

GROWTH AND PRODUCTION OF MAIZE: TRADITIONAL LOW-INPUT CULTIVATION

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Summary

Maize (*Zea mays L.*) is the most important cereal crop in the world after wheat and rice. While in western countries maize production is highly mechanized, in many other - mainly developing countries - the crop is still grown by smallholders and medium-scale farmers, using traditional and low-input cultivation techniques. Yields under those circumstances are much lower.

The centre of origin for maize is in Mesoamerica, but the crop has now spread over more than 100 countries. No crop has received more intense genetic and cytogenetic attention than maize, and this explains the large variations in yields, from more than 12 tons/ha in commercial farming to less than 1 ton/ha in traditional low-input family farms in developing countries.

There are many maize cultivars, each of them with a specific growth cycle, and with a wide range of tolerance to environmental conditions. It is essentially a crop of warm countries, but most of the crop is grown in the frost free and warmer parts of temperate regions and in the humid (sub)tropics with a well-defined dry season. Under traditional farming, maize is often cultivated in association with other (food) crops, and is usually not fertilized. Traditional cultivars are susceptible to pests and diseases.

Maize is an important staple food in developing countries, in particular in Latin America and Africa, and a basic ingredient for local drinks and food products. It is also an outstanding feed for livestock, high in energy, low in fiber and easily digestible. As a source of starch, it is a major ingredient in industrialized food products.

1. Introduction

Maize (*Zea mays L.*) is the most important cereal crop in the world after wheat and rice. It is grown in more diverse regions than any other crop; vast genetic differences occur among the kinds of maize grown in these disparate areas. It is cultivated from northern Europe and Russia to South Africa, eastward through Asia, the Himalayas, China, Southeast Asia and the Pacific Islands, westward from Puerto Montt in Chile to New Brunswick in Canada. The name “maize” is derived from the Spanish connotation *maiz* for the plant. In the USA it has for a long time been named *Indian corn*, or simply corn. In South Africa it is known as *millies*, from the Portuguese word *milho*.

Maize has multiple uses. In most developing countries maize is grown as a food crop (grain maize); in other countries (USA, Brazil) it is an important animal feed or is a basic compound for ethanol production. In this chapter the focus is on grain maize and its use as a staple food in many tropical areas, Latin America, Africa and Asia in particular.

The global world production of maize exceeds 780 million tons per year (Table 1), compared with almost 500 million tons of wheat and just less than 400 million tons of rice. The USA is by far the biggest producer (over 330 million tons in 2007; 42% of the world production), occupying double the area of any other crop planted in the country. It should however be noted that a major part of this is used for fodder and production. In the world ranking the USA is followed by China (152 million tons), Brazil (52 million tons), Mexico (23 million tons) and Argentina (21 million tons). The corresponding area planted has over the past 40 years increased by more than 40%. Both the global production and the area harvested show a steady increase since the 1960s.

Area/ Country	Grain Production (in 10 ³ MT)				
	1961	1990	2000	2003	2007
World	205,007	483,343	592,477	645,231	788,112

USA	91,388	201,532	251,854	256,278	331,175
China	18,027	97,213	106,178	115,998	152,418
Brazil	9,036	21,347	31,879	48,327	52,112
Mexico	6,246	14,635	17,557	20,701	23,512
Argentina	4,850	5,400	16,780	15,044	21,755
India	4,312	8,961	12,043	14,984	18,955
France	n.d.	9,400	16,018	11,990	14,357
Indonesia	2,283	6,734	9,677	10,886	13,287
South Africa	5,293	9,180	11,431	9,705	7,125
Nigeria	991 (1962)	5,786	4,107	5,203	6,724
Hungary	n.d.	n.d.	4,984	4,532	4,026

Table 1. Maize grain production (in 10³ MT) in the major maize production regions and countries in the world (Source: www.fao.org)

Maize production in the USA, and in other developed countries in Europe, South America and Australia, is highly mechanized and based on commercial production methods using selected hybrids and agrochemicals. Production and management practices in these areas have been described in full detail in the companion chapter on *Growth and Production of Maize: Mechanized Cultivation*.

These highly-mechanized production conditions are, however, in clear contrast with those in many developing countries, where maize is most often grown by medium- and small-scale farmers. Cultivation practices in these areas are generally less sophisticated; seed and plant quality is much lower; pests and diseases are much less under control; and cultivation techniques are by far less advanced or are even very traditional. In this chapter the focus is mainly on these traditional and low-input forms of maize cultivation, with most examples drawn from Africa and South America.

2. Origin and Distribution

There is some controversy on the origin of maize, though it is generally accepted that its centre of origin is located in Mesoamerica, primarily Mexico and the Caribbean. Maize as we know it today has never been found growing in a wild state. Its domestication, probably from a wild *teosinte* form (*Euchlaena mexicana*), is believed to have started some 6,000 to 7,500 years ago in the Mexican highlands. Archeological evidence from Mangelsdorf, Reeves, MacNeish and others (reported by Purseglove, 1975) and supported by radiocarbon dating, have indicated the existence of wild maize cobs in Mexico 5200-3400 BC, followed by a gradual extinction of wild maize in favor of modern varieties through a more intensive cultivation.

Introgression of *Tripsacum* into maize also occurred in South America, where *teosinte* is absent. The question of the separate domestication of maize in South America, in particular in Peru, still remains hypothetical.

Maize was the staple food of most pre-Columbian, Mesoamerican, South American and Caribbean cultures, whose life revolved around the *milpa* (cornfield). The crop is still

associated with the Mesoamerican peoples' identity. Later it spread to North and South America and was brought by Columbus to Spain, from where it was further distributed throughout the world.

Maize has been introduced in Africa, and later in other tropical countries, mainly by Portuguese and Arab explorers in West and East Africa, from where it spread inland through the slave-trade routes, and later to Asia. Maize was a major cash crop on the West African Coast at the height of the slave trade in the seventeenth and eighteenth centuries, being used to provision slave ships and the forts where the slaves were assembled prior to shipment overseas. The crop was reported in China in 1573, but had probably been taken there at an earlier date by the Portuguese. It is likely that the Spaniards took it to Manila from Acapulco in the sixteenth century.

Because of its wide climatic adaptability maize cultivation expanded rapidly and the grain became soon a part of the local diet as a diversification of traditional root crops (cassava, yams, sweet potatoes) and various small grains. Maize is now cultivated in more than hundred countries.

Table 2 depicts production figures for a number of countries where maize is mainly cultivated by medium- and small-scale farmers. National production figures here are much lower than in the countries listed in Table 1, where cultivation is mainly by modern and highly-mechanized methods; in Nigeria, South Africa, China, India and Indonesia the production is mixed. Moreover, annual fluctuations in smallholder's yields are noteworthy, obviously due to adverse weather conditions and the occurrence of devastating pests and diseases, which are more difficult to control.

While in the 1960s the national production exceeded hardly 1 million MT in most African, South American or Asian countries (Table 2) total maize production has increased everywhere over the past 45-50 years. In some cases this was achieved with spectacular results, but generally speaking the gradual increase was only about 2% per year. The main reasons for this development were the worldwide promotion for the crop (Green Revolution), improved biotechnological research and the release of high-yielding varieties, and improved hybrid seeds in many developing countries.

Region/Country	Grain Production (in ,000 MT)				
	1961	1990	2000	2003	2007
North Africa and Middle East					
Egypt	1,607	4,798	6,474	6,530	6,243
Turkey	1,017	2,100	2,300	2,800	3,535
West and Central Africa					
Ghana	226	552	1,012	1,288	1,100
Ivory Coast	99	484	577	600	531
Mali	70	197	215	451	690
Nigeria	See Table 1				
East and South Africa					
Ethiopia	743	1,636	2,682	2,744	3,337

Kenya	940	2,289	2,160	2,710	2,928
Malawi	815	1,343	2,501	1,983	3,226
South Africa	See Table 1				
Tanzania	590	2,445	1,965	2,614	3,659
Zambia	660	1,093	1,040	1,157	1,366
Zimbabwe	1,014	1,971	2,108	1,059	952
Latin America					
Colombia	757	1,213	1,204	1,513	1,733
Guatemala	518	1,272	1,054	1,053	1,294
Peru	340	632	1,241	1,353	1,361
South and South-East Asia					
China	See Table 1				
India	See Table 1				
Indonesia	See Table 1				
Nepal	843	1,230	1,414	1,569	1,819
Pakistan	487	1,184	1,643	897	3,605

