

Biotechnology and food security

[Science](#), [Agriculture](#)



This essay is an attempt to demonstrate why and how biotechnology and agricultural technology have been recommended in the quest to increase food production and reduce its cost. In order to achieve this, relevant concepts and examples will be discussed and a conclusion will then be drawn from the discourse. Anderson (2009) notes that obtaining enough food is an important concern for every nation in the world, and in some countries food shortage is an extremely serious problem. Worldwide, about 840 million people, or about 14 percent of the total population, do not have adequate food. These people suffer from undernutrition, a condition of nutrient deficiency that causes general weakness and fatigue, stymies mental and physical development in children, and makes people susceptible to potentially fatal diseases such as dysentery, whooping cough, and tuberculosis. The majority of the world's undernourished people live in China, India, Africa, and Latin America. She further argues that creating an adequate world food supply poses two challenges. The first is to provide enough food to meet the needs of the earth's expanding population, without destroying natural resources needed to continue producing food. The second challenge is to ensure food security—that is, to make sure all people have access to enough food to live active, healthy lives. Just producing enough food does not guarantee that the people who need it are able to get it. If people do not have enough money to buy food—or to buy the land, seeds, and tools to grow food—or if natural or human-made disasters such as drought or war prevent them from getting food, then people are at risk for undernutrition even when there is an adequate food supply. In industrialized countries, poverty typically prevents people from obtaining food; in

developing countries, the circumstances that cause food insecurity include poverty, low crop yields, and unproductive economic policies. It is not possible to fix a clear decade or series of events as the start of the agricultural revolution through technology. Among the important advances were the purposeful selective breeding of livestock, begun in the early 1700s, and the spreading of limestone on farm soils in the late 1700s. Mechanical improvements in the traditional wooden plow began in the mid-1600s with small iron points fastened onto the wood with strips of leather. In 1797, Charles Newbold, a blacksmith in Burlington, New Jersey, reconceived of the cast-iron moldboard plow (first used in China nearly 2, 000 years earlier). John Deere, another American blacksmith, further improved the plow in the 1830s and manufactured it in steel. Other notable inventions included the seed drill of English farmer Jethro Tull, developed in the early 1700s and progressively improved for more than a century; the reaper of American Cyrus McCormick in 1831; and numerous new horse-drawn threshers, cultivators, grain and grass cutters, rakes, and corn shellers. By the late 1800s, steam power was frequently used to replace animal power in drawing plows and in operating threshing machinery (Evans, 1998). The demand for food for urban workers and raw materials for industrial plants produced a realignment of world trade. Science and technology developed for industrial purposes were adapted for agriculture, eventually resulting in the agribusinesses of the mid-20th century. In the 17th and 18th centuries the first systematic attempts were made to study and control pests. Before this time, handpicking and spraying were the usual methods of pest control. In the 19th century, poisons of various types were developed for use in sprays,

and biological controls such as predatory insects were also used. Resistant plant varieties were cultivated; this was particularly successful with the European grapevine, in which the grape-bearing stems were grafted onto resistant American rootstocks to defeat the *Phylloxera* aphid. Improvements in transportation affected agriculture. Roads, canals, and rail lines enabled farmers to obtain needed supplies from remote suppliers and market their produce over a wider area. Food could be protected during transport more economically than before as the result of rail, ship, and refrigeration developments in the late 19th and early 20th centuries. Efficient use of these developments led to increasing specialization and eventual changes in the location of agricultural suppliers. In the last quarter of the 19th century, for example, Australian and North American suppliers displaced European suppliers of grain in the European market. When grain production proved unprofitable for European farmers, or an area became more urbanized, specialization in dairying, cheese-making, and other products was emphasized. According to Smil (2000), the impetus toward increased food production following World War II (1939-1945) was a result of a new population explosion. A so-called green revolution, involving selective breeding of traditional crops for high yields, new hybrids, and intensive cultivation methods adapted to the climates and cultural conditions of densely populated countries such as India temporarily stemmed the pressure for more food. A worldwide shortage of petroleum in the mid-1970s, however, reduced the supplies of nitrogen fertilizer essential for the success of the new varieties. Simultaneously, erratic weather and natural disasters such as drought and floods reduced crop levels throughout the world.

Famine became common in many parts of Africa south of the Sahara.

Economic conditions, particularly uncontrolled inflation, threatened the food supplier and the consumer alike. These problems became the determinants of agricultural change and development. Many of the innovations introduced to agriculture by the scientific and Industrial revolutions paved the way for a qualitative change in the nature of agricultural production, particularly in advanced capitalist countries. This qualitative change became known as industrial agriculture. It is characterized by heavy use of synthetic fertilizers and pesticides; extensive irrigation; large-scale animal husbandry involving animal confinement and the use of hormones and antibiotics; reliance on heavy machinery; the growth of agribusiness and the commensurate decline of family farming; and the transport of food over vast distances. Industrial agriculture has been credited with lowering the cost of food production and hence food prices, while creating profitable businesses and many jobs in the agricultural chemistry and biotechnology industries. It has also allowed farmers and agribusinesses to export a large percentage of their crops to other countries. Farm exports have enabled farmers to expand their markets and have contributed to aiding a country's trade balance. At the same time, industrial-scale agriculture has had adverse environmental consequences, such as intensive use of water, energy, and chemicals. Many aquifers and other water reservoirs (see Groundwater) are being drained faster than they can be renewed. The energy required to produce nitrogen-based synthetic fertilizers, to operate heavy farm equipment, to manufacture pesticides, and to transport food over long distances involves burning large amounts of fossil fuels, which in turn contribute to air pollution and global warming. The use of

synthetic fertilizers has affected the ability of soil to retain moisture, thus increasing the use of irrigation systems. Fertilizer runoff has also stimulated algae growth in water systems. Finally, herbicides and insecticides in many cases have contaminated ground and surface waters. Klinkenborg (1995) observes that during the 20th century, a reaction developed to industrial agriculture known as sustainable agriculture. While industrial agriculture aims to produce as much food as possible at the lowest cost, the main goal of sustainable agriculture is to produce economically viable, nutritious food without damaging natural resources such as farmland and the local watershed. Examples of sustainable agricultural practices include rotating crops from field to field to prevent the depletion of nutrients from the soil, using fertilizers produced naturally on the farm rather than synthetic products, and planting crops that will grow without needing extensive irrigation. Sustainable agricultural practices have seen great success in parts of the developing world where resources such as arable land and water are in short supply and must be carefully utilized and conserved. Agricultural technology Since ancient times, when cultures first began cultivating plants, people have used tools to help them grow and harvest crops. They used pointed tools to dig and keep soil loosened, and sharp, knifelike objects to harvest ripened crops. Modifications of these early implements led to the development of small hand tools that are still used in small-scale gardening, such as the spade, hoe, rake, trowel, and scythe, and larger implements, such as plows and larger rakes that are drawn by humans, animals, or simple machines (Smith, 1995). Much of the world's arable land is still tilled under conditions that do not permit use of expensive modern machinery. However,

modern machinery is used extensively in the United States, Canada, the United Kingdom, Western Europe, and Australia. According to Smith (1995), modern large agricultural implements, adapted to large-scale farming methods, are usually powered by diesel- or gasoline-fueled internal-combustion engines. The most important implement of modern agriculture is the tractor. It provides locomotion for many other implements and can furnish power, via its power shaft, for the operation of machines drawn behind the tractor. The power shafts of tractors can also be set up to drive belts that operate equipment such as feed grinders, pumps, and electric-power generators. Small implements, such as portable irrigators, are often powered by individual motors. Many types of implements have been developed for the activities involved in growing crops. These activities include breaking ground, planting, weeding, fertilizing, and combatting pests. Ground is broken by plows to prepare the seedbed. A plow consists of a bladelike plowshare that cuts under, then lifts, turns, and pulverizes the soil. Modern tractor plows are usually equipped with two or more plowshares so that a wide area of ground can be broken at a single sweep. Harrows are used to smooth the plowed land and sometimes to cover seeds and fertilizer with earth. The disk harrow, which has curved, sharp-edged steel disks, is used mainly to cut up crop residues before plowing and to bury weeds during seedbed preparation. Rollers with V-shaped wheels break up clods of soil to improve the aeration of the soil and its capacity for taking in water (ibidem). Some cereal crops are still planted by broadcasting seeds—that is, by scattering the seeds over a wide area. Machines for broadcasting usually consist of a long seedbox mounted on wheels and equipped with an agitator

