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Zambia: Strengthen the plant, Strengthen the people It is estimated that nearly one in every nine people suffer from hunger around the world. Zambia, similar to other stage three (based on the Demographic Transition Model) African countries, is experiencing rapid exponential population growth. With an annual population growth rate of 0.3% and a projected population of 41 million people by the year 2040, new strategies for food cultivation are vital to meet recommended nutrition standards and the needs of the next generation of Zambians (Zambia Population, 2020). Dramatic innovations in food science and technology are increasingly necessary to feed the demands of our developing world. As climate change continues to impact the agricultural landscapes of many nations, its destructive forces are another obstacle contributing to global hunger. Withered by drought and an annual infestation of fall armyworm (FAW, *S. frugiperda*), Zambia's poor harvests are depleting grain storages, subsequently, malnutrition and developmental stunting in children are on the rise.

Zambia's population rests at 17.4 million, most residing in rural areas, but is projected to increase exponentially (Zambia Population, 2020). Similar to the government of the United States of America, the Republican government of Zambia consists of three branches. President, Edgar Chagwa, is the leader of the executive branch and current head of the state (Chepkemoi, 2017). In addition to the government departments dedicated to food and livestock like those in the United States, Zambia also operates the Ministry of Agriculture. Responsible for all policies regarding farming, irrigation development, seed standards, and more, the Ministry of Agriculture plays a large role in the country's many agricultural industries. Zambia's climate is classified as tropic with semi-arid regions in the south. While parts of Zambia are known for their iconic waterfalls, the southern region of the country receives less rainfall and some years, Victoria Falls has been known to dry up entirely.

Maize is the staple grain of the region and the crop most heavily cultivated, however, due to its limited supply, its exportation is strictly prohibited. As many of the surrounding nations combat grain shortages and poor harvests, Zambia limited trade and centered their efforts on distributing grain to their own people. Zambians rely on maize for nearly every meal and boil maize to create porridges and traditional dishes such as Ugali (Lusaka Times, 2018). 32% of Zambia's land is used for agricultural purposes and a majority of people cultivating that land are subsistence farmers (Trading Economics, 2020). Small subsistence farming operations, however, are struggling to provide sufficient grain to their families and make a living wage due to the deteriorating health of their crops. Agricultural industries employ roughly 85% of the nation, yet more than 60% of Zambians live below the poverty line (WRENmedia, 2012). Impoverished families, typically consisting of parents and 3 children, are being affected by chronic malnutrition. Developmental stunting and nutritional deficits have been reported to delay the growth of children and increase Zambia's child mortality rate (CMR) to 57.8 (US CMR is 5.8 deaths/1000 children) (Knoema, 2018).

In addition to the 800,000 experiencing a food crisis and 300,000 in emergency status, over 2 million of

Zambia's 17 million people are classified as "food stressed" (GRFC, 2019). This trend will remain unchanged as the maize harvests fall due to low rainfall and the presence of invasive species. President Lungu, attributes the cause of such pervasive dry seasons to climate change. The insufficient rainfall contributes to record low crop yields and, in turn, depleted grain storages. In 2019, harvests hit a record low of 2 million metric tons (Mitimingi, 2019). Another significant obstacle damaging maize harvests is the infestation of an invasive species, fall armyworm.

The fall armyworm is native to the Americas but has quickly reached every corner of Africa since its arrival in 2016 and is expected to do the same in Asia as well. Identifiable by the inverted "Y" in the head of the caterpillar, Fall Armyworm have begun to gather the attention of agricultural experts from all over the world for the last decade due to their rapid expansion. The mature moth can travel great distances and it is fall armyworms' migratory ability that has allowed it to spread and be classified as an invasive species in over 40 countries as of 2020 (cabi.org, 2020). *Spodoptera frugiperda* has four life stages but is most destructive as larvae. Hatching from eggs in the stalks of plants, armyworm larvae eat their way out of maize, damaging the crop from the inside-out and damage the plants' reproductive structures. FAW feed on more than 350 plant species but primarily consume the many varieties of cultivated grasses such as rice, maize, wheat, sorghum, and sugarcane. Destruction from armyworms accounts for an estimated 160 million USD in damage every year, contributing greatly to Zambia's poor harvests and food insecurity (Mwambazi, 2019).

In order to combat the infestation of fall armyworm (FAW) and increase yields during dry seasons, I recommend biological solutions and increasing armyworm predation. Funding for my solution can be provided by the Food and Agriculture Organization of the United Nations (FAO) as an extension of their new project. The FAO has recently published a detailed three-year outline titled, Global Action for Fall Armyworm Control. The new program, projected to begin in 2020, is equipped to spend 500 million USD to strengthen sustainable pest control efforts that target Fall Armyworm (FAO, 2020). Currently, however, programs and radio workshops created by Zambia's Ministry of Agriculture exist to provide FAW education to subsistence farmers and encourage low-cost cultural control solutions. These workshops educate farmers as to how to identify if their crops are affected, hand pick and remove pests, and provide helpful information from FAW experts (Mwambazi, 2019). Campaigns such as this yield some positive results but after several seasons of implementation, FAW continues to plague farms. While the chemical approach may be effective, there are mounting safety concerns. On small family farms, pesticides can be easily ingested by growers and residents and have unknown health consequences for people and the environment. To limit Zambians' exposure, I aspire to propose more natural or biological solutions.

