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UNDERSTANDING CEREAL CROPS II MAIZE, SORGHUM, RICE, AND MILLET

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PREFACE

This paper is one of a series published by Volunteers in Technical Assistance to provide an introduction to specific state-of-the-art technologies of interest to people in developing countries. The papers are intended to be used as guidelines to help people choose technologies that are suitable to their situations. They are not intended to provide construction or implementation details. People are urged to contact VITA or a similar organization for further information and technical assistance if they find that a particular technology seems to meet their needs.

The papers in the series were written, reviewed, and illustrated almost entirely by VITA Volunteer technical experts on a purely voluntary basis. Some 500 volunteers were involved in the production of the first 100 titles issued, contributing approximately 5,000 hours of their time. VITA staff included Suzanne Brooks handling typesetting and layout, and Margaret Crouch as editor and project manager.

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VITA is a private, nonprofit organization that supports people working on technical problems in developing countries. VITA offers information and assistance aimed at helping individuals and groups to select and implement technologies appropriate to their situations. VITA maintains an international Inquiry Service, a specialized documentation center, and a computerized roster of volunteer technical consultants; manages long-term field projects; and publishes a variety of technical manuals and papers.

UNDERSTANDING CEREAL CROPS II

Maize, Rice, Millets, Sorghum

by VITA Volunteers Roy M. Stephen and Betsy Eisendrath

I. INTRODUCTION

Cereal crops, or grains, include a wide variety of plants that are members of the grass family (Gramineae) grown for their hard seeds or kernels, which are used primarily for food. Grains are rich in carbohydrates and contain substantial amounts of protein,

as well as some fat and vitamins. They are the staple food for most of the world's population. Over 70 percent of the world's harvested area is planted to grains, for an output of a billion and a half tons a year.

All grains consist of the same three basic parts: (1) the endosperm or starchy interior of the seed, the food source for the developing seedling; (2) the germ or embryo; and (3) various covering layers.

Most grains can be grown under a variety of weather and soil conditions, and most are cultivated in a number of different regions. However, oats and rye are most often grown in cool climates with poor soils, and wheat and barley in mild climates with better soils. Maize is preferred in warm temperate and subtropical areas. In moist tropical areas, rice is predominant; in drier tropical areas, sorghum and millets. These eight are the most widely cultivated grains. Less common grains, having limited production, include wild rice and Job's tears. There are also several plants, like flax, buckwheat, and amaranths, that are often mistakenly referred to as grains, but are not members of the grass family.

This paper focuses on production and use of maize, sorghum, rice, and millet. "Understanding Cereal Crops I" covers wheat, oats, rye, and barley.

It is not known exactly how long ago people began to eat wild grains, but 75,000-year-old implements have been found that may

have been used for milling them. Grains were among the first plants to be domesticated. This discovery lies at the source of recorded history, for it was the cultivation of grains that made it possible for human beings to end their constant wanderings in search of food. With the cultivation of grains, they could settle together in communities. By 3000 B.C. they were growing all the major grains we raise today.

Many of today's varieties of these grains, however, are improved varieties that have been developed at places like the International Rice Research Institute (IRRI) in the Philippines and the International Maize and Wheat Improvement Center (CIMMYT, from its name in Spanish) in Mexico. Researchers at centers like these work to develop strains that will produce higher yields, lodge(*) less, tiller more, resist diseases and pests, and have an improved nutritional value.

In combination with improved agricultural techniques, these hybrids have produced dramatic increases in yields. But there are limitations. To achieve the full yields of which they are capable, they often require irrigation and increased inputs of fertilizers, as well as of pesticides and herbicides in some cases.
These create further pressures on already strained water and fuel resources, as well as a need for larger capital investment.
Moreover, a new variety of grain seldom remains under cultivation for more than three to five years before new strains of diseases and pests develop to which the variety is susceptible.

ADVANTAGES AND DISADVANTAGES OF GRAIN CROPS

Grain crops have the following advantages:

1. There is a grain crop, and often more than one, suited to almost any climate or soil.

2. They give farmers the highest yield per unit of land of any crop.

3. They can be grown using manual labor, but are well-suited to mechanized farming, which makes them significantly less labor-intensive and less expensive to produce.

4. They are easy to handle and compact to transport and store.

5. Under good storage conditions, they can be kept for a long time.

6. They are rich in starch and calories, and provide significant amounts of protein, as well as some fat and vitamins.

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(*) Lodge: the tendency of the grain stem to fall over from the weight of the seed head. Tiller: capable of producing more than one shoot from the root of the plant.

The disadvantages of grain crops include the following:

1. They are more vulnerable to damage from pests and diseases than legumes.

2. They must be dried thoroughly before storing, and cannot be stored in a humid place.

3. Their protein does not supply all essential amino acids. It must be supplemented with protein from other sources.

MAJOR USES OF GRAINS

Grains as Food

Grains supply over 65 percent of the calories that people consume worldwide. In parts of the world where most of the grain crop is used as human food, they supply an even higher proportion--80 percent in the Far East and Southeast Asia, and over 70 percent in Africa and the Middle East.

People consume grains in a variety of forms: whole, in porridges and soups, dried, and ground into flour that is used to make flat and leavened breads, noodle products, and cakes and cookies. People eat syrups and oils extracted from grains, and drink beer and other beverages brewed from them.

The outer hull of most grains is indigestible and must be removed before the grain can be eaten. Often the grain is milled further

to remove the germ and the inner layers of the endosperm's covering. This improves the keeping qualities of the grain and makes it more uniform in appearence, but results in major losses in its nutritional value.

Grains as Feed

When grain is used as animal feed, it is consumed in the form of seeds themselves, and as pasturage, hay, and silage. Worldwide, animals consume about the same amount of the grain crop as people do, but if current trends continue the animals will soon be consuming the greater proportion.

Feeding grain to animals being raised for meat is an inefficient use of the crop. It takes, for example, 4 kilograms of grain to produce 1 kilogram of pork, and between 7 and 8 kilograms of grain to produce 1 kilogram of beef.

Nonfood Uses of Grains

The nonfood uses of grains are much less important than the food uses. Hulls are used as fuel and mulch, and straw is used as a packing, thatching, and bedding material. Grains are used industrially in the manufacture of soaps, solvents, alcohols, plastics, and paper.

II. MAJOR GRAIN CROPS

This section summarizes the cultivation requirements and primary

uses of four major grains--maize, sorghum, rice, and millet. More detailed information for specific grains on specific sites may be obtained from local agricultural extension services, ministries, and research stations.

RICE

Rice (Oryza sativa) is widely grown on all continents, especially in warm areas. There are two general groupings of Oryza sativa: the japonica cultivars, which have short grains, produce high yields, and are best suited to the subtropics; and the indica cultivars, which have long grains, produce low to medium yields, and are best suited to the tropics.

Rice probably originated in Southeast Asia, and there are records of its being grown in China as early as 2800 B.C. At present China is by far the leading rice-producing country, followed-by India, Indonesia, Bangladesh, and Thailand. Ninety-six percent of the world's rice crop is eaten in the country where it is grown. Its primary use is as human food, but rice products are also used for livestock feeds, construction, fuel, rope, and a number of industrial products.

Rice is classified as an annual, but can be a perennial when soil moisture and temperature are optimum. It can be divided into upland and lowland types. Upland rice is not irrigated and not grown submerged, but is fed by seasonal rainfall. Its yields are much lower than those of lowland rice. Upland rice accounts for less than 10 percent of world rice production. Lowland rice is

usually grown submerged for 60 to 90 days.

Rice can adapt to a wide range of conditions. Is is grown from sea level to an altitude of well over 3,000 meters. Optimum temperatures are 21[degrees]C-38[degrees]C during the 18-week-long growing season,
Best water temperatures for lowlands rice are 77[degrees]C-84[degrees]C. (Water temperatures above 85[degrees]C cause poor root development.) IRRI's Farmer's Primer on Growing Rice reports that one hectare, of rice plants requires at least 8 million liters of water during a growing season, with a water depth of approximately 5 to 10 centimeters necessary to control weeds.

Rice does best on fairly heavy alluvial soils with impermeable subsoils. It can tolerate pH values from 4.5 to 8.5 but does best on neutral to slightly acid soils, with a pH around 6 for lowland rice. In order to control weeds and avoid yield losses due to continuous cropping, rice is often grown in rotation with other crops.

Rice is frequently raised without chemical fertilizers. Bluegreen algae growing in the water in which the rice is submerged may fix some atmospheric nitrogen, but for the best yields additional fertilization is needed. This is especially true for the improved cultivars that have been developed, which can tolerate high levels of nitrogen without lodging. Some of these dwarf types respond well to 130 kilograms or more of nitrogen per hectare. On many soils phosphates, and sometimes potassium, can also be applied with good effects. Rice responds well to green

manuring.

There is great variation in yields. They are heaviest when the rice is grown under irrigation and fertilization. Yields average 1,680 kilograms per hectare for lowland rice, but may go as high as 6,720 kilograms per hectare under optimum, conditions. Yields for upland rice are lower. Yields are generally higher in warm temperate regions with low summer rainfall and high light intensity than in the humid tropics, where plant diseases and soils of low fertility are more common. Yields per hectare are much higher for rice than for wheat, but rice is expensive in terms of human effort. Where its production is most labor-intensive, it can require over 1000 person-hours per hectare.

Production

To prepare a seedbed for rice, the land is disked, and plowed 10 to 15 centimeters deep. The clods are broken into fine particles. (Small clods of soil can remain if the rice is to be broadcast in water.) Dung, sewage, or chemical fertilizer may be applied, and the surface is smoothed.

Upland rice can be sown broadcast or drilled. As little as 28 kilograms of seed per hectare may be enough, but 78 kilograms per hectare is used for a good stand. It can be grown without irrigation. Cultivation and weeding are much the same as for any other cereal crop.

Lowland rice is grown in fields divided by small earthen levees

that are generally about half a meter high and one-and-a-half meters wide; they hold the water at the desired depth. The terrain is smooth, but sloped slightly to facilitate draining. Growing rice in water increases yields and helps control weeds.

The seed may be planted directly in the field, or it may be sprouted in a flooded nursery, and the seedlings transplanted about a month later. They are set 15 to 30 centimeters apart, with 2 to 4 plants to each hole. The advantages of transplanting are that it saves irrigation water and makes it possible to raise two and even three crops a year. Rates of seeding vary, usually between 78 and 112 kilograms per hectare though the quantity can go considerably lower or higher on occasion.

The water is drained away 10 to 15 days before harvest. The rice is usually harvested with a sickle or mechanically, with a combine or binder thresher. The harvested rice is often dried in pits, then threshed by trampling or with manual implements. For maximum yields, harvest should take place when the grains of the standing rice have a moisture content of 18-27 percent. After harvesting, the rice needs to be dried until this moisture has been reduced to 12-14 percent, so that the rice will not deteriorate in storage.

Diseases and Pests

The most harmful disease in the blast caused by the fungus Pyricularia oryzae. It attacks the plant at all stages of its development. It is both seed- and air-borne. Chemical control is

effective, but not economic for small growers. Brown leaf spot is another important disease.

Rice probably suffers more harm from birds than does any other grain crop except perhaps millet, and is attacked by rodents both when growing and when stored. It is also subject to damage from at least a hundred species of insects, especially from stem borers. Other major insect enemies include the brown plant hopper, the green leafhopper, and the gall midge. Barnyard grass (Echinochloa), red rice, and witchweed (striga) are major weed problems. Both cultural and chemical means of controlling them are used.

Varieties of rice that can resist many diseases and pests have been bred. Unfortunately, the diseases and pests usually soon find a way around the resistance by developing new strains.

Uses

Rice supplies one-quarter of all calories consumed by human beings worldwide, and is a staple food for over half of the world's population. It is grown primarily as human food.

The protein content of rice is less than that of wheat or maize, and it is low in the essential amino acid lysine. Brown rice, which has undergone only enough milling to remove the indigestible outer hull, is the most nutritious form. Further processing results in white rice, which has lost the bran and germ. It

cooks more quickly and is easier to store than whole grain brown) rice, but is much lower in protein and minerals. Converted or parboiled rice has been treated with steam to force nutrients into the kernel before polishing takes place; it lies between brown and white rice in nutritional value.

Products derived from rice for human consumption include flour and oil, and wine and beer. The by-products of milling, including the nutritious bran, are used for animal feed, as is straw, which is also made into mats and thatching. The hulls are put to industrial uses, and serve as mulch and fuel.

MAIZE

Maize (Zea mays), also known as maize or Indian maize, is the world's third most important grain for human consumption. It is also widely used as a livestock feed and as a raw material for industry. The United States produces almost half the world's crop, followed by China, Brazil, Romania, Mexico, and the Soviet Union.

Maize probably originated in Central America and spread from there into South America, and then to North America and the rest of the world. Maize comes in a remarkable variety of types and is extremely adaptable. It grows as far north as Siberia and as far south as New Zealand, from below sea level to over 3,660 meters. However, it is a significant crop only where its temperature and moisture requirements are best met. The minimum temperature for germination and growth is 10[degrees]C or slightly less.

A mean temperature between 20[degrees]C and 27[degrees]C during the growing period usually gives maximum yields.

Maize grows best in areas with an annual precipitation of 500 millimeters or more; it may also grown under irrigation. Intake of water is highest during the pollination and early grain-filling stages. Adequate fertilization enhances maize's efficiency in using water.

Maize is a short-day or neutral annual. It is cultivated in all kin ds of soil, but prefers loamy, well-drained soil with an abundance of nutrients. A pH between 5.5 and 8.0 gives best yields.

Maize takes between 60 and 140 days to mature. Yields range between 672 and 1,790 kilograms per hectare, but may go substantially higher with hybrid seeds under optimum cultivation and fertilization.

Production

Maize is sometimes grown continuously, but more often is raised in rotation with other crops. The land where maize is to be planted needs to be well pulverized, but fairly compact. It also needs to be free of weeds and stubble. This is achieved by plowing and harrowing and disking two or more times.

It is common to apply barnyard manure to land that is going to be planted to maize; it supplies elements that the maize plants need

and improves the texture and organic matter content of the soil. If barnyard manure is not available, a legume crop may be grown and then plowed under as green manure before the maize is planted. These can supply a substantial quantity of nitrogen, but often not enough for maximum yields. Maize needs ample nitrogen throughout the growing season. A mixed fertilizer is often applied before or during planting, with a second application about 20 to 30 days after the seedlings have emerged. Soils vary in their needs, but a rough estimate of the elements removed by maize plants producing 500 kilograms of grain per hectare is: 32 kilograms of nitrogen, 6.5 kilograms of phosphorus, and 9 kilograms of potash. These elements need to be replaced if yields are to remain high.

Maize for grain is usually planted 5 to 7.5 centimeters deep, in rows spaced 76 to 100 centimeters apart. Between 11 and 17 kilograms per hectare of seed are used. The rate of planting for maize varies with the variety and growth period of the maize, the type and fertility of the soil, and the amount of water available. Planting rates in drier areas may be about half of those where rainfall is adequate. Varieties that mature quickly are planted closer together than varieties that use the whole growing season.

Weed control is an important part of raising maize. The land should be thoroughly cultivated before planting, and the crop should be kept weed free while the maize plants are young. Cultivation or herbicides, or a combination of the two, can be used.

It is common to leave the maize ears on the plant until the shucks turn dry and brown and the seeds are dry and hard. Then they are picked from the standing plants by hand or by machine. Methods and times of harvesting will vary depending on the equipment available and on whether the maize is to be used as fodder, silage, or grain.

The moisture content of maize to be stored is very important. For shelled maize it should be reduced to a maximum of 13 percent. This usually means that the maize must be further drier after harvesting. If the maize is not dry enough, it is vulnerable to molds. Moldy maize may develop aflatoxin, a poison that can cause cancer. Generally speaking, the lower the moisture content, the longer the maize can be safely kept.

Diseases and Pests

Maize is subject to many diseases. The leaf blight caused by the organism Helminthosporium is common. It has resulted in considerable damage in humid maize-growing areas of Africa. Gibberella is a fungus that can cause rots in maize; plants infected with it are comparatively safe for cattle, but poisonous for other animals and human beings. Several viral diseases attack maize, including streak virus disease, transmitted by the leafhopper. The development of maize strains resistant to these diseases is the most promising means of combating them.

The husks of the maize help to protect the ears against bird and some insect damage during the ripening period. Witchweed

(Striga) can damage maize plants considerably before they have emerged from the soil.

Uses

Dried seed of maize contain around 9 percent protein, 4 percent fat, and 77 percent starch. Maize protein is deficient in two essential amino acids, lysine and trytophan. Strains of maize like opaque-2 that have much higher lysine and trytophan contents than ordinary maize have been developed. However, they have disadvantages, especially when grown in tropical climates: lower yields, higher moisture content, and greater susceptibility to diseases and pests. Is is likely that high lysine/trytophan hybrids without these drawbacks will be available in the future. Maize also contains nutritionally significant amounts of thiamine (vitamin B1), and yellow maize seeds contain beta-carotene, from which the body produces vitamin A. Maize contains niacin, but not in an easily absorbable form; as a result people, especially children, whose diet relies too heavily on maize are likely to suffer from the disease pellagra.

Maize can be prepared in a number of ways. The whole ear can be roasted, baked, or boiled. The kernels can be ground into a meal that is mixed with water to make a porridge or dough. Maize cannot be made into a leavened bread, because it does not contain gluten, but it can be made into flat cakes. It can be preserved by drying, canning, or freezing, and processed into grits, corn-flakes, oil, starch, or alcohol.

Maize and its by-products are also fed to animals, and are used in making soap, laundry sizing, plastics, alcohols, and a number of other industrial products.

MILLETS

Millet is the name applied to several different small-seeded annual grasses with fibrous root systems and abundant foliage. They are grown mainly in the same regions where sorghum is grown, mostly where rainfall is limited. Millets are often grown as a mixed crop with legumes, and are frequently intended for use as cash crops and emergency hay. In much of the world, particularly in the United States and the Soviet Union, millets are used mostly as animal feed. But where they are most important, in India, Pakistan, and Africa, they are grown for human consumption. About 85 percent of world production is used as human food.

Millets are higher in more essential amino acids than are wheat, oats, rice, barley, and rye; however, millets lack lysine. And their protein does not contain gluten, so porous breads cannot be made from millet flour.

Sorghum is called millet in some parts of Asia and Africa.

Pearl millet

Pearl millet (Pennisetum glaucum), also known as cattail or bulrush, is the most commonly grown millet in the world. It is widely raised as a food grain in India, the Near East, and the

Savanna zones of Africa, representing about 40 percent of world millet production. A very nutritious flour can be made from it. It is best suited to warm areas with 38-50 centimeters of rainfall per year, preferring light showers followed by intense sunshine. It can also be grown under irrigation. Heavy rains are damaging to pearl millet. Once it has established itself, it resists drought well.

Pearl millet grows best on sandy loam soils, but it is often grown on poor soils, even gravelly ones. It is the most productive cereal crop for very infertile and dry soils in India and Africa. It responds well to heavy fertilization.

Pearl millet is usually grown in mixtures or rotations. At the end of the hot season, around the first rain, the land is plowed two or three times or worked with a disk harrow. The seed is sown broadcast or drilled in rows that are closer when the crop is intended for grazing or hay than when it is intended for grain. The seeding rate is 22.5-28 kilograms per hectare for the fodder crop, but 7-11 kilograms or less for the grain crop. The millet is usually hand weeded and hoed.

Pearl millet takes four months to come to maturity, but when it is grown for fodder it is harvested while the stalks are still green. The yield is 450-900 kilograms of grain per hectare when it is grown alone and rainfed. The irrigated yield is at least twice as much.

Green ear, a downy mildew, is the major disease attacking pearl

millet in Africa. High atmospheric humidity increases the likelihood of the disease. Grain smut and the Poisonous fungus ergot are also common. Except during prolonged storage, insects are less of a problem for millet than for many grains, but birds are a major source of damage to the standing crop.

Foxtail Millet

Foxtail millet (Setaria italica), also known as Italian millet, accounts for about a quarter of world millet production. Having probably originated in India, it is grown today in India. Africa, and many parts of Far East. Foxtail millet is one of the fastest-growing and best millets, especially for fodder. It produces yields almost as good as those crops that take much longer to come to maturity.

It is raised both as a rainfed and as an irrigated crop, is very resistant to drought, and is not particular about soil. It is. however, sensitive to frost. As a rainfed crop, it should be sown at the beginning or end of the rainy season. As an irrigated crop it can be sown at any time. but the most common time is right before the hot season. It is grown by itself or mixed with other crops. The land is prepared by plowing once and harrowing two or three times. Because of the small size of the seeds, the seedbed needs to be firm. It also needs to be completely clear of weeds, because young foxtail millet competes poorly with weeds. Land where the irrigated crop is going to be planted undergoes a particularly thorough preparation, including manuring. The seed is sown broadcast, at a rate of 7-17 kilograms

per hectare in semiarid regions, and at higher rates where there is more moisture. Foxtail millet can also be seeded with a drill. Close spacing of the plants helps suppress weeds. No cultivation, besides one weeding is needed when the crop is grown by itself; where it is mixed with other crops, it is cultivated along with them.

Foxtail millet matures in 70-120 days. The ripe heads are cut and heaped for a week to dry, then threshed under the feet of cattle or with a stone roller or mechanical thresher. The rainfed crop grown by itself yields 450-900 kilograms of grain per hectare. Irrigation will double the yield.

Foxtail millet is subject to kernel smut, which can be controlled by seed treatment. Other diseases that attack it include mildew, leaf spots, and bacterial blight.

The grain needs to be husked before using; it is cooked like rice, or made into porridge. Foxtail millet is used as an animal feed, especially as emergency pasture, hay, and silage. Before being fed to animals, the seed should be finely ground. The hay contains a substance that acts as a diuretic on horses that consume it as their only food.

Finger Millet

Finger millet (Eleusine coracana), also called Ragi and African millet, is grown in India and Africa, and accounts for 11 percent of world millet production. It is a very hardy crop. It can be

raised where there are 50-100 centimeters of rain; it can also be grown under irrigation in the hot season. In India, the rainfed crop is grown from May to August, or from July to November; the irrigated crop is grown year-round. It is usually produced on loams and sandy loams.

Finger millet does best on a clean, smooth, friable seedbed. Usually there is one plowing right after the harvest of the previous crop in the rotation, then two or three more plowings or harrowings after the rainy season begins. The crop is manured regularly; commercial fertilizers are often applied. The irrigated crop is fertilized more liberally than the rainfed one.

Finger millet is sown broadcast or in rows. Sometimes seedlings about a month old are transplanted to rows 25 centimeters apart, with 15-20 centimeters between seedlings in the row, and with two or three seedlings at each point. Transplanting is done when the rainy season is well under way. The seed rate for broadcast sowing is 11-34 kilograms per hectare. The crop is hand-weeded once, and cultivated two or three times.

It takes three to six months for the crop to reach maturity. The heads of the irrigated crop do not all ripen at the same time, but are gathered as they mature. Otherwise, the plants are cut close to the ground, tied into sheaves, and stacked to dry. Later they are threshed. The rainfed crop yields 560-1000 kilograms of grain and about 2240 kilograms of straw per hectare, the irrigated crop two or three times as much.

Finger millet grains contain about 72 percent carbohydrates and between 6 and 11 percent protein. They are ground into a nutritious but somewhat bitter flour that can be used to make cakes, porridge, or pudding. In Africa, a beer that is rich in B vitamins but keeps only a few days is made from the germinated grain. Under good storage conditions, whole finger millet can be stored up to 10 years. This makes it a good famine food.

Proso Millet

Proso millet (Panicum miliaceum), also known as common millet, bread millet, and broomcorn millet, has been grown as a human food since prehistoric times. It has been cultivated in China for at least 20 centuries. It is still grown there, as well as in the Soviet Union, India, and Europe. It is often grown as an emergency crope usually on poor soils. The only soils that it cannot grow on are coarse, sandy ones. It is a short-season crop that can require as little as 60 days from seeding to maturity. It is most commonly grown during the rainy season, but is sometimes raised during the dry season as an irrigated crop, receiving one or two waterings. It requires fairly warm weather and is easily injured by frost.

Barnyard Millet

Barnyard millet (Echinochloa colona var. frumentacea) is grown mainly in India. It is hardy and fast-growing. It can be raised in the dry season, and at altitudes of up to 1,980 meters. It is grown entirely as a dry-land crop on poor soils, usually in sandy

and marshy areas. It is resistant to drought and to waterlogging.

The land is plowed and harrowed once or twice, and the seed is sown broadcast or drilled, then covered by harrowing or plowing. The seeding rate is 9-11 kilograms per hectare. Sometimes seedlings are transplanted. Barnyard millet is usually sown alone, but sometimes it is rotated or grown mixed with another crop. Barnyard millet is not usually manured, and is weeded only as necessary.

It takes between three and four months to mature. The plants are cut close to the ground, tied into sheaves, stacked about a week to dry, then threshed. The average yield is 340-670 kilograms of grain, which needs to be husked before using. It may be cooked as rice is or ground into flour. It also makes an excellent animal feed. The straw, however, is of inferior quality and-is-used as feed only when no better fodder is available.

Koda Millet

Koda millet (Paspalum scrobiculatum) produces an inferior quality grain, but is grown on a fairly large scale for food and livestock feed in India and Africa, usually on light, stony upland soils. Seeding takes place at the beginning or end of the rainy season. The land is plowed or harrowed three or four times. The seed is sown broadcast or drilled at a rate of 17-22 kilograms per hectare. Koda is grown alone or mixed. It is rarely intercultivated or manured.

When the Koda millet is mature, in five to six months, it is cut close to the ground, tied in sheaves, and stacked for about a week. Then it is threshed and winnowed. Yields are from 450 to 900 kilograms of grain per hectare. The grain needs to be well matured; it should be stored about six months before being used as food. The stiff hull must be removed before the grain is eaten. The straw generally goes into a compost pile or is used as bedding rather than being fed to cattle.

