grow their crops more easily, more reliably, and with higher returns.

In the past, scientific findings were applied mostly to commercial agriculture, but that was because larger scale farmers are usually easier to reach and more susceptible to change.

Knowledge is not detrimental to subsistence farming, and the polarization that now pervades rhetoric and thinking worldwide is deplorable.

REDUCING VULNERABILITY TO CLIMATE

Helping farmers to deal with the uncertainties of the early rains - not to mention the droughts, sandstorms, and high soil temperatures - are perhaps the most valuable interventions that can be made. These would provide more secure environments early in the planting season and would do much to reduce a farmer's vulnerability to total crop failure before the crop is even started. Following are six possibilities.

Tillering

The pearl millets grown in the Sahel tend to be nontillering - each seed puts up only a single stem. This adds a major vulnerability because if that stem dies in a drought or sandstorm, for example, the plant is lost.

But certain pearl millets put up as many as five heads - not all of them at once. In this case, then, the destruction of a stem still leaves the plant alive and with a chance to rebound.

Other things being equal, adding some tillering types would dramatically reduce the severity of crop losses in the bad years and it would reduce the need to replant damaged fields. And in the good years when the rains are plentiful and timely, two or three (or perhaps more) stems would all emerge and survive, thereby doubling or tripling the yield.

Deep Planting

In the United States, researchers are studying how different types of pearl millet perform while in the seedling stage. They have found that the seedlings show large differences in the length and in the speed with which they lengthen.

By selecting types that produce tall seedlings and rapid elongation they have been able to plant the crop as deep as 10 cm 14 to 130 mm and 6 to 40 mm, respectively.

This gives the newly germinated and highly vulnerable seedling a better chance at surviving: it can reach deeper moisture; it is less likely to be killed if the soil surface dries out; and, if it is a fast grower, it can perhaps get through to the air before the soil crusts over.

Although the tests were done in germinators and greenhouses in the United States, they successfully identified lines possessing improved stand-establishment capabilities of high potential value for the subsistence farmers facing the elements a world away.

Water Harvesting

There are many possible ways to help concentrate moisture at the base of seedlings. A companion report identifies a considerable number.

That these are likely to have significant value is suggested by a recent paper on the use of soil imprinting and tied ridges. Both techniques produce little "basins" around the plants where water collects.

In the trials (conducted in an area of West Africa where annual rainfall is 600-900 mm), tied ridges captured 85-100 percent of the rainfall received on the site during the season. Normal ridging or flat planting captured only 55-80 percent - the rest was lost as runoff. Tied ridging also reduced the soil's surface bulk density, maintained soil fertility (by reducing losses of soil nutrients), and improved the soil's water-holding capacity. In the case of the pearl millet crop, tied ridging increased the depth of rooting, the root density, the vegetative growth, and the yields - and it did it in both wet and dry years.

Transplanting

The use of nurseries is one of the oldest strategies to avoid water stress in the seedling stage. For centuries, Asians have transplanted rice seedlings and West Africans have transplanted sorghum seedlings. Now farmers in parts of Asia are transplanting maize in the same way. Direct sowing is of course much easier, but wherever catastrophic failure is a probability, transplanting provides added security.

In this process, the seeds are planted not in the fields, but in small irrigated nurseries; they are taken to the fields only after the rains have commenced in earnest. This technique seems particularly promising with subsistence pearl millet (not to mention other crops in this book) because the crop must be established during the least favorable season, the time available is often short, the water supply limited, and the weather unpredictable. On top of all that, the farmer feels pressure to plant early because the family needs food and because the growing season is all too brief.

Transplanting not only overcomes the hazards of the unreliable early rains, but compared with a seeded crop, the transplanted crop is in the field for a much shorter time. It also needs far less water for an equivalent yield, and its resistance to the elements is greater. Growing the seedlings in a nursery also allows the farmer to cull diseased plants and thereby reduce the intensity of infection.

Although transplanting is so far associated mainly with other crops, there seems to be no reason why it couldn't prove most beneficial with subsistence pearl millets. Indeed, in a few parts of India and Africa this is already practiced, and with considerable success.

Mulching

As we have noted, burning-hot soil is one of the major hazards to the newly planted subsistence millets. Anything that could cool the surface of the land would help. Apparently, little or no innovation has yet been applied to this problem, although some tests using shade have resulted in a tenfold increase in survival and yield.

Windbreaks

The "sand-blasting" effect can surely be overcome by various kinds of barriers around (or at least on the windward sides of) the fields. One suggestion is the use of vetiver (Vetiveria zizanioides) hedges. This tall, extremely rugged grass would probably be unaffected by the blasting sand as its stems are enclosed in tough sheaths. When the time for planting crops arrives - even at the end of the driest of seasons - this perennial should still be standing stiff and straight and able to battle the wind.

IMPROVING CROP MANAGEMENT

Ideas on helping subsistence farmers handle their crops with less work or higher returns can be found in various books, journals, research-station reports, and PVO newsletters, for example. We have included a few ideas in the appendixes to this volume. It is thus not our intention here to belabor such fairly well-recognized issues as the use of fertilizers, optimum levels of tillage, optimum crop population size, and the use of less-laborious cultivation practices such as hoes, plows, and draft animals.

There are, however, some promising lines of research that fit in with the spirit of innovation that lies at the heart of this book. Following are three examples.

Cropping Systems

Subsistence pearl millets are essential components of traditional agricultural systems. They are usually intercropped with cereals such as sorghum and maize or with legumes such as cowpea or peanut. To most farmers, the combined production is more important than the yield from either crop by itself. This mixed cropping is difficult for today's researchers to deal with, but there are some interesting developments. One is dwarfing.

To reduce the size of a cereal plant is a common strategy (see next chapter). It provides a compact plant that is more resilient, easier to handle, and higher yielding. In the case of subsistence pearl millets, however, dwarfing is done not for such a yield advantage.

Researchers have found that simply reducing the plant height can contribute greatly to the associated cowpea and other low-growing legumes.

The millet no longer shades its shorter companion, which, with the increased photosynthesis, results in better yields. Initial results in Niger are quite encouraging. Farmers there have adopted dwarf millets eagerly.

Building Tilth

The soil under subsistence pearl millet is usually coarse textured, containing at least 65 percent sand. Such porous sites are not only poor in fertility, they are very poor at holding water. Any rain that does fall tends to drain away below the reach of the roots. Ways to keep it in the root zone would bring marked benefits, both in the crop's yield and its reliability.

It has been found, for example, that leaving crop residues in the field dramatically raises pearl millet yields in West Africa's deteriorating semiarid areas. In three recent trials, grain yields rose by 300, 450, and 550 percent, respectively. The residues not only increased the sandy soil's moisture-holding capacity, they also lowered soil temperatures and boosted fertility.

Biological Fertilization

The areas where subsistence pearl millet is prevalent are usually so remote and so poverty stricken that despite the soil's barrenness commercial fertilizer can seldom, if ever, be used.

But all plants, even those as robust as subsistence pearl millets, need food in the form of nitrogen, phosphorus, potassium, and a few so-called "micronutrients." How to provide plant foods under subsistence conditions is one of the greatest of all agronomic challenges - not just for Africa and not just for pearl millet.

In certain places, deposits of rock phosphate have been located. This almost insoluble phosphorus-containing mineral has seldom been tapped for fertilizer in the past. But it is potentially a major source of phosphate for regions in extremity. Unlike standard soluble fertilizers, it doesn't provide an instant jolt of good nutrition, but it is nonetheless a most valuable source of a prime nutrient that plants need to remain healthy, robust, and high yielding. Certain parts of West Africa have deposits of rock phosphate that could be tapped for this purpose.

For providing nitrogen to a subsistence farmer's crops, probably nothing is more practical than biological sources. Nitrogen can be obtained in this way by:

· Incorporating crop residues or animal manures into the soil;
· Using leguminous food plants (such as cowpea or peanuts) in crop rotations;
· Intercropping with herbaceous soil-building legumes such as stylosanthes or macroptilium; or
· Incorporating nitrogen-fixing tree species such as Acacia albida into the fields.

With pearl millet there is also the potential to get nitrogen directly from a beneficial microorganism that can live on its roots. Such nitrogenfixing symbioses between a plant and a microbe are characteristic of many legumes, but of only a few grasses. Pearl millet is one of those few. It benefits from a nitrogen-fixing bacterium called azospirillum. Recent trials in Maharashtra, India, have shown that when pearl millet plants were inoculated with azospirillum, the yield of both grain and fodder was significantly increased.