The Fall Armyworm population remains unchecked in African countries due to the lack of a cold season and the absence of its natural predators. During the colder months of the year in the United States, FAW are forced to migrate south. The time consuming migration that FAW undergoes in North America plays a key role in the success of young crops. The delayed arrival of FAW prevents the larvae from causing damage early in the development in the plant and decreasing yields. Unlike North America, Africa's favorable conditions year round allow FAW to have continuous generations, roughly 4-6 per year,

causing their numbers to explode with devastating consequences (Agboyi, 2020). FAW populations are also unable to devastate crops in North America as they have in Zambia due to the presence of natural predators. Ladybugs, lacewings, minute pirate bugs, and trichogramma wasps are all examples of natural enemies of FAW that are native to North America who consume *S. frugiperda* at various life stages (Planet Natural Research Center, 2018). These species play a pivotal role in the ecosystem as they prevent pest populations such as Fall Armyworm from dominating the region. While the introduction of these predators into Zambia would, in theory, be a viable pest control solution, the addition of new species may alter the ecosystem dramatically and have unintended consequences.

In order to curb the FAW population and avoid the introduction of a second potentially invasive species, the conservation and importation of existing predators in nearby areas of Africa may be a more viable solution. As many predators that feed on *S. frugiperda* are polyphagous, more selective parasitoids make better candidates for introduction and conservation. While there is limited information on the topic and research is ongoing, some of the most promising species include the larval parasitoid, *Coccygidium luteum* and the egg-larval parasitoid, *Chelonus bifoveolatus*, both currently native to Ghana and Benin (Koffi, 2020). *Pheidole megacephala*, *Haematochares obscuripennis* Stål, and *Peprius nodulipes* are ideal candidates for predation as well, however, they are less selective. Biological control would not only decrease environmental exposure to pesticides but it would be more sustainable than alternative methods. Biologic control is often more cost effective as well, while some projects may require continuous release, others may not need any intervention post introduction. The new species would reproduce, feed on immature FAW, and protect subsistence farmers crops more naturally. Costs are relatively low as previous projects report expenses as low as \$1,500 excluding salaries (Shelton, 2007).

Even without the presence of FAW, drought damages maize harvests across the country. Solutions to combat drought have been implemented in other countries through the use of genetic engineering. Drought-resistant maize strains increase leaf-transpiration efficiency and are reported to produce larger harvests despite dry climates (Bunce, 2010). Research conducted by the University of Cape Town has also cited that substitution of the ARGOS8 gene, affecting ethylene, a natural plant hormone, can increase plants' ability for osmotic adjustment and cellular elasticity (Science Direct, 2019). These changes would enable plants to use water more efficiently, therefore, require less water, and in turn be able to survive in drier climates. Genetically engineered seeds are more expensive than the traditional maize seed, however, they have the ability to improve yields during water shortages (Lusaka Times, 2016). A scientific consensus on the safety of genetically modified foods is fairly well established, and GMOs are commonplace in developed countries as "93 percent of the corn and soy planted in the United States is genetically modified", however, public opinion in Zambia still wavers (Plumer, 2015).

The former President, Levy Mwanawasa, notably refused all genetically modified food aid from entering the country in 2002, despite the nation's dire hunger crisis at the time. To this day, Zambia's National Biotechnology Authority restricts genetically-modified food from entering the country with very select exceptions (Nkonde, 2019). Unfortunately, the potential health concerns are not the only thing that is preventing Zambia and other African nations from cultivating GM crops.

There are other legitimate economic and environmental obstacles that prevent Zambia from investing in genetically engineered seeds. With a limited choice of supplier and increased cost, roughly \$80.00 more per acre, Zambia's argument to abstain from GM seeds and desire to prevent becoming dependent on western seed manufacturers is valid (Jennings, 2020). More recently, however, African governments' hesitation to plant genetically engineered crops is due to the risks it poses to the genetic diversity of their indigenous seeds. Cross pollination with native crops could irreversibly alter the genetics of their crops and endanger their existing complex farming system. In changing climates such as Zambia's, genetic variation among plants would also be more advantageous than a single crop. While combating climate change, a diverse range of maize varieties more equipped to handle drought may be what allows Zambian farmers to improve harvests and maintain grain storages at more consistent levels. Assuring the safety of genetically-modified foods to a skeptical nation is a challenge but I believe incorporating aspects of genetic engineering and the most modern solutions available would be most effective in curbing Zambia's hunger crisis. Rather than avoiding all genetic modification, a hybrid approach to seed selection that is more culturally appropriate and considers Zambia's concerns surrounding GMOs would likely be successful in restoring maize yields during years of drought.

Global hunger is an issue that weighs heavily on those who are affected. Food is a resource easily taken for granted in many areas of the developed world as in my own community, food insecurity is discussed infrequently. Insufficient nutrition can slow development and negatively impact Zambia's youth. This food discrepancy is a large inequality existing between the developing and developed world. By implementing the latest biotechnology and biological pest control methods, however, the Zambian people can refill essential grain storages and nourish their youth, lessening the disadvantages of their circumstances. It would be in the best interest of the nation of Zambia and the world to pursue such worthy endeavors with the latest agricultural innovations.

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