Could, and should, genetic engineering of plants, be used to help provide sustainable resources to society?

I will explore why we need to be mindful of plant security and the ways we can increase plant productivity. One way scientists can help is through genetic engineering and I have used two examples that I believe to be reliable sources of information. The research and subsequent development of new varieties of plant both came from Government departments, the American Department of Agriculture and the National Banana Research Programme in Uganda. These examples will demonstrate that genetic engineering could be used to help society with its food needs, and then the issue of whether they should be, or not, is discussed.

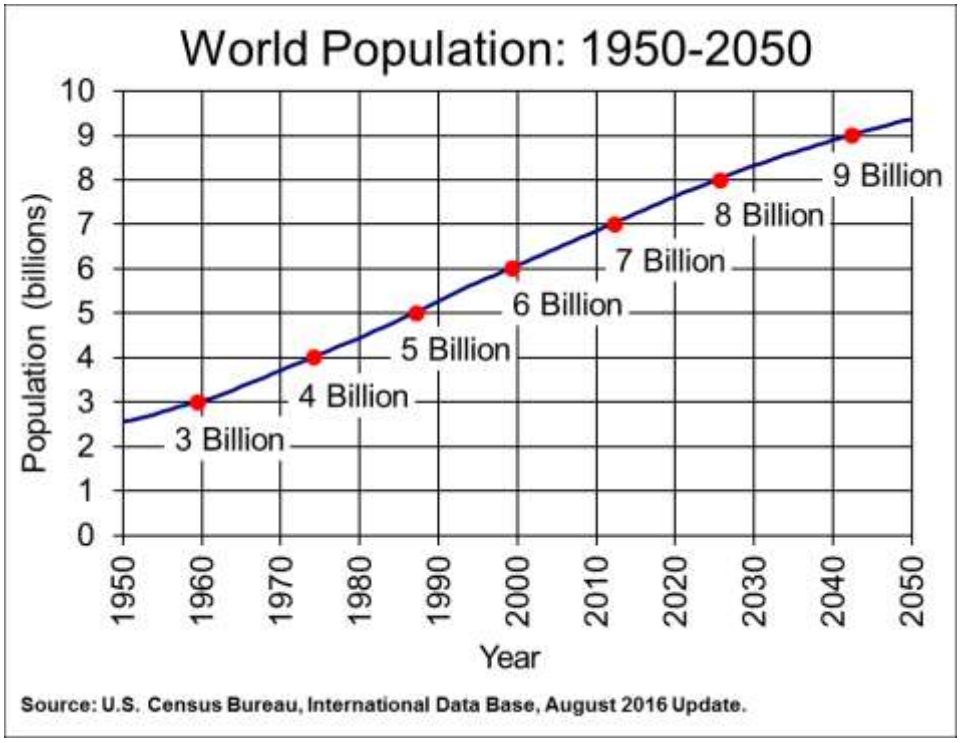

Figure 1 2016 Population current and projected from U.S. census

The human population of planet earth has grown continuously in recent years, as seen in Figure 1. The current population is 7.8 billion people and the U.S. Census Bureau says it will reach over nine billion by 2050[1]. The United Nations has a worst case scenario of 16 billion by 2100[2.] It is clear from these figures that there is a pressing need for food security. We already have hunger and famine demonstrating we don't have capacity to feed the world as it is. We are living in a period of climate change causing increased weather events, like flooding and droughts. A study published in *Nature*, found that "drought and extreme heat reduced crop yields by as much as 10% between 1964 and 2007"[3].

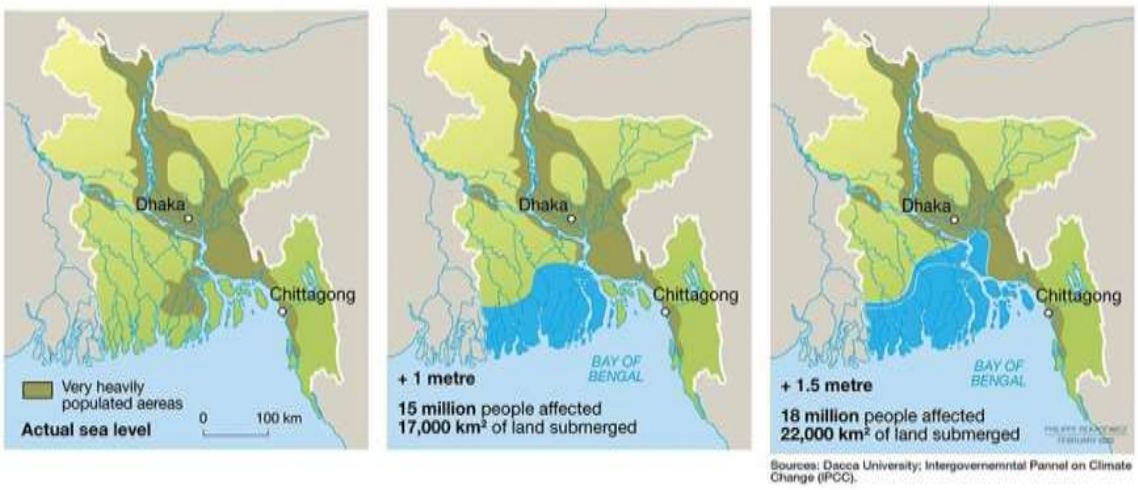

Figure 2 showing actual and projected sea level rises affecting Bangladesh from Dakka University

Climate change is also melting ice caps leading to rising sea levels. This puts further pressure on the land available for people, crops and animals. Figure 2 shows that in Bangladesh, 18 million people and 22,000km^2 of land would be impacted by a 1.5m sea level rise. A BBC report of 2019 stated that by the end of the century "sea levels are expected to rise along the Bangladesh coastline by up to 1.5m"[5].

Our current farming methods are insufficient to feed the growing population given these pressures on our land. Farming also has to become ever more intensive, using chemical fertilisers and insecticides, which are very bad for the environment of our planet and all it's inhabitants. Plants are an often overlooked part of society and it's easy to forget how widespread their use is, and their importance to us. We use plants in many ways, for example, clothing, fuel, cattle feed and for human consumption.

But to produce enough plants to sustainably feed our hungry world, productivity of our food plants needs to improve. This process can happen naturally but would take hundreds of years. This is where plant scientists can and have helped. Farmers and plant scientists have done traditional plant breeding for a long time. For example, Norman Borlaug[6] worked tirelessly to breed wheat, which could resist stem rust and he did manage to triple wheat yields. This is conventional cross breeding, and it takes many generations of plants to achieve success, but it could be argued that, in the face of climate change, we don't have that time.

As well as the long timeframe, there is also the disadvantage of linkage drag. This is where it is hard to isolate the good trait in your parent, so you bring undesirable traits, and it takes longer to breed them out. A third disadvantage to conventional plant breeding is the limited availability of genetic diversity. A conifer tree may have a drought resistant gene, but it may be incompatible with the wheat plant. There is a small gene pool of closely related plants available for breeding.

One way to improve conventional breeding is to use the technique of speed breeding. According to an article published in 2018 “speed breeding is a powerful tool to accelerate crop research and breeding” [7]. The authors achieved up to 6 generations a year for spring wheat, through single seed descent and using LED lighting. This approach is certainly quicker but, but the other disadvantages remain.

A scientific method of improving our crops is to use genetic engineering. This is “the deliberate modification of the characteristics of an organism by manipulating its genetic material” [8]. Genetic engineering overcomes the limitations of traditional cross breeding as a desired trait can be instantly inserted into a plant, there is no small gene pool and no linkage drag. Around the world in recent years, scientists have been able to achieve successes in the genetic engineering of plants, which has helped with crop productivity and security.

Plants come under attack all the time, this can be weather related i.e., drought or flooding, prolonged heat, or frost or pest or disease related. When humans are under attack, we have the ability to run away, or as we are seeing currently, we use science to come up with a solution. Plants can have permanent defence mechanisms, like the spines on a cactus, but it’s a bit like us wearing full chainmail every day. It’s far better to have inducible defence responses that work when needed.

One-way scientists have genetically engineered plants is via their defence systems. When a plant perceives attack, it sends a message to its nucleus and a response is initiated. There are 3 stages to this, the perception stage, the signalling stage, and the response stage. The 1st stage basically is where the plant begins to realise something is wrong. Small molecules called elicitors fall onto the membrane receptors. The 2nd stage is where the issue in the plant is being sent to the nucleus. Then a response (3rd stage) is released to protect and defend the plant. This might be producing a toxin that makes the plant taste horrid to an insect or triggering a metabolic slowdown to get through stress. Isolating the gene responsible enables plant scientists to insert this gene into other plants to give them the same protection. The more plants that have defences against pests or climatic stress, means fewer losses and a more sustainable food supply for the planet. This is a process that could take decades with conventional breeding.