to distribute the seeds. Broadcast seeds are not always covered by a uniform or sufficient depth of soil, so seeding is more often done with drills, which produce continuous furrows of uniform depth. Specialized implements called planters are necessary for sowing crops that are planted in rows, such as corn. Corn planters and other similar machines have a special feed wheel that picks up small quantities of grain or separate kernels and places them in the ground (ibidem). Fertilizer can be distributed during the winter or shortly before seeding time. Commercial fertilizers are commonly distributed, along with seeds, by drills and planters. Manure is distributed most efficiently by a manure spreader, which is a wagon equipped with a bottom conveyor to carry the fertilizer back to a beater attachment, which disintegrates it and then scatters it on the ground. After crops have begun to grow, a cultivator is used to destroy weeds and loosen and aerate the soil. A flame weeder, which produces a hot-air blast, can be used to destroy weeds growing around crops, such as cotton, that have stems of tough bark. The weeds are vulnerable to the hot air, but the tough stems protect the crops from damage. Chemical herbicides applied in the form of a spray or as granules are used extensively for destroying weed. Insecticides are applied to soil and crops in the form of granules, dust, or liquid sprays. A variety of mechanical spraying and dusting equipment is used to spread chemicals on crops and fields; the machinery may be self-powered, or drawn and powered by a tractor. In areas where large crops of vegetables and grain are grown, airplanes are sometimes used to dust or spray pesticides (Winston, 1997). Chemical pesticides are used in nearly all modern farming operations. However, increasing concern over the harmful effects that pesticides may

have on the environment has led to the use of alternative forms of pest control. For example, farmers use crop rotation to prevent pests that feed on a certain crop from becoming entrenched and infesting the field. Also, certain pests are controlled by introducing an organism that damages or kills the them, but leaves the crops unharmed. Finally, scientists genetically engineer crops to be more resistant to troublesome pests (open citation). Most cereal crops are harvested by using a combine—a machine that removes the fruiting heads, beats off the grain kernels, and cleans the grain as the combine moves through the fields. The cleaned grain is accumulated in an attached grain tank. Corn (maize) is harvested by a combine or a machine called a corn picker. As the corn picker moves along the rows, the ears are picked from the stalks and are husked. The ears are then transferred either to a sheller, which removes the kernels from the ear, or to a wagon trailing behind the machine. Hay harvesting usually requires several steps. First, the hay is cut close to the ground with a mower. After drying in the sun, most hay is baled. In baling, the pickup baler lifts the hay to a conveyor that carries it to a baling chamber, which compresses the hay into bales weighing up to 57 kg (125 lb) and ties each bale with heavy twine or wire. A machine called a field chopper cuts down green hay or field-cured hay for use as animal feed. After being cut down, the hay is stored in a silo and allowed to ferment; this type of animal feed is nutritious and resistant to spoilage. Alfalfa and other legume hay is harvested in some areas with a hay cuber. This machine cuts the plants close to the ground and, after field curing, chops them into a fine mash and compresses the mash into cubes that are more easily shipped and stored than are bales. Specialized

machinery is used to harvest large root crops such as potatoes and sugar beets. Mechanical cotton pickers and strippers are used in harvesting nearly all of the cotton grown in the United States. Mechanical pickers have rotating spindles that twist the cotton fiber from the boll. Before picking, the leaves of the cotton plant are removed by means of a chemical defoliant spray. Light-boll, stormproof cotton is harvested by strippers that comb or brush the cotton from the plant and lift it into a trailed wagon. More efficient mechanical pickers continue to be developed (Smith, 1995). Specialized machines are also used to harvest fruits and vegetables. Some mechanical fruit pickers that are used to harvest deciduous tree fruits, such as plums, cherries, and apricots shake the fruit tree, causing the fruit to fall onto a raised catching frame that surrounds the tree. Nut crops can also be harvested in this manner. In addition, plant breeders use modern methods such as genetic engineering to develop varieties of fruits and vegetables that are tougher and hardier for easy harvesting by machines. For example, a variety of tomato has been bred for a tougher skin that reduces bruising. In addition to the kinds of agricultural machinery being used on large modern farms, a wide range of automated devices became available to farmers through the revolution in electronics. Today, an increasing number of farmers use personal computers to keep records, manage their farms' business, and connect to information centers that can help them solve the problems they confront in the operation of their farms. The practical significance of agricultural technology is that it substantially reduces the amount of human labor needed for raising crops (thus reducing production costs and subsequently reducing commodity prices for consumers). The

average amount of labor required per hectare to produce and harvest maize, hay, and cereal crops has fallen to less than a fourth of what was required only a few decades ago. Mechanization, together with improved crop varieties, better techniques, and more efficient food processing, has enabled the small percentage of the population living on farms in developed countries to produce enough food to feed their nations. Agricultural technology has also made it possible to produce food on a large scale than would have been possible by using human labor. Biotechnology

