centres of diversity

global heritage of crop varieties threatened by genetic pollution

GREENPEACE

Many millennia ago, our

6000 BC great

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1900 AD great

1925 AD great-

1950 AD grand-

1975 AD parents

2000 AD ***started to develop and maintain the diversity of crop varieties that secure all our food today. It is up to us whether we will be remembered as the terminator generation or whether we pass this global heritage of crop diversity on to our***

great great great great great great great great great great great great great great great great great great great great

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6000 AD great-

grandchildren

"Our planet's essential goods and services depend on the variety and variability of genes, species, populations and ecosystems.
The current decline in biodiversity is largely the result of human activity and represents a serious threat to human development."

Agenda 21

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A threat to centres of diversity

Centres of diversity are places where the special interrelation between our crop plants and their wild relatives is still apparent. In such places, tens of thousands of varieties of rice, potato, maize, or other food staples are still grown and used by local people. Centres of diversity are the basis not only for food security, but also for cultural traditions.

The introduction of genetically engineered (GE) plants into agriculture poses a serious threat to our centres of diversity. In particular wild plants and local crop varieties risk acquiring the genetically engineered traits, giving rise to strains of plants with a fitness advantage over their neighbours. This could severely disrupt local ecosystems. Any release of GE plants in centres of diversity – either through seed or commodity import – poses a serious threat to our biological heritage, cultural roots, and global food security.

A centre of diversity refers both to the region in which a crop originates – and where we find the widest range of related species – and to the region of early breeding and improvement of a crop into specific varieties. It is a generic term, encompassing the diversity both of specific crop varieties and of wild relatives and related species.

Rice originates from the south-eastern Himalayan region and was bred into more than 100,000 different varieties all over Southeast Asia

A crop's region of origin and the site of its own greatest diversity are not always the same place. This is because farmers elsewhere may develop the crops much further. Rice, for instance, originates from the south-eastern Himalayan region, but it was further domesticated and bred into more than 100,000 different varieties all over India, Vietnam, Thailand, China, and Malaysia – places now considered centres of diversity of rice.

In the 1920s, the Russian botanist Nicolai Vavilov was the first to identify certain centres of origin of crop plants. These are areas where a multitude of crops plants originated and developed. This concept was revised several times during the past decades. Currently, it is generally accepted that three general centres of origin do exist – in the Near East, in northern China and in Mexico. In these well-defined regions, whole complexes of crop ancestors were domesticated. These crops were cultivated further outside their original regions, creating thousands of new landraces (farm bred crop varieties, which became stable, distinct lines), and thus establishing secondary centres of diversity.

The ecological debate on the risks to crop diversity must focus on the centres of diversity of individual crops rather than simply looking at agriculture as an homogenous whole.

Centres of diversity –

a basis for food security and cultural values

Diversity represents the world's biological and cultural heritage. It is also the biological mechanism that allows us to cope with changing environmental conditions, ensuring food security in the long term.
In order to overcome new epidemics of pests and diseases or to adapt a crop to changing climatic conditions, farmers and plant breeders need a broad genetic base of their crop plants. This may include varieties that are not necessarily commercially interesting or high yielding, yet confer resistance to biological stress in less than ideal conditions.

In the 1970s, a strain of grassy stunt virus destroyed rice plantations in India and Indonesia. Over the next four years, scientists screened nearly 7,000 rice varieties in search of a gene that conferred resistance to the virus. Only one population of Oryza nivara – a wild relative of common rice in Uttar Pradesh, India – contained this trait, and it was subsequently bred into many rice varieties.[1] Disastrous crop losses have demonstrated time and time again that genetic uniformity makes crops vulnerable to pests and diseases. The Irish Famine in the 1840s was caused by a new potato pest that spread rapidly in the uniform potato fields. In 1974, Zambia lost 20% of its maize harvest, when the highly-uniform hybrid varieties were infested with mould, similar to the 1970 maize-disaster in the USA when southern corn leaf blight hit the US corn belt, destroying 15% of the total national harvest and costing (then) $1 billion. Similar crises have occurred with other crops, including grapes, coffee, citrus fruits, and sugar cane.

Million of people died in the Irish Famine of the 1840s, when the uniform potato crop was hit by a new potato pest

This illustrates the importance of agricultural biodiversity for our food supply. Jack Harlan, the pioneering American botanist and plant breeder, warned that genetic diversity 'stands between us and catastrophic starvation on a scale we cannot imagine'.[2]

Food security is not all that is at stake. Agriculture and culture are inextricably related: diverse crops and cultural traditions can be seen in the world's contrasting culinary preferences. The many varieties of potatoes once developed and nurtured in remote parts of Italy and Spain were chosen to suit the regional cooking styles as well as their ability to grow in those areas. The qualities of these varieties are now being recognised and valued by local growers and consumers.
Local culinary preference has had a great influence on the development of crop varieties: much store is set by beans of certain colours in South America, while in Africa, mottled beans are preferred. So it is fair to suggest that food and crop varieties are symbolic of a culture as a whole. In Asia, rice is synonymous with employment, fortune, and fertility as well as food, and it is woven into countless stories and religious practices.
Maize is native to Mexico, and this staple crop forms a primary basis of much indigenous culture. For centuries, people in Central America developed new maize varieties, adapted

'... genetic diversity stands between us and catastrophic starvation on a scale we cannot imagine'

not only to their local conditions, but also to their special cultural and culinary needs: A soup called pozole is prepared from the maize variety Cacahuacintle, which has a light sweet flavour. Zapalote – a dwarf variety – is especially suited for small, hard tortillas. Some green and purple maize varieties are sweet enough to use as a cocoa-like powder to be mixed with milk.

The description of the crops outlined in this report can only hint at their pivotal importance for millions of people – not just as part of their diet, but as part of their lives and their mythology. In considering such marvels as the 2000-year-old rice terraces of the Ifugao of Lozon in the northern Philippines, it is fair to say that agriculture has been the foundation of culture.

Genetic erosion –

a threat to food security and cultural diversity

Droughts, wars, and other catastrophes can cause the extinction of many local varieties

Worldwide, centres of diversity are endangered. This reduction in genetic diversity is called genetic erosion. In the 1950s and 60s, it was realised that the genetic variation of cultivated plants in their centres of diversity was beginning to disappear at an alarming rate. Plant breeders and botanists were among the first to raise concerns and catalogue the reduction of genetic diversity through new, often hybrid commercial varieties. The primary cause of genetic erosion is the replacement of older varieties by a limited number of standard varieties through economic or political changes.

Bt-Cotton in the USA: ‘Do not plant south of Tampa‘

’In Florida do not plant south of Tampa (Florida Route 60). Not for commercial sale or use in Hawaii‘. This label is on every seed bag of Monsanto‘s genetically-engineered Bt-cotton sold in the US. What is special about Hawaii and south of Tampa? What makes the USA prohibit the commercial growing of a GE crop in a specific region, while the very same crop is grown on more than 2 million hectares (1998) in the rest of the country? In Hawaii, the reason is called *Gossypium tomentosum* – a wild plant related to cotton. In southern Florida, feral cotton *(Gossypium hirsutum)* occurs in the Everglades National Park and the Florida Keys. In both cases, free exchange of genetic material with cultivated cotton is possible. The US Environmental Protection Agency was concerned about gene transfer from the GE varieties to the wild relatives and asked Monsanto to keep the Bt cotton out of the areas where close relatives grow.

Reasons for the rapid destruction of agricultural biodiversity are often interrelated:

- Use of traditional varieties is declining in areas with advanced commercial seed markets and farmer education programmes that promote the use of high-yielding varieties.

- In some regions, farmers are forced by official authorities to plant large blocks of single 'modern' (hybrid) varieties.[4]

- Droughts, wars, and other catastrophes can cause the extinction of many local varieties. International food aid programmes usually supply the farmers with 'modern' (hybrid) seed, because traditional varieties are not easy to obtain in larger quantities and are frequently not included on official seed registers, which only consist of commercial varieties. A single year of growing the alien seeds could be enough for a farmer to lose his/her traditional seedstock forever.

- In export-oriented economies, the expansion of pasture or cash crop monocultures reduces the area used by small farmers and destroys rural agricultural systems that rely on traditional varieties.

- In many regions of the South, there has been a cultural shift from traditional subsistence crops like cassava and sorghum to 'modern' food products (wheat bread, noodles, rice). This is because imported foods are cheaper in the marketplace, due to trade agreements, and there is no longer a commercial market for indigenous foods.

According to FAO estimates, 75% of the global genetic diversity of our crop plants has been lost during the last century.[5] The case of southern Italy is very well documented in terms of the loss of traditional varieties through genetic erosion. Several studies, one in 1950 and others in the 1980s, have allowed scientists to make detailed comparisons and calculate the loss of genetic diversity. Within this 30-year period, nearly all old varieties of wheat, chickpea, lentil, onion, tomato, and eggplant disappeared from the region. The average loss of varieties for cereals was as high as 71% and for vegetables – despite abundant gardens that could have provided good refuges for many varieties – even 81%.[6] A study on the genetic erosion of 57 crop species involving more than 5000 distinct varieties in South Korea showed disastrous results. Within eight years, from 1985 to 1993, 82% of the original varieties became extinct.[7] Similar figures indicating catastrophic genetic erosion have been reported from many regions of the world. In 1970, only 50 traditional rice varieties were left in China, compared to 8000 in general use in 1949.[8] Only 20% of local maize varieties reported in Mexico in 1930 are still known.[9]

Forty years ago botanists realised that the genetic diversity of our crop plants was disappearing at an alarming rate

Save diversity – Eat it!

'Plow your garden – taste the difference' is the motto of a project that was initiated last year by Greenpeace Germany. As part of its genetic engineering campaign, Greenpeace Germany sought to raise awareness about the threat to crop diversity by sending packages of GREENSEEDS – seeds of rare and endangered tomato, radish, and bean varieties – to many of its members. Participants in this campaign to preserve the diversity of our vegetables also get to taste the difference. This is just one of the many examples from around the world of initiatives to celebrate plant diversity. Many non-profit organisations around the globe try to find seeds from old varieties and distribute them to interested private persons. Through the joint effort of thousands of home gardeners, many varieties are re-grown every year, their seeds exchanged and thus saved from extinction. This is an urban version of the practice of millions of small farmers around the world. When commercial seed producers lose interest in a variety, it is dropped from their catalogues. Thus de-listed and no longer for sale, it soon becomes forgotten and extinct if it is not saved in the non-commercial environment.

The time will come when traits necessary to overcome a major breeding problem like pest resistance are simply no longer available. This problem first became evident some decades ago, and international efforts were undertaken to preserve crop diversity. However, the samples of the many thousands of varieties were not kept alive in their traditional environments (in situ), but rather in artificial storage facilities, so called gene banks (ex situ). Seeds of millions of varieties were collected worldwide and stored under controlled conditions (low humidity, low temperature) in gene banks run by international organisations, local governments, or research institutes. Although many are situated in the South, they are primarily funded and directed by the North. The seeds have to be replanted on a regular basis to ensure their viability (ability to germinate). 1300 gene banks worldwide contain roughly six million accessions.[10] Seeds from one variety found at a specific locality in the field are counted as one accession at each gene bank. Thus the overall number of distinct varieties is much lower because many samples are stored in several gene banks (see Appendix 2).

Despite the impressive record of gene banks, they are a poor option for preserving crop diversity in the long run because:

- Many seeds die during storage. In 1991, the FAO reported that only half of the accessions to the gene banks in the Latin American Maize Programme could be evaluated due to lack of viable seed.[11]
- Seeds stored in gene banks are no longer subject to natural selection. They cannot adapt to changing climate conditions or newly emerging pests and diseases. Several generations in a gene bank increases the risk that seeds will lose their adaptability. In addition, these seeds are subject to an artificial selection pressure in gene banks, i.e. adaptation to the cold storage conditions.
- The loss of variation within gene banks can be considerable. At the University of Kyoto, in the most important wheat collection in Asia, only five plants per accession are grown for regeneration, reducing within-population variation.[12]
- Samples in some gene banks are virtually useless for breeders, scientists, and conservationists, as the plants' distinct characteristics are not recorded.[13] Most of the local farmers' knowledge gained from working with these seeds for generations is not stored with the seed specimens.
- Most collecting for gene banks has been carried on in the vicinities of major road networks, so important regions have been missed out by collecting expeditions. In the case of wheat, for example, vast areas of Eastern Europe, southern regions of the former Soviet Union, and North Africa – all of which are areas of vital diversity – have been bypassed.[14]

75 % of the global genetic diversity of crop plants has been lost during this century

A much more sustainable way to save the diversity of our crop plants is to preserve them in their traditional environments. There is little point in a vast array of diversity being kept on ice or in museums of diversity, unless it can be made available to the farmers who need it and who will keep it alive and invigorated. Examples such as the partnerships between the Ethiopian gene bank and local farmers, who constantly exchange germplasm, probably best exemplify an ideal future role for gene banks.

...the release of a transgenic crop in its centre of origin is not a good idea.

R.J. Cook,
USDA Agricultural
Research Service[15]

No traditional breeder is able to cross a carp with a potato, or a bacterium with a maize plant

Genetically engineered plants:

a new threat to centres of diversity

The Green Revolution with its uniform hybrid varieties and the associated social and economic changes has been a major cause of the decline of crop diversity. The introduction of genetically engineered (GE) plants intensifies this move toward crop uniformity – and escalates the loss of crop diversity. But GE crops are more than just the next generation of high-tech varieties. They feature two specific characteristics that could make them a special threat to centres of diversity:

- Firstly, GE plants contain genes and traits that are completely new to the target species, its environmental context, and its genetic background. While traditional breeding can move genes only among related varieties or closely related species, genetic engineering allows for a movement of genes across radically different species. No traditional breeder is able to cross a carp with a potato, or a bacterium with a maize plant. There is no history of bacterial genes in maize. There was no evolution or selection over thousands of years that would have qualified the bacterial gene to be an integrated part of the maize population. The effect of newly introduced genes and gene fragments under real world conditions, in different climates or in reaction to different pests or diseases, is completely unpredictable, posing a threat not only to the crop, but also to related species and the ecosystem.

- Secondly, the process of genetic engineering is neither targeted nor precise but a rather crude intervention or bombardment. The newly introduced gene could end up being integrated anywhere in the plant genome. It can neither be directed to a specific site within the plant's genes, nor is the site of integration necessarily known afterwards. Because the expression of a given gene or gene fragment depends heavily on the site of integration and the genetic background, it is merely a matter of luck if the newly introduced gene works as expected and no major changes in the plant performance are induced. Several natural mechanisms are known (e.g. pleiotropy, epistasis, or position effects) to influence the specific outcome of a foreign gene transfer and these cannot be anticipated.

These are the two fundamental differences between conventional plant breeding and genetic engineering. Either can have unforeseen consequences when GE plants are released into the environment. The risks are greatest in the centres of diversity, where the newly introduced genes may find the best opportunity to escape and where vital resources are at stake.

The risk of gene flow is greatest in the centres of diversity

Genetically engineered seeds could be picked up by birds and dropped elsewhere

Once released into the environment, GE plants cannot be contained or confined. Like all living organisms, GE plants reproduce and this is an opportunity for gene flow beyond the designated area of growth. Seeds can be picked up by birds and dropped elsewhere, potato tubers can be removed by bigger mammals, or reproducible plant parts could just be dislocated by wind. The major escape path for the newly introduced gene into the wild is via pollen transfer.

When a GE plant flowers, the pollen contains the newly introduced genetic material and can carry it to another plant, fertilise it, resulting in seeds that will also contain the engineered gene. The only precondition for this kind of gene flow is the presence of compatible plants in the vicinity. This is almost inevitable in a plant's centre of diversity where a GE crop will be surrounded by compatible plants – be they local varieties and landraces of the crop or wild species – and will facilitate the transfer of the new gene into local populations. It has been proven that oilseed rape, maize, sunflowers, potato, sorghum, and many other crops can crossbreed with wild plants that grow in their centre of diversity.

DANGER FROM PROMISCUOUS PLANTS?

An alarming report was recently published by the scientific journal 'Nature'.[18] Genetically engineered herbicide resistant plant, *Arabidopsis thaliana* (Thale cress), showed an unexpectedly dramatic increase in their ability to donate pollen to wild Arabidopsis plants growing nearby, while their conventional counterparts were mainly self-fertilising. Why a trait such as herbicide resistance causes an increased outcrossing capacity is completely unknown and still needs further explanation. This result high-lights the possibility that effects unrelated to the desired trait can result from a genetic modification.
If this example is transferred to the situation of wheat in its centre of diversity, a fearsome (though completely hypothetical) scenario may arise: Wheat is a strict self-fertiliser, i.e. the flowers are not fertilised by pollen from another plant but from the plant's own pollen. If wheat acquired the ability to outcross and to pass this ability on to the many local varieties in its centres of diversity, we might witness major vegetational changes in these areas. Plants that have been subject to extremely minor genetic exchange during the past millennia would suddenly become part of one big gene pool with genes floating freely between the different varieties. It is impossible to forecast the impact of such an event on the natural vegetation and the cultivated wheat diversity in Ethiopia or in the Fertile Crescent, but the odds are that it would prove disastrous.
This scenario is highly hypothetical as it remains to be proven whether the observed effect on Arabidopsis would occur in other species. In light of the research into unexpected effects produced by GE Thale cress, there seems to be no criteria for any valid risk assessment, nor any excuse to continue experimenting with our future.

Genetically engineered plants' impact on local varieties and natural ecosystems

Many crop species have close relatives that are already considered major weeds

While it is commonly agreed amongst the scientific community that gene flow is likely in a centre of diversity, its impact is debatable. One major fear is the possibility that the newly introduced gene will confer a selective advantage and will thus enable the plant to out-compete and overrun other natural vegetation. The risk is greatest when a wild relative of a GE plant is already considered a weed. Should this weed acquire – via pollen transfer – new genetic material conferring a selective advantage, it might wreak havoc in both agriculture and natural habitats.

Many crop species – such as oilseed rape, potato, tomato, or beans – have close relatives that are already considered major weeds. It is obvious that many of the traits favoured by genetic engineers would confer a fitness advantage, especially resistance to pest and diseases or tolerance to drought and salinity.[16] Researchers at the University of North Carolina found recently that insecticidal oilseed rape containing a bacterial gene (Bt) had a higher fitness than the conventional oilseed rape. The GE plants produced significantly more seeds than their natural counterparts. The researchers concluded that '*insecticidal oilseed rape could pose an ecological risk upon environmental release. Since oilseed rape is already a minor weed in certain areas, the ability to strongly resist defoliation may allow it to selectively persist to a greater extent by replacing non-transgenic naturalised populations.*'[17]

'insecticidal oilseed rape could pose an ecological risk upon environmental release'

Greenpeace demands

Greenpeace believes that any irreversible release of genetically modified organisms (known as GMOs) into the environment is irresponsible given the present state of knowledge about their possible adverse effects on the environment and human health.

*** No irreversible releases of genetically engineered organisms into the environment**

There is already sufficient evidence that the release of GMOs can have irreversible effects and that their genetic pollution may lead to self-replicating and man-made destruction of the environment.

Any country with a centre of diversity for one or more crop plants under its jurisdiction should take specific legislative measures to forbid the introduction and cultivation of genetically engineered varieties of these crops. As small-scale field trials also present the risk of outcrossing, these should be banned as well.

*** No releases of genetically engineered plants in their centres of diversity**

Living entities like maize kernels, potatoes, tomatoes, or cereal grains can generate new plants. Even if the intended use is processing for food or feed, there is always the risk of spill-over or use for replanting.

*** No import of genetically engineered food commodities into their centres of diversity**

For countries neighbouring those where genetically-engineered crops are grown, there is always the risk of unwanted or illegal introduction of genetically-engineered material. One example is Mexico – centre of maize diversity. Mexico shares a border with the USA, where millions of acres are planted with genetically engineered maize varieties. It can be anticipated that a significant amount of genetically-engineered maize is transferred through commodity import, illegal import, or pollen flow to Mexico and threaten its unique diversity of maize.

*** Consultation of neighbouring countries in high risk areas and measures to prevent illegal transfers**

Prior consultation with neighbouring states should be mandatory before any country can decide to grow genetically-engineered crops. Measures must also be taken to prevent illegal international movement of genetically engineered crops to centres of diversity.

Urgent national and international measures are required to stop genetic erosion and to protect the global heritage of the world's crop diversity in their regional environment and cultural context.

*** Protect the global heritage of crop diversity for future generations**


Centres of Diversit
Rapes
Beet
Sunflower
Maize
Bean
Cassava
Tomato
Potato
Cassava
Tomato
Bean
Potato
Maize
Maize

ty for major food crops

Selected crops

Maize

Maize= zea mays, from the Greek, zeia, meaning grain and Arrawak maïs, meaning the stuff of life.

Origin and distribution: Maize (*Zea mays*) was probably first cultivated about 7000 years ago. The earliest examples of maize are tiny cobs found in the Bat Cave of Tehuacan, New Mexico, dated about 3600BC.[19] Maize derives from a variety of teosinte (*Zea mexicana*) that grows wild in Mexico. In pre-Columbian times, maize was introduced into South America, where further domestication took place. As a consequence, there is a particularly high variation of maize across nearly all of South America.[20]

Centres of maize diversity: Maize evolved in Mexico and was further domesticated in South America[21]

History: According to the Popul Vuh, the holy book of the Mayas, the gods created man last. The gods tried to create man three times. First, they made him out of clay – but he seemed too weak and was dissolved by the first rains. Second, they made him of tropical wood. This resulted in hard, emotionless beings that did not respect their gods, so they had to be destroyed. Some of them survived the catastrophe and these became the monkeys of today. The third, successful attempt was the creation of man out of maize.

The Mayan god of the maize is called *Yum Kaax* who is depicted on many old Mayan pictures, his head typically looking like a maize ear. The Mayan word for maize (*k'ol*) is also the word for cultivation. For the Mayas, maize was the symbol of life. The Mayas of today still use the expression: '*maize is our blood*'. When a child is born, its umbilical cord is often cut above a maize ear.[22]

Over centuries of domestication, the Indians discovered the secrets of maize cultivation. They devised a planting system consisting of mounds made by the men after land clearance. The women then moved onto the prepared land, poking holes in the mounds and dropping four or six maize seeds in each. Later, they added a few beans and a few squash seeds. When the maize emerged, the beans (which fix nitrogen in the soil in a form usable by plants) climbed up the maize; the squash covered the base, keeping the weeds down.

The time of planting was an exact science in ancient Mesoamerica. The Europeans, who depended entirely on the Indians for any hope of survival, were told '*When the young leaves of the oak tree are the size of a squirrel's ear, then plant.*' In Iroquois legend maize, beans, and squash were represented as the three inseparable sisters, always grown together and always eaten together. Maize is about 10% protein, but is deficient in certain amino acids and niacin in a digestible form. When eaten together, the holy trinity supplies all dietary needs. In addition to this, the Indians always added ash (lime) to the cooking pot. This softens the skin of the maize kernel – but it also releases the bound form of niacin, making it available to the human digestive system.

The Mayan word for maize (k'ol) is also the word for cultivation

Maize was a staple crop, not only for the Central and South American indigenous people, but also for the Navajo, Hopi, and Sioux cultures in Northern America. Common myths appear in various forms as far north as Lake Superior.
The Maya people called maize '*ixim*', the Inca '*hara*', and the Aztec '*tlaolli*'. In the Arrawak language that was spoken by indigenous people on the island of Guanahaní, maize was called '*maiz*', the origin of its name in many European languages.[23]

Introduction to Europe and beyond: Columbus noted in his diary on November 4, 1492 while he was on Guanahaní (today called Watlings Island), that *''there was a great deal of tilled land sowed with a sort of beans and a sort of grain they call 'Mahiz', which was well tasted baked or dried, and made into flour.'*[24]

Maize cultivation in Europe started at the beginning of the 16th century in southern Spain, followed in the 1530s by Portugal, France, and Italy (Venetia). By 1563, maize was familiar enough around southern Europe to appear in the painting 'Summer' by Archimbaldo. Maize rarely replaced other grain crops – rather, it was cultivated on fallow land or in farmers' gardens. In its first decades in Europe, maize was neglected by the landowners and was not a commercial crop. In those times, the farmers' gardens were the 'private areas' where the peasants grew their subsistence products with no tax or tribute to pay. It took several decades before landowners in some regions like north-east Italy realised the economic potential of maize. In the 18th century, maize (polenta) became increasingly the staple – sometimes only – food source of the poor in the Mediterranean regions. The effect on people's health was devastating.

In its first decades in Europe, maize was restricted to farmers' gardens, where the peasants grew their subsistence products with no tax or tribute to pay

A diet solely based on maize led to a dangerous and lethal illness called pellagra (literally, rough skin), which caused skin lesions, sore mouth, nausea, and even mental disturbances. The poor 18th century rural population was not able to acquire even the tiniest amounts of meat or fresh vegetables that would have been enough to fight pellagra. It is symbolic of the incredible poverty and social injustice of 18th century Europe.[25]

In Africa, a disease called kwashiorkor, literally meaning '*the disease of the elder child when a new one is born*', is caused by a deficiency of vitamins and proteins when the mother's milk is withdrawn and replaced by corn. Kwashiorkor is still a major cause of child mortality in many parts of the world.

Maize was transported to the Philippines as early as 1519 by Magellan on his quest to reach the Spice Islands by a westward route; by 1555 it was sufficiently important in some parts of China to rate a mention in the regional history of Honan. By the 17th century, it had transformed agricultural life in Yunnan and Szechuan and became a life saving crop for migrants forced out into the hills from the overpopulated Yangtze delta.

In Central America, all parts of the maize plant are used: the grain for food, the cane for juice, the leaves for wrapping food and the dry cane for construction material [26]

The Portuguese introduced maize farming to sub-Saharan Africa to provide ship's stores for the slave trade. The English trader, Sebastian Cabot, used it as currency in exchange for slaves. It was readily adopted because, in comparison to other grains, it grew rapidly and its cultivation was undemanding. Once dried, it stored well and germinated for several years after harvest.

Maize is the world`s largest staple crop

Maize is the daily food of today's Mayas. Their most basic meal, eaten three times a day, is tortillas with beans. For preparing tortillas, the maize ears are shelled and the kernels are put in boiling water with lime. After some hours the maize is taken out and washed. It is now ready to be milled. In most Mayan villages women can be observed arriving at the local mill with baskets full of maize kernels and carrying the maize dough away. The woman picks up small amounts of dough, slaps it deftly between her hands into the classic circular shape: the tortilla, that is cooked on a clay or steel plate above a fire .[27]

In industrial nations, only a very small proportion of maize directly serves human consumption. Roughly two thirds of the world's maize production is used as animal fodder. Around ten percent is processed to starch and sweeteners and five percent is converted into ethanol for fuel production. One third of maize starch is used in the food industry, the rest goes into hundreds of applications: from toothpaste to latex paint, the metal, paper and ceramic industries, glue and dye fixing. Recently, techniques to produce plastics based on maize starch have been developed. Other major maize products for human consumption are beer and whiskey.[28]

Trade: Maize is the world's largest staple crop, with an annual production in 1998 of more than 600 million tonnes.[29] The USA is the world's biggest producer and exporter of maize and maize products (see Appendix 4). As 22% of the national corn area in the USA was covered with GE lines in 1998,[30] most of the US-maize shipments are probably contaminated to some degree with GE kernels. This is of special importance for Mexico, centre of maize diversity, and also a principle buyer of US-maize. The table below lists the major countries importing unmilled maize from the USA. These countries are thus most likely to be introducing – often unwillingly and unwittingly – thousands of tonnes of GE organisms.

Most of the US-maize shipments are probably contaminated to some degree with genetically engineered kernels

Country	**US-maize import (1000 tons)**
Japan	14,856
Mexico	3,886
Taiwan	3,863
Rep. of Korea	3,577
Egypt	1,843
Colombia	1,228
Saudi Arabia	977
Algeria	845
Venezuela	699
Dom. Rep.	660
Canada	650
Morocco	388
Turkey	378

Importers of unmilled US-maize in 1998[31]

The value of diversity: The impressive diversity of maize was highlighted by Fowler and Mooney[32]: *'A Papago Indian type in North America matures as a dry flour corn in fifty-five days, while one Colombian variety requires sixteen months. Some corns have just eight leaves, others have up to forty-two. Plant height varies from 40cm to 700cm; ear length ranges from 4cm to 40cm; and the number of rows of kernels from eight to twenty-six. The weight of a thousand kernels can be as little as 50 grams for one Peruvian variety to as much as 1,200 grams for another.'*

A fast maturing variety in Colombia was given the name *matahambre*, which translates as 'hunger killer'

Maize diversity is directly related to food security. The many varieties have different growing characteristics suited for changing climate conditions. In Chihuahua, Mexico, the fast growing variety *Apachito* is planted when the rains are delayed.[33] Colour varieties correlate with varying maturation periods. Blue and red pigments in cornstalks help corn varieties warm up quickly on cool mornings. This makes them especially suitable to be planted earlier in the year.[34] A fast maturing variety in Colombia was given the name *matahambre*, which translates as 'hunger killer'.[35]

The Hopi Indians allotted one type of corn to each family in the village, and it was that family's responsibility to maintain the purity of that variety through the generations.

Clawson[36] describes the typical maize growing procedure of a smallhold farmer in Mexico: *'The farmer will inspect his field 2–4 weeks after he has sown his white maize, when the young plants are 4–6 cm high. He often finds that the maize has germinated unevenly. Rather than allowing part of his land to remain unproductive, the farmer will replant the barren sections with blue-coloured maize. The blue is considered superior in taste to the white but its yields are lower. Its greatest asset, however, is that is has a maturation period 2–4 weeks shorter than that of the white maize. If, by some misfortune, part of the blue maize fails to germinate, the peasant will turn as a last resort to his red maize, which is considered inferior in both taste and yield but which has the shortest maturation period. Multicoloured maize in Nealtican thus functions as a crop insurance and life-protection mechanism.'*

The toll of uniformity: In 1961, a new maize disease was reported for the first time in the Philippines. It became known as the southern corn leaf blight and caused a 15% loss of the US maize harvest in 1970. Some Southern states lost half their harvest. The real culprit was not the disease but crop uniformity. The whole American crop was vulnerable to the new fungus because nearly all commercial hybrid varieties sold in the USA were genetically identical in at least one respect. They all carried genes that conferred male sterility, a trait necessary to produce hybrid seed. It was a local maize variety found in Africa that provided the genetic basis for resistance against the southern corn leaf blight.[37]

Farmers believe that teosinte´s presence in the maize field enhances next year's maize quality

Gene flow: Maize easily hybridises with certain varieties of teosinte, the wild relative of maize and a frequent volunteer in the field in Mexico and Guatemala.[38] Maize/teosinte hybrids are actually cultivated. The farmers believe that teosinte´s presence in the maize field enhances next year's maize quality.[39] In some regions of Mexico teosinte is considered a weed.[40]

Extensive gene exchange in both directions is evident in Chalco, south of Mexico City, where the weedy teosinte race mimics the local race of maize in size, colour, and growth patterns.[41] Genes placed in maize by genetic engineering could be transferred to teosinte and under some circumstances could spread to the entire teosinte population. Two teosinte species, *Zea perennis* (until recently thought extinct) and *Z. diploperennis*, have highly restricted distributions in the Mexican state of Jalisco[42] whilst others are more widely distributed throughout Mexico and Guatemala.[43] Maize has never been found growing in its wild state.

In 1998, 6.5 million hectares of GE maize were grown in the USA

Genetic engineering: In the USA (mainly in the Southern states), not far from maize's centre of diversity, millions of hectares of GE maize are growing,[44] most of them with a fitness-enhancing trait of insect resistance. Huge amounts of GE maize are entering Mexico as commodities[45], and nobody can exclude the possibility that GE maize is already grown in Mexico. Poor farmers might grow imported food-maize, or seed maize might be imported illegally from the United States to Mexico.

Maize is the biggest market for seed companies, as a very high percentage of maize is hybrid seed. Hybrid seed is not sterile, but it loses its specific vigour in the next generation, making it an economic necessity for the commercial farmers to buy new seeds every year.

According to the Mexican authorities, by 1998 32 experiments with GE maize had been approved in Mexico (see list below). It remains unclear which of these tests were performed under contained conditions (laboratory, greenhouse) or in the field. In 1998, the US-based company Asgrow was allowed to plant herbicide resistant GE maize in the field for seed production, while applications from Monsanto to plant insect resistant GE maize in the field were cancelled for unknown reasons[46]. Little information about safety measures and monitoring of the wider environmental impact of these field trials is available.

Trait	1993	1994	1995	1996	1997	1998
Herbicide tolerance	1			1	4	4
Insect resistance (Bt)			2	7	10	1
Marker gene		2				

Experiments with GE maize in Mexico (data from the Secretaria de Agricultura, Comision Nacional de Sanidad Agropecuria de Mexico, www.sagar.gob.mx/users/conasag/ensayo.htm).

In terms of genetic engineering experience, maize is by far the most advanced crop (see Appendix 6). GE maize was grown in 1998 on 8.3 million hectares worldwide.[47] As of December 1998, ten GE maize lines were approved for commercial use in the USA (see Appendix 5)[48], mainly herbicide and insect resistant types. Further developments are in the pipeline. Taking field trials of GE maize in the USA as an indication (see table below), maize lines with altered product quality, fungal resistance, and male sterility ('agronomic properties') are on their way to commercialisation. In Europe, GE maize commands the highest number of field trials (see Appendix 7).

By 1998, 32 experiments with GE maize had been approved in Mexico

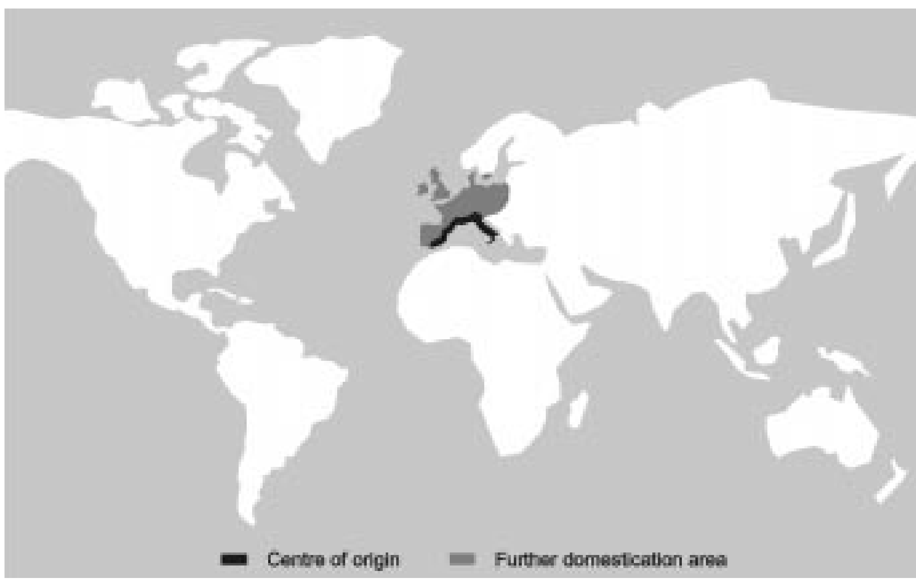
No. of field trials with GE maize in the USA in 1997 and 1998.
Only the major companies and traits are listed. The total number of maize field trials was 529 in 1997 and 730 in 1998.[60]

Trait	AgrEvo	Cargill	DeKalb	Du Pont	Monsanto	Novartis	Pioneer
Insect resistance	8	3	17		91	53	63
Herbicide tolerance & insect resistance	169	12	4		32	1	1
Herbicide tolerance		6	27		106	9	32
Product quality	10		15	45	32		45
Agronomic properties	61	9	14		5	2	46
Fungal resistance	14		5			10	43

Oilseed rape / Canola

Origin and distribution: Members of the brassica or cabbage family were prized in Ancient China as a source of oil before they were bred as green vegetables. Rapeseed (*Brassica napus*) originates in the western Mediterranean and was domesticated all over Europe. Rapeseed itself exhibits weedy characteristics, and it might even be of weedy origin: one theory holds that rapeseed was introduced to Central Europe as a weed amongst cereal crops. Later its value as a fodder and oil crop was realised, and several hundred years ago selection and breeding of the former weed began in Europe. It is grown twice a year, as both winter and spring oilseed rape.

Centres of rapeseed diversity: Rapeseed evolved in the western Mediterranean area and was further domesticated in Europe[49]



Use: Traditionally used as a source of oil and for animal fodder, in the 20th century, it has been largely grown for industrial use in the food industry, for margarine and cooking oil, in soap manufacture, and as an industrial lubricant.

Rapeseed oil can be used as fuel in diesel engines, and companies such as Volkswagen are developing it as biodiesel. Mixed with castor oil, it can be used as a lubricant in internal combustion engines. Vegetable oils (sunflower, mustard, and rape) are better than alcohol as a diesel extender, with mixtures of up to 75% possible, compared with 20% mixtures of alcohol.[50]

Trade: Canada is the world's biggest producer and exporter of oilseed rape (see Appendix 4). As 45% of the national canola (rapeseed) area in Canada was covered with GE lines in 1998[51], most of the Canadian rapeseed shipments are probably contaminated to some degree with GE seeds. The majority of the Canadian canola harvest is exported as (living) seeds that could germinate in the country of import and give rise to new GE plants. This is of special importance for Europe, the centre of oilseed rape diversity, where some years saw several hundreds of thousands tonnes of canola seeds imported from Canada.[52] Interestingly, the export of living Canola seeds to Europe declined in recent years and is now down to zero (August 1998 until January 1999).[53] This might be connected to growing awareness of GE canola imports in Europe and to the fact that not all GE canola lines grown in Canada have market approval in the EU.

Socio-economic impact: There is one GE rapeseed line, approved for unrestricted use in the USA, that deserves special attention as it poses a special threat to small farmers in some developing countries. Calgene (now a Monsanto subsidiary) has developed GE canola that produces oil rich in lauric acid, a special oil compound for use in the soap industry and for special food purposes.

Export of Canola seeds to Europe declined in recent years and is now down to zero

Traditionally, coconut oil and palm kernel oil from the tropics are the only high-volume source of lauric oils. Together, the Philippines and Indonesia account for approximately 81% of global coconut oil exports. Jesus Arranza, of the United Coconut Association of the Philippines, described the potential impact of GE rapeseed-derived lauric oil on the Philippine economy at the 1993 World Conference on lauric oils:

'Should this happen [commercialisation of Calgene's GE high-lauric rapeseed], lauric oil users would have more vegetable-oil options, and the coconut oil share of lauric oil exports would drop substantially. Lauric rapeseed would certainly have an advantage over other lauric oils, since the former is not a perennial crop. Thus, lauric rapeseed output may be increased in a relatively short time, depending on the requirements of the market. Also, since rapeseed is grown mostly in the European Community and Canada, and is beginning to be grown on US farms, the decision to support an indigenous lauric oil in these areas is far more convenient than importing lauric oils from the tropics. This could have devastating effects on the economy of the Philippines.'[54]

Gene flow: An array of rapeseed relatives grow in Europe. Some of them are cultivated as crops; others are known as weeds. Spontaneous hybridisation between rapeseed and at least four weedy relatives has been proven in several scientific experiments: *Brassica campestris*, also known as wild turnip, bird rapeseed or *B. rapa*,[55] *B. juncea*,[56] *B. adpressa* and *Raphanus raphanistrum*[57] are all known as weeds at least in some areas of Europe, and they can form fertile offspring with cultivated rapeseed under natural conditions. Rapeseed is a persistent volunteer as the seed heads shatter easily. All the brassicas, both cultivars and wild, have high seed dormancy. Rapeseed can readily germinate up to several years after harvest.

Danish researchers found that genes that have been introduced into rapeseed by genetic engineering can easily introgress into a weed population. In an experiment, one backcross was sufficient to obtain plants that resemble the weedy *B. campestris* but contained the transgene from rapeseed.[58] There is no doubt that any GE rapeseed grown commercially in its centre of diversity will forward the newly introduced genes to wild and weedy relatives.

There is no doubt that any GE rapeseed grown commercially in its centre of diversity will forward the newly introduced genes to wild and weedy relatives

As rapeseed was one of the first major crops to be genetically engineered in Europe, several experiments to assess its ability to pollinate plants in the vicinity were performed during the past decade. The aim was to determine a 'safe' distance for field trials with GE rapeseed plants. However, the results differed by several orders of magnitude – some researchers found only 0.1% outcrossed seeds at 1m distance from a field with GE rapeseed, whilst others found 1.2% outcrossing even at a distance of 1.5 kilometres.

The conclusion that can be drawn from all these experiments is there is no 'safe' distance for rapeseed in a field trial. Depending on environmental conditions, pollen can travel over large distances and pollinate plants far away from the experimental plot.

In summer 1998, France decided to prohibit any commercial growing of GE plants that have the ability to pass their genes to wild relatives (i.e. oilseed rape and beet) for two years. The French government will grant no approval for GE lines of these two crops. The decision for this moratorium was taken by France in view of the fact that any release of GE oilseed rape or beet would be irreversible due to the high probability of outcrossing and hybridisation with wild relatives.

In summer 1998, France put a two year moratarium on any commercial growing of GE plants that have the ability to pass their genes to wild relatives (namely oilseed rape and beet)

Genetic engineering: Rapeseed is a major crop in both Canada and the EU. Three years ago, Canada started commercial planting of herbicide resistant GE varieties. The area planted with GE canola doubled from 1.2 million hectares in 1997 to 2.4 million hectares in 1998, equivalent to 45% of the Canadian canola area.

Also in Europe, rapeseed belongs to the first generation of GE crops that are ready for commercialisation. The company leading this work is Plant Genetic Systems, recently bought up by AgrEvo (which itself may soon be a part of Hoechst/Rhône-Poulenc's merger Aventis). They have developed a male sterility system that allows for the production of hybrid seeds to increase yields. The first male sterile GE rapeseed lines have been approved in the European Union, but due to the French moratorium and increasing consumer pressure in Europe, no GE rapeseed is yet grown commercially in Europe, although many and large scale field trials are being conducted in the EU.

Trait	AgrEvo/PGS	Monsanto	Rhône - Poulenc
Herbicide tolerance	5	7	3
Male sterility	15		

No. of field trials with GE rapeseed in the EU in 1997 and 1998.
Only the major companies and traits are listed. From June 1991 until June 1998 a total of 268 field trials with genetically engineered rapeseed were performed in the member states of the Europaen Union.[59]

In the US, rapeseed is only of limited economic importance. This explains why commercialisation of GE rapeseed in the US is much slower than some other crops. Only one line is approved for unrestricted use in the USA – Calgene's GE Laurical canola.
However, AgrEvo seems set to target the US-American market with male sterile GE rapeseed ('agronomic properties' in table below), and Monsanto is obviously preparing for some herbicide resistant lines as well as rapeseed with altered oil composition through its subsidiary Calgene.

Rapeseed belongs to the first generation of GE crops that are ready for commercialisation in Europe

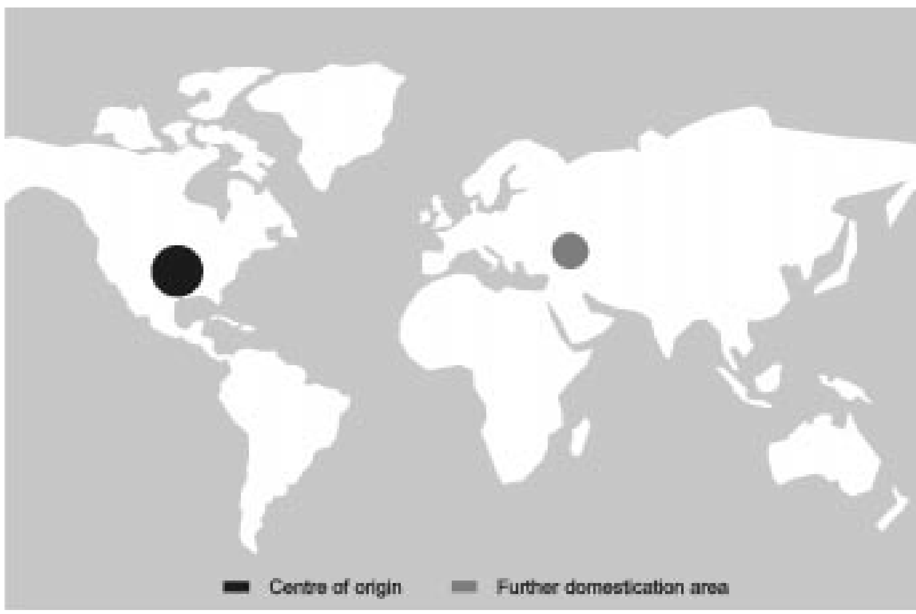
No. of field trials with GE rapeseed in the USA in 1997 and 1998.
Only the major companies and traits are listed. The total number of rapeseed field trials was 56 in 1997 and 121 in 1998. AgrEvo is about to acquire Cargill's US seed business.[60]

Trait	AgrEvo	Monsanto /Calgene	Cargill
Herbicide tolerance	4	49	12
Product quality		38	10
Agronomic properties	15	10	
Herbicide tolerance/insect resistance	4		
Fungal resistance			3

Sunflowers

Origin and distribution: the sunflower (*Helianthus annuus*) is probably the only major crop that evolved within the present boundaries of the United States. The wild sunflower has been an important food plant to the indigenous people of western North America. Cultivation of sunflower fields in pre-Columbian times is reported especially from the Pueblo cultures. They used sunflower seeds for direct use as food and prepared a sort of bread from the milled seeds.

Centres of sunflower diversity: Sunflowers evolved in North America and were further domesticated in the former USSR[61]



History: The Spaniards introduced the sunflower to Europe in the 16th century. A report from 1569 describes the cultivation of sunflowers in the Royal Gardens of Madrid, and soon after it was distributed all around Europe. But for nearly 250 years, the sunflower remained a garden flower, rather than an important food crop. Although a British patent in 1716 describes the extraction of oil (*'How from a certaine English Seed might be Expressed a Good Sweet Oyle...'*) from sunflower seeds, this technique did not catch for some decades and the sunflower had only limited commercial value as a coffee substitute or in confectionery. Cultivation on a bigger scale started in Europe in the 1830s, in Russia. After the first experiments by a Russian farmer called Bokarjew, the first sunflower oil mills were built in Russia and, within two decades, sunflower cultivation started on a grand scale in Russia, where later major breeding efforts were undertaken and a second centre of diversity arose.[62] Today, the sunflower is the world's fourth most important oil crop, after soya, palm, and rapeseed oil.[63]

Gene flow: Cultivated sunflowers hybridise with some related species that are native to the USA: *Helianthus exilis* in California, *H. agrophyllus* and *H. debilis* in Texas, *H. petiolaris* at the West Coast and *H. tuberosus* in the eastern States.[64] Sunflowers are modest cross-pollinators, capable of transferring their pollen over large distances. Two Swedish researchers found a 15% outcrossing rate even at a distance of 200m. Over 1000m the rate dropped to 0-2%.[65] In the USA, an isolation zone of 6.4km is recommended to protect commercial sunflower seed nurseries from unwanted wild sunflower pollen.[66]

Wild *Helianthus annuus* is a native, annual weed that is widespread throughout much of the USA. Gene flow between wild and cultivated sunflowers is extensive, and crop genes move continually into wild populations, where they can persist for many years.[67] Some wild relatives of sunflowers are confined to a few localities and are near extinction. The serpentine sunflower *Helianthus exilis* is restricted to a small part of California, and *H. nuttallii parishii* seems to be already extinct. Nine other sunflower species are considered rare.[68]

The sunflower is probably the only major crop that evolved within the present boundaries of the United States

Genetic engineering: Until 1996, there were very few field trials with GE sunflowers. One reason might be the limited value of the sunflower market for the seed companies; another reason is probably the high risk associated with sunflower trials in the US. As a centre of sunflower diversity, several wild and endangered sunflower relatives grow in the USA that could acquire the newly introduced gene through cross-pollination even during a limited field trial. During the past two years, Pioneer – the world's largest seed company, recently taken over by Agro-Chemical giant DuPont – started 15 field trials with GE sunflowers. Pioneer concentrates on two issues: fungal and insect resistance. The underlying mechanism of this resistance is dubbed 'confidential business information' by Pioneer and therefore cannot be assessed in detail. But both traits can be considered fitness enhancing and pose a threat to the genetic diversity both of sunflower varieties and of their wild relatives in the USA. Although the ecological risk is evident, the US Department of Agriculture does not require Pioneer to apply for a release permit, and the USDA performs no environmental assessment. A simple notification procedure allows Pioneer to perform trials at will. A total of 10 field trials with GE sunflowers had been approved in the EU by June 1998 (see Appendix 7).

Some wild relatives of sunflowers are near extinction

Trait	**Pioneer**
Fungal resistance	9
Insect resistance	5
Virus resistance	1
Total	15

No. of field trials with GE sunflowers in the USA in 1997 and 1998.
Only the major company is listed. The total number of sunflower field trials was 8 in 1997 and 11 in 1998.[69]

Rice

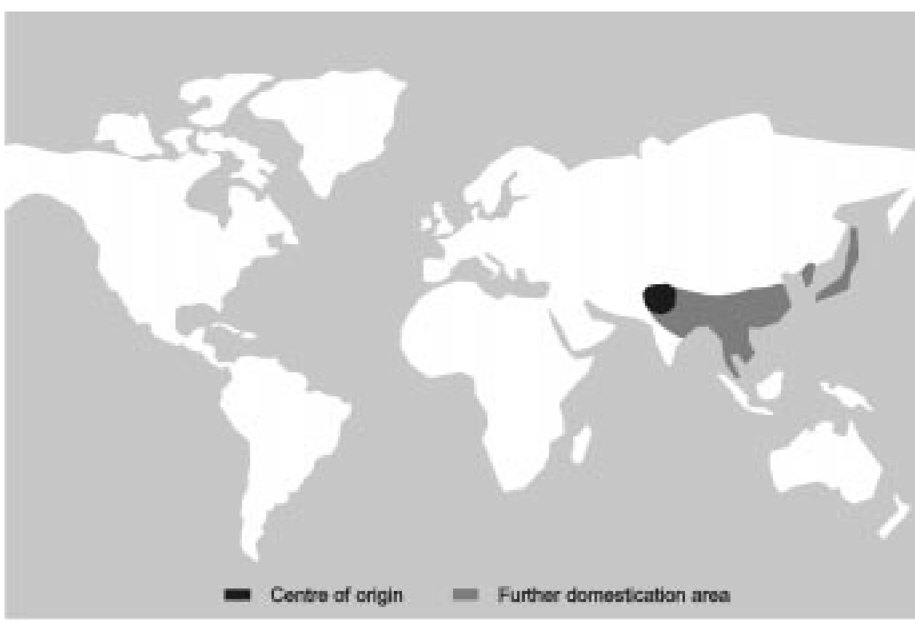
Don't ask me
what rice is.
Don't ask me
my advice.
I've no idea
what rice is,
all I have
learnt is
its price

B. Brecht[70]

Origin and distribution: Rice (*Oryza sativa*) was domesticated in South Asia about 12,000 years ago and adapted itself to a wide range of environments, leading to an estimated 140,000 local rice varieties. [71]

Rice originates from the Himalayan region of north-east India and evolved further in different regions of Southeast Asia. The indica-type appeared first, on the Ganges Plains and in Vietnam and southern China. Indica rice was bred into japonica rice in the Yellow River and Yangtze area of China, and into javanica rice in the Malaysian Archipelago.[72] These areas are the centres of rice diversity. The oldest recorded rice remains are from Mohenjodaro in Pakistan (2500BC), India (2300BC) and Thailand (3500BC).[73]

African rice belongs to another species, *Oryza glabberima*, which has its centre of diversity in West Africa.[74] This species was central to the prosperity of an African rice kingdom, which flourished on the flood plains of the Niger, near Timbuktu, in the 16th century. When the Portuguese introduced *Oryza sativa* to the Guinea Coast, they found local people already practising complex rice irrigation systems, including methods to deal with excess salinity.



Centres of rice diversity: Rice evolved in north-east India and was further domesticated in different areas of Southeast Asia[75]

Use and history: Rice is of great cultural importance for most Asian societies. In ancient India, rice was called ’sustainer of the human race‘. It is the major staple crop for nearly half the world’s population. In Asia, where rice accounts for nearly 80% of the daily calorie intake, it is the key to food security.[76] The Western custom of throwing rice at the wedding bride is borrowed from the Far Eastern religious significance of rice, where it is linked with fertility.

In Chinese and many of the other languages of Southeast Asia, rice is synonymous with agriculture or food. In Thai, *od kow di*, ’without rice‘, signifies starvation. *Java* means ’rice‘[77], and the Japanese word for ’bountiful rice field‘ is *toyota*.[78]

The earliest historical references are found in Chinese writings of about five thousand years ago, when it was stated that the privilege of sowing rice was reserved for the Emperor. Irrigated rice was a comparatively late arrival in terms of world agriculture, as the necessary technology required a relatively advanced civilisation compared to the cultivation of tubers such as yam and taro. Nevertheless, by 2000BC, a huge diversity of rice varieties were already being grown and used. In the Ayurvedic *Materia Medica* from 1000BC, Indian rice varieties are grouped based on their duration, water requirements, and nutritional values.[79]

In modern Chinese, ‘iron rice bowl’ means job security, while ‘breaking the rice bowl’ means being unemployed

Rice reached Japan around 100BC, when it was introduced from China to the island of Kyushu. Today, the Japanese have a preference for short grain rice, which is primarily used only for sweet dishes in the rest of Asia.

The Japanese word for ‘bountiful rice field’ is toyota

In most of Europe, rice was an exotic imported product, valued as highly as the eastern spices that were primarily used as ingredients for sauces. The Italians, who had shown some interest in rice growing since the 10th century, began intensive rice farming in the Po valley from 1522. The new fashion had spread from Portugal, where the court of King Manoel the Fortunate had set the trend when Vasco da Gama had brough rice, amongst other new foods from India in 1499. Rice had always been taken very seriously by the Turks in Asia Minor and by the Arabs, who introduced it to their colonies in Spain. By the 16th century, it became even more widely used in Spain and the Netherlands as well. In the 19th century, rice made a transition from the valued, exotic crop to a staple grain of the poor, suited to feeding the masses.[80]

Rice cultivation in the USA dates from about 1685 when it was introduced to South Carolina,[81] with seed brought on ships from Madagascar. Many of the slaves from northwest Africa, shipped in to work the rice fields, possessed experience and knowledge of rice cultivation their masters lacked. In the early years of American rice cultivation, many of the methods used were derived from traditional African practices.

Trade: Rice is the world’s third most important staple crop with an annual production of 561 million tonnes in 1998,[82] most of it for direct human consumption. In Asia only a small part of the harvest is traded, indicating the great importance of rice for food security in many nations. The USA grows less than 2% of the world’s total rice crop, yet it is the fourth largest exporter, selling up to 60% of its yield abroad.

Rice is the world's third most important staple crop and the food basis for half the world´s population

The value of diversity: In the 1970s, when Asian rice harvests were threatened by a variety of grassy stunt virus, resistance was found in only one rare variety of the wild species, *Oryza nivara*. The extreme rarity of this resistance is curious. More than 6700 samples of cultivated and wild rice varieties were screened, and only this one type was found to be highly resistant to the virus. One reason for this genetic rarity is that the disease was minor until the development of high-yield varieties that could be grown all year round in monocultures. This provided a permanent reservoir for the virus and excellent conditions for the transmitting insects. As the virus was only a minor problem in traditional rice cultivation, there had been no selection pressure on rice varieties to develop resistance.[83]

In 1977, a strain of ragged grassy stunt virus again flared up in India, this time needing the resistance conferred by a variety of a wild Taiwanese rice held in a gene bank. This variety had become extinct in the wild, as the Taiwanese had concentrated on growing Green Revolution hybrids at the expense of their indigenous diversity.[84]

Indonesia alone has more than 13,000 indigenous rice varieties

Indonesia alone has more than 13,000 indigenous varieties.[85] For centuries, the paddies of Indochina produced amazing yields. The secret was the symbiotic relationship between a tiny floating fern, *azolla*, and blue green algae, *anabaena azollae*, which together, convert atmospheric nitrogen into ammonia and soluble nitrates in an accessible form for rice.

Gene flow: There are 25 known wild relatives of rice. About ten of them easily crossbreed with cultivated rice. While the cultivated forms are predominantly self-pollinated, their wild relatives cross-pollinate.[86] Intermediate forms between wild and cultivated rice are found in areas with high genetic diversity.[87]

The following wild relatives of rice are known weeds. They are highly compatible with cultivated rice, i.e. they can crossbreed under natural conditions and produce fertile offspring:

Species	distribution
Oryza rufipogon	widely distributed in Southeast Asia, Oceania, and South America; usually found in deep water swamps;
Oryza nivara	found in Deccan plateau in India, many parts of Southeast Asia and Oceania; it thrives in ditches, waterholes, and edges of ponds
Oryza fatua	throughout southern and Southeast Asia in canals and ponds adjacent to rice fields and in even within the fields.

Sample of weed races indicate that considerable hybridisation is taking place and that geneflow is largely from cultivated to the wild forms.[88] An escape of genes from GE rice plants to wild and weedy relatives seems likely.

Genetic engineering: Some potential GE rice varieties have been extensively quoted in the public debate to stress the health benefits of genetic engineering. One of the first promises was the reduction of allergenic proteins in rice. However this turned out to be far too complex a task and thus had to be dropped by the scientists involved. Yet the 'low allergy rice' is still a prominent argument frequently used by the GE industry. So is the vitamin-A-rice, and the iron-enhanced rice. In fact, both deficiency of vitamin A and iron, can cause severe illnesses. As with maize, a diet solely based on rice is a bad choice and will ultimately lead to deficiency symptoms. To enrich rice with some major vitamins and minerals through genetic engineering is end-of-the-pipe technology and obviously the wrong way to guarantee a healthier diet. Poverty is the reason behind deficiency illnesses, which could easily be fought with the addition of some soybeans (tofu) or greens to the daily diet of the poor. Traditional cultivation practices, involving rotating techniques or intercropping of different crops on one field, have long guaranteed a balanced food supply even for the poorest families.

An escape of genes from GE rice plants to wild and weedy relatives seems likely

Rice has not been a primary target for seed companies, possibly because it proved difficult to develop GE rice. In addition, it is not easy to produce hybrid rice, which makes it less attractive for seed companies. Only hybrid seed guarantees a steady money flow for the seed company, because it cannot be replanted and must be bought every year by the farmer. 80% of the rice seed in Asia is still farm-saved seed.[89]

Little information is available on field trials of GE rice in its centre of diversity. Details on GE research and development in China are not publicly available. At least one field trial with bacterial resistant GE rice developed by the International Rice Research Institute (IRRI) has been performed in China.[90] The IRRI, funded by World Bank and other international institutions, developed several GE rice varieties resistant to insects, fungi or bacteria, but little field testing has been done so far.

In Japan, the government has approved a total of 15 field trials.[91] This comprises four virus resistant lines, three low-protein rice varieties for Sake brewing, three herbicide-tolerant varieties, one reduced allergy line, and four lines with altered compounds. The reduced allergy line is not any longer pursued by the company. The last approval for a field trial dates back to 1995.[92]

The Japanese government has approved a total of 15 field trials with GE rice

In 1999, the Brazilian National Biosecurity Technical Committee (CTNBio) ordered the destruction of a field of GE rice plants in the state of Rio Grand do Sul. The experiment with herbicide-resistant rice plants, developed by AgrEvo, was set on fire as it did not comply with the states' compulsory biosecurity measures.[93]
One of the major incentives for developing herbicide-resistant rice for the USA at least is the persistent problem of red rice, a weedy variety that commonly occurs in southern USA. It is seen as commercially unacceptable because of its red pericarp (covering the grain) and causes losses of hundreds of million dollars annually. As it is genetically similar

to commercially grown rice, selective herbicides have not been available and other forms of control have been commercially prohibitive.

So far only one herbicide tolerant rice variety produced by AgrEvo has been approved for unrestricted use by the US Department of Agriculture, in April 1999.
In 1998, the number of field trials with GE rice in the US jumped to 62 from 18 in 1997. It looks like Hoechst/AgrEvo and Monsanto are preparing for a commercialisation of herbicide tolerant rice varieties in the near future (see chart below).

A herbicide tolerant rice variety produced by AgrEvo is approved for commercial use in the USA

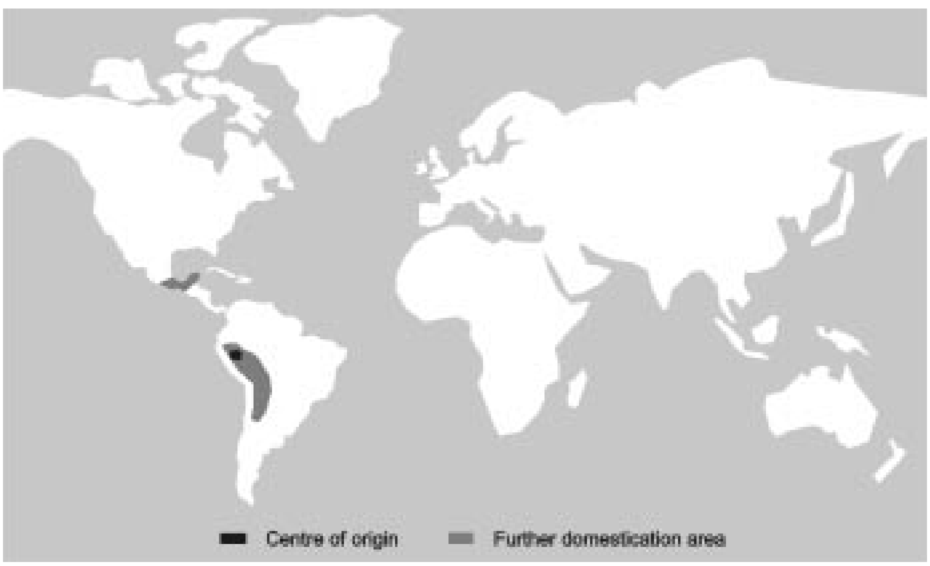
Trait	**AgrEvo**	**Monsanto**
Herbicide tolerance	37	15
Agronomic properties		6
Product quality		2

No. of field trials with GE rice in the USA in 1997 and 1998.
Only the major companies and traits are listed. The total number of rice field trials was 18 in 1997 and 62 in 1998.[94]

Potatoes

Origin and distribution: Potatoes (*Solanum tuberosum*) originated in the Andean region of Central Peru, where the greatest number of tuberous *Solanum* species is found.[95] A second concentration of species diversity is in southern Mexico.[96]

The history of potato domestication is still subject to scientific debate, but there is good evidence that the common potato *Solanum tuberosum* is the result of a cross between two wild potatoes, *S. stenotomum* and *S. sparsipilum*, the latter being a common weed in Bolivia and Peru.[97] According to evidence from ceramics and radiocarbon dating, potatoes were already domesticated at least 7000 years ago.[98]



Centres of potato diversity: Potatoes originated in the Andes of Central Peru and were further domesticated in the Andes and in southern Mexico[99]

History: In pre-Columbian Peru and Bolivia, the potato was not only the most important staple crop, but also of cultural and religious importance. The Incas worshipped the goddess *Aro-Mamma* (potato mother), and buried potatoes with their dead. In 1547, Gieza de Léon reported that during a potato procession a llama was sacrificed to pour its blood over the seed potatoes.[100] Artefacts from 2nd century graves show the sophisticated potato art of the indigenous people, with potato-shaped pottery.[101] Potatoes were simply called *papas*, tubers, by the Indians.

The edible dried potato product *chuño* has long been an important produce in Andean Peru, valued for its nutrition, convenience, shelf-life, and availability during famine.[102] *Chuño* is prepared by leaving fresh potatoes spread out on grass or straw for several days. Then they are carefully squeezed to remove any water. Finally they are dried again in the sun.[103] Special potato varieties with a high glycoalkaloid content are still grown today in frost-prone areas of the Andes for the preparation of *chuño*.

Introduction to Europe: In 1565, the Spanish King Philippe II received several potato tubers as a gift. He sent some of the exotic fruits to Pope Pius IV in Rome and, in the following years, the potato spread throughout Europe, mainly as an exotic rarity for botanical gardens. A first written record of potato consumption in Europe is a letter from the Hospital de la Sangre in Seville in 1573, documenting the ordering of potatoes.[104] From Spain, the potato was taken to Italy, then England in 1586, and then Germany in 1601. Due to their similarity with truffles, potatoes were dubbed *taratoufli* (Spain) or *tartufoli* (Italy), which gave rise to the German name *Kartoffel*. The Latin name *Solanum tuberosum esculentum* translates as 'edible, tuberous nightshade'.[105]

In pre-Columbian Peru and Bolivia, the potato was the most important staple crop

Initially the importance of potato as a food crop seems not to have been properly communicated to Europeans. It was unclear whether the small green fruit or the tuber was intended as the edible product in the sixteenth century Europe. Kinship with the tomato, which also belongs to the nightshade family, and the phallic shape of the tuber was reason enough to label it as an aphrodisiac.[106]

By the end of the 18th century, potatoes had been adapted to the northern European climates[107] and were identified as a staple food that could reliably feed the masses when other crops failed.[108] Potatoes gave significantly higher yields on marginal soils than wheat or barley, and were especially valuable in wartime situations, when their subterranean location protected them from pilferage and destruction.[109] But it took some time for the potato to become widely accepted: the rural population strongly opposed the unknown, unpleasant-tasting crop and refused to plant it. Perhaps this reticence was influenced by the culinary uses of potatoes: even in the 19th century they were often used for bread baking – with fairly poor results. In addition, the potatoes of those days were of poor quality, watery, and sometimes even poisonous. In the view of rural people, these features qualified the potato for animal feed perhaps, but not for human consumption.

Due to their similarity with truffles, potatoes were dubbed tartufoli, which gave rise to the German name Kartoffel

The local authorities, realising the great potential of the potato to feed the masses reliably during wartime, took various measures to force peasants to plant the new crop. In Italy, the church was used for this purpose, and instructions for potato planting were delivered during mass.[110] In Germany, King Friedrich Wilhelm I ordered the planting of potatoes and threatened his people with drastic penalties if they failed to comply.[111] In 1746, his son, King Friedrich II renewed this edict ('Kartoffelerlass') and forced the landowners to plant potatoes on one-fifteenth of their land.[112]

The introduction of potatoes in North America took place in the 18th century, via England and the Bermudas.[113]

Use: Potatoes are predominantly used for direct human consumption today. A significant share is also used as animal feed and for starch production. Potato chips were invented in 1853 by George Crum, an Indian cook in a high-class restaurant in Saratoga

Springs, New York. A guest complained that his french fries were too thick. When Crum prepared a second portion of thinner fries and the guest was still not satisfied, he fought back, cut the potatoes into the thinnest of slices and fried them crispy. This dish was appreciated not only by the guest himself, but also by many of the other guests in Saratoga Springs. Since then, their success has been global.[114]

The value of diversity: Ecuadorian villagers prefer their traditional varieties to the high yielding varieties promoted by the government for several reasons. Taste is one prominent argument, as well as shorter cooking time – an important economic argument. One farmer reports: *'Our own varieties have a much better price on the local market, as the people know and appreciate them.'* Another argument is the particular agronomic qualities needed for the low input agriculture.[115]

Traditional practices are able to overcome accumulation of virus diseases in tubers, the major problem in seed potato production. Ecuadorian farmers often grow potatoes at different altitudes. High up in the Andes, the virus transmitting insects can hardly survive, while in the lower areas they pose a serious threat to potato propagation. Farmers reserve part of the harvest from higher altitudes to sow in the plains, thus assuring that the seed potatoes are relatively virus free.[116]

By planting their seed potatoes high up in the Andes, Ecuadorian farmers ensure that the seed potatoes are relatively virus-free

Globally, about 5000 potato varieties are grown today. Andean farmers cultivate some 3000 of them.[117] More than 1000 varieties of potatoes in the Andes have their own names.[118] In rural Peru, an average of 20 or more different potato varieties can be found growing in one field.[119] In the Quechua or Aymara languages, variety names are often descriptive of appearance (*cat's face, black girl, llama's tongue, puma's paw*) or function (*potato for fever, potato for weaning of children from mother's milk*).[120] Potatoes grow from below sea level to an altitude of 4500m, from the Arctic Circle to southern Africa.[121] It is difficult to keep potatoes in gene banks because they are not stored as seeds, but as tubers, which are difficult to maintain. Of the 6500 potato samples kept at the International Potato Centre in Lima, 5000 are replanted each year.[122] Only 50 percent of wild *Solanum* species are stored in gene banks.[123]

The toll of uniformity: When cultivated potatoes were taken to Europe, they passed through a genetic bottleneck. Until 1851, the European crop seems to have been based entirely on only two introductions, one to Spain in the 1570s and another one to England around 1590. This genetic uniformity made European potatoes extremely vulnerable to epidemics.[124] It ultimately led to the Irish Famine in the 1840s. Potatoes grown in Europe lacked resistance to the blight. In 1845, *Phytophtora infestans*, a fungus causing potato leaf blight, hit Ireland for the first time. The potatoes began to turn black and rot in the ground. Due to their very limited genetic variation, the fungus had no barriers and soon spread around the country and destroyed the harvest. The famine continued for five years. One to two million people died, and as many migrated to North America.

In rural Peru, an average of 20 or more different potato varieties can be found growing in one field

Cary Fowler and Pat Mooney have noted that the Irish Famine was the consequence of not only the devastating effect of a fungus meeting genetic uniformity, but also a particular social and economic system.[125] In Ireland, the potato was the staple crop of the poor. Three-quarters of the land was planted with cereal crops, but nearly all of this was exported to England. In 1847, Ireland produced enough agricultural products to feed Ireland twice over, but the people starved because they could not afford to keep or buy the grain they raised.

Catch 22: Conventional breeders rely on the genetic diversity of their crop which, in turn, is threatened by the result of their work – the modern high-yielding varieties. Dr. Carlos Ochoa highlighted this dilemma in a letter to Cary Fowler and Pat Mooney in 1983: *'I remember that near to 25 years ago I was exploring Northern Peru. At that time, it still was possible to find dozens of interesting primitive potato cultivars. 20 years later it was more difficult to find such variability. Many of them, like ´Naranja´ for instance, probably are extinct. The main reason, I am sorry to say, is the introduction of ´Renacimiento´, one of the varieties that I bred, long time ago, for this country.'*[126]

Gene flow: There are approximately 200 wild *Solanum* species in South and Central America, many of which can crossbreed. According to potato specialists, geneflow from GE potatoes to wild species is inevitable.[127] Preliminary results from the US risk assessment programme indicate that cultivated potato can form hybrids with the majority of its tuber bearing relatives.[128] Cultivated potato is highly compatible with *Solanum sucrense*, a well-known weed in the Andean region.[129] More than 20 wild species of potato have contributed genes to domestic potatoes.[130]

Genetic engineering: There have been several field trials of GE potatoes in its centre of diversity. In 1993, frost-resistant potatoes produced by the Central University of Venezuela were field tested in Bolivia.[131] By 1995, the International Potato Centre (CIP) had performed three field trials in Peru or in neighbouring Andean countries.[132]

GE potatoes are already marketed in the USA and Canada. Monsanto has full approval for two lines, an insect resistant potato (NewLeaf) and a potato line with combined insect and virus resistance. The insect resistant line contains a *Bt*-toxin that is targeted at the Colorado potato beetle. It is grown on nearly 100,000 hectares of land in the US.[133]

In 1998 a Greenpeace investigation revealed that GE potatoes had been introduced on a large scale into Georgia. Although Georgia has no regulatory framework to assess the ecological and health risks of genetically engineered crops, Monsanto cut a deal with the Georgian government and exported a total of over 130 tonnes of seed potatoes in 1996, which were planted and sold also in subsequent years. It became evident that the GE potatoes were beyond control after harvest and were freely distributed around the country and even exported to Russia and Azerbeijan. Risk assessment, monitoring and

informing the farmers did not meet any perceivable standards.[134]
Monsanto's GE potatoes have also been introduced to the Ukraine. They have reportedly been picked up by neighbouring gardeners from test plots in 1997 and 1998 and made it to the local markets without any further notice and approval.[135] It remains unclear whether field trials with GE potatoes have been or are being performed in Eastern Europe, as most countries do not publish data on field trials.

The next generation of GE potatoes – developed nearly exclusively by Monsanto – will probably have altered starch composition and fungal resistance (see list below). Field trials in Europe – where no commercial approval has been granted so far for GE potatoes – also concentrate on altered product quality, namely altered starch composition (see Appendix 7).

The next generation of GE potatoes will have altered starch composition and fungal resistance

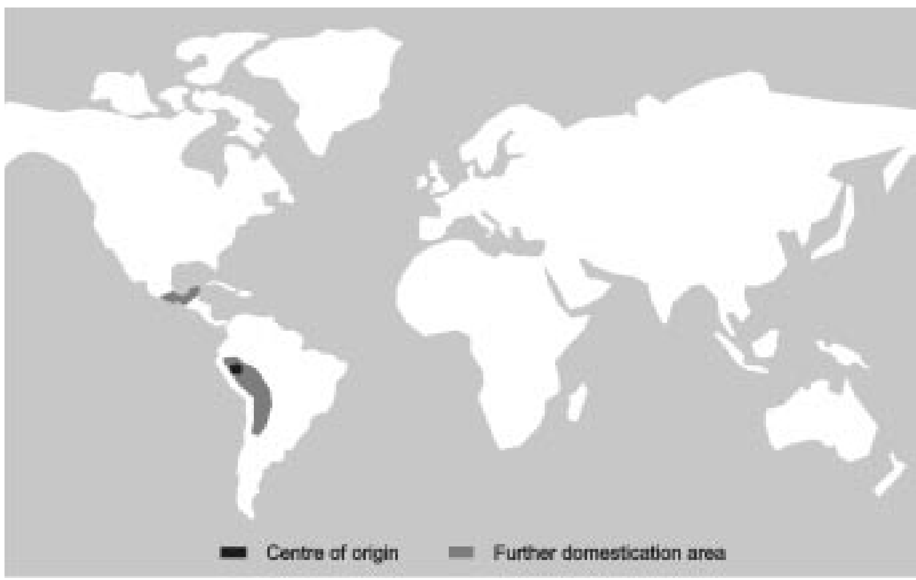
Trait	**Monsanto**
Insect resistance/virus resistance	100
Product quality	65
Insect resistance	39
Fungal resistance, also in combination with other traits	31
Multiple	15
Virus resistance	7
Total	259

No. of field trials of GE potatoes in the USA in 1997 and 1998.
Only the major company is listed. The total number of potato field trials was 120 in 1997 and 213 in 1998.[60]

Tomatoes

Origin and distribution: Tomatoes (*Lycopersicon esculentum)* originated on the west coast of South America, but domestication took place in Mexico. One of the wild Andean species managed to reach Mexico in ancient times, where indigenous people domesticated the newcomer.[136] Although wild relatives of tomato are restricted to the Andes, the greatest variation of cultivated tomatoes can be found in the Veracruz-Puebla area in Mexico.[137]

Centres of tomato diversity: Tomatoes originated on the west coast of South America and were domesticated in Mexico[138]



History: The pre-Columbian Indians of Mexico and Peru cultivated highly-developed tomato varieties. After its introduction to Europe at the beginning of the 16th century, the tomato was used as a vegetable only in the Mediterranean region. It was regarded as poisonous in Northern Europe. It soon became known as *poma amoris* (love apple) or *poma aurea* (golden apple) throughout Europe, before the Mexican name *tomatl* became more widely used in Europe. In Northern Europe, tomato plants were restricted to horticulture until the mid 19th century.[139] In a German cookbook from 1832, *'pomi d´oro'* are mentioned as a common ingredient for soups in Southern Europe, providing a pleasant taste and a nice reddish colour. The author was indignant about the fact that this *'spicy fruit is neglected in Germany'*.[140]

Trade: Tomato accounts for half of the world market for vegetable seeds with estimated annual sales of US $1.6bn.[141] Tomatoes are the most widely-produced vegetable with an annual production of 89m tonnes in 1998. The biggest producers are China (16m tonnes), USA (10m tonnes), Turkey (6.6m tonnes) and Egypt (6m tonnes).

The value of diversity: During a 1962 expedition in the Peruvian Andes, the botanist Hugh Iltis discovered a quite unspectacular, tiny wild relative of the commercial tomato, with small greenish-white berries. It was later named *Lycopersicon chmielewskii* by the famous tomato breeder Charles Rick. Eighteen years later and after ten generations of backcrossing, Rick was able to cross the wild species with cultivated tomatoes. The offspring had bigger fruit and – commercially most important – a higher content of solids. The new hybrid had up to 8.6% solids, a quantum leap compared with the 4.5-6.2% of conventional tomatoes. This is equivalent to an additional value for the US-food industry of US $8m annually.[142]

The intriguing diversity of tomato relatives is highlighted by a species that was found growing along the beach on one of the Galapagos islands, at a distance of only 5m from the sea, exposed to the salt spray and in very salty soil.[143]

The loss of diversity: The US Department of Agriculture (USDA) has a list of 10,000 old varieties that have been developed all over the world. Much of this diversity has already been destroyed. A study by the Rural Advancement Foundation International (RAFI) in 1982 found that 80% of commercial tomato varieties listed in 1903 by the USDA were no longer found in US seed banks.[144]

Gene flow: Tomatoes and wild relatives can intercross easily. Spontaneous hybridisation with *Lycopersicon pimpinellifolium*, a weed in Peru and Ecuador, is common and introgression of *L. pimpinellifolium* genes into tomatoes has been observed.[145] The wild tomato form *L. esculentum var. cerasiforme*, which can interbreed with cultivated tomatoes, is considered a weed in the US, Honduras, and Taiwan.[146]

Tomatoes can forward their genes easily to wild and weedy relatives

In most regions of its cultivation, the tomato is considered a self-pollinator with only very limited outcrossing. But it has been shown that outcrossing rates tend to increase in tropical regions. Experiments in Peru revealed outcrossing rates as high as 25.7%.[147]

Genetic engineering: According to the Mexican authorities, by 1998 22 experiments with GE tomatoes had been approved in Mexico. It remains unclear whether these tests were performed under contained conditions (laboratory, greenhouse) or in the field.[148] Most of the lines tested had the delayed ripening trait found in the famous 'FlavrSavr' tomato in the USA, the first GE crop ever to get approval for commercial use worldwide.