An example I have looked at is the problem of Plum Pox Virus, the most serious disease in plum trees. Affected trees can lose 90% of its fruit prematurely and is unsuitable for consumption or even industrial processing [9]. An American research scientist, Ralph Scorza, was lead author of a peer reviewed paper describing the process of genetically engineering a virus resistant plum tree [10]. I believe this paper to be a reliable source of information. The United States Government Department of Agriculture decided in 1989 to fund the research and development of a genetically modified Plum Pox resistant fruit tree. Scorza worked to produce the HoneySweet tree through genetic engineering. Successful trials around the world led to it passing through the U.S. regulatory system by 2011, the first woody perennial tree to have done so [11].

The scientists involved achieved this success, from start to finish, in little over 20 years. Conventional methods of cross breeding plum trees, with associated problems of linkage drag and small gene pool, would have taken many decades more.

Another example of successful genetic engineering helping to make a plant more productive and sustainable comes from Uganda. Ugandans eat more bananas per capita than anyone else, up to three times their bodyweight every year [12], but a disease called Xanthomonas Wilt swept the country, destroying the plants and contaminating the soil. Scientists at the country's National Banana Research Programme (so again I believe the source of information to be reliable) modified bananas with a sweet pepper gene, known to give resistance in other vegetables. Six out of the eight new Banana varieties created showed complete resistance to the Wilt and field trials began according to the Guardian article of 2011.[13] A more recent paper of 2017 by Leena Tripathi el al [14] demonstrates the need to produce these modified varieties "in the absence of known host plant resistance among banana genotypes, genetic engineering provides a cost-effective alternative technique to develop Xanthomonas wilt resistant banana varieties"[15].

These are just two examples of genetic engineering that have helped to mitigate the problems of food security that society is facing. In the years to come, many more projects could further help global crop sustainability, but there is still the question of whether it should. In Uganda, as in the U.K., scientists who "play God" with plants come up against criticism[16]. Public perception remains sceptical and as a society, we haven't yet accepted genetic engineering as a fully safe process. People worry that modified genes will end up in weeds and create monster problems in the countryside, that eating genetically engineered food may disrupt our gut flora and may lead to anti-biotic resistance or allergic reactions.

As seen during this current pandemic, there will always be people who don't trust the scientists. Only continuing success stories and the passage of time with good education will hopefully change the sceptic's minds. Genetic engineering is a heavily regulated industry, research and development has to be thorough and face robust scrutiny. But, I argue, that's what scientists do anyway, thoroughness and scrutiny as well as pushing boundaries, are features of scientific discovery. I believe people should have faith in scientists and the system they operate in.

I am a child of the 21st century and I can see the enormous challenges ahead for our planet. We are facing over-crowding, climate change, sea level rise and resource pressures in every direction. We haven't been living very sustainably and have harmed our planet as a result. We have to come up with new ways to increase our plant productivity without the need for more chemicals on the land. More people means more food needed and quickly. We do not have the time that Norman Borlaug had to produce his stem rust resistant wheat which tripled yields. Plants face many challenges of climate and pests and we have a scientific way to help them be more productive. Genetic engineering could, and should, be one of the tools we use to help crop security and enable plants to feed the planet.

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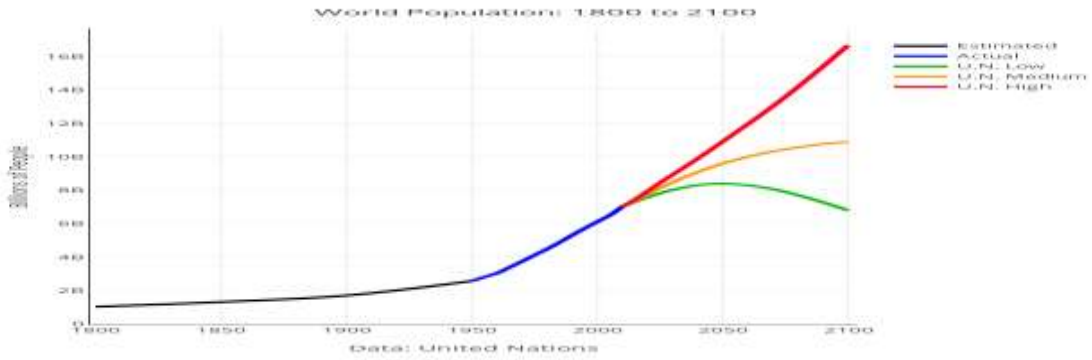

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