Pearl Millet Helps Namibia

Namibia's farming lands are among the driest and most unpredictable to be found. Perhaps for that reason, its farmers rely on mahangu (pearl millet) to provide the basic foods to keep their families fed. In the north of the country, where two-thirds of the population live, it is the staple.

In the past, Namibia's farmers could hope to obtain only about 300 kg of grain per hectare - a pitifully small amount. Indeed, production was so low that the country had to import maize to feed its people.

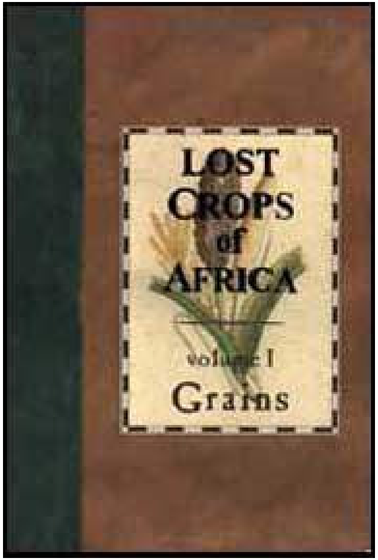
In 1986, however, the country asked ICRISAT for help, and 50 highly productive varieties were brought in and planted out for testing. In March 1987, at the new nation's first "Farmers' Field Day," approximately 100 farmers came to see the results. The variety Okashana 1 proved particularly impressive even though the rainfall that season had been only 170 mm (but well distributed).

Namibia then requested 200 kg of Okashana 1 seed for multiplication, large-scale testing, and demonstration to farmers. At the March 1988 Farmers' Field Day, 250 visitors showed up to buy Okashana seed. A year later, more than 500 farmers came, and they bought about 4 tons of the seed.

Since this new variety's arrival, Namibia's farmers have reaped bumper harvests. Even using traditional cultivation practices, they doubled their yields. But those who employed better methods obtained yields of 2.4 tons per hectare, about eight times the traditional amount.

Okashana 1 results from intensive plant breeding at ICRISAT, but it still retains its rustic resilience and is especially suited to subsistence farmers' needs. Among its characteristics are high grain yield, large seed size, early maturity, resistance to downy mildew, and ability to mature grain even when end-of-season droughts rob the plants of moisture.

According to Wolfgang Lechner, of the Mahanene Research Station at Oshkati, more than half of Namibia's pearl-millet farmers now grow the new variety. "Okashana 1 gives a light-colored flour that is highly acceptable," Lechner explains. "With this and the increased yields, within a couple of years the country may not have to rely on maize imports any more. That will save us a lot of valuable foreign exchange."



(BOSTID, 1996, 372 p.)

6. Pearl Millet: Commercial Types

Although it is one of the best means for sustaining life in the most desolate and difficult parts of the farming world, pearl millet also grows well under pampered conditions - under irrigation and in equable climes, for example. Because this fact is not widely known, most people dismiss pearl millet as a crop for good lands, pointing out that its low yield, low harvest index, and generally low fertilizer response mean that it cannot match the better known cereals under high-tech management.

However, it is far too early to dismiss pearl millet as a crop for regions that now grow modern maize and wheat and rice. The plant, as we have said earlier, has remarkable qualities, and some of its environmental resilience happens to be of the type that Latin America, North

America, Australia, Europe, and others may soon need desperately. Moreover, pearl millet is no longer a rustic relic. Hybrids and other advanced forms are coming available for worldwide use. The old impressions no longer hold.

In fact, a new vision of this ancient crop's potential is becoming clearer from research in the United States, where pearl millet is already exciting increasing interest.

Indeed, fast-maturing types that ripen grain in as few as 90 days after planting and can be harvested by giant combines are now viewed as important resources for a vast belt spanning the nation from the Carolinas to Colorado.

This recognition is starting a new era in pearl millet production. For almost the first time the crop is being seriously investigated with sophisticated methods in the world's finest research facilities. Malesterile forms, dwarfs, hybrids, and even some very unusual hybrids that produce fertile seed, have all recently been created. So far (at least in the United States), the emphasis has been on producing pearl millet as a feed grain - and with excellent reason: in U.S. Department of Agriculture trials, beef cattle, young pigs, and poultry fed pearl millet grain have grown as well as (or better than) those eating maize (see box).

