

Savannah Lim  
Burnsville Senior High School  
Burnsville, MN  
Ethiopia, Factor 1

### **Increasing Ethiopia's Crop Yield Through The Breeding of Disease Resistant Varieties**

Ethiopia is one of the world's oldest countries, and yet remains one of the poorest nations on the globe. This can be attributed to several factors, one of which is crop failure. Plant disease proves a formidable threat to subsistence farmers and overall crop production. Efforts should be taken to research sustainable practices and disease resistant plant breeds. To increase crop yield, improved plant varieties can be created and put to use. Humanitarian organizations could support these actions by funding programs that spur agricultural productivity.

Ethiopia is located on the Horn of Africa. The country lies under tropical latitudes and neighbors Somalia, Kenya, Sudan, Eritrea and Djibouti. The terrain is one of the most rugged and varying in all of Africa. Its topographic features include the Western Highlands, the Eastern Highlands, the Western Lowlands, the Eastern Lowlands, and the Rift Valley (Ethiopia, *Encyclopædia*). The hottest areas are found along the edge of the country, while the coolest temperatures are found in the central highlands. About 75% of precipitation falls between the months of June and September (Ethiopia, *World*).

Although 60% of government funding has been spent on agriculture, water, and road development in the last seven years, Ethiopia continues to fight against food insecurity. Food production is hindered by extreme and erratic weather conditions, such as droughts or floods. This causes the nation to be highly dependent on food imports and easily affected by changing global food prices. 44% of the population lives below the poverty line (Sniderman).

The population is overwhelmingly rural. Approximately 90% of the country's inhabitants are engaged in subsistence agriculture (Ethiopia, *World*) while the rest reside in urban areas (Mohr). The typical Ethiopian subsistence family structure is patriarchal, with the father as head of the household and the mother in charge of caring for several children. As children are socially required to care for adults, there are often three or four generations living under the same roof (Mohr).

The diet of an Ethiopian farm family is quite simple. Bread, made from grains like millet, sorghum, wheat, and teff, is a major component of every meal. Vegetables and animals are often grown or raised at home. On special occasions, meat is served. Other elements of cooking include *berbere*, a spicy red pepper paste, *niter kibbeh*, a spice-infused clarified butter, and *injera*, a sourdough pancake-like bread. Most dishes have a stew-like consistency (Ethiopian).

Access to education is limited. In rural communities, one fourth of all Ethiopian children are not able to attend school (Health). Instead, they must help their families with farm work and chores at home. Low enrollment levels are also caused by school supplies fees and insufficient emphasis at home on a proper education. However, public education is free at all levels. Primary education is compulsory from seven to twelve years of age. Secondary education, which takes up four years, is comprised of two-year cycles. Primary schools are generally accessible, whereas secondary schools are scarce. Overall, the public education system is deteriorating from lack of adequate funding, teaching staff, facilities, and space. As a result, literacy rates are much lower than world averages. Only half of the male population is literate. Female literacy is even lower, with rates ranging from one-third to two-fifths (Ethiopia, *Encyclopædia*).

Although major cities have hospitals with full-time doctors, access to modern health care is very limited and in the countryside, virtually nonexistent. The distribution of healthcare specialists across the nation is highly unbalanced. 62% of doctors and 46% of nurses are concentrated in the capital of Addis Ababa,

where a mere 5% of the population lives (Mohr). This negatively impacts rural areas, where there is about one doctor for every 70,000 people (Health). Thus, many complex conditions go untreated and children are not provided the necessary health care. With the highest number of HIV/AIDS infections in the world, the provision of medical facilities in Ethiopia is crucial. Moreover, the annual income of a subsistence family is usually too low to send someone to a hospital. Although government health spending has risen, the current health expenditure is far below the average of other sub-Saharan African countries (Mohr).

