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Engineered Agriculture for Increased Production of Food

Abstract

World demand for a variety of crops has skyrocketed during the last century. This demand suggests a growing trend for the coming decades. Artificially modified agricultural products need to be improved to satisfy the world's growing demand.

Through controlled pollination and genetic modification, modified crops have demonstrated desirable traits relative to unmodified crops. Engineered agriculture can produce abundant and nutritious agricultural products. For example, India's adoption of irrigation and cross breeding has increased its agricultural production significantly. China has produced new hybrid rice that yields 15-20% more rice than that produced in earlier years. Some recent genetically engineered agricultural products are useful also because of their resistance to harsh weather.

To produce more and better agricultural products for the world's needs, genetic modification of crops requires technical improvements, and increased acceptance by farmers and consumers everywhere, especially in Asia and Africa.

Introduction

In addition to improvements in irrigation and methods for fertilization, genetic engineering is required to produce the necessary quantity and quality of agricultural products for feeding the world's growing population. Two methods are used to change a plant's genetic properties. They are artificial pollination and genetic modification.

In the last century, to improve agricultural production, the common method was artificial pollination, or crossbreeding. This artificial selection process of plants to produce desirable traits is called "domestication".

Modern plant breeding uses new genetic-engineering techniques to map the crop's DNA sequence. Through minor DNA-sequence modifications, done by bacteria transduction or DNA-sequence bombardment, scientists produce a new plant with more desirable properties. The resulting plants are often referred to as transgenic plants. Genetically modified (GM) agriculture produces better soybeans, cotton and corn. Genetically modified crops provide a partial solution to the world's increasing demand for food.

However, there are some objections to new genetically-engineered agricultural products because of subsequent toxicity and allergies. Further, because many crops are engineered to be herbicide-tolerant, environmental hazards may follow from the transfer of herbicide resistance to weeds. "The general public's knowledge of GM foods still remains low." (McCracken) At present, a large fraction of the public has a negative perception of these strangely labeled foods. According to a 2003 study, "more than half of the public [in Britain] is opposed to GM food." (Scott)

The Problem

The world populations reached 6 billion in 1999; it is estimated to double in the next 50 years. (Waun) Figure 1 shows the world's population over a 300-year period.

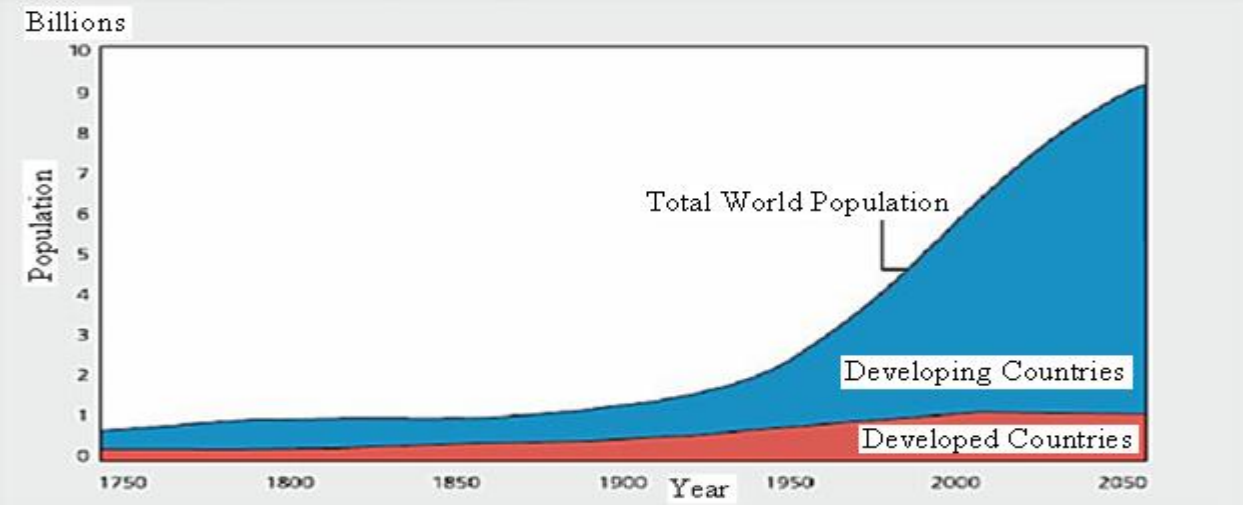

Figure 1: World Population in billions from 1750 to 2050 (estimate). (Source: Waun)

Food supply is a major concern for the 21st century. Most of the world's growth in population is in developing countries. Many poor countries will not be able to feed their people without new engineered agriculture. With declining arable land due to increase of cities as well as climate changes, agricultural production must become more efficient. Famine in poor countries may cause severe economic and political instability.

