CULTIVATED PLANTS, PRIMARILY AS FOOD SOURCES

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Summary

Today the world's population totals 6 billion people. Over 800 million do not have adequate food, and 1.3 billion people live on less than $1 a day. Global food demand is forecast to double, and possibly triple, by the year 2050, when 10 billion people will need to be fed worldwide. Currently, 80 percent of the global population resides in the developing world and that percentage is expected to increase. To ensure adequate nutrition for this growing population, food production must be expanded faster than the population.

There are 350,000 plant species in the world, and about 80,000 are edible for humans. However, at present only about 150 species are actively cultivated, directly for human food or as feed for animals and, of these 30 produce 95 percent of human calories and proteins. About half of our food derives from only four plant species: rice *(Oryza sativa*), maize *(Zea mays)*, wheat (*Triticum ssp.)*, and potato *(Solanum tuberosum).*

Actions must be taken now to ensure that the world will be able to produce the food needed in the future. Global and national agricultural policy changes are necessary to create greater rewards for food producers and processors in developing countries, and increased resources for agricultural research and development are needed to accelerate and integrate conventional and biotechnology applications that produce higher yielding crops and safer foods.

There have been remarkable developments in agriculture in the past four decades. High-yielding varieties of the important cereals have been successfully developed, and much progress has been made in increasing food yields per hectare of land.
Despite the remarkable progress made in increasing food production at the global level, approximately half of the people of developing countries do not have access to an adequate food supply.

This theme-level chapter is not a simple summary of the forthcoming topic- and article-level contributions, but rather a historical consideration of cultivated plants, which at the same time tries to discuss the world's plants food situation from a global point of view. Future trends are emphasized in this chapter.

1. Introduction

1.1. Cultivation

It is perhaps appropriate that the term "crop" is broad and somewhat ambiguous because many of the plants we grow for food are not fully domesticated, and the word covers all that which is harvested regardless of its status as a domesticate. We must therefore make the distinction between cultivated and domesticated as clear as possible. The terms are often used synonymously but actually they have quite different implications.
To "domesticate" means to bring into the household. In the case of domesticated plants and animals, we mean that they have been altered genetically from their wild state and have come to be at home with humans. Since domestication is an evolutionary process, there will be found all degrees of plant and animal association with humans and a range of morphological differentiation, from races identical to those in the wild, to fully domesticated races. A fully domesticated plant or animal is completely dependent upon humans for survival. Therefore, domestication implies a change in ecological adaptation, and this is usually associated with morphological differentiation. There are inevitably many intermediate states.

To "cultivate" means to conduct those activities involved in caring for a plant, such as tilling the soil, preparing a seedbed, weeding, pruning, protecting, watering, and manuring. Cultivation is concerned with human activities, while domestication deals with the genetic response of the plants or animals being tended or cultivated. It is therefore quite possible to cultivate wild plants, and cultivated plants are not necessarily domesticated.

The cultivated plants belong to about fifty-five families. Although most families contribute very little (for example, *Orchideaceae* provides vanilla, *Tropoeolaceae* presents us with Tropoeolum, *Pasifloraceae* with Passiflora), an enormous percentage of the food for humankind is supplied by the *Leguminosae* and *Gramineae*. Considering food plants only, and discounting forages, drugs, narcotics, fibers, and so on, the grass family contributes twenty-nine cereals plus sugarcane to the list, and the legume family contributes forty-one crops, mostly pulses, tubers, and edible pods. Other strong contributors are *Solanaceae*, eighteen crops (fruits, spices, one tuber), *Cruciferae*, thirteen crops (leafy vegetables, oil, root crops), *Cucurbitaceae*, thirteen crops (squash, pumpkin, fruits, oil seeds), *Rosaceae*, eleven crops (mostly fruits), *Liliaceae*, eleven crops (edible bulbs**),** *Umbeliferae*, nine crops (mostly spices and salad vegetables), and *Araceae*, eight crops (all tubers).
Another conspicuous feature is the large number of vicarious domestication. If one species proves suitable for domestications, then a similar, related species is likely to be useful as well. There are forty genera on the list in which two or more species were domesticated independently. Some of the more frequently appearing genera are:

- *Solanum*, 7 ssp.

- *Brassica*, 6 ssp.
- *Prunus*, 6 ssp.
- *Allium*, 5 ssp.
- *Vigna*, 6 ssp.
- *Dioscorea*, 5 ssp.
- *Phaseolus*, 4 ssp.
- *Amona*, 7 ssp.
- *Capsicum*, 5 ssp.
- *Cucurbita*, 5 ssp.

The same kinds of plants were often selected in different parts of the world. Aroid tubers were domesticated in Asia, the South Pacific Islands, South America, and possibly Africa. Yams were domesticated in Africa, Asia, and South America. Cotton was domesticated independently in Mexico, in South America, and in Africa, India, or both.

The genera with Old World-New World vicarious domestication are *Amaranthus, Canavalia, Dioscorea, Gossypium, Ipomoea, Lepidium, Lupinus, Prunus*, and *Solanum*. Sometimes similar plants are put to quite different uses. In the Americas, amaranths were pseudocereals, in Asia they are pot-herbs. *Hibiscus cannabinus* and *Corchorus olitorius* are pot-herbs in Africa and fibers in India. *Lepidium* is a spicy green salad in the Near East but a root crop in the Andes.

1.2. Which Crops Feed the World?

While a great variety in food plants adds immeasurably to the quality of life, it is obvious that most of those contribute relatively little to the nutrition of the world's population.

Most of the food for humankind comes from a small number of crops and the total number is decreasing steadily. In USA in the past forty years, many vegetables and fruits have disappeared from the diet and the trend is going on all over the world. More and more people, will be fed by fewer and fewer crops.

It is important to know, then, which crops really feed the world. There are too many ways to evaluate crops. One may use estimates of total production, hectarage, monetary value, nutritive value, or other criteria. Table 1 lists the most important crops in the world, but some of them are not primarily food crops.

Coffee is not very nutritious, but it does generate money and one can buy food with money. Cotton not only generates money, but the seed is edible and a good deal of cottonseed oil is processed for human consumption. World production of potato is comparable to that of the most important cereals, but potatoes contain much more water and the nutritive value is less.

The production of maize is about the same as that of rice, but most of the maize goes into livestock feeds and by the time it is converted to meat and milk, its caloric value for human food is much reduced.

Crops	**Production in 2000 (million t)**	**Comments**
Cane sugar	1 271	Low nutritive value
Maize	596	Much fed to livestock
Rice	593	Mostly human food
Wheat	582	Mostly human food, good protein
Potato	302	Mostly human food, high in water
Beet sugar	255	Low nutritive value
Manioc	171	Estimates poor, local consumption
Soybean	162	Much fed to livestock, high protein and oil content
Sweet potato	138	Estimates poor
Barley	136	Some fed to livestock
Tomato	99	High in water, vitamins
Sorghum	59	Some fed to livestock
Banana	58	Estimates poor, local consumption
Cottonseed	54	Important edible oil
Yams	38	
Peanut	31	High oil and protein
Millets	27	Mostly human food, beer
Oats	26	Much fed to livestock
Sunflower seed	26	Important edible oil
Rye	21	Some fed to livestock
Palm oil	21	High caloric value
Bean (dry)	20	High nutritive value
Cotton	19	Fiber
Pea	12	High nutritive value
Chickpea	9.3	High nutritive value
Coffee	7.0	Cash value, caffeine
Tobacco	6.9	Cash value, tars and nicotine
Rubber	6.7	Cash value and no food value
Lentils	3.2	High nutritive value
Cocoa	3.2	Cash value, and food value
Tea	2.9	Cash value, caffeine
Citrus	2.8	High in water, vitamins
Sesame	2.7	Mostly human food high oil

Source: (FAO yearbook 2001)

Table 1. Some of the most important crops in the world

Of an estimated 350,000 plant species in the world, about 80,000 are edible for humans. However, at present only about 150 species are actively cultivated, directly for human food or as feed for animals and, of these, 30 produce 95 percent of human calories and proteins (Table 2).

About half of our food derives from only four plant species: rice (*Oryza sativa*), maize (*Zea mays*), wheat (*Triticum ssp*.) and potato (*Solanum tuberosum*). Similarly, only three species (cattle, swine, and chicken) dominate animal food and, although many marine species are still gathered from the sea, this technology is changing with the rise of aquaculture.

Food crop	Fresh harvested product (Mt)
Cereals	Wheat (554), rice (551), maize (515), barley (143), sorghum (54), oat (29), millet (27), rye (23)
Oilseeds and legumes	Soybean (126), cottonseed (58), coconut (47) rapeseed/canola (35), groundnut (29), sunflower (27)
Vegetables	Tomato (84), cabbage (46), watermelon (40), onion (37), bean (18)
Fruits	Banana/plantain (85), orange (57), grape (55), apple (50), mango (19)
Tubers	Potato (285), cassava (164), sweetpotato (136), yam (33)
Sugar crops	Sugarcane (1168), sugarbeet (265)

Source: Janick J. (2001) New Crops for the 21st Century, 307-327pp. In: *Crop Science: Progress and Prospects*, Edited by J. Nösberger, H. H. Geiger and P. C. Stuik, CABI Publishing

Table 2. The thirty major food crops, 1995 (megatonnes of fresh harvested product)

The contribution of different commodity groups to edible dry matter and protein is listed in Table 3, but it is important to note that the value of fruits and vegetables to human nutrition and health via nutritients, vitamins, and minerals is ignored.

While many plant species provide non-food uses such as fibers, timber, industrial chemicals, and medicines, even here only a few cultivated species dominate, such as pine (*Pinus spp*.), cotton (*Gossypium spp*.), and rubber (*Hevea brasiliensis*).

Commodity group	**Total edible dry matter (%)**	**Total protein (%)**	Main species
Cereals	69	55	Wheat, maize, rice, barley
Legumes	6	13	Soybean
Vegetable oil seeds	3	2	Rapeseed
Tubers and starch crops	8	5	Potato, cassava, sweet potato
Sugar crops	4	0	Cane, beet
Vegetables	2	<1	Tomato, cabbage, onion
Fruit	<1	<1	Grape, apple,

			coconut, orange
Meats and products	6	13	Cattle, swine, poultry
Fish	<1	4	
Other	2	7	

Source: Janick J. (2001) New Crops for the 21st Century, 307-327pp. In: *Crop Science: Progress and Prospects*, Edited by J. Nösberger, H. H. Geiger and P. C. Stuik, CABI Publishing.

Table 3. Contribution of various commodity groups to world production of edible dry matter and protein.

1.3 Protein Problem

We can sharpen the focus on the world food situation by concentrating on the protein problem. In the first place, the human body does not require protein at all; what is required is a supply of certain essential amino acids, which the body cannot synthesize. We can do something about improving the protein situation by increasing the biological value of the proteins that are produced.

The most common deficiencies in protein quality of cereals are in the lysine, methionine, and trytophan. Rice also tends to be deficient in threonine. In some cases the shortages are marginal. Good-quality high-protein wheat for example, is a good source of dietary protein. Lysine is the primary limiting amino acid, but there is enough available to sustain life and health.

In maize, however, lysine is so low that serious symptoms of malnutrition may develop, especially in children. The dietary disease called kwashiorkor is caused by lysine deficiency in a situation of low protein intake.

Obviously, much more protein would be available if we stopped feeding protein-rich crops to animals. The United States produces 70 percent of the world's soybeans, but only about 2 percent of it is consumed directly by humans. Almost all of it is processed for feeding poultry, swine, and cattle.

The animals are then consumed and while animal protein is of better quality than vegetable protein, the conversion is wasteful in terms of total protein in human food. The time will probably come when North Americans will eat less meat, and that time has long been at hand for most of the people of the world.

In Asia and Africa nearly 80 percent of the protein of human diet is supplied by plants, and about 20 percent from animal sources. In developed parts of North America nearly 70 percent of the protein is from animal sources, and only 30 percent from plants. Population pressures may force changes in these ratios (Table 4).

	Cereals excluding beer	Roots and tubers dry equivalent	Pulses	Vegetables	Fruits excluding wine	Vegetable protein	Meat	Eggs	Fish. seafood	Milk. whole	Animal protein
FAR EAST	34.9	1.5	3.3	3.8	0.6	**49.5**	8.3	2.4	4.5	2.3	**19.6**
South Asia	34.0	0.8	6.3	1.8	0.6	**46.5**	2.0	0.5	1.6	4.6	**11.2**
East and South Eastern Asia	33.1	0.8	2.2	2.4	0.8	**45.8**	6.5	1.4	7.5	0.6	**17.9**
China	36.7	2.5	0.7	6.5	0.5	**54.4**	15.5	4.9	6.0	0.7	**28.9**
NEAR EAST	47.1	1.2	4.0	3.8	1.6	**60.3**	8.6	1.4	1.6	4.8	**20.4**
Africa	32.5	3.6	5.0	1.7	1.0	**47.4**	5.5	0.6	2.0	2.4	**12.3**
North Western Africa	53.1	1.2	3.9	3.0	1.0	**64.3**	7.0	1.3	1.8	4.4	**17.8**
Central Africa	13.4	5.4	3.0	1.0	1.2	**28.8**	4.8	0.1	2.2	0.7	**8.3**
Western Africa	31.7	5.6	5.1	1.9	1.0	**50.4**	3.8	0.7	2.8	1.0	**9.3**
Eastern Africa	25.0	3.6	6.5	0.6	1.0	**39.2**	4.2	0.3	1.3	2.5	**9.4**
South Africa	40.6	1.2	1.7	1.5	0.5	**47.1**	12.7	2.0	2.1	3.9	**23.5**
LATIN AMERICA AND CARIBBEAN	25.5	2.0	6.5	1.4	1.5	**39.8**	19.8	2.1	2.6	7.9	**36.0**
Mexico	37.5	0.5	6.9	1.8	1.4	**50.5**	17.9	4.0	3.1	7.2	**36.6**
Central America	35.4	0.5	6.9	1.5	1.3	**48.2**	15.2	3.4	2.6	6.9	**31.9**
Brazil	21.0	1.7	9.8	1.2	1.6	**39.3**	27.4	1.8	1.8	10.5	**40.6**
DEVELOPING REGIONS	33.9	1.9	3.9	0.8	3.2	**48.5**	9.1	2.0	3.7	3.1	**20.2**
EUROPE	30.0	4.0	1.7	3.6	1.0	**43.6**	23.7	3.7	5.5	9.1	**53.5**
Eastern Europe	34.3	4.0	2.0	3.9	0.8	**47.7**	21.3	3.3	2.5	9.6	**45.2**
Western Europe	26.1	3.3	2.3	4.0	1.5	**41.8**	29.9	3.9	6.5	7.4	**63.9**
North America Developed	24.8	2.7	2.8	3.8	1.4	**41.9**	40.4	4.1	4.7	10.0	**71.7**
North America Developing (Bermuda)	15.9	1.7	0.9	8.0	2.3	**34.8**	29.8	2.5	12.5	2.2	**54.9**
Oceania	22.6	3.5	4.1	2.9	1.6	**38.2**	30.8	1.7	4.9	7.1	**54.7**

DEVELOPED REGIONS	28.9	3.2	1.8	3.5	1.0	**43.2**	25.9	3.8	6.6	8.7	**55.3**
WORLD	32.8	2.2	3.5	3.3	0.9	**47.4**	12.8	2.4	4.4	4.3	**27.9**

Source: FAO database (1999)

Table 4. Protein consumption, gram/capita/day

The most radical solution of all to the protein question would be to synthesize the essential amino acids in a chemical plant. All of them have been synthesized in a laboratory on a small scale, but only two are in commercial production: lysine and methionine. These two are the most critical for people on cereal diets and routine enrichment of cereal products could prove very beneficial for those without adequate dietary protein.

2. History of Crop Production

2.1. Gathering People

Gatherers clear or alter vegetation with fire, sow seeds, plant tubers, protect plants, own tracts of land, houses, slaves, or individual trees, celebrate first-fruit ceremonies, pray for rain, and petition for increased yield and abundant harvest. They spin fibers, weave cloth, and make string, cord, baskets, canoes, shields, spears, bows and arrows, and a variety of household utensils. They paint pictures, carve masks and ritual objects, recite poetry, play musical instruments, sing, chant, perform dances, and memorize legends. They harvest grass seeds, thresh, winnow, and grind them into flour. They do the same with seeds of legumes, chenopods, cucurbits, crucifers, composites, and palms. They dig roots and tubers. They detoxify poisonous plants for food, and extract poisons to stun fish or kill game. They are familiar with a variety of drug and medicinal plants. They understand the life cycles of plants; know the seasons of the year, and when and where the natural plant food resources can be harvested in greatest abundance with the least effort.

There is evidence, that the diet of gathering peoples was better than that of cultivators, that starvation was rare, that their health status was generally superior, and that there was a lower incidence of chronic disease.

2.2. What Do Gatherers Eat?

Fifty-eight tribes have been classified according to their degree of dependence on hunting, fishing, and gathering. There is nothing special about the 44°N line of latitude except that it divides this sample rather neatly. There are not many gathering tribes at high latitudes because plant resources are not so abundant there. Tribes like the Copper Eskimo live entirely on meat and fish; they have no choice. In middle latitudes where there is a choice, food is primarily of plant origin (gathering) for most tribes. The pattern has not changed much since the introduction of agriculture; more than 95 percent of plant foods produced today are grown at latitudes below 44°N.

Despite the geographic and ecological bias of the sample it seems reasonable to conclude that in the millennia before agriculture most people were gatherers rather than hunters, and that the bulk of their food was of plant origin.

Our most reliable information might come from Australian areas where agriculture was not practiced, and where none of the plants were domesticated. Even so, Australians were recorded as having gathered and used over 400 species belonging to 250 or more genera.

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Biographical Sketch

Professor Dr György Füleky was born at Ekecs, Hungary in 1945. He obtained his M.Sc. in Chemistry and Physics from Eötvös Loránd University, Budapest, in 1968; a Dr. Univ. in Soil Chemistry from the Agricultural University of Gödöllö in 1974, and a Ph.D. in Soil Fertility from the Hungarian Academy of Sciences in Budapest in 1978. He began his career as a research fellow of the Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences. He was associate professor at the Department of Agricultural Chemistry in 1983–8, and at the Department of Soil Science and Agricultural Chemistry, University of Agricultural Sciences, Gödöllö, from 1988, Head of Department from 1900. He was Vice Dean of the Faculty of Agricultural Sciences in 1987–94, and since 2000 Vice Rector of the Szent István University Gödöllö.

His teaching subjects are soil fertility and plant nutrition, and his research activity has focused on the chemical and biological testing of soil fertility, description of the processes of soil nutrient supply, and the impact of agriculture on the environment. He is a member of the International Union of Soil Sciences since 1974, and on the Editorial Board of *Agrokémia és Talajtan*, editor-in-chief of the *Bulletin of Szent István University*, and a national representative of Hungary in the European Society of Agronomy.