The average size of a farm is less than one hectare (Rural). Wheat, barley, and potato are amongst the most common crops produced by subsistence agricultural households (Sodo). 86% of Ethiopian agricultural land is used to cultivate grains. Teff is grown in the cooler highlands, while sorghum thrives in the hotter lowlands due to its hardiness and drought resistance (Crop).

Agricultural practices for smallholder farmers involve mixed crop and livestock systems. Ethiopia is one of the African countries with the largest numbers of livestock (Ethiopia, *Encyclopædia*). Farming activities vary across the country, as they are determined by the physical properties of the plot. Three different types of land based on physical criteria are identified as *gedena*, *dehri-bet*, and *wolfri*. *Gedena* describes land near or around the home. These areas are the most varied landscapes in terms of fencing, conservation structures, and perennial plant species. They are also the most intensely cultivated. More members of the family contribute work on *gedena* than on other categories of land. *Dehri-bet* is located further from the household than *gedena* and therefore is not as meticulously farmed. *Wolfri* includes the fields farthest from the household. Because of their location, full days must be set aside to work on these plots (Beyene, Gibbon, and Haile 7-9).

Although Ethiopia's land is regarded as its most promising agricultural resource, the full potential of farming has yet to be unleashed. Despite soil erosion, overgrazing, and deforestation, almost half the potentially farmable land is available for use (Ethiopia, *Encyclopædia*). Agriculture accounts for 42% of the GDP, 80% of exports, and 80% of the labor force. Still, numerous obstacles lie on the path to a more productive agricultural sector. Productivity levels are low at about 1.7 tons per hectare for major crops that are often vulnerable to drought and disease (Rural). The country is plagued with periodic drought, soil degradation from ineffective agricultural practices and overgrazing, deforestation, high population density, undeveloped water resources, and poor transport infrastructure (Background). These issues make it especially difficult and costly to bring foods to market. Additionally, natural disasters and market shocks leave subsistence farming families at risk of severe impoverishment.

Employment, earning a living wage, and access to food markets and adequate nutrition are also riddled with problems. Employment opportunities are worst for child laborers and those who have not completed schooling because they are often unable to accumulate the human capital needed for beneficial employment (Guarcello and Rosati 1). The population is growing at 2.79%, resulting in a labor force that is growing faster than what the economy can effectively employ. Hence, the unemployment rate is 20.6% in the cities and 2.6% in rural areas (Ethiopia, *International*). The country suffers from underdeveloped infrastructure and communication systems, making it difficult to find and maintain a job. Another point of concern is gender inequality. Because early marriage forces girls to end their schooling, they have significantly less job opportunities than men, whom education and other priorities are more emphasized upon. The United Nations Population Fund describes the disparities between women and men: The employment status of women is affected by occupational segregation, gender-based wage gaps, and the devaluing of their work compared to men (Gender). Nevertheless, earning a living wage is extremely tough for both men and women. The minimum wage is 0.47 USD per day. A third of the population, including rural families, lives on less than 1 USD a day. A typical family of five requires about 61 USD every month to survive, but even with two wage earners in the family, it receives only half the income needed for subsistence (Ethiopia, *Encyclopedia of the Nations*). This results in the family's reliance on the children to contribute to the household income. Hunger is hard to avoid. In a rural area, the market is one

to three hours away on foot. With such limited access to food and nutrition, it is no surprise that more than 35% of the population is malnourished (Hunger).

Increasing crop yields and improving disease resistance through the research and breeding of improved plant varieties can provide relief to suffering subsistence farmers. Crop disease always brings impending disasters. Strains of yellow rust or late blight are constant worries to farmers as entire fields can be ravaged. Affected crops must then be excavated, treated with pesticide, or burned. If the family does not produce enough food, they may face starvation or poverty. In 2006, 31-100% of potato crops were decimated from late blight disease. In 2010, wheat rust disease destroyed 410,000 hectares of wheat field (Bachrach). Bad harvests impair the farmer's ability to repay loans (Devereux and Guenther). Such measures make it even harder for farmers to afford food, medical attention, and other necessities to survive. Malnutrition and micronutrient deficiencies are exacerbated by these situations.

Currently, the Ethiopian government is attempting to find ways to breed higher-yielding and more disease resistant crops. Crop failure is prevalent throughout the nation. In 2008, Ethiopia appealed for 325 million USD in food and humanitarian aid after drought and crop failure more than doubled those in need of emergency assistance to 4.6 million. These circumstances are severe enough that hundreds of thousands of families are unable to buy food and tens of thousands of children suffer from acute malnutrition and illness (Rice). The environment is indirectly affected by plant disease. Damaged fields may require interventions that cause soil erosion such as excavation, burning, or pesticide spray. Furthermore, with higher occurrences of crop failure, more land must be prepared for mixed cropping and more water must be used. Women, the rural and urban poor, and developing countries are disadvantaged in such events. Women and children in particular are the most adversely affected when there is crop failure. Unlike men, women and children cannot run away safely and are left on the site to deal with the consequences (Zabarenko). Since rural farmers produce crops for their own survival and for maintaining an income, plant disease is a huge concern as it can wipe out entire fields. The urban poor are not as affected because they do not have direct ties to crop production. Developing countries suffer the most from crop failure because less crop production is more detrimental to their agriculture-based economies.

Crop failure is becoming of more central importance. Another strain of yellow rust is about to hit Ethiopia and late blight continues to constrain potato production. Trends are assessed through acreage expansion and yield increase. Measurements indicate that the situation is fluctuating: From 1998 to 2008, crop yields for barley, maize, sorghum, and teff rose and fell multiple times, with teff being the only grain to increase in yield, by about 20%. Wheat and barley production is expected to fall 10% in 2011 due to an outbreak of yellow rust (Taffesse and Chamberlin). Although there has not been drastic improvement or decline, the state of the subsistence farm family remains unpredictable. New strains of disease can morph, putting any crop field at risk.

Reducing the severity of crop disease will increase crop yield and provide a better source of food and income for the family. As 90% of the country's residents earn a living from subsistence farming, prospects and lifestyles would look much better (Ethiopia, *World*). Families will have money to pay for necessary foodstuffs and will be able to earn more money from their harvests. With better-performing crops, there will be less environmental degradation. Monocropping may become more efficient and mixed crop lands will be less extensive. Irrigation will also be more effectively implemented and water resources will be better managed, since there will be less land that needs watering. The economy will progress and poverty will decrease. As agriculture contributes to half the country's GDP, improvements to the agricultural sector will raise the productivity of a flailing economy (Ethiopia, *Encyclopædia*). A larger farm output will allow women to have access to nutrition, education, and job opportunities. Girls may spend less time in the fields and more time in school. With a source of food, women can focus more on securing jobs and overcoming gender barriers at the workplace. Smallholder farmers will see an increase

in the productivity of their plot, and thus an increase in income and stability. Urban dwellers may experience a better standard of living from increased government funds.

Apart from the hindrances of physical farmland, other factors affect the increase of crop yields and the occurrence of crop disease. Climate change, for instance, poses a constant threat to agriculture. Although some plants may be more resistant, prolonged periods of drought can still destroy them. Water scarcity is another obstacle to production. 49 million people lack access to water resources. In rural Ethiopia, women and children must walk up to six hours to find water. The jugs used to carry water back to the village may weigh forty pounds (Ethiopia, *Water.org*). It is even more difficult to collect enough water to sufficiently cultivate a hectare of farmland. Without water, plants will not be able to grow. Poor farming practices can lower yields - overgrazing and deforestation erode soils, which leads to desertification and poor plant growth. Issues like these can lower crop yield and worsen the effects of crop disease. If they persist, subsistence farming communities will continue to experience impoverishment. If conditions improve, families will be lifted out of severe poverty and yields would increase, moving the economy forward.