More and more, however, America's pearl millet proponents are realizing that they have in their hands a potential new food grain for the nation and for the world.

There are good reasons for that assumption. Despite the current widespread notion that pearl millet is a second-rate cereal, the plant actually has a high potential growth rate - higher even than sorghum. Like maize and sorghum, it has the super-efficient C4 photosynthesis. Some types mature very fast and can produce two or even three generations a year if conditions permit. And there are other advantages as well. Pearl millet is, for example, "a plant-breeder's dream" and can be developed quickly into numerous and widely different forms. It is a crosspollinating species on which several different breeding methods can be successfully employed. And, by a strange twist of genetic luck, it can also be easily inbred.

In terms of large-scale commercial production, therefore, this crop is poised for revolutionary advances. It stands at about the point maize did in the 1930s. Hybrids are known but are not in widespread use; yields are only a fraction of what they might be; and although the basic understanding of the crop's physiology and genetics is still rudimentary, it is beginning to become clear. Seizing the opportunity now could propel pearl millet (like maize since the 1930s) to far higher levels of productivity by using the best of modern techniques. Indeed, pearl millet might well result in a similar leap in food production in many new areas.

Reasons for thinking this are not hard to find. The world's drylands are faced with an increasingly serious food crisis. Already this is becoming clear in the Middle East. For example, in 1989 Syria's parliamentary speaker announced at a meeting called to discuss Arab development and population problems that, unless the Arab world produces more food, one-third of its people will face starvation. In such places the world's most drought- and heat-tolerant cereal obviously has vital promise.

All in all, then, this plant's adaptability to both good and bad conditions makes it a potentially outstanding food crop for vast areas of a "greenhouse-afflicted', world where climates may change wildly from decade to decade or even from year to year, and where more and more people must obtain food from hot, dry soils.

The chances for boosting pearl millet's productivity and usefulness are good, but the improvements may not come rapidly. To make the crop a modern and globally useful food resource, varieties with large, dense, spherical, light- colored kernels that taste good are needed. In addition, improved dehulling characteristics are vital if pearl millet is going to be employed in human foods on a truly wide scale.

Eventually, all of these and more seem likely to come about, as can be seen from the following promising lines of development.

HIGH-GRAIN TYPES

The worldwide cereal-breeding advances of the last 100 years have increased rice, wheat, and maize yields dramatically, but, contrary to popular perception, the plants still produce about the same amount of growth (that is, their overall dry matter is largely unchanged).

Yields have risen because the plants were reconfigured to reduce the proportion of stems and leaves and increase the proportion of seeds. Usually, this meant reducing the plant height, but sometimes it also meant increasing the number of seedheads per plant.

Such rearranged plants have been the key to the remarkable jump in cereal yields that have occurred in most parts of the world. They respond well to good management; they make it possible to use fertilizer and other inputs profitably; and they create an upward spiral of yield and income that goes far beyond food production alone. For example, they help farmers to rest part of their land to restore its physical condition and fertility.

As of now, however, Africa's pearl millets are not of the rearranged type. After centuries of trying to stretch their heads above the rampant weeds, they are too tall for maximum grain production. In creating excess stalk, they are consuming energy and moisture that could be used to develop more grain.

Also, they cannot fully enjoy the benefits of fertilizer because it makes the plants top-heavy so that rain or wind can easily topple them into the dirt. Paradoxically, more fertilizer can mean less yield.

This was the situation of Mexico's wheats before the 1950s when genes from Japanese dwarf varieties helped create short, strongstemmed plants that could hold their heavy heads up during lashing winds and pounding storms. Strengthening the plant's architecture allowed fertilizer to work to the fullest benefit and was a prime component of the wheats that generated the Green Revolution.

A similar transformation is now occurring with pearl millet. Strongstemmed dwarf types are being put to use for the first time. Such types have already been developed in the United

States, for example. Yields of 4,480 kg per hectare have been achieved on research stations, and demonstration plots on farms in 1991 yielded 3,024 kg per hectare.

Millet in the USA

Although pearl millet has long been grown in the United States, few Americans have ever heard of it. That may soon change, however. A number of pioneering researchers see this crop as a valuable grain for the nation. High-yielding cultivars are being