22 experiments with GE tomatoes have been approved in Mexico

In 1996, Greenpeace investigated a greenhouse trial of GE tomatoes in Guatemala. Even the greenhouse trial – which is intended to contain the genetic material in a safe manner and prevent uncontrolled spread – was not contained. The doors of the greenhouses were kept open, access to the greenhouse was not restricted: even domestic animals such as goats from neighbouring farms could get in, and the tomatoes were dried in open areas. This example highlights the possibility of gene flow even from greenhouse trials.[149] It is worthwhile remembering that tomato seeds are among the most resistant to digestion and pass through the intestine intact. Thus they are readily dispersed by birds or mammals.

Today, some five GE tomato lines have been approved for commercialisation in the USA (see Appendix 5), but it seems that most of them are not grown commercially or failed economically. There are still some ongoing field trials of virus and insect resistant tomato lines that might lead to commercial GE varieties in a couple of years.

In the European Union an application by Zeneca for commercial approval of delayed ripening GE tomatoes via Spain is still pending. Zeneca has been making promotional sales of GE tomato puree from genetically modified US tomatoes in Great Britain since 1996. These sales were cancelled by the supermarkets in 1999.

No. of field trials of GE tomatoes in the USA in 1997 and 1998.

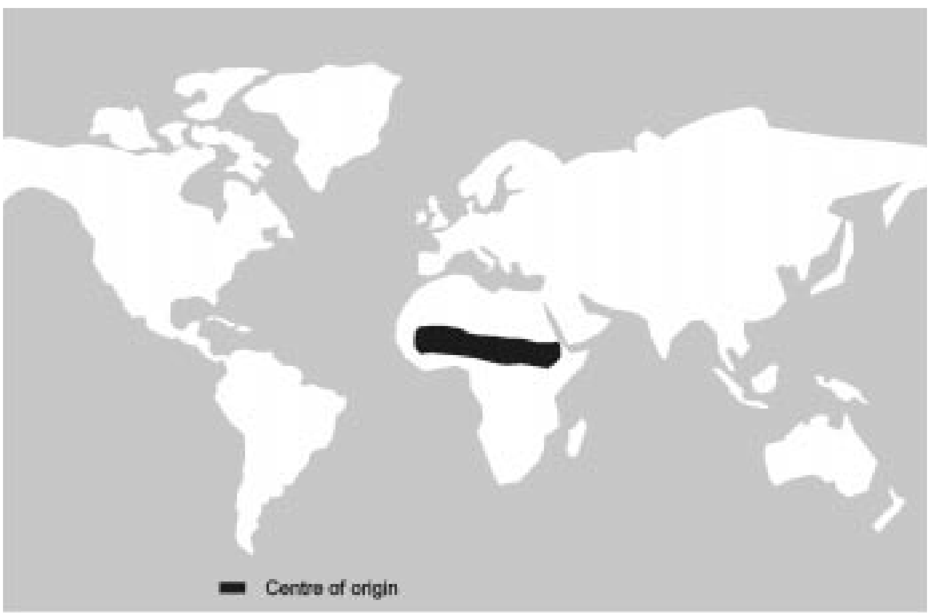
Trait	Calgene	DNA Plant Tech	Seminis	Zeneca
Product quality	2	11	4	13
Virus resistance	7		8	
Insect resistance	7		1	
Fungal resistance	2	2	4	
Total	19	14	18	13

Only the major companies and traits are listed. The total number of tomato field trials was 56 in 1997 and 61 in 1998.[60]

Sorghum

Origin and distribution: The greatest variation of both cultivated (*Sorghum bicolor*) and wild sorghum is found in north-eastern Africa. Wild sorghum probably occurred as a weed in cereal fields before domestication took place some 6000 years ago in what is now Ethiopia[150] and/or, according to Harlan[151] and Odenbach,[152] in the sub-Saharan savannah belt that stretches from Lake Chad to the eastern Sudan.

It reached India around 1000BC, probably as ships' provisions on the *dhows* that regularly travelled the Africa-India route in those times. Soon thereafter it reached China.[153]



Centres of sorghum diversity: *Sorghum bicolor* was domesticated in the sub-Saharan savannah belt, possibly in several independent episodes[154]

Use: Sorghum is the fourth most important cereal crop after wheat, rice, and maize, and is a dietary staple of millions of the world's poorest people in the Sahelian zone of Africa, the Near and Middle East, India, and China. Sorghum embraces numerous varieties adapted to different ecological niches. Sorghum is particularly hardy and drought-resistant. It is the predominant cereal in areas too hot and dry for maize.

In India, certain varieties can be used as rice substitutes, as are some West African types known as 'poor man's rice'. Main use of sorghum is as porridge or a dough-like paste. Another popular use in India is as *rotti* (bread), a round, flat cake. Even pop sorghum and sugary sorghum (to be eaten like sweet corn) are known. Sorghum beer is also very popular. Although sorghum is a staple food crop in Africa and India, it is used mainly as animal feed in the West.

In the 1950s, sorghum hybrids with a yield increase of 20-50% were bred in the USA, where sorghum soon became a major feed crop. Today half of the world's sorghum production is used as animal feed.

Valuable diversity: Sorghum is known to have such a wide variation that a wholly satisfactory botanical classification is difficult. Sorghum can grow from sea level up to an altitude of 2700m. It varies greatly in height, which may range from 45cm to over four metres. Sorghum tolerates a wide range of soil conditions with a pH range of 5.0 to 8.5. It can withstand drought periods and salinity better than other cereals like maize. Sorghum remains dormant during a drought period and then grows well afterwards, but it also outyields maize on high rainfall sites as it can better withstand very wet conditions.

One threat to genetic diversity is overgrazing. One form of wild sorghum has virtually disappeared from some sites due to overgrazing, and a wild relative of wheat has been reduced throughout Asia to rocky habitats where it can escape grazing.[155]
The process of domestication and human selection still continues. Jack Harlan, a pioneering scientist in the theory of centres of diversity, once found an African farmer selecting crook-necked sorghum plants for the following year's planting. Why did he save these types? Because, the farmer replied, they are easier to hang from the roof.[156]

Sorghum is a dietary staple of millions of the world's poorest people in Africa and Asia

Well known diversity: Some twenty years ago, an American scientist collected sorghum varieties in Ethiopia and analysed them back in the States. He discovered that one sorghum variety had a very high protein content and excellent baking qualities. He could have saved himself some laboratory time if he had asked the farmer who gave him the seed. This variety is called *sinde lemine* in Ethiopia, meaning 'why bother with wheat?'.[157]

Hybrid Sorghum is a major feed crop in the USA

Gene flow: A close relative of sorghum is johnsongrass (*Sorghum halepense*), one of the most noxious weeds in the USA and worldwide. Wild johnsongrass populations can be found all over the USA. Johnsongrass competes with maize, soybean, cotton, and other crops for sunlight, water, and nutrients, thus reducing crop yield by up to 45%. Cultivated sorghum and johnsongrass can cross under natural conditions.[158] Gene flow from cultivated sorghum to johnsongrass can occur even over large distances. An outcrossing rate of 2% had been found in a distance of 100m.[159]
Wild and cultivated sorghum continuously influence each other through introgression and gene exchange. Crosses of sorghum with wild relatives have resulted in very persistent weeds in Africa[160] as well as in the USA.[161] *Sorghum propinquum*, a wild relative growing in China, is fully interfertile with cultivated sorghum.

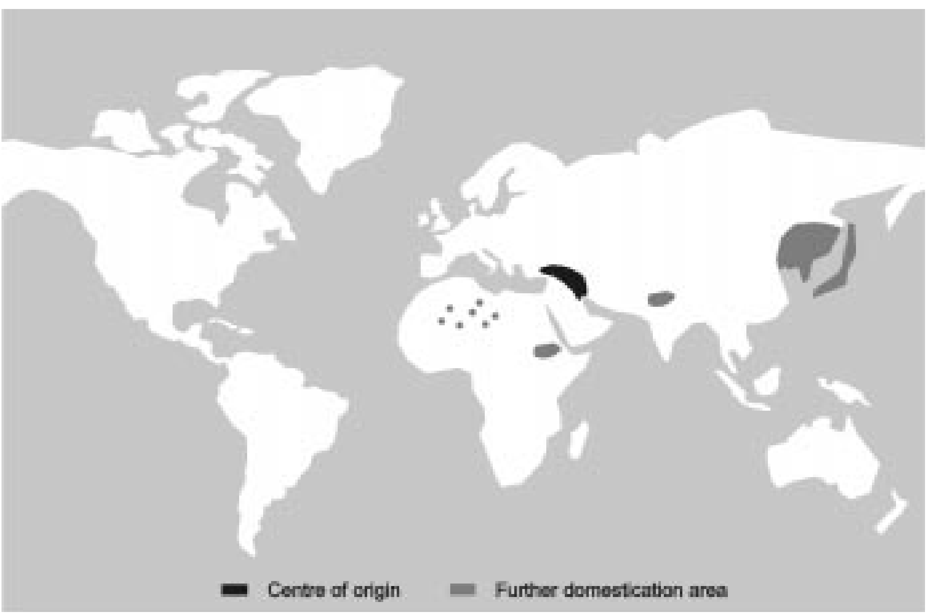
Genetic engineering: The first field trial of GE sorghum containing a marker gene was approved in the USA in 1998.

Other major crops

Wheat

There are two main species of wheat that are economically important: common or bread wheat (*Triticum aestivum*) is by far the most important wheat and the second most important crop worldwide. The second species, macaroni or durum wheat (*Triticum turgidum durum*), is grown in dry parts of the world, such as the Mediterranean area, India, Russia, Ethiopia and other African countries.[162]

Wheat domestication probably took place in the area of the Fertile Crescent. Bread wheat resulted from the spontaneous hybridisation between two wild species, believed to have happened about 8000 years ago in a field in what is now western Iran.[163]



Centres of wheat diversity: Wheat originated in the Fertile Crescent in the Near East. Further domestication of bread wheat (Triticum aestivum) took place in the Saharan oasis, China, Japan, and the Hindu kush, while durum wheat (Triticum turgidum durum) has a secondary centre of diversity in Ethiopia[164]

With an annual production of 591m tonnes (1998) wheat is one of the most important cereals, second only to maize. The largest producer is China, while the USA, Australia, and Canada are the most important exporters. 70 % of wheat production is for human consumption while around 15% is for animal fodder. (see Appendix 4).

Traditional varieties are sometimes perfectly adapted to local conditions. Some wheat varieties in India have developed a new strategy to cope with drought. They shed lower leaves to form mulch, which helps retain soil moisture.[165]

Wheat is the luxury grain of the cereals. During the Roman Empire, it was the crop of the

Wheat is one of the most important cereals, second only to maize

urban population. The white wheat was reserved for the upper class, while peasants and underlings ate black bread made of rye or other less valued grains. A twelfth century poem from Wilhelm of Aquitaine valued wheat bread as much as pepper or wine: *'the bread was white and the wine was fine and the pepper plentiful*.'[166]

Wheat accounts for 410,000 accessions in gene banks, with some 95% of the traditional varieties and 60% of the genetic diversity of wild relatives collected and stored in the gene banks. The major collections are concentrated in industrialised countries: the biggest is in the former USSR, the following two in the USA.

410.000 wheat samples are stored in gene banks worldwide

Traditional wheat varieties in Greece had virtually disappeared by the 1970s, except in remote mountain areas. Greek law required 'modern', high yield wheat varieties to be grown. Not even 10 percent of the wheat varieties grown in Thessaly and Macedonia are local.[167]

Gene flow and genetic engineering of wheat: There are 27 wild *Triticum* species that are distributed in the Mediterranean area and Southwest Asia. The centre of the distribution is Turkey, Syria, Iraq, and Iran, which contain nearly 20 of the wild species. Some of them (e.g. *T. triuniciale, T. ovatum, T. cylindricum*) that are known to be weedy and that grow in a wide array of climatic conditions, are close relatives of both domesticated species and can form natural hybrids with them. The specific genetic structure of the genus *Triticum* accounts for the comparatively high rate of successful hybridisation and geneflow between many *Triticum* species. Many spontaneous hybrids and back-crossed progeny have been found in Greece, Turkey, and Israel. Under artificial, laboratory conditions, fertile offspring could be obtained from the cross-breeding of the two cultivated species with any of 21 wild species.[168]

In the USA, jointed goatgrass (*Aegilops cylindrica*) is a major weed in wheat producing areas. It is interfertile with wheat, and hybrids between wheat and goatgrass occur in the field. Recent research demonstrated that fertile offspring of these hybrids could be obtained under natural conditions. Geneflow from wheat to this noxious weed seems likely.[169]

Although wheat is a very important crop worldwide, it has only limited value for the seed market. As no hybrid wheat is available, farmers can save their own seed and replant it several times before buying commercial seeds. Therefore, little research has been done by the big biotech companies on wheat – with the exception of Monsanto.
It is Monsanto's ultimate goal to produce GE hybrid wheat. If successful, a huge new mar-

ket for wheat seed would be created, with unforeseeable consequences for farmers and agriculture around the world. Monsanto has already bought major wheat breeding companies in Europe and has introduced into wheat several new GE traits such as fungal resistance or herbicide tolerance. But the crucial question remains whether Monsanto will be able to produce hybrid seed in the near future and thus generate a new market.

Geneflow from wheat to jointed goatgrass, a noxious weed in the USA, is likely

A total of 62 field trials with GE wheat had been approved in the US in 1997 and 1998 (see Appendix 6), and 10 field trials were approved in the EU by June 1998 (see Appendix 7). Cassava (*Manihot esculenta*) is also known as manihot, manioc, or yucca. The tuberous roots contain varying amounts of toxic cyanogenic glycoside. Around 70% of the Cassava plants with high amounts of the glycoside (100mg/kg and more) are classified as bitter and require special processing prior to consumption. Roots with lower glycoside contents are classified as sweet.

Cassava

Sweet cassava was probably first domesticated in Mexico/Guatemala, while the bitter cassava was domesticated in the north-eastern part of South America.[170] Most diversity among the 98 wild cassava species can be found in two areas: north-eastern Brazil extending towards Paraguay and western and southern Mexico.[171] In Brazil, the diversity increased through intraspecies crosses and by hybridisation with wild manihot species. The weedy *Manihot saxicola, M. melanobasis* and other weedy species may derive from cultivated cassava.[172]

Significant and unique diversity of cassava has evolved and has been developed by farmers in Africa after it was brought there from Latin America, which makes Africa a secondary centre of diversity.

Cassava is a staple crop throughout the tropics and is essential to food security in most regions of Africa. More than any other staple crop, it is suited to the security needs of the traditional farmer. It can withstand harsh environmental conditions, including drought, weeds, pests, and soils ranging from a pH factor of 5.0 up to 9.0. One of the greatest assets of cassava is that it has no specific maturity period when it must be harvested and

Centres of cassava diversity: Cassava originated in the Amazon lowlands and Mexico/Guatemala. Secondary centres of diversity arose in sub-Saharan Africa and Indonesia[173]

it has an ability to continue to grow and store well in the ground following the initial harvest of some of the tubers. Once dug, it must be processed immediately as they store very poorly and generally begin to rot within two days of harvesting.[174] Worldwide losses after harvest are estimated to be one fifth of the production annually.