Table 2. Maize grain production (in ,000 MT) in major maize growing African, Latin American and Asian countries with a dominance of medium- and small-scale farmers. Evolution over the past 40 years. (Source: www.fao.org)

Africa - The large and sudden rise in maize cultivation in some African countries – both in terms of yield and in area planted - since the 1980s followed the introduction of different new hybrids from the USA and South America, all of them classified as *White Southern Dents*. The local yellow maize in Africa is derived from early introductions of Caribbean flints and from later ones through CIMMYT in Mexico. In Kenya and Tanzania, where there is a bi-modal rainfall pattern, the predominant maize types adapted to a shorter growing season. In West and Central Africa where this bi-modal rainfall pattern does not exist the cultivars with a longer growth cycle adapted best (Ristanovic, 2001).

The expansion of maize on the African continent has several reasons. First, its taste has been easily accepted by the local population and, therefore, it could rapidly replace traditional starchy food like sorghum and millets. It also became important when foodstuffs had to be transported to feed labor and populations which were not self-sufficient. Additional reasons for this rapid adoption and expansion include (Purseglove, 1975; Pingali and Heisey, 1999):

- It gives one of the highest yields per person/hour of labor spent on it;
- It provides nutrients in a compact form; it is easily transportable;
- The husks give protection against birds and rain;
- It is easy to harvest and does not shatter;
- It stores well if properly dried;
- It can be harvested over a long period, first as immature cobs, but can be left

standing in the field at maturity before harvesting;

- Cultivars with different maturing periods are available;
- In terms of taste, many people prefer maize to their local cereals.

About two thirds of all African maize is produced in eastern and southern Africa. South Africa is the largest producer with about 35% of the total regional production. Nigeria is the second most important producer followed by Ethiopia, Tanzania and Kenya. Malawi has made an enormous progress due to the start of an important seed distribution program. The tremendous drop in production since 2000 in Zimbabwe is due to the political unrest in the country.

In sub-Saharan Africa maize production extends over approximately 20 million ha, and the total annual production is about 25 million tons (6% of total world production). In North Africa and the Middle East the only maize producing countries of importance are Egypt and Turkey; it accounts for approximately 15% of all African maize production.

West and Central Africa account for hardly 5.2 million tons. While relatively less important than in eastern and southern Africa, maize still provides a major source of calories, especially in parts of Nigeria, Ghana, Benin and Ivory Coast, and is a major component in the local diet. In these countries maize is almost exclusively grown on small family farms.

Asia - In south-eastern Asia, maize has never been as dominant as in Africa and South America, mainly because rice was plentifully available as a staple food. Only where the region was too dry for rice production, has maize taken its place in the local food economy.

Yield increases as part of the Green Revolution have nevertheless been most spectacular in Asia, especially between 1965 and 1985, because this resulted directly from the introduction of high-yielding cultivars and a more efficient use of inputs. By the late 1980s, however, crop yields had reached a point of diminishing returns to further intensification, mainly due to a combination of factors such as: degradation of land due to intensive cultivation, declining infrastructure and research investments; and increasing opportunity costs of labor. Additional factors that were responsible for local fluctuations were: (a) market and road infrastructure, and (b) subsidy policies. Yields are nowadays maintained at reasonable levels by the substitution of better knowledge and management skills for higher levels of input use, in particular related to appropriate timing and methods of fertilizer application (Singh and Morris, 1997).

Latin America – Except in Brazil and Argentina where part of the crop is cultivated in big estates, most maize in Latin America is grown by small farmers for local consumption. Local corn is grown from sea level to the Altiplano (over 2,000 m) in Guatemala, 2,700m in Mexico and even to 3,800 m elevation near Lake Titicaca in Bolivia and Peru. It is found from desert oases to zones with more than 5,000 mm rainfall along the western coast of Columbia, and up to about 42° S in Chile. At higher latitudes the frost free growing season is too short and the crop does not mature, making it only useful for fodder.

Maize yields under traditional farming in Latin America remain relatively low and suffer from the too limited availability of adapted seed varieties and shortage of labor ((Sain and Lopez-Perreira, 1999).

