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Colombia, Sustainable Agriculture
Colombia: Saving Coffee and the Country

Some of the most popular coffee roasts in the United States today are French, Italian, and Colombian. It should be no surprise then that the third largest producer of coffee in the world is Colombia, surpassed only by Brazil and Vietnam (Penarredonda). Several of the most well known coffee companies in the world source their coffee from the combined effort of nearly 500,000 family-run coffee farms in Colombia. For example, these companies include Juan Valdez, Folgers 100% Colombian, and Starbucks. In 2017, coffee accounted for approximately 6.9% of Colombia's GDP and had an export value of nearly 2.7 billion dollars ("Colombia" *OEC - Colombia (COL) Exports, Imports, and Trade Partners*). This is why a coffee fungus called *Hemileia vastatrix*, commonly referred to as coffee rust, has become so devastating. If the coffee rust epidemic is not resolved, the future of coffee and the lives of the Colombian people will be changed forever.

Colombia has a projected population of 49.85 million people for the year 2019 ("Colombia Population 2019"). Bogotá, the capital of Colombia, is home to 7.9 million people ("Colombia Population 2019"). The size of a typical Colombian family was 3.9 people in 2018 ("Average Household Size in Colombia"). Many Colombians are employed in the fields of mining, manufacturing, and agriculture. Colombia is rich in mineral deposits; however, only four percent of the gross domestic product comes from mining. The manufacturing sector employs about 35% of the workforce in the country ("Colombia" *Countries and Their Cultures*). Colombia's main manufacturing exports are textiles, garments, chemicals, and metal products ("Colombia" *Countries and Their Cultures*). Agriculture plays a large part in Colombia's national economy. Nearly 16.14% of employed Colombians work in agriculture, and the majority of these employees work for family farms or own one themselves. In 2017, 6.46% of Colombia's GDP came from agricultural goods ("Colombia - Share of Economic Sectors in the Gross Domestic Product (GDP) from 2007 to 2017"). Colombia has a total land area of 113,891,400 hectares, and nearly twenty-seven percent of it is used for agriculture ("Colombia - Agriculture"). The average farm size is roughly 211 hectares as of 1997; however, most of these farms are "too small to provide a living" ("Colombia - Agriculture"). The country's main cash crops and exports include coffee, rice, bananas, plantains, cocoa, beans, potatoes, and sugarcane.

Colombia is an expansive country that is highly biodiverse. Venezuela borders the country to the west, the Caribbean Sea and Panama to the north, the Pacific Ocean to the east, and Ecuador, Peru, and Brazil to the south. All of these countries are also very biodiverse. The growth of crops in Colombia is localized by region due to the diverse landscape of the country; therefore, the typical diet varies by region. For example, the coastal diet is high in seafood, such as fish and lobster, because the people in this region are close to the ocean, whereas the inland diet includes foods such as rice, beans, steak, and plantain because the crops and livestock are grown and raised closer to the interior of the country. Many diets in the country are full of meat and potatoes and consist of many foods influenced by the Spanish culture. Most families get their food from a supermarket or a type of open-air market. Foods are generally cooked in a standard kitchen consisting of a stove and other necessary kitchen tools. Most meals include foods that have been fried, baked, or boiled. The method of cooking depends on the specific location in the country. The wages for different jobs in the country are based on the type of work being done. Physical and semi-skilled laborers are given low wages while workers who are highly educated, such as managers and professionals, are paid much better ("Colombia" *Countries and Their Cultures*). Colombia's average wage of \$692 per month is less than half of the global average, which is \$1,480 per month (Peters). However, wages for a Colombian worker can be as low as \$296 per month (Wade). Based on this income,

it is hard for families to meet their basic needs. Forty point three percent of the rural population is currently living in poverty (“Colombia - Employment in Agriculture (% of Total Employment)”). The minimum wage can be particularly devastating to coffee farmers. When coffee rust attacks a plant, the farmers know that there will be a smaller production yield that year. This decline in production directly affects the farmers who are already struggling to make ends meet by forcing them to live in poverty. Colombia is the world’s third leading exporter of coffee and is therefore sensitive to market price fluctuations that also affect farmers’ profits (“Colombia” *Countries and Their Cultures*).

Colombia is governed as a republic with an authoritarian presidential figure and three governing branches including the executive, legislative, and judicial (“Colombia: Government”). The president is elected by popular vote and may only serve one, four-year term. The Congress of Colombia is elected through a national vote and representatives may serve an unlimited number of terms. The country’s constitution protects the people of Colombia and their rights from being taken away by the government (Longley). The protection provided by the government has been pivotal in maintaining land ownership rights for farms (“History of Coffee in Colombia”). Colombia’s government largely benefits from the production of coffee through tariffs on all coffee exports, making it worthwhile for the government to protect the land of coffee farmers. (“History of Coffee in Colombia”).

In recent years, Colombia has endured a number of political challenges. Immense destruction to the economy, land, and population is a result of the nearly fifty years of conflict between Colombia’s government and an opposition group called the Fuerzas Armadas Revolucionarias de Colombia (“Colombia” *World Food Programme*). Because of this destruction, the country has had a hard time rebuilding itself since a peace agreement was signed in 2016. One industry struggling to rebuild is the coffee industry.

Colombia’s political instability has resulted in a lack of education for the youth, particularly families living in poverty or without substantial resources. Forty-two percent of children from the most impoverished homes start school later than their peers, and fifty percent of youth living in poverty never attend school. Thirty-seven point two percent of all Colombian students did not continue their education past high school in 2010. This is primarily due to either a lack of financial resources or lack of access to schools. The country’s lack of education for its youth has widened the pre-existing inequalities of social class, gender, income, and ethnicity (Thomas). One step that has been taken to increase school attendance in the most impoverished areas of Colombia is the Everyone Learns program that was implemented in 2012. This program focuses on improving mathematics and language studies for elementary school students and has reached nearly 2.4 million of the country’s youth (Thomas). Nearly 3,000 of Colombia’s top teachers have joined this effort by leading the program to meet its goals and educate as many students as possible (Arvizo).

Colombia’s social classes reflect ethnicity and income. People of European ancestry make up the majority of the upper class, while people of mixed, African or Indian descent make up the middle and lower classes. Disadvantaged individuals face discