Term Paper
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"Nana Banana from Texarcana
How she loves bananas.
Not too ripe and not too green
But somewhere in between."
- Charles G. Lang, "Nana Banana"

The banana is a sweet, tasty snack that brings joy to millions of people around the world every day. It's cheap and has plenty of nutrients, crucial factors for many low-income people around the world; one estimate says that a typical person in Uganda or Rwanda might eat 550 pounds of bananas per year.[1] But it's also a fruit that is surprisingly vulnerable to disease. The strain of banana that you can find in your grocery store - known as the Cavendish - has been under attack around the world from a virus known as Panama disease, which is extraordinarily robust and resistant to pesticides. Sooner or later, the disease will wipe out the current Cavendish - it has happened before, with a previous popular strain of banana. Researchers are working as hard as they can, introducing genetic modifications to find a Cavendish variation that is resistant to the virus. It remains to be seen whether they will succeed, and whether consumers will reject the new, genetically modified banana. A world without bananas would be a shame.

Every now and then you hear stories about animals from different species that successfully mate, for example a donkey and a horse. The offspring typically inherits some traits from both its mother and father, but is commonly sterile. The banana, the common fruit you see all around the world, was born the same way, as a cross between two South Asian plants, *Musa acuminata* and *Musa balbisiana*.[2] This cross was not performed with high tech science in a

[1] Craig Canine, *Smithsonian Magazine,* "Building a Better Banana," October 2005.
[2] Matt Castle, *Damn Interesting,* "The Unfortunate Sex Life of the Banana," 24 August 2009.

laboratory, but occurred naturally over ten thousand years ago, and early farmers recognized the health benefits of the hybrid species. Like the animal hybrids, the banana is sterile - it's not able to reproduce. But it contained so many carbohydrates that early farmers would take shoots of existing banana plants and cultivate new plants from them.

However, this process is fragile. Imagine if humans reproduced by finding one good human and then cloning him or her a million times. While the chosen human might be incredibly intelligent, witty, or beautiful, it would be a tremendous mistake to put all of our genetic eggs in one basket. Humans have durability in diversity - a disease which affects 95% of the population will not wipe out the human race, because the other 5% contain a gene to counter it. The banana does not have this advantage – new bananas are created through a direct genetic copy, so a disease which kills one banana will kill them all.

This actually happened once in the past. Up until 1960 or so, people ate a type of banana called the Gros Michel. It was sweeter than the current Cavendish, and had a thicker skin, so it was easier to ship over long distances. But it fell prey to a disease called the Panama disease, and soon went out of mass production. It was then replaced by the Cavendish, which was acknowledged to be inferior to the Gros Michel.

But starting in 1992, the Cavendish has been assailed by a new strain of Panama disease known as Race 4 as well as a virus called black sigatoka, which attacks the roots of banana trees and prevents them from photosynthesizing. Controlling the sigatoka and preventing it from attacking banana plants currently uses up about 20% of the cost of producing a banana.[3] But fighting the disease without improving or replacing the Cavendish will only work for so long. Scientists are also working to introduce strains of the Cavendish that will resist black sigatoka.

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[3] Canine, 2005.

So far, it is proving difficult to produce a strain of the Cavendish that meets the exacting criteria of a worldwide supply chain. There are several desirable non-obvious qualities of the current Cavendish that make it suitable for worldwide distribution. In particular, it consistently ripens after about one week, and its ripening schedule is highly predictable. It also must resist pesticides (or insects), and grow fruit of a consistent size. These traits allow growers to pick the non-ripe Cavendish off the tree and ship it around the world, so that it will ripen within a day of arriving at the average grocery station. Any replacement would have to meet the same demanding worldwide production and delivery standards.

How is the Cavendish replacement being produced? One of the largest problems is that the Cavendish itself is 100% seedless, so it cannot be used as part of a cross breed - any replacement will probably have to have a different set of parents, although some progress has been made on getting the Cavendish to reproduce.[4] Currently there are many other banana candidates, but which lack in some important dimension, such as their taste, the time to ripen, the thickness of their skin, or their resistance to disease and insects. The process begins with one of the 300 varieties of bananas that exist in the wild, but are not in widespread commercial use.

The groups are taking two different approaches to find a suitable Cavendish replacement. The first is composed mainly of traditional banana growers, who are raising new hybrids in the wild and testing their fitness. The second is composed of scientists, who are fiddling with the banana DNA in laboratories to try and produce a new, better fruit.

Even in seed-bearing strains, most individual fruits lack seeds, so the search for cross breeds begins with a tedious search through hundreds of fruits for a single banana seed (about one in every 300 plants has seeds). At most a third of seeds found actually germinate. It can take

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[4] D.K. Becker et al, "Genetic transformation of Cavendish banana (Musa spp. AAA group) cv 'Grand Nain' via microprojectile bombardment," *Plant Cell Reports* 19:3.

up to two years to see the results of a cross, and to learn that the tested mixture is unsuitable. However, breeders have 40 years worth of crosses to work with, and have produced several noteworthy strains, including the Goldfinger strain.

The other group working on a Cavendish replacement works in laboratories, using DNA modification techniques, described in a 1991 paper by Gawel and Jarret.[5] The most well-known group is in Leuven, Belgium. They modify the DNA of bananas by using the same techniques we have studied in class for fusing outside genetic material with regular banana DNA. This technique is quicker than the hybrid cross technique, but there are worries that consumers will reject a genetically engineered plant. Despite the different approaches taken by the two groups, they share information about promising new strains and techniques. These papers mainly note the promise (and past performance) of genetic engineering for producing a disease-resistant banana[6] and leave aside the ethical considerations of genetic engineering.

Unlike most articles about genetic engineering, which present it as an unfounded, dangerous new technology, the article in question, "The Unfortunate Sex Life of the Banana," does a good job of covering the banana's history to the present day, and the reasons behind its precarious position. The author does anticipate a reader's concerns about "human-assisted reproduction" by noting that this is the only way bananas can reproduce, and that another well-known fruit, the navel orange, reproduces in a similar way. "Human-assisted reproduction" of bananas is less controversial than genetic engineering, because it's the only way bananas can reproduce, and it has been practiced for thousands of years.

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[5] N.J. Gawel and R.L. Jarret, "A modified CTAB DNA extraction procedure for Musa and Ipomoea," *Plant Molecular Biology Reporter* 9:3.

[6] Leena Tripathi, "Genetic engineering for improvement of Musa production in Africa," *African Journal of Biotechnology 2:12*.

The article's implicit conclusion is that we need to find a replacement for the Cavendish if we want to continue enjoying bananas in the near future, and that genetic modification is one of the more promising techniques for identifying a successor. It is widely acknowledged that the Cavendish will eventually fall prey to the Panama disease and be wiped out; it is only a question of when.[7] Already, banana growers are feeling the pressure of disease in their crops, and having to move away from land that was previously used for banana cultivation. The article also provides a factual short summary of the problems with genetic diversity and reproduction of banana species.

The process of genetically modifying banana DNA to produce a successor may be controversial because many consumers are resistant to genetically modified organisms. However, this resistance ignores the banana's history as a hybrid, a cross of two unlikely parents. Using DNA techniques to create a new banana may create strains that would not be found in nature, but it also can be viewed as a more efficient and more effective version of what nature, and banana growers, are doing with hybrid crosses in the wild. Furthermore, scientists are currently in a race against time to find a new product, and we should not abandon the laboratory approach for fear of losing the banana, a staple in diets around the world.

It's also possible that consumer fear about genetic engineering is not that important for the economic success of the banana. Once a strain is identified in the lab, the same techniques that have been used to grow bananas for thousands of years - replanting the shoots of an existing plant - can be used to plant it around the world, so there's no active "laboratory" technology needed to produce further generations of the plant. Furthermore, a large majority of banana eaters are in low-income nations, where the banana is an excellent source of carbohydrates and

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[7] Dan Koeppel, *Popular Science,* "Can This Fruit Be Saved?" June 19, 2005.

nutrients. Concern about the method of plant production is almost exclusively limited to those consumers who have the means to purchase alternative fruits. It is unlikely that consumers in low-income countries will care how their bananas are grown - I don't have evidence, but I would guess that knowledge about genetic engineering techniques among fruit consumers in low-income countries is not very high.

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