The main producer is Nigeria, followed by Brazil, Congo, Indonesia and Thailand. There are various way to remove the cyanide content of cassava to make it suitable for consumption, such as drying, grating, and squeezing out the juice followed by toasting or cooking and fermentation. It is then processed to flower and paste for baking, soups, stews and countless other recipes, or to chips or starch. In Thailand, nearly all the production is for export as animal fodder, which accounts for about 20% of the world harvest.

When cassava is the only source of nutrition it can cause severe deficiency diseases. Also early consumption without proper detoxification, especially in drought and famine situations, causes massive degenerative nerve diseases, such as Konzo, which leads to spastic paraperesis.[175]

Cassava is essential to food security in most regions of Africa

Gene flow and genetic engineering of cassava: In Brazil (especially southern Goias and western Minas Gerais), nearly 40 wild manihot species are growing, some of which are weedy (e.g. *M saxicola, M. melanobasis*). They cross readily with cultivated cassava.[176]

Compared to other crops, conventional breeding of cassava has been neglected in the past by the majority of research institutions and international organisations.[177] Only very limited work has been done on higher yields or improved postharvest characteristics. However, in 1988 the international Cassava Biotechnology Network was established, funded by European donor countries, USAID, and the Rockefeller Foundation. Its goal is the development of GE cassava varieties and their introduction into several developing countries. By 1996, the first GE varieties were produced in four labs in Columbia, Switzerland, the USA, and the Netherlands, and first field trials are expected in 2001.[178]

GE cassava is currently being developed by an international research initiative

Beans

The common bean (*Phaseolus vulgaris*) has several probable domestication centres in Latin America. Although it is usually stated that the common bean originated in Central America, there is evidence for one or two other areas in the Andes and another possibility in Columbia.[179] The earliest remains of cultivated beans date back to 6000BC and were found in a Peruvian cave.[180]

Five species out of the 55 in the genus *Phaseolus* were domesticated in pre-Columbian times. In the Aztec and Incan empires, great importance was given to *Phaseolus vulgaris*, which was even used to pay tributes.[181] In pre-Columbian times, *Phaseolus*-beans were distributed throughout the Americas, from what is now the USA to Argentina.[182]

Centres of common bean diversity: *Phaseolus vulgaris* was domesticated in Central America and in the Peruvian Andes. Secondary centres of diversity arose in different regions of Latin America[183]

Like maize, the colour variation of beans is attributable to different germination patterns. In cooler, highland zones of Central America, one advantage of sowing multicoloured beans is the different germination rates of the different seeds. Since the arrival of the first rains in spring is generally erratic, traditional farmers assure the survival of some of their varieties by planting seeds of different colours.[184]

Gene flow and genetic engineering of beans: Cultivated common beans can hybridise with wild forms of *Phaseolus vulgaris* and perhaps with *P. coccineus*.[185] Although a self-fertiliser, outcrossing rates of up to 66 percent have been reported. Hybridisation with another bean species (*P. polyanthus*) has been observed under natural condition.[186] No field trials of GE beans have been approved so far in the European Union or in the USA, but one field trial with insect resistant red beans, developed by the National Agriculture Research Centre, was approved 1999 in Japan.[187]

Beet

Beet (*Beta vulgaris*) is a relatively young crop that was brought into cultivation just 3000 years ago. Its first use was as a leafy vegetable (mangold). Historical evidence suggests mangold cultivation in Babylon around 800BC. Aristophanes mentions, at 425BC, the use of the beet root for animal fodder.[188] Beet was probably domesticated in the eastern Mediterranean area, where the wild beet *Beta maritima* still is abundant. The use of leaves and roots of the wild plants has probably led to the vegetable beet varieties such as Swiss chard or red beet.[189]

Centres of beet diversity: Beet originated in the coastal areas of the eastern Mediterranean and was further domesticated in Western and Central Europe[190]

While red beet has long been used as a vegetable, cultivation of fodder beet started only 300 years ago in Central Europe. Beet production on a wide scale only started when its use for sugar production was discovered and sugar beet was developed.

Beet production on a wide scale only started 200 years ago, when its use for sugar production was discovered

It has long been known that some beet varieties are especially sweet tasting. The French agriculturist Olivier de Serres mentioned in 1600 in his *Théatre d'agriculture* a beet variety with a succulent root from which a dark red syrup-like juice could be produced. In 1747, the German chemist Andreas Sigismund Marggraf discovered in the roots of white mangold a 'salt' that was identical to *'true, perfect sugar'* from sugar cane.[191]

Sugar beet is an example of an industrial crop, bred only for processing in centralised factories. In the mid 18th century, the sole source of sugar was sugar cane, making sugar a luxurious good that had to be imported from the colonies. A scholar of A.S. Marggraf, F.C. Achard, started selection of beets in 1786 and built the first sugar factories in Europe, with strong support from the Prussian government. At that time, a public debate on sugar import was initiated which focused on human rights (sugar cane was produced by slaves

Cultivated beet can easily form hybrids with wild beet

in the colonies), but the driving force for the government was probably the economic goal of reducing expensive imports. The final breakthrough for sugar beet cultivation in Europe was an edict issued by Napoleon in 1811, who, due to the continental blockade, had to cope with a shortage of sugar. He ordered plantation of 32,000ha sugar beet in 1811, and 100,000 ha in 1812.[192] At the beginning of the 19th century, breeding of sugar-enriched beet varieties led to the first sugar beet variety *Weisse schlesische Zuckerruebe*, the parent of all sugar beets. Within 100 years, sugar contents of beet was raised from 2% to over 15%. Between 1835 and 1914, per capita consumption of sugar in Germany increased from 2 to 25kg annually.[193]

Gene flow and genetic engineering of beet: Three wild *Beta* species from the Mediterranean region, Canary Islands, and Madeira easily hybridise with cultivated beet.[194] In Northern Europe, spontaneous hybridisation between cultivated beet and wild beet *Beta vulgaris maritima* has been observed. The hybrids are now considered weeds in beet fields.[195] Experiments have proved that beet pollen can successfully fertilise other beet plants within a distance of several hundred metres (see Appendix 3).

The European beet is an important one, and several companies are engaged in genetic engineering of sugar and/or fodder beet. As in the USA, the main GE trait is herbicide tolerance, but two of the largest European seed companies, KWS (Germany) and Novartis, are also working on virus resistant lines. A total of 197 field trials with GE beet have been approved in 1997 and 1998 in the EU; 93 trials were approved in the USA. (see Appendix 6) Commercial approval has not yet been granted either in the USA or in Europe.

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Appendix 1 Centres of diversity of some major crops

	Originates from	**further domesticated in**	**Reference**
Maize (*Zea mays*)	Mexico	South America	Zeven & de Wet 1982
Rape Seed (*Brassica napus*)	Western Mediterranean	Europe	Zeven & de Wet 1982
Rice (*Oryza sativa*)	SE Himalaya/NE India	– India, Vietnam, S China (race indica) – China, Korea, Japan (race japonica) – Malaysia (race javanica)	Zeven & de Wet 1982
Sunflower (*Helianthus annuus*)	USA	former USSR	Zeven & de Wet 1982
Sorghum bicolor	Subsaharan Africa, Sudan/Chad	– Africa – India	Zeven & de Wet 1982, Harlan 1971
Tomato (*Lycopersicum esculentum*)	west coast of South America	Mexico	Zeven & de Wet 1982
Potato (*Solanum tuberosum*):	Andes of Central Peru	– Andes in Peru, Bolivia, NW-Argentina – Southern Mexico	Zeven & de Wet 1982, Hawkes 1996
Bean (*Phaseolus vulgaris*)	– Central America (Mexico, Guatemala) – Andean region of South – America (Peru, Bolivia, Colombia)		Zeven & de Wet 1982
Cassava (*Manihot esculenta*)	- Central America - northern South America	– Brazil – Southern Mexico – subsaharan Africa – Indonesia	Zeven & de Wet 1982, Prescott-Allen & Prescott-Allen 1988
Wheat (*Triticum aestivum, Triticum turgidum*)	Fertile Crescent	– Ethiopia dum (T. turgi durum, durum wheat) – Saharan oases, Sudan (T. aestivum, bread wheat) – China, Japan (T. aestivum) – Hindukush (T. aestivum)	Zeven & de Wet 1982, Perrino 1996
Beet (*Beta vulgaris*)	Eastern Mediterreanean	– Europe – Central Asia	Zeven & de Wet 1982

Appendix 2

Stored diversity – major crops in gene banks

Crop	Distinct samples	Coverage in % varieties/wild species
wheat	125,000	95/60
rice	90,000	75/10
maize	50,000	95/15
sorghum	30,000	80/10
tomato	10,000	90/70
potato	30,000	95/40
bean	40,000	50/10
beet	3,000	50/10

Number of distinct samples in worldwide gene banks.
The percentage of the real world diversity covered by gene banks is just a rough estimate and probably far too high (Reid & Miller 1989).

Appendix 3

Outcrossing distances of some food crops

Beet (*Beta vulgaris*)	200 m 400 m 600 m	0.42% 0.11% 0.12%	Jensen & Bogh 1941 (in Dark 1971 , Journal of the National Institute of Agricultural Botany 12: 242-266
	0–80 m 80–200 m >200 m	7.7% 1.2% 0.3%	Archimowitsch 1949 (in Free 1970, Academic Press, London/NY)
	6 m 10 m 12 m	17.1% 5.4% 0.7%	Archimowitsch 1949 (in Free 1970)
	<1 m 10 m 15 m 20 m 25 m 30m	0.8–3.8% 0.25–0.4% 0.2–0.6% 0.04–0.13% 1% 0.02–0.05%	Dark 1971, Journal of the National Institute of Agricultural Botany 12: 242-266

Rapeseed **(*Brassica napus*)**	46 m 137 m 366 m	2.1% 1.1% 0.6%	Stringham & Downey 1982, Agronomy Abstracts: 136-137
	1 m 3 m 12 m 24 m 36 m 47 m	1.5% 0.4%, 0.02% 0.004% 0.001% 0.0003%	Scheffler et al. 1993 Transgenic Research 2: 356-364
	200 m 400 m	0.016% 0.004%	Scheffler et al. 1995 Plant Breeding 114: 369-371
	11 m	0.012 %	Paul et al. 1995, Euphytica 81: 283-289
	1 m 16 m 32 m	0.1% 0.001% 0.001%	Pauk et al. 1995, Euphytica 85: 411-416
	100 m 360 m	0.5% 3.7%	Timmons et al. 1996, Nature 380: 487
	1500 m 2500 m	1.2% 0.08%	Timmons et al. 1995, Euphytica 85: 417-423
Sunflower **(*Helianthus annuus*)**	3 m 200 m 400 m 1000 m	<27% 15% <5% 0 – 2%	Arias & Rieseberg 1994, Theoretical and Applied Genetics 89: 655-660
Tomato (*Lycopersicon esculentum*)	22 m	<0.1%	Currence & Jenkins 1942 (in Free 1970, Academic Press, London/New York)
Potato **(*Solanum tuberosum*)**	4 m >4,5 m	0.05% 0%	Tynan et al. 1990, J. Genet & Breed. 44: 303-306
	<3 m <4.5 m <6 m <7.5 m <10.5 m	0% 0.022% 0% 0.004% 0%	Conner 1994, The Molecular and Cellular Biology of the Potato; Wallingford: 245-264
	3 m 10 m 20 m	2% 0.017% 0%	McPartlan & Dale 1994, Transgenic Research 3: 216-225
Sorghum bicolor	5 m 50 m 100 m	2 – 12% 0% 2%	Arriola & Ellstrand 1996, American Journal of Botany 83: 1153-1160

Trade figures (crops in alphabetical order)

Appendix 4

Mt = Metric tonnes

Cassava production (Mt)		**Dried cassava exports (Mt)**		**Dried cassava imports (Mt)**	
World total	164,044,807	World total	3,326,893	World total	4,124,358
Nigeria	30,409,250	Thailand	2,722,114	Netherlands	1,043,740
Brazil	24,304,700	Indonesia	247,001	Spain	850,220
Thailand	18,083,600	Netherlands	139,339	Belgium -Lux	668,430
Congo	16,800,000	Belgium	61,590	Republic	584,842
		-Lux		of Korea	
Indonesia	15,134,021	Costa Rica	38,000	China	300,484
Ghana	6,999,509	Viet Nam	30,500	Portugal	238,932
India	5,868,300	Germany	30,107	Germany	148,806
anzania	5,704,000	Ghana	22,000	Turkey	106,777
Mozambique	5,336,741	Tanzania	21,000	France	77,664
China	3,600,744	Ecuador	2,475	Italy	40,837

Cassava production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively. [29]

Cassava use (Mt)	
Food	93,362,676
Food Manufacture	2,321,160
Feed	31,201,197
Seed	95
Waste	30,340,694
Other Uses	5,030,219

Cassava use (1997)

Maize production (Mt)		Maize exports (Mt)		Maize imports (Mt)	
World total	584,935,147	World total	73,229,767	World total	71,767,712
USA	233,867,008	USA	41,791,696	Japan	16,097,484
China	104,705,412	Argentina	10,965,354	Republic of Korea	8,312,626
Brazil	34,600,876	France	7,340,280	China	5,786,713
Mexico	17,656,258	China	6,617,333	Egypt	3,059,000
France	16,832,000	South Africa	1,690,750	Malaysia	2,744,600
Argentina	15,536,000	Hungary	1,192,097	Mexico	2,518,862
India	10,531,000	Zimbabwe	402,944	Spain	2,503,236
Italy	10,004,697	Brazil	358,204	Netherlands	1,769,074
Indonesia	8,770,851	Germany	353,358	Colombia	1,734,088
Canada	7,180,000	Canada	263,205	United Kingdom	1,472,912

Maize production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively.[29]

Maize use (Mt)	
Food	101,882,833
Food Manufacture	50,529,550
Feed	395,636,598
Seed	5,248,538
Waste	24,203,357
Other Uses	13,406,948

Maize use (1997) [29]

Potato production (Mt)		Potato exports (Mt)		Potato imports (Mt)	
World total	291,870,802	World total	6,871,884	World total	6,906,757
China	47,638,698	Netherlands	1,443,720	Netherlands	1,190,078
Russia	37,039,712	Germany	940,845	Germany	645,413
India	25,065,400	France	874,057	Belgium-Lux.	714,400
USA	21,116,000	Belgium-Lux.	871,613	USA	346,916
Poland	20,775,644	Canada	436,656	Spain	465,697
Ukraine	16,700,800	USA	314,522	Italy	425,608
Germany	12,067,359	Italy	233,257	France	284,867
Netherlands	7,973,000	Egypt	232,963	UK	241,502
UK	7,125,000	Turkey	222,288	Canada	260,337
France	6,686,000	UK	190,880	Algeria	217,000

Potato production (1997) and trade (1997). Countries with the highest production and exporting volumes, respectively.[29]

Potato use (Mt)	
Food	168,120,739
Food Manufacture	15,672,276
Feed	51,111,196
Seed	35,483,067
Waste	22,296,179
Other Uses	7,048,808

Potato use (1997)[29]

Rapeseed production (Mt)		**Rapeseed exports total (Mt)**		**Rapeseed imports total (Mt)**	
World total	35,436,843	World total	6,399,012	World total	5,908,374
China	9,544,008	Canada	2,837,272	Japan	2,061,945
India	6,942,300	France	2,208,131	Germany	1,236,247
Canada	6,393,000	Germany	250,651	Mexiko	562,323
France	3,495,000	Australia	394,213	Belgium-Lux.	397,822
Germany	2,866,510	UK	176,953	USA	319,775
UK	1,527,000	Czech Republic	93,242	UK	306,892
Australia	860,000	Hungary	77,328	Netherlands	261,896
Poland	594,899	Slovakia	49,464	Poland	148,942
Czech Rep.	561,460	Belgium-Lux.	45,162	Canada	127,856
USA	415,640	Denmark	41,180	Bangladesh	123,200

Rapeseed production (1997) and export (1997). Countries with the highest production and exporting volumes, respectively [29]

Rapeseed use (Mt)	
Food	682,442
Food Manufacture	31.446,414
Feed	2.317,418
Seed	426,095
Waste	1.022,986
Other Uses	119,006

Rapeseed use (1997) [29]

Rice production (Mt)		Rice exports (Mt)		Rice imports (Mt)	
World	580,201,506	World	18,070,713	World	18,643,256
China	202,701,300	Viet Nam	3,000,000	Iran	973,000
India	125,200,000	Thailand	3,240,142	Brazil	816,116
Indonesia	49,377,056	India	2,133,554	Nigeria	731,000
Bangladesh	28,182,800	USA	2,296,002	Philippines	722,397
Viet Nam	27,645,800	Pakistan	1,767,206	Iraq	684,000
Thailand	23,338,544	China	1,009,916	Saudi Arabia	665,000
Myanmar	17,673,100	Australia	654,603	Malaysia	639,612
Japan	12,531,000	Uruguay	648,878	South Africa	591,660
Philippines	11,269,000	Italy	632,398	Côte d'Ivoire	470,001
USA	8,114,600	Argentina	537,634	Senegal	402,010

Rice production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively.[29]

Rice use (Mt)	
Food	510.697,801
Food Manufacture	5.019,285
Feed	17.964,326
Seed	18.269,320
Waste	26.411,468
Other Uses	1.098,588

Rice use (1997) [29]

Sorghum production (Mt)		Sorghum exports (Mt)		Sorghum imports (Mt)	
World	62.627,644	World total	6.374,499	World total	6.531,715
USA	16.590,000	USA	5.134,429	Japan	2.781,417
India	9.000,000	Argentina	661,212	Mexico	2.188,522
Nigeria	7.297,000	France	237,574	Israel	439,000
Mexico	5.711,564	Australia	178,121	Spain	302,942
China	4.266,755	China	111,994	China	79,530
Sudan	3.159,000	Netherlands	7,868	Ethiopia	78,500
Argentina	2.499,000	Zimbabwe	7,250	Rep. of Korea	75,779
Ethiopia	2.040,390	Nicaragua	6,888	Honduras	70,529
Australia	1.425,000	Uruguay	5,488	Chile	66,029
Burkina Faso	942,885	Venezuela	4,650	Turkey	52,639

Sorghum production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively.[29]

Sorghum use (Mt)	
Food	25,396,319
Food Manufacture	2,438,364
Feed	29,753,597
Seed	873,782
Waste	3,842,137
Other Uses	34,112

Sorghum use (1997)[29]

Sugar beet production (Mt)	
World	268,238,584
France	34,311,000
United States of America	27,112,000
Germany	25,768,900
Turkey	18,552,700
Ukraine	17,662,800
Poland	15,886,194
China	14,970,000
Italy	13,802,670
Russian Federation	13,879,930
United Kingdom	11,084,000
Spain	8,582,600

Sugar beet production (1997). Countries with the highest production volumes.[29]

Sugar beet use (Mt)	
Food	112
Food Manufacture	257,915,751
Feed	6,322,176
Seed	no records
Waste	911,241
Other Uses	2,338,674

Sugar beet use (1997)[29]

Sunflower production (Mt)		Sunflower exports	Total (Mt)	Cake (Mt)	Oil (Mt)	Seed (Mt)
World	23,721,879	World	11,843,284	3,380,073	4,340,008	4,123,203
Argentina	5,450,000	Argentina	3,927,351	2,113,666	1,745,693	67,992
Russia	2,831,360	France	1,631,411	100,701	436,300	1,094,410
Ukraine	2,308,400	Ukraine	1,366,977	105,600	187,057	1,074,320
France	1,995,000	Russia	969,222	722	18,500	950,000
USA	1,707,000	Belgium-Lux.	581,145	222,746	293,238	65,161
Spain	1,373,200	Netherlands	563,267	246,052	236,211	81,004
China	1,210,002	USA	509,790	15,815	357,893	136,082
India	1,150,000	Romania	427,402	180,760	221,870	24,772
Turkey	9,000,000	Hungary	398,061	24,542	218,018	155,501
Romania	857,860	Spain	216,357	43,436	132,378	40,543

Sunflower production (1997) and export (1997). Countries with the highest production and exporting volumes, respectively.[29]

Sunflower use (Mt)	
Food	420,056
Food Manufacture	22,879,446
Feed	992,424
Seed	505,290
Waste	395,969
Other Uses	4,814

Sunflower use (1997)[29]

Tomato production (Mt)		Tomato export	Total (Mt)	as whole tomato	as tomato paste	Tomato import	Total (Mt)	as whole tomato	as tomato paste
World	87.487,893	World total	4.977,449	3.535,953	1.441,496	World total	4.769,728	3.580,908	1.188,820
China	16.387,394	Spain	1.032,412	958,918	73,494	USA	765,311	742,464	22,847
USA	10.762,000	Mexico	700,380	687,637	12,743	Germany	748,928	621,692	127,236
Turkey	6.600,000	Netherlands	613,648	607,769	5,879	France	426,636	366,710	59,926
Egypt	5.873,441	Italy	537,529	132,559	404,970	UK	391,822	296,721	95,101
Italy	5.574,497	USA	326,322	179,093	147,229	Netherlands	298,829	268,437	30,392
India	5.300,000	Turkey	291,533	132,010	159,523	Russia	235,955	206,000	29,955
Spain	2.941,700	Morocco	191,940	188,653	3,287	Canada	213,274	162,255	51,019
Brazil	2.640,764	Belgium-Lux.	166,068	162,781	3,287	Saudi Arabia	137,204	129,978	7,226
Iran	2.547,075	Greece	162,099	4,349	157,750	Italy	129,225	30,003	99,222
Greece	2.013,279	China	135,226	28,444	106,782	Poland	83,381	54,538	28,843

Tomato production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively.[29]

Tomato use (Mt)	
Food	77.850,120
Food Manufacture	304
Feed	1.140,004 (in Turkey 990,004 Mt tomatoes are used as feed)
Seed	(no data available)
Waste	7.502,412
Other Uses	410,501

Tomato use (1997)[29]

Wheat production (Mt)		**Wheat export (Mt)**		**Wheat import (Mt)**	
World total	612.380,458	World total	106.749,735	World total	105.136,817
China	123.290,193	USA	25.768,091	Italy	6.976,749
India	69.274,704	Australia	19.377,867	Egypt	6.902,000
USA	67.523,000	Canada	18.857,913	Japan	6.315,254
Russia	44.257,720	France	14.600,399	Iran	6.017,000
France	33.847,000	Argentina	8.766,763	Brazil	4.850,161
Canada	24.200,000	Germany	3.861,972	Indonesia	3.611,931
Germany	19.826,800	United Kingdom	3.645,254	Algeria	3.508,490
Australia	19.417,000	Kazakhstan	2.792,388	Rep. of Korea	3.325,469
Turkey	18.650,000	Denmark	1.059,727	Spain	2.973,761
Ukraine	18.403,900	Hungary	970,817	Belgium-Lux.	2.854,258

Wheat production (1997) and trade (1997). Countries with the highest production, importing and exporting volumes, respectively.[29]

Wheat use (Mt)	
Food	418.917,186
Food Manufacture	6.413,120
Feed	95.894,946
Seed	37.637,049
Waste	24.667,892
Other Uses	7.004,993

Wheat use (1997)[29]

Explanatory notes on World Production and Use

Production

Figures relate to the total domestic production whether inside or outside the agricultural sector, i.e. it includes non-commercial production and production from kitchen gardens. Unless otherwise indicated, production is reported at the farm level for crop and livestock products (i.e. in the case of crops, excluding harvesting losses) (...)

Food

This comprises the amounts of the commodity in question and of any commodity derived thereof not further pursued in the food balance sheet, available for human consumption during the reference period. Food from maize, for example, comprises the amount of maize, maize meal and any other products derived thereof available for human consumption. (...)

Food Manufacture

Food manufacture is where the commodity goes out of the food system, usually for industrial use, e.g., soap, but it could cover tourist use of food, as tourists are not part of the population.

Feed

Comprises the amounts of the commodity in question and of edible commodities derived thereof not shown separately in the balances fed to livestock during the reference period, whether domestically produced or imported.

Seed

Comprises all amounts of the commodity in question used during the reference period for reproductive purposes, (...) whether domestically produced or imported. Whenever official data were not available, seed figures have been estimated either as a percentage of supply (...)or by multiplying a seed rate with the area under the crop in the subsequent year.

Waste

Comprises the amounts of the commodity in question and of commodities derived thereof not further pursued in the balances, lost through waste at all stages between the level at which production is recorded and the household, i.e. waste in processing, storage and transportation. Losses occurring before and during harvest are excluded. Waste from both edible and inedible parts of the commodity occurring in the household is also excluded. Technical losses occurring during the transformation of primary commodities into processed products are taken into account in the assessment of respective extraction/conversion rates.

Other uses

Comprise quantities of commodities used for manufacture for non-food purposes, e.g. oil for soap, and statistical discrepancies.

Source: FAO 1999 (http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture)

Explanatory notes on trade

(...) To make the coverage of this yearbook as complete as possible, official trade data have sometimes been supplemented with data from unofficial sources. Use has also been made of trade information supplied by other national or international agencies or organizations. (...)

In a few instances, when information is available in terms of quantities only, corresponding values are estimated, using unit values based on data from trading partners. (...)

Differences between figures given for total exports and total imports of any one commodity may be due to several factors, e.g. the timelag between the dispatch of goods from the exporting country and their arrival in the importing country; the use of a different classification of the same product by different countries; or the fact that some countries supply data on general trade while others give data on specific trade.

Source: FAO 1999 (http://apps.fao.org/cgi-bin/nph-db.pl?subset=agriculture)

Appendix 5 Transgenic crops approved for commercial use in the USA

The chart below is extracted from a publication of the Union of Concerned Scientists.[196] The crops listed below had been cleared by the respective US regulating agencies (USDA, FDA, EPA, depending on the crop and trait, approval of all or some of these agencies is needed in the US) for unrestricted use (farming, food use) as of December 1998.

Product	Institution	Altered Trait
Canola (Oilseed rape)	Monsanto/ Calgene	Altered oil composition -- high lauric acid (for expanded use of rapeseed oil in soap & food products)
Radicchio	Bejo Zaden	Male sterility/ resistance to herbicide glufosinate
Corn	Monsanto	Resistance to corn borer (Bt)
Corn	Hoechst/AgrEvo/PGS	Resistance to corn borer (Bt)
Corn	Novartis	Resistance to corn borer (Bt)
Corn	Mycogen	Resistance to corn borer (Bt)
Corn	Novartis/Northrup King	Resistance to corn borer (Bt)
Corn	Monsanto/DeKalb	Resistance to corn borer (Bt)
Corn	Monsanto	Resistance to herbicide glyphosate & to corn borer (Bt)
Corn	Monsanto/DeKalb	Resistance to herbicide glufosinate
Corn	Hoechst/AgrEvo	Resistance to herbicide glufosinate
Corn	Hoechst/AgrEvo/PGS	Male sterility/resistance to herbicide glufosinate
Cotton	Monsanto/Calgene Poulenc/Rhone	Resistance to herbicide bromoxynil
Cotton	DuPont	Resistance to herbicide sulfonylurea
Cotton	Monsanto	Resistance to bollworm & budworm (Bt)
Cotton	Monsanto	Resistance to herbicide glyphosate
Cotton	Monsanto/ Calgene/ Rhone Poulenc&	Resistance to herbicide bromoxynil bollworms & budworms
Papaya	Univ. Hawaii/ Cornell Univ.	Resistance to papaya ringspot virus
Potato	Monsanto	Resistance to Colorado potato beetle(Bt)

Product	Institution	Altered Trait
Potato	Monsanto	Resistance to potato beetle (Bt) and potato virus Y
Soybean	Monsanto	Resistance to herbicide glyphosate
Soybean	DuPont	Altered oil composition – high oleic acid (to increase stability and reduce polyunsat. fatty acids
Soybean	Hoechst/AgrEvo	Resistance to herbicide glufosinate
Squash	Seminis Vegetable Seeds/ Asgrow	Resistance to watermelon mosaic 2 & zucchini yellow mosaic viruses
Squash	Seminis Vegetable Seeds	Resistance to cucumber mosaic, watermelon mosaic 2, & zucchini yellow mosaic viruses
Tomato (cherry)	Agritope	Altered ripening (to enhance fresh market value)
Tomato	Monsanto/Calgene	Delayed ripening (to enhance fresh market value)
Tomato	DNA Plant Technology	Delayed ripening (to enhance fresh market value)
Tomato	Monsanto	Delayed ripening (to enhance fresh market value)
Tomato	Zeneca/PetoSeed	Thicker skin, altered pectin (to enhance processing value)

Appendix 6 Field trials with transgenic crops in the USA

Crop	No. Of trials
Corn	1259
Potato	333
Soybean	271
Cotton	183
Rapeseed	177
Tomato	117
Beet	93
Rice	80
Tobacco	67
Wheat	62
Melon	48
Poplar	27
Grape	24
Creeping bentgras	21
Sunflower	19
Sugarcane	14
Alfalfa	12
Brassica oleracea	11
Strawberry	10

US-field trials in 1997-98. A total of 2937 field trials with genetically engineered plants were approved by USDA-APHIS in 1997 and 1998, comprising the above listed crops as well as another 32 plants with less than 10 field trials in 1997 and 1998, including Sorghum with one trial in 1998.

Trait	No. of trials
Herbicide tolerance	1,093
Insect resistance	870
Product quality	553
Virus resistance	305
Agronomic properties	270
Fungal resistance	212
Marker genes	100
Others	81
Bacterial resistance	40
Nematode resistance	5

US-field trials in 1997-98. The transgenic crops tested in the US between 1997 and 1998 included 10 different traits. Many crops where engineered with two or more different traits. Thus the above listed trials sum up to more than 2937 trials, as each trait of each trial was counted.

Trait	Beet	Corn	Potato	Rape-seed	Rice	Sun-flower	Tomato	Wheat
Herbicide tolerance	87	218		81	58			18
Product quality		169	93	53			59	6
Insect resistance		275	47	5		8	15	
Herbicide & insect resistance		255		4				
Agronomic properties (mainly male sterility		152		25	7			10
Fungal resistance		75	43	3	3	10	8	18
Insect & virus resistance			100					
Others		50		6				
	4							
Virus resistance	6		23				19	9
Bacterial resistance			8				10	

US-field trials in 1997-98. The number of field trials with the major crops mentioned in this report and the traits introduced into these crops.

Appendix 7 Field trials in the EU 1997/98

Species	FR	IT	GB	ES	NL	DE	BE	SE	DK	FI	GR	PT	IE	AT	Total
maize (zea mays)	160	78	6	42	13	18	22				5	3		1	348
oilseed rape (brassica napus)	93		77	3	10	29	38	14	2	2					268
beet (beta vulgaris)	51	20	30	14	16	20	9	6	23	4			4		197
potato (solanum tuberosum)	7	6	26	3	39	21	1	14	7	2		4		2	132
tomato (lycoper-sicon esculentum)	5	42	1	15	2						1	2			68
sunflower (heli-anthus annuus)	5			3	2										10
wheat (triticum aestivum)			6	2			2								10
rice (oryza sativa)		1													1

Until June 30, 1998, a total of 1256 notifications for field trials with genetically engineered organisms where made in the EU according to the list of SNIFs (summary notifications) circulated under Article 9 of 90/220. Notification does not necessarily mean that the trials were performed.

centres of diversity

global heritage of crop varieties threatened by genetic pollution

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prepared by Dr. Jan van Aken
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Genetic Engineering Campaign
Chausseestr. 131 – 10115 Berlin – Germany
e-mail: ge@diala.greenpeace.org
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