

Student 2: High Merit

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Farmers began selectively breeding corn around 10,000 years ago by choosing the most favourable corn kernels to plant.

Biologists can now genetically manipulate corn for desirable traits. Genetically modifying corn plants, however, has had wider biological implications.

1 Selective breeding of corn was originally done by ancient farmers saving kernels from the best plants as seeds for the next year's crops. They chose kernels with specific traits such as the ability to grow well in various climates, soil types and produced the largest number of kernels and kernel rows. Each kernel is a seed that has resulted from a female egg fertilised by a male pollen grain. This means only the best or most suitable kernels will reproduce and the gene pool of the next generation will have a higher frequency of the favoured genes. 2 Over time, the quality of the crop will increase as the favoured offspring reproduce repeatedly. However, planting a kernel from a corn plant that appears to have one or some of the desirable traits is not always reliable. The outcome of selective breeding is not always guaranteed, because of hidden genes and mutations that can happen. 2 Even though its phenotype may seem to be suitable, the genotype (and therefore phenotype) of its offspring may not be suitable. 1 If the original plant had a recessive gene in its genotype that was not expressed in its phenotype, and its egg was fertilised with a male pollen grain that also had a recessive gene, there would be a chance of the kernel being homozygous recessive. This would mean that the particular phenotype expressed in the original corn plant would not be expressed in the new plant.

1 Selective breeding has become easier with time, as people found ways to figure out an organism's genotype. With this knowledge, farmers can now deliberately cross two members of the same species that both possess either homozygous dominant or homozygous recessive genes and almost guarantee a purebred offspring. The first way was by using a test cross. By crossing one organism that is showing the dominant form of a trait with another of the same species that is homozygous recessive for the same trait; it is possible to determine the other organism's genotype from the traits expressed in the offspring. Other more efficient methods like marker assisted selection (MAS) are now used for indirect selection of a genetic determinant of a trait of interest. MAS can be useful for traits that are difficult to measure, exhibit low heritability, or are expressed late in development. Steps for MAS include firstly mapping the gene or quantitative trait locus (QTL) of interest by using different techniques and then use this information for marker assisted selection. The markers to be used should be close to gene of interest in order to ensure that only a minor fraction of the selected individuals will be recombinants. Generally, not only a single marker but rather two markers are used in order to reduce the chances of an error due to homologous recombination.

1 Since humans have begun selectively breeding corn, the genetic diversity has decreased as kernels are being selected for certain qualities and those qualities only. Another biological implication is that the outcome may not be completely successful because of linked genes. Linked genes are those that are found on the same chromosome and tend to be transmitted together. For example, alleles for both kernel colour and kernel size lie on the same chromosome. A farmer may select a kernel that is the desirable size, but with that trait may also come a negative trait such as susceptibility to disease, infertility, or the wrong colour, etc. The negative consequences of using and/or reproducing that plant would probably outweigh the positive features. Similarity within species also means that if the species comes into contact with a disease, there is a high chance of the whole species being wiped out. Its scarcity will have implications on other things. For instance, it could have detrimental effects on ecosystems because if one species is removed from a food chain it will impact all other species in the chain. 2

Genetic cloning of whole corn plants is another way to produce crops with desirable traits. The techniques used allow scientists to introduce certain genes into a plant without having to go through the risky trial-and-error process of selective breeding, and have a higher success rate because biologists have more control throughout the process. It is relatively easy to add certain genes one species may not naturally possess. Genetically modified corn crops include Bt corn, Bt sweet corn and Roundup Ready Corn. These crops have been modified for specific beneficial traits to assist with pest resistance and herbicide tolerance. The technique used for cloning of Bt corn is a form of transgenesis, which is when genes from one organism are transferred to another organism of a different species. Bt corn came about to try to prevent corn crops being destroyed by pests such as insects. 'Bt' stands for the soil bacterium *Bacillus thuringiensis*. This pathogen produces toxins that act as insecticides and kill insects. Scientists insert a gene from the bacterium into a corn cell in order to reduce the damage done particularly by the European corn borer (ECB) that eats corn stems. To make Bt corn, biologists start with a Ti-plasmid (tumour inducing plasmid) in *Agrobacterium tumefaciens*. Plasmids are genetic structures that can replicate independently of chromosomes, and this particular type of plasmid is used often as a means to transfer genetic information from one organism to another. Researchers investigated how the Bt bacterium kills particular insects, and found that it has two types of toxins. One of the types is cytolysins (Cyt) which are toxic to insects such as beetles and flies. The other type is the crystal delta-endotoxins (Cry) which are toxic to moths and butterflies. Scientists found that Cry is toxic to the ECB. The Bt Cry gene is extracted from the *Bacillus thuringiensis* bacterium using enzymes called restriction endonucleases, which act as scissors to cut out the desired gene. The gene is then inserted into a corn 'expression cassette'. From there the expression cassette is inserted into the Ti-plasmid by putting the cassette into a plasmid, this means millions of copies of it can be produced. The duplicates of the foreign gene are then inserted into the corn cell genome where the cells reproduce and generate new plants that are resistant to insects like the European corn borer. This technique is used because *Agrobacterium* is a naturally occurring soil bacterium that infects some plants and causes crown gall disease.

A biological implication of pest resistant (Bt corn) is that there will be very little genetic diversity within the population, as the plants have been cloned and reproduced from the same one plant, meaning all their genes will be identical. In the same way that little genetic variation affects selectively bred plants, it will affect genetically modified plants. If all the corn plants have identical DNA they will all be susceptible to the same things, such as; particular diseases, drought, floods, bad soil quality and herbicides/pesticides, etc. Another biological implication of Bt corn is the possible negative effects it can have on populations other than those intended. A study done in 1999 found that Bt corn is also toxic for Monarch butterfly larvae. They suffered a significant decrease in fitness when their normal diet was dusted with Bt corn pollen. The effect of Bt corn on other species does not only affect the particular species, but also a whole ecosystem and food chain/web within it. If one organism becomes scarce, it will influence the way the other species in the chain interact and survive.

As there is little genetic variation in selective breeding, if a species is wiped it will have effects on other organisms as part of an ecosystem and food chains and food webs. The aim of plant breeders is to assemble a collection of genes in a crop like corn to make it useful and as productive as possible. The world population has topped seven billion people and is expected to double in the next 50 years. Ensuring an adequate food supply is a major challenge in years to come to ensure the survival of the human species.

Corn plant cloning takes more time to set up than selective breeding because of the more complex science behind it. But once perfected, it is very quick to clone and genetically modify corn plants. Farmers do not have to select traits and wait for their crops to grow to be able to select seeds to use. With selective breeding it may take years of trial and error to see any progress.