Biotechnology is the manipulation of biological organisms to make products that benefit human beings. Biotechnology contributes to such diverse areas as food production, waste disposal, mining, and medicine (Steinberg and Cosloy, 2000: 5). Although biotechnology has existed since ancient times, some of its most dramatic advances have come in more recent years. Modern achievements include the transferal of a specific gene from one organism to another (by means of a set of genetic engineering techniques known as transgenics); the maintenance and growth of genetically uniform plant- and animal-cell cultures, called clones; and the fusing of different types of cells to produce beneficial medical products such as monoclonal antibodies, which are designed to attack a specific type of foreign substance (Reiss and Straughan, 1996). The first achievements in biotechnology were in food production, occurring around 5000 B. C. Diverse strains of plants or animals were hybridized (crossed) to produce greater genetic variety. The offspring from these crosses were then selectively bred to produce the greatest number of desirable traits. Repeated cycles of selective breeding produced many present-day food staples. This method continues to be used

in food-production programs. Maize was one of the first food crops known to have been cultivated by human beings. Although used as food as early as 5000 B. C. in Mexico, no wild forms of the plant have ever been found, indicating that corn was most likely the result of some fortunate agricultural experiment in antiquity. The modern era of biotechnology had its origin in 1953 when American biochemist James Watson and British biophysicist Francis Crick presented their double-helix model of DNA. This was followed by Swiss microbiologist Werner Arber's discovery in the 1960s of special enzymes, called restriction enzymes, in bacteria. These enzymes cut the DNA strands of any organism at precise points. In 1973 American geneticist Stanley Cohen and American biochemist Herbert Boyer removed a specific gene from one bacterium and inserted it into another using restriction enzymes. This event marked the beginning of recombinant DNA technology, commonly called genetic engineering. In 1977 genes from other organisms were transferred to bacteria. This achievement eventually led to the first transfer of a human gene, which coded for a hormone, to *Escherichia coli* bacteria. Although the transgenic bacteria (bacteria to which a gene from a different species has been transferred) could not use the human hormone, they produced it along with their own normal chemical compounds (Aldridge, 1998). In the 1960s an important project used hybridization followed by selective breeding to increase food production and quality of wheat and rice crops. American agriculturalist Norman Borlaug, who spearheaded the program, was awarded the Nobel Peace Prize in 1970 in recognition of the important contribution that increasing the world's food supply makes to the cause of peace ([http://www. nobel. se/peace/laureates/1970](http://www.nobel.se/peace/laureates/1970)). Coates,

Mahaffie and Hines (1997) argue that biotechnology can be used to enhance animals and plants for food production. Hybrids (offspring of unrelated varieties or species) of desirable characteristics can be developed. In agriculture, genetic advances enable scientists to alter a plant or animal to make it more useful. For instance, some food crops, such as oranges, potatoes, wheat, and rice, have been genetically altered to withstand insect pests and diseases, resulting in a higher crop yield. Tomatoes and apples have been modified so that they resist discoloration or bruising on their way to market, enhancing their appeal on supermarket shelves. The genetic makeup of cows has been modified to increase their milk production, and cattle raised for beef have been altered so that they grow faster. Generally speaking, bio- and agricultural technologies help to increase food production through increased yields, by enabling plants and animals to offer better nutrition, repel pests, and flourish in hostile environments. More than 6 billion people live on earth today, double the number just a half century ago. Yet most of the world's land that is suitable for current food production systems is already cultivated. Natural resources, such as water and arable soil, are under increasing pressure. The world's farmers — especially those in developing countries — face tremendous challenges to meet the increasing demand for food in the coming decades. Biotechnology is playing an important part in the comprehensive strategy to help these farmers. Biotech crops can be easily adopted by farmers all over the world, because they require nothing more than planting new, enhanced seeds or cuttings. Some experts believe that biotechnology could boost world crop productivity by as much as 25%, by improving plants to tolerate harsh conditions like drought