One way to answering the problem of crop failure is through the breeding of improved plant varieties that are more resistant to disease. One of the most distressing diseases is late blight, which is a major bottleneck to potato production in Ethiopia. Use of fungicides was found to improve potato production in east Africa (Tesserra and Giorgis). According to the Food and Agriculture Organization of the United States, Ethiopia has the greatest potential for potato production. 70% of Ethiopian land, mainly in highland areas, is suitable for growing the potato. In fact, its growth is expanding steadily. Production has increased from 280,000 tons in 1993 to 525,000 tons in 2007 (Potato). In July 2011, I began conducting research in Gortner Lab at the University of Minnesota on the effects of benzothiadiazole, an environmentally friendly fungicide, on *Phytophthora infestans* (the fungus that causes late blight). Should the fungicide benzothiadiazole successfully inhibit fungal growth, it is a potential solution to reducing the damages of late blight. Not only can the fungicide be applied directly to the potatoes to prevent further deterioration from the disease, but it might also be able to be bred into the potato to create a type resistant to late blight. DL-3-amino butyric acid, or BABA, is another safe fungicide that has been shown to inhibit *Phytophthora infestans* (Y et al.). DL-3-amino butyric acid may also be bred into the potato for disease-resistance. Potatoes that have acquired systemic resistance to pathogens may be bred together to produce a stronger variety of potato. Defender, created by an ARS researcher, is the only U.S. commercial potato with late-blight-resistant tubers and leaves (Wood). Farmers can plant Defender potatoes in their fields to combat late blight or use potatoes that have been bred with Defender. These methods could be applied to other crops to increase production.

Several Millennium Development Goals (numerical benchmarks made by world leaders for tackling poverty) can be used to realize objectives within Ethiopia's agricultural community. The first, third, fourth, and seventh Millennium Development Goals should be used to solve crop failure by 2015. Other policies, practices, and investments must be made to reach these goals. The minimum wage of Ethiopia should be raised so that families can earn enough money to feed their children and maintain their health. Gender discrimination should be eradicated from the workplace. More funds should be allocated to the building of more hospitals and clinics in rural areas where there are none. Policies should be made to discourage non-sustainable agricultural practices.

Communities, the national government, corporations, and other organizations must do their part and support those goals and recommendations. Communities should implement labor sources and share indigenous planting techniques to ensure the best harvest. The national government of Ethiopia should support programs that focus on sustainable agricultural practices, distribution of disease-resistant plants, and institutions that research the breeding of hardier crops. Corporations could donate to these programs. Other well-known organizations like the World Bank, United Nations, and FAO can help fund agricultural projects that aid subsistence farm communities and relieve their poverty. Lastly, rural

farmers should cooperate and collaborate to share labor and agricultural know-how while those in the cities should purchase locally grown crops to support the work of Ethiopian farmers.

The importance of crop disease on the economy cannot be underestimated. Subsistence farming families are at the mercy of evolving strains of pathogens and climate change, which can bring sudden bouts of drought or flooding. When entire hectares of agricultural land are consumed with disease, there is little to no hope left for a family's survival or income. Once better systems of farming are implemented and plants are adapted to resist diseases rampant in Ethiopia, crop yields will increase and poverty rates will decrease. Fungicides such as benzothiadiazole or DL-3-amino butyric acid could play revolutionary roles in the breeding of disease-resistant crop varieties, such as the potato, which is one of the most important staple crops in the nation. Additionally, existing varieties that are resistant to disease could be bred with other varieties or planted in fields. Along with Millennium Development Goals, better employment policies, wage policies, and actions by the government and humanitarian organizations will help Ethiopia get one step closer to reaching economic stability and further development. With a growing population and struggling economy, the country is far from becoming a tertiary society. However, increasing awareness and aid may one day help the country to finally lift itself out of poverty.

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