Sanwa Millet

Sanwa millet (Echinochloa crusqalli var. frumentacea), also called Japanese barnyard millet, is grown for its grain in Africa, India, and the Far East. Because it is fast-growing, yielding in six to eight weeks, it makes an excellent cash crop. It is also a good emergency fodder crop, growing better than foxtail millet under cool conditions and where soils are not well drained. Its cultivation is similar to that of Proso millet.

Little Millet

Little millet (Panicum miliare) in a hardy, quick-growing millet that can withstand both drought and waterlogging. It is cultivated in much the same way as barnyard millet is. Its yields and uses are also similar.

SORGHUM

Sorghum (Sorghum vulgare or Sorghum bicolor) is native to Africa. It has been widely cultivated there and in Asia for four millenia. Today sorghum is grown in almost every country of the world except in those of northwestern Europe. It is especially important in China, India, Egypt, and Sudan. In Africa, it is a staple food; in other parts of the world it is used primarily as animal feed.

Sorghum can be grown at elevations up to 900 meters. It is suited to areas where rainfall is low, 30-100 centimeters from planting to harvest. Its extensive root system makes it more resistant to drought than maize, though it cannot tolerate a drought that is too prolonged. It responds well to having sufficient moisture, and may be grown as an irrigated crop. Prolonged waterlogging is detrimental.

Sorghum is grown on a variety of soils including light sandy soils, but it does best on heavy clay loams. It tolerates both salinity and acidity better than maize does. Sorghum can be grown on soils with a pH between 5 and 8.5. It needs warm soil for germination and hot weather for growth; the minimum temperature it can withstand is 16 [degrees]C. In semiarid regions, sorghum is usually grown alone; where moisture is adequate it can be grown mixed with other crops, most often with legumes.

Kinds of Sorghum

The many different types of sorghum can be classified into four groups:

1. Forage sorghums (Sorghum vulgare var. saccharatum), also known as sweet sorghums or sorgos

The largest of the sorghums, the forage sorghums have soft, tasty stems and an abundant sugary sap. These are particularly well suited for forage and for syrup. Some are highly drought-resistant. For hot, dry regions, they are the most dependable and highest-yielding crop for forage and silage. They make good pasturage even when other grasses fail.

2. Grain sorghums (Sorghum vulgare Pers. or Sorghum bicolor)

Grain sorghums have stalks that are not sweet, and are less juicy than those of forage, sorghums. The grain sorghums have a nutritive value that is 90 to 95 percent that of maize; they contain more protein, about the same proportion of carbohydrate, and less starch. They are used for animal feed, and for brewing and making starch, oil, and industrial alcohol.

3. Grass sorghums

Grass sorghums include Sudan grass (Sorghum vulgare var. sudanense), Johnson grass (Sorghum halepense), and one or two other species. Grass sorghums are grown entirely for forage. Sudan grass looks similar to forage sorghum, but has smaller stems and seeds. Its yields are smaller than those of forage sorghum, but it requires even less water and is easier to cure. It is palatable to livestock, and is good for pasturage and hay.

Sudan grass is often grown as a supplementary crop in rotations. Johnson grass is grown for forage, but compared to Sudan grass, it has a lower food value, produces a smaller yield even on rich soil, and is less tolerant of soil acidity. It has perennial rhizomes, so it can sometimes become a pest in fields planted to other crops.

4. Broomcorn (Sorghum vulgare var. technicum)

Broomcorn has long, straight branches that are used to make brooms. It produces very limited quantities of foliage and seed and is little grown in the tropics.

Cultivation

Sorghum generally is planted late in the rainy season so that it matures during the dry season, which helps keep insect and mold damage to a minimum. It is important to prepare the seedbed thoroughly. It needs to be plowed and harrowed. It is then tilled, preferably twice, and allowed time to settle to form a firm seedbed before planting. In dry areas, moisture conservation techniques should be used. For irrigated crops, a thorough preplanting irrigation is desirable.

Sorghum is sown broadcast or in rows, and is sometimes drilled in regularly spaced holes. The seed is usually covered with 2.5-5cm of soil. It needs to be planted deep in semiarid regions. For the grain crop, the seeding rate is between 5.5 and 13.5 kilograms per hectare; for the fodder crop, between 34 and 84 kilograms.

The amount of moisture available is the most important factor determining how much seed is to be used, the quantity going up as the amount of available moisture increases. The highest rates are used under optiumum moisture and soil conditions.

Sorghum is a heavy feeder, exhausting the soil much more than maize does, particularly of nitrates. It responds well to applications of manure or compost or chemical fertilizers.

Sorghum planted in rows usually requires two to four cultivations to control weeds. Sorghum is more sensitive to herbicides than maize, which limits the chemicals' usefulness for controlling weeds in fields planted to sorghum, though sometimes preemergence herbicides are used.

The grain crop matures in four to five months. Mechanical harvesting and threshing are desirable. If they are not availabe, the plants are cut by hand and stacked to dry. The grain is dried before storing, with the moisture content of the stored grain kept under 10 to 12 percent. Average yields are around 1,100 kilograms per hectare but may range from below 335 kilograms to above 4,500 kilograms.

Diseases and Pests

Sorghum is susceptible to many diseases. The smuts are among those of the greatest economic importance. Some are seedborne and can be controlled at little cost by chemical treatment of the seeds, but the only weapon against others is breeding for

resistance. Head mold flourishes under humid conditions; it can be limited by timing planting so that the crops begin to mature as the rains are ending. Other diseases include downy mildew, leaf blight, and charcoal rot.

Over 150 kinds of insects attack sorghum. Important among them are the shoot fly, which can be chemically controlled, and the stem borer, armyworm, earhead bug, midge, and locust. Stored sorghum is particualry vulnerable to insects. Keeping the storage area cool and dry plays an important role in limiting damage from this source. Birds are troublesome to sorghum, particularly the weaverbird (Quelea quelea), for which there is no effective economical control. The very tenacious witchweed (Striga) can cause serious damage. Hand-weeding and herbicides are used against it.

Uses

Most of the sorghum grain produced in Africa and in tropical Asia is used as human food; that produced elsewhere is used mostly as livestock feed. Sorghum grain is, on average, 70 percent carbohydrate, 12 percent protein, and 3 percent fat; it is rich in vitamin B1. The protein in sorghum is lacking in the essential amino acid lysine. Sorghum protein is also often combined with tannin in such a way that the human body cannot make use of it. (High-tannin varieties are less vulnerable to damage from birds, which appeals to farmers). For these reasons, sorghum is less nutritious for people than maize, and a diet based entirely on sorghum is very likely to lead to protein deficiency. Moreover,

when sorghum is polished as rice is, it loses much of the limited protein it contained and becomes even less nutritious. Unmilled sorghum grain can be ground into a flour that is mixed with water to make a porridge, paste, or soup; sometimes it is mixed with wheat flour to make bread. Sorghum flour must be used as soon as it is ground, because it turns rancid very quickly. Malt made from germinated sorghum grain can be used to brew a beer that is rich in B vitamins. Syrup is made from sorgo.

Sorghum grain has a hard hull. Before it can be fed to animals, it should be ground, rolled, or heated to make it more digestible. Sorghum silage has about the same composition as maize silage.

The leaves, shoots, and germinating seeds of some kinds of sorghum contain a substance that produces the poison hydrocyanic acid (also called prussic acid), sometimes in enough quantity to kill livestock. For this reason care should be taken in feeding fresh sorghum. Young plants have the highest prussic acid content. There is no danger from grain, hay, or silage.

III. QUESTIONS TO ASK BEFORE PLANTING A GRAIN CROP

The overview presented above is intended to give the reader a sense of the requirements of the various grain crops. Before attempting to raise any grain in an area where it is not presently grown there are a number of preliminary questions that should be answered. Further guidance should be obtained from local agricultural specialists.

Some of the questions to be considered are:

1. Is the climate suitable for this crop?

2. Are the type of soil and its pH and salinity characteristics known, and are they suitable for this crop?

3. Are fertilizers available to meet the crop's nitrogen, phosphate, and potassium needs?

4. Can the crop's moisture needs be met through naturally available water? If not, is enough water available for irrigation? Does the cost of irrigation compare favorably with the benefits the crop will yield? Is the necessary equipment available? Is the terrain suitable?

5. Have sources of supply been found for seeds. fertilizers, pesticides, herbicides, equipment, and anything else that may be needed for growing this crop?

6. Is enough capital available to purchase the necessary equipment and supplies?

7. Is the farmer able to invest the time and effort needed to grow the crop successfully?

8. Has information been gathered about the varieties and hybrids that are available? Has a choice been made about

which plant?

9. what kind of erosion control, if any, will be necessary if this crop is planted? Are the resources for carrying it out available?

10. If part of the harvest is to be kept for later use, are storage facilities available that can keep the grain cool, dry, and safe from pests?
11. Is there a market for the grain or grain products?

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