Many regions in Asia and Africa depend on only a few agricultural products. However, many of these crops, such as rice, do not contain sufficient nutrition. For example, blindness due to Vitamin A deficiency cannot be consistently prevented when the primary food is rice. Regrettably, a large variety of agricultural products is too expensive for many parts of the world. An unlucky year in agriculture may lead to famine. The world faces a need significantly to improve agriculture production.

Engineering Solutions

There are two ways to alter a plant's specific traits – controlled pollination and genetic engineering. Either way (or both) can be used, followed by careful selection to yield better species. Artificial selection is a process for choosing a plant with specific desirable properties.

Controlled Pollination

Controlled pollination of agricultural products has been practiced for thousands of years. Cross-breeding (pollination) of different species with desirable traits often yields a new generation with combined or enhanced desirable properties. Artificial selection is applied to many experimental specimens to obtain the most successful new hybrid products. In the last few decades, new innovative ways of artificial (influenced by human) cross-breeding have yielded favorable results.

In 1974, Chinese engineers successfully transferred the male sterility gene in wild rice to conventional rice to produce a cytoplasmic genetic male-sterile (CMS) hybrid combination. The U.S. Food and Agriculture Organization (FAO) reported that this first generation hybrid seed yields 15 – 20 % more than the high-yielding varieties of classical rice. Chinese average rice yields have increased from 3.5 to 6.2 ton per hectare, more than enough to feed the nation's population, despite a steady decrease in arable rice land. The International Rice Research Institute (IRRI), the United Nations Development Program (UNDP), and the Asian Development Bank have strongly encouraged hybrid rice breeding as well as continuation of hybrid-seed production and research.

Hybrid-rice is particularly useful for improving the agriculture of poor countries where arable land is scarce. In Egypt, hybrid rice yields about 35% more than inbred rice under saline-land conditions. Hybrid-rice production can promote agricultural diversity by using excess rice land for other agricultural products. Figure 2 shows the collaboration required for the dissemination of hybrid-rice technology.

Figure 2: Networking of hybrid-rice production and research is a collaborative effort. (FAO's 2004 rice report)

Controlled pollination provides an effective way to increase the quality and quantity of food production. However, this method alone is not enough to satisfy the world's rapidly growing demand. Cross-breeding is inevitably limited by the available original gene pool. The vast majority of experimental hybrid products yield inferior species. Therefore, to improve the species' desirable traits, agricultural scientists have developed a method that alters the plant's DNA sequence. This procedure is called genetic modification (GM). In effect, GM is similar to speeding up the process of evolution.

Genetic Modification

The genetic modification procedure begins by extracting DNA from an organism, then modifying it using some knowledge of how a change in a specific sequence changes the traits of the organism. DNA sequence bombardment and bacterial DNA transduction are common methods for DNA modification. The modified DNA is then reinserted into the organism's genome to yield a GM specimen. If the specimen is succeeds in producing the desirable traits of the plant, then the sample is used to produce copies of the GM product. Desirable traits

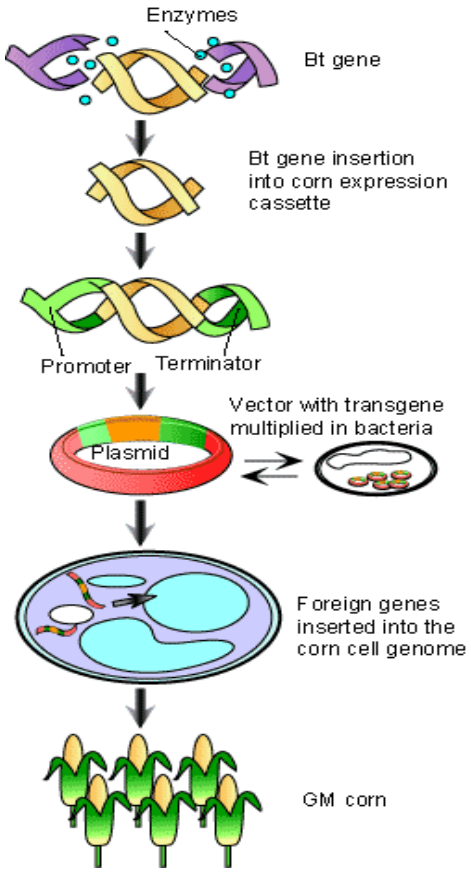

Figure 3: Schematic of GM food Production (Chaudry)

commonly include better taste, resistance to disease, harsh weather, and insects, and resistance to rotting during long-distance-travel. Because GM food can expand the gene pool of agricultural products, the cross-breeding method can then, perhaps, produce new and better products. Figure 3 shows a schematic of the GM food-production process.