(Prakash, 2001). And to resist pests and diseases, which still reduce global production of food by more than 35% annually, at a cost of more than \$200 billion (Krattiger, 2000). In the United States of America (U. S.), biotech crops have helped U. S. farmers prevent the loss of approximately 8 billion pounds of crops in 2005, according to experts (Sankula, 2006: 9). According to James (2007: 3-5), an estimated 12 million farmers in 23 countries — 12 developing and 11 industrialized — have planted biotech food and fiber crops. More than 90% of those farmers are small-holder or resource-poor farmers from developing countries. These crops are boosting yields to help feed more people. And poor farmers are increasing their incomes. For example, James (2003: 89) reports that farmers planting biotech maize in the Philippines have boosted yields by 40 percent, for instance; their income has gone up 34 percent. Enhanced crops can also help the poor get the nutrition they need — once they become available in the market, protein-rich potatoes could be used to treat malnutrition and enhanced “ golden rice” could help prevent child blindness and death for millions of the world’s poor who suffer from Vitamin A deficiency (MacPherson, 2002). Trends show that every year, more and more of the world’s farmers turn to biotechnology as one way to meet the demands of our growing population. A robust pipeline of new, enhanced crops are in field tests around the world today — like pest- and disease-resistant foods and plants that use water more efficiently. Exciting biotech research will continue to bring advances for farmers around the world. Additionally, genetically modified (GMO) or biotech food make improvements in food processing possible. The first food product resulting from genetic engineering technology to receive regulatory approval, in 1990, was

chymosin, an enzyme produced by genetically engineered bacteria. It replaces calf rennet in cheese-making and is now used in 60 percent of all cheese manufactured. Its benefits include increased purity, a reliable supply, a 50 percent cost reduction, and high cheese-yield efficiency. When something is produced in large quantities, its cost price usually falls.

According to the theory, or law, of supply and demand, the market prices of commodities and services are determined by the relationship of supply to demand. Theoretically, when supply exceeds demand, sellers must lower prices to stimulate sales; conversely, when demand exceeds supply, buyers bid prices up as they compete to buy goods. The terms supply and demand do not mean the amount of goods and services actually sold and bought; in any sale the amount sold is equal to the amount bought, and such supply and demand, therefore, are always equal. In economic theory, supply is the amount available for sale or the amount that sellers are willing to sell at a specified price, and demand, sometimes called effective demand, is the amount purchasers are willing to buy at a specified price (Samuelson and Nordhaus, 1998). The theory of supply and demand takes into consideration the influence on prices of such factors as an increase or decrease in the cost of production, but regards that influence as an indirect one, because it affects prices only by causing a change in supply, demand, or both. Other factors indirectly affecting prices include changes in consumption habits (for example, a shift from natural silk to artificial silk fabrics) and the restrictive practices of monopolies, trusts, and cartels. In the view of many economists, the multiplicity of such indirect factors is so great that the terms supply and demand are inclusive categories of economic forces affecting prices, rather

than precise, primary causal factors (Banock, 1999). Theoretically speaking, the basic argument here is that due to increases in food production (increased supply) brought about by advancements in bio- and agricultural technologies, food costs are reduced. Figure 1 illustrates the relationship between demand, supply, and equilibrium. Demand (shown by the diamond shaped line) generally increases as prices go down, while supply (shown by the shaped square line), usually increases as prices go up. The equilibrium point (where the demand and supply line intersect) shows the combination of price and quantity at which buyers and sellers agree. Figure 1 However, the price-determining mechanism of supply and demand is operative only in economic systems in which competition is largely unfettered. Increasing recourse, in recent times, to governmental regulation of the economy has tended to restrict the scope of the operation of the supply-and-demand mechanism. It was greatly restricted in Zambia and other countries by the governmental price regulations and rationing during post-Independence era. Basically, the main reason why agricultural and biotechnology have been recommended is because of the realization that food supply is supposed to be responsive to growing demand due to the population explosion. The major benefits from the use of the technologies include: Increased crop productivity ; Enhanced crop protection; Improvements in food processing; Improved nutritional value; and etcetera. The use of farm implements has labor-saving effects and increased yields. Everything in life has its benefits and risks, and genetic engineering is no exception. Much has been said about potential risks of genetic engineering technology, but so far there is little evidence from scientific studies that these risks are real. Critics have

cited issues such as biological warfare, biodiversity loss, proliferation of viral genes that are resistant to pesticides and other drugs, unintended impacts on non-target organism, health risks, etcetera (Wright, 1996). Responsible scientists, farmers, food manufacturers, and policy makers should recognize that the use of transgenic organisms should be considered very carefully to ensure that they pose no environmental and health risks or at least no more than the use of current crops and practices. Modern biotechnology represents unique applications of science that can be used for the betterment of society through development of crops with improved nutritional quality, resistance to pests and diseases, and reduced cost of production. Biotechnology, in the form of genetic engineering, is a facet of science that has the potential to provide important benefits if used carefully and ethically. Society should be provided with a balanced view of the fundamentals of biotechnology and genetic engineering, the processes used in developing transgenic organisms, the types of genetic material used, and the benefits and risks of the new technology.

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