MAIZE

BY DR. FRANKLIN W. MARTIN

Published 1989

ECHO TECHNICAL NOTE

WHY GROW MAIZE?

Maize (*Zea mays*; other common names – corn) is the third most important food crop in the world, surpassed only by two other grains, wheat and rice. Maize is a widely adapted crop, capable of production during the appropriate season in almost all parts of the world where farming is done. Maize is represented by thousands of varieties, some producing in as little as 70 days, others needing up to 9 months to reach maturity. Furthermore, maize is represented by a number of distinct races that evolved in Mexico and Central and South America, its geographical origin. These groups hybridize freely.

Some of the most important market classes (U.S. market classes) are:

- Flint. Small, hard endosperm grains, early maturity, high seed germination, now used mostly in poultry feeds.
- Dent. The tip of the seed is dented. Wedge-shaped grains with hard corneous endosperm but much starch.
- Flour. Contains principally soft starch, good for flour production, often with very large seed.
- Waxy. The large amount of starch consists chiefly of the fraction amylopectin. This now is used in the U.S.A. as a substitute for cassava starch.
- Sweet. The starch has been replaced chiefly by sugar. Corn-on-the-cob is its principal use.
- Pop. A small grain with hard endosperm surrounding a small amount of starch.

Most of the commercial maize of the world have been bred from both dent and flint types.

Anyone interested in maize should know about hard endosperm opaque II maize. In brief, this is maize bred for high protein value (balanced amino acids) that is also suitable for grinding as flour or processing as tortillas. (In the Uses Section of this report, see the information on quality protein maize (QPM), which was developed from this opaque variety).

Maize is high yielding per area and per man-hour. Several immature forms are used as food. The mature grain can be stored until needed and easily transported. The quality of the protein value is moderate in normal maize, high in the new "quality protein maize." Maize is versatile in its uses. It is a principal staple food and animal feed in many parts of the world. It is often preferred as a food over other grains.

ECHO, 17391 Durrance Rd., North Ft. Myers FL 33917, USA
Phone: (239) 543-3246; Fax: (239) 543-5317
e-mail: echo@echonet.org; website- http://www.echonet.org/

CLIMATIC & SOIL REQUIREMENTS OF MAIZE

Because of its large number of diverse cultivars, maize has a very wide range of tolerance to the environment. Nevertheless, in any particular locality, the range of cultivars that are highly adapted and thus highly productive is always limited. Thus, it might be useful to discuss some of the limits. Maize is susceptible to freezing and dies rapidly after a frost. It is almost never grown over 10,000 feet of elevation. It does not produce well in extremely arid regions. However, these generalities need some explanation.

Maize is a hot season crop and is grown principally in temperatures between 21 - 30 C (70 - 86 F), though seeds germinate best at a lower temperature, between 18 - 21 C (64 - 58 F). Adequate rainfall or water is very important during germination and the first month of growth. Drier conditions can be tolerated during the second and third months. Hot dry temperatures with inadequate water can lead to failure of the tassel, or later, inviability of the pollen. However, dry weather is preferred during maturation of the grain as the grain can be damaged by fungi during wet weather. If rainy seasons are short, maize can be planted at the beginning of the rainy season and matured during the dry season. Early maturing varieties are frequently used. If the rainy season is shorter, usually sorghum or millet is planted. If the rainy season is long, varieties that are very late are planted or the maize is planted during the rainy season when it will mature later during the dry season. Thus, time of planting as well as variety are of critical importance in many localities.

Maize is sensitive to day length and temperature. Thus, varieties that are adapted to the long days of the temperate summer will frequently be small, early, and unproductive in the short days of the tropical summer.

Maize is very tolerant of soils but is less productive in quite acid soil (pH 5.0 and less) or alkaline soil (pH 8 or more). Otherwise, almost any tillable soil is suitable, and water and fertilizer become the critical needs. Very old varieties, including primitive, late varieties in Central America have low fertilization requirement. Newly developed varieties, especially early and/or hybrid varieties, have a high requirement for fertilizer (especially nitrogen).

Disease resistance is sometimes important in maize production. Diseases are often very localized, and thus local knowledge is always desirable.

STAGES OF GROWTH AND DEVELOPMENT

GERMINATION

While more seeds will germinate at 18 C than at higher temperatures, the seeds will germinate more rapidly from 20-24 C. Germination can occur in as little as 4 days. While moisture must be adequate, excess moisture as well as cool conditions increase growth of fungi and thus the need for seed-protective chemicals. Such treatment will usually increase seed germination and thus yields. The large maize seed contains enough nutrients to support growth of the seedling for about a week. During seedling growth, roots are all primary and do not become the principal roots of the mature plant.

PRE-TASSEL MAIZE

Starting within a few days of germination, the plant depends for nutrients and growth on external conditions, particularly soil fertility and moisture, adequate temperature and sunlight. At the beginning of this period the principal roots originate from the crown. During this period growth is very rapid, and the size and weight of the plant double many times. Until the plants are knee high they are especially susceptible to flooding because the meristem (growing point) is still below the soil level and is easily damaged. The stalk may branch at this early age, but normally not later. About one new leaf is produced every two days, each somewhat larger than the last. The tassel begins to form at the growing tip.

TASSELLING AND POLLEN PRODUCTION

Tassels (male flowers) mature as silks (which botanically are the styles of the maize flower) are developed. Nutrients in the soil are of great importance during tassel emergence, pollen shedding, and fertilization. Water is especially necessary during this period, and even brief periods of wilting can reduce yields. Very hot, dry air can drastically reduce pollen viability. If different maize varieties are being grown and seed is desired for planting, the varieties must be isolated from each other or planted at different times so that they do not tassel at the same time.

KERNEL FORMATION

This phase of growth consists of several stages: the "blister stage," which is the youngest growing fertilized ovules, "roasting ear stage" (18-21 days after pollination), "dough stage" (24-28 days after pollination), "near maturity," and mature but not dry (52-58 days after pollination). At this stage the stalk can be bent over to protect the drying kernel from rain and birds. After 3 weeks the maize can be harvested for optional further drying, optional shelling, and storage.

AGRONOMIC PRACTICES

The ground is usually tilled (by hand, animal drawn plow, or tractor) to incorporate crop residues, weeds, and manures in the soil, and to open the soil to rain penetration. The soil should be moist on planting, or irrigated after planting. Plowing can follow contours to reduce erosion. Early planting is recommended, but only if ears will then mature at time when weather will permit them to dry. Planting time is critical.

Maize is usually planted in rows, 70-100 cm (27 - 39 inches) apart. Fertilizer is best placed in the row, below and to the side of the seed. It is not adequate to simply broadcast maize seed, as is often done with smaller seeded grasses. Any fertilizer is useful; maximum amounts per hectare are 150 kg of nitrogen, 50 kg of phosphate, and 50 kg of potash.

Seeds are placed 2 cm below the soil, more if the soil is sandy. Spacing depends on row width and intensity of cultivation. Thirty to sixty thousand plants per hectare (1-2 seeds per foot in rows 3 feet apart) represent low to high densities of planting. If you have reason to question whether the seed is still of good quality, plant perhaps 100 grains in a small space which you can keep well watered. If the percent that germinate is low, you will need to make allowance for this by planting at a proportionally higher density.

Small farmers often cannot afford herbicides. If this is not a problem and herbicides are recommended for the area, use them according to their particular instructions. Otherwise, cultivation by hoe or using animal or tractor power will be necessary, preferably removing weeds while they are small. Cultivation should be shallow so as to reduce maize root damage.

The use of disease and insect resistant varieties is the most inexpensive control method. Chemical pest control depends on the pest, the legality, and the locally recommended substances.

HARVEST AND STORAGE OF GRAIN

The maturation of maize has already been discussed under life cycle. When the kernel is mature, usually about 60 days after tasseling, a "black" layer appears where the grain is attached to the husk. If it is rainy when maize is mature, the maize plant should be bent over just below the ear and allowed to dry 2-3 weeks longer in the field. This is not done if maize will be harvested with a combine. However, this may not be sufficient drying. Moist maize can mold. Moisture content should be reduced to 10-12%. This degree of drying can be obtained by drying in the sun. If reduced further, to 8%, only obtainable in a solar or other type of grain dryer, maize seed will be in optimum condition for long-term storage. The only really good way to determine percent moisture is to weigh a

sample very accurately, dry it at 93 C (200 F) in a household oven, and weigh again. Percent moisture is calculated by dividing the difference in weight before and after drying by the weight before drying.

Third World small farmers use several techniques to fully dry harvested maize. All depend on protection from rain and circulation of hot, dry air (hot air even if not "dried" will remove more moisture than air at ambient temperature.) Maize still on the cob will tolerate more moisture without mildew and will be better protected from insects and disease by the husk.

The Peace Corps has a helpful book entitled *Small Farm Grain Storage*. Individuals working with peasant farmers in the Third World can usually obtain a free copy of Peace Corps books by writing to the Information Collection & Exchange Office, 1490 K St. N. W., Room 804, Washington, DC 20526 USA.

Shelling the maize reduces the bulk that must be stored. This reduces the size of storage or grain drying facilities that must be constructed. In all cases, husks are removed before shelling. There are mechanical and hand devises to do this efficiently. If maize is not dry enough, the kernels will be damaged during shelling. The wooden hand-held sheller can handle up to 80 kg/hour, hand cranked shellers yield 50-130 kg/hour, Ransomes Cobmaster (Ransomes, Ltd., Ipswich 1P3906 England) can shell 750 kg maize per hour or more. Shelled maize is winnowed to remove dust, dirt, chaff, and broken pieces. A fairly good cleanup can be done with screen of an appropriate size.

After harvest, drying, and shelling, maize can still be lost from rodents and disease. For rodents, tight storage structures, traps, cats, and warfarin baits are recommended. For insect pests in general, storage structures, containers, including fiber bags, or disinfection with a week solution of Malathion is recommended. Fumigation to kill existing insects is done with either methyl bromide or a 3:1 mixture of ethylene dichloride and carbon tetrachloride. Use manufacturer's directions. Usually methyl bromide is released at the upper surface of a container of maize grain. The second mixture is sprinkled or poured on the surface of the grain in the container. Keep fumigated maize protected from insects. A third treatment that will protect from insects for 2-3 months is Malathion, sprayed on as follows:

57% emulsifiable Malathion	Water	Amount of Maize
1cc	40cc	350 lbs. maize
10cc	400cc	1.5 tonne maize
100cc	4000cc	15 tonnes maize

This treatment needs to be repeated each 2-3 months. Maize grain can be used as a food two months after treatment.

Remember that all these chemicals are poisonous and must be used with knowledge and control.

You might want to try coating the stored grain with a very small quantity of cooking oil. Although the reports I have read have been with other grains, the book *Natural Crop Protection* says that it also works with maize. They say that oils of peanut, coconut, safflower, mustard, rhizinus, cottonseed and soybean and maize oils are effective, but sunflower oil is not. (The book is published by Agrecol, c/o Okozentrum, CH-4438, Langenbruck, Switzerland. The price in 1987 including airmail postage was $17.)

Here is an example of oil treatment from EDN 26-1. "Burus Ali in Nigeria reports they have had success in their community projects by adding 1 tablespoonful (about 5 ml) of peanut (groundnut) oil to each kilogram of cowpea. In this way, 1 liter of oil will treat about 200 kg (440 pounds) of peas. After thorough mixing, peas treated this way can keep 4-6 months without any problem. Beetles lay their eggs on the surface, then larvae bore into the seed and later emerge as mature beetles leaving a characteristic hole. Oil interferes with egg laying and

development of larvae. Once inside the seed, oil has no effect. If about 6 months after treatment farmers begin to see holes left by emerging beetles, they can extend protection easily up to a year by a second identical treatment. This is based on a procedure recommended by the International Institute of Tropical Agriculture there in Nigeria." Also see EDN 14-3.

Another "organic" approach to insect control is the use of wood ash. Don Mansfield in Mali wrote of an unsuccessful attempt in peanut storage, but the results are instructive and applicable to maize as well. "I tried have heard of placing a mixture of dry neem leaves and ashes in barrels of peanuts. I put a thin coating about every foot. It has been almost impossible to keep peanuts here for any length of time without serious damage by the weevils. The people here use a powder of DDT and Malathion, which seems very dangerous when they intend to eat the peanuts."

"Why did it not work, since even wood ash by itself is supposed to be effective? The book *Natural Crop Protection* suggests the effect of ash is in part due to its filling the small spaces between the seeds. Newly hatched weevils have more difficulty finding partners and are forced to deposit all their eggs on a small number of seeds, thus preventing an explosive buildup of populations. Even a large amount of sand is often effective. Perhaps this experiment should be repeated, mixing the ashes thoroughly with the seeds rather than layering them.

USES OF MAIZE

STANDARD MAIZE VARIETIES

Vegetative parts. Sprouted seeds, growing tips, and very small ears are sometimes used fresh and raw, cooked, or pickled as specialties.

Immature ears. Large but immature ears of maize are frequently boiled or roasted as a vegetable.

The whole dried grain. Seldom used except as animal feed, more rarely fermented with or without cracking or steeping, or to produce whiskey, or further processed into natural and synthetic substances. The whole grain is often heated with lye to remove the hull, then cooked as hominy, coarsely ground as grits or ground to make a meal used for tortillas.

Maize meal. Grinding dried seed by primitive or modern techniques followed by sieving and regrinding of course residue is standard practice. The resulting meal is then boiled, as porridge or gruel; formed into cakes and fried; mixed with wheat flour and made into cornbread; sieved to produce coarse grits; also used as cooked cereal, and processed as cornflakes.

Steeped grain. By wet milling, the germ and bran (hull) are separated from the starch. The starch is used entire as a food, fermented to produce alcohol or hydrolyzed to dextrins, sugars, and syrups. During preparation of maize oil, the germ can be extracted then dried and used as a food. The bran is used as animal feed.

QUALITY PROTEIN MAIZE

(By Dr. David Unander)

Although maize is easy to grow and extremely productive, it has nutritional limitations. Kernels of dry maize typically have 9-10% protein. About half of this protein, however, is in a chemical form that is not easily digested. An even more serious problem is that maize proteins are low in two amino acids, lysine and tryptophan, which the body cannot make itself. (Amino acids are the basic units of proteins; those amino acids which the body cannot synthesize itself must be part of the diet in one form or another.) A diet low in lysine leads to symptoms of protein deficiency, even if plenty of the other essential amino acids are being consumed. In addition, these two amino acids are involved in the synthesis of niacin, one of the B-vitamins, and maize is also low in vitamin B per

se. Thus people who have a diet consisting of little else than maize develop a niacin-deficiency disease, called pellagra, whose symptoms include dermatitis, diarrhea and mental confusion.

Many American Indians traditionally prepared their maize flour with a solution including lime, (derived from wood ash, shells or other sources). Chemical studies have shown that the calcium in the lime frees for easier digestion the small amount of niacin that is present in the kernels. Thus pellagra was rare or absent, even though maize was the chief grain for many tribes.

Maize has also commonly been served with legumes, in the Americas usually beans. Since legumes are high in lysine and tryptophan, this combination meets complete protein needs. Legumes generally yield less and cost more in the market than maize, however, so that the poorest people sometimes cannot purchase them. Legumes are also hard to digest for young children (under 2 yr.).

A new approach to the nutritional limitations of maize came in 1963, when a gene for higher levels of lysine and tryptophan was discovered at Purdue University in Indiana. Unfortunately, this gene also produced many undesired effects on plant growth, disease resistance and the cooking quality of the grain. After many years of breeding, this gene has been incorporated into maize populations of acceptable yield and cooking quality. These are being promoted as "quality-protein maize" or QPM.

Basically, seed of these new varieties cannot be distinguished from conventional maize seeds in milling or cooking characteristics, but they provide a quantum boost in nutritional quality. Not only are the kernel proteins of QPM lines much higher in lysine and tryptophan, they are also have a much higher percentage of protein which is easy to digest. In some experiments, the modified maize protein approached the quality of milk proteins.

One very important limitation to QPM varieties is that the seed must be produced in isolation from conventional maize. If the two cross-pollinate, plants grown from the resulting seed will generally yield less and lose their nutritional advantage. Since maize is wind-pollinated, 1/4 mile between plants of different varieties is a commonly cited recommendation, when seed is to be saved for the following season. If there is any question of pollen coming from another field, seed should be saved from the center of the field rather than the edges. Most plants in the center of the field will be heavily covered by pollen from neighboring plants and will have only a small chance of being fertilized by distant plants. If only a small amount of seed is desired, a few maize plants could be self-pollinated by hand, using paper bags to cover the ear and tassel before (and for the ear) after pollination.

Dr. Wayne Haag with Global 2000 told ECHO of a novel way to ensure purity of varieties in Brazil. They have chosen a white QPM variety. Any kernel that is yellow has been cross pollinated and is discarded. If the QPM varieties are not available in your country, write to CIMMYT, Apdo Postal 6-641, Col Juarez Deleg., Cuauhtemoc, 06600 Mexico D. F. for a small packet.

DOING YOUR OWN MAIZE IMPROVEMENT

VARIETIES OF MAIZE

It would not be useful to attempt to catalog the maize varieties of the tropics. However, varieties can be divided into two types, open pollinated and hybrid. Open-pollinated varieties are those in which the seed may be produced year after year by the farmers themselves. The plantings to be used as seed should be as large as possible and seed for the next year should be selected from large, vigorous plants producing large, full ears. In many parts of the tropics open-pollinated maize is still the most practical.

Hybrid maize is produced by controlled crossing of selected inbred lines. While this maize will often be the most productive, farmers cannot save their own seed, for subsequent generations will be highly variable and less productive.

MAIZE IMPROVEMENT

Bob Short in Mexico is teaching farmers to improve their own open pollinated (i. e. not hybrid) maize varieties. To be sure, the people already select the best ears for seed, but the selection is made from a pile after the harvest. Selection based on ear size only can cause more problems than you might think. This brings up an interesting story.

In the early 1900's in the United States a popular magazine, "Wallace's Farmer," and a professor at Iowa State University promoted maize competitions. These became annual events all over the Midwest. Judging was based on a vision of the ideal maize: uniform ears, 10 inches long, with even rows and deep kernels shaped like a keystone. At one of the professor's talks a 16-year-old boy (the editor's son) asked whether seed from the ideal ear would produce more maize than any other. "Of course," he replied, though he had not tried it. The boy's persistence made him nervous, so he collected 25 ears of the best show maize and 25 of the poorest. The highest yield came from an ear no maize-show judge would look at twice. As a whole, the highest-ranked show ears produced less than those that ranked lowest. The boy went on to school, and later formed what was to become the largest maize seed company in the world, Pioneer Hybrid, and eventually became Secretary of Agriculture.

Bob finds that even after selecting the best ears for seed, about half of the plants produce a poor ear, if any at all. Bob decided that the basic traits that he wanted were present in one plant or another in the field of "criollo" maize, though not necessarily on the same plant. He wrote, "Our method of selection is simple. The first thing we do is detassle the poor plants before pollination. This ensures that reasonably good plants will be the male parents of the maize. Then we select the ears to be kept for seed in the field. We take from the best plants which produce a good ear, taking into account the quality of the roots, stem, disease resistance, leaf area, etc." The important difference in this method is that good ears come from plants that are also known to be good.

"We have seen problems of in-breeding, so now recommend that seed come from fields that are at least half a hectare in size and that a minimum of 400 ears be selected. The selected ears are shelled and the seeds are thoroughly mixed together and saved for the next planting.

Bob says that they have definitely improved the quality of their own maize. It is difficult to convince farmers to change to it though because improvement is too slow to be seen quickly. A few are beginning to try it and he hopes that in 5-10 years it may be widespread.

I asked Dr. David Unander, a plant breeder on ECHO's Board of Directors, to comment. Highlights of his reply follow. "How many ears should one save to avoid inbreeding? Plant breeding texts and research suggests a minimum of 30 plants to avoid serious inbreeding, but much more is better. Unneeded seed can always be eaten. The extent of inbreeding is a function of the percentage of the population saved and will increase substantially if much less than 10% of the harvest is saved and mixed in the seed bin."

Dave suggests a way to further improve the technique. "Because differences among plants depend on the local spot in which the maize plant is grown, mentally divide the field into little blocks of 10-20 plants each (or more in a larger field). Be sure to select the best ear or ears from each of these imaginary blocks. Plants with mediocre genetic traits may have done well just because they grew in an unusually fertile spot, and plants that are outstanding may have done poorly if they grew in a poor part of the field." [I imagine this would also help to keep in your pool of seeds traits that would enable the best performance possible in those poor parts of the field].

A special merit of Bob's method is "that he has thought out exactly what he wants to select: he has a mental picture of what a good maize plant would be like for his area. This is one of the most important things to establish before beginning any breeding program."