The prevailing GM procedure is relatively new. The rotting-resistant Flav-Savr tomato was the first commercially grown GM food released into the market in 1994. GM bananas are engineered to include human vaccines against hepatitis B. Rice has been modified with addition

of iron and vitamins to alleviate chronic malnutrition in poor countries. Soybeans are engineered to resist Roundup, a much-used herbicide that is relatively harmless for the environment.

Trait	Advantage	Sample Product
Pest-Resistance	Less damage by insect, virus, bacteria, etc.	Corn
Herbicide-Resistance	Hebicides will kill only weeds, not crops	Cotton
Delayed Ripening	Can be shipped with less damage	Tomato
Miniature Size	Improved eating quality	Watermelon
Improved Sweetness	Better tasting	Sweet peas
Cold-Resistance	Withstands freezing and thawing	Strawberries
High Starch	Absorbs less oil when fried	Potato
Polyester Gene Added	Better fiber properties	Cotton
Growth Hormone Added	Faster growth	Salmon
Hepatitis B Virus Protein Added	May provide immunity to Hepatitis	Banana

Table 1: Sample **GM food data** (University of Michigan)

Table 1 shows some GM agricultural products (and Salmon) along with their special traits. Over the ten-year interval 1995 to 2005, GM food on the market has increased by a factor of 50. The U.S. produced the majority of these GM products.

Many U.S. consumers are frightened by new GM food, whereas farmers of African are content to have a surplus of food. To avoid famine in Asia and Africa, the spread of GM technologies is as important as the technology itself. Controversies concerning GM food need to be resolved to assure its development, and future use.

GM Food Controversies

Some environmentalist and religious organizations oppose the genetic modification of foods. Environmentalists are concerned that GM foods might pose environmental hazards such as pesticide-resistant weeds. The pesticide-resistant property of a product may transfer from GM

crops to these weeds. Public interest groups are worried that GM foods may create new and unexpected allergic reactions.

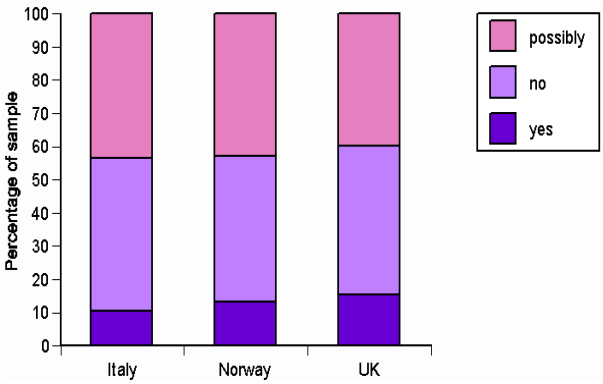

Figure 4: Statistics of public opinion concerning GM-food acceptance.
Survey Question: "Will you eat GM food?" (Miles)

Figure 4 shows results from a survey of public opinions regarding GM food in three European countries. These controversies must be resolved through education and through continuing developments that assure safety of GM foods.

Bringing GM food to the market is a costly and lengthy process. However, economic studies have shown that GM foods stimulate global economies. (ISAAA News) There is much evidence to indicate that engineered crops are beneficial in the long run.

Some religious organizations object to GM food because they believe that artificial modification of plants is unethical. Much patience and effort will be needed to overcome this objection. Development and use of GM crops require close collaboration of many different groups of people. It is necessary for the general public to recognize the need for GM Products to feed the world's increasing population.

Conclusion

Cross-breeding and genetic modifications provide two techniques to raise agricultural production in the world. These methods have already proven to be successful. In the foreseeable future, scientifically engineered agricultural products are needed to feed the world's growing population. These engineering methods will also provide agricultural security that is less dependent on fluctuating environmental factors such as weather and insects. Further developments will depend strongly on overcoming resistance from some segments of the public.

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