3. Botany

Maize is a 2-3m high grass with a solid single stem (stalk), 3-4 cm in diameter, with clearly defined nodes and internodes. The number of internodes ranges from 15 to 20. These are short and fairly thick at the base, but become longer and thinner near the terminal male inflorescence. The leaves arise from the nodes, alternately on opposite sides on the stalk.

Emergence after planting is quite fast and range from 4 days in warm soil to 20 days in cool soil. In moist warm soil the radicle emerges 2-3 days after planting, and the plumule breaks through the seed-coat 1-2 days later. The radicle grows out to produce the first seminal root, after which three or four adventitious roots grow out sideways from the embryo; they supply most of the soil-derived nutrition during the first few weeks. The permanent or coronal roots arise from the crown just below the soil surface once the seedling is growing well. Later on, more adventitious roots develop from above-ground nodes and grow into the soil, their function being to anchor the plant and support its upright position.

Maize is a monoecious grass with male and female flowers borne in separate inflorescences on the same plant. Although it is self-fertile, the plant's monoecious character and protandry ensure a cross-pollination of 90-95%. The tassel male inflorescence is a terminal panicle, up to 40 cm long, which stretches out from the enclosing leaves at the top of the stalk. The male or staminate flowers are present within spikelets on the branches. The stamens elongate at anthesis and the pollen is released by the anthers.

The female inflorescence, called the ear, develops on a short side-branch, which emerges from the axil of one or more of the middle leaves. An ear is a modified spike of which the central axis or cob bears paired spikelets, with one fertile flower each, in longitudinal rows. Hence, each ear will always have an even number of rows of kernels. The styles, called silks, are long and unbranched with short outgrowths called trichomes, which emerge from the husks at the top of the ear. After pollen has fallen on a receptive silk, the grain germinates, and grows a pollen tube down the inside of the silk, through which pass two sperm nuclei. When they reach the ovule, one nucleus fertilizes the haploid egg to form a diploid embryo, while the second fuses with the diploid central cell to form the triploid endosperm. The ovary wall and the ovule coat fuse to form the pericarp (hull, seed-coat).

The maize kernel consists of the embryo (10-13% of the grain), endosperm and pericarp and may differ in color, structure and chemical composition. The endosperm, in absence of the testa, is united with the pericarp. The most common kernel colors are yellow and white, though in some landraces they may also turn to red, purple or brown. The different kernel colors on the same ear are due to the out-crossing nature of the crop. The kernel structure depends on the type and nature of the endosperm. Commercial maize is classified into flint, dent, flour, sweet and pop types, depending largely on the

degree of hardness of the endosperm (see below, Taxonomy and Classification).

Maize pollen are anemophilous, i.e. dispersed by wind. In calm weather and because of its large settling velocity most pollen falls within a few meters of the tassel; with high wind however, pollen can be carried distances of up to 500 meter. Pollen is shed over a number of days. It is very sensitive to high temperature and low air moisture. Under favorable conditions it is viable during 24 hours, whereas the silks are receptive for a much longer time, i.e. 7 to 12 days. This means that there is usually a good overlap in the timing of pollen shedding and silking, which ensures good seed setting. However, hot and dry weather usually delays silking and hastens pollen shedding, which may result in poor or no seed setting.

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Biographical Sketch

Willy Verheye is a former, now retired Research Director at the National Science Foundation, Flanders, and a Professor in the Geography Department, University of Ghent, Belgium. He holds a MSc. in physical geography (1961), a PhD. in soil science (1970) and a Post-Doctoral Degree in soil science and land use planning (1980).

He has been active for more than thirty-five years both in the academic world, as a professor/ research director in soil science, land evaluation, and land use planning, and as a technical and scientific advisor

for rural development projects, especially in developing countries. His research has mainly focused on the field characterization of soils and soil potentials, and on the integration of socio-economic and environmental aspects in rural land use planning. He was a technical and scientific advisor in more than 100 development projects for international (UNDP, FAO, World Bank, African and Asian Development Banks, etc.) and national agencies, as well as for development companies and NGOs active in inter-tropical regions.

W. Verheye is the author or co-author of more than 100 peer reviewed papers published in national and international journals, chapters in books and contributions to the Encyclopedia of Life Support Systems (EOLSS). He is Honorary Theme Editor for the EOLSS, Themes 1.5: Soil Sciences, Land Use and Land Cover, and 1.5A: Crops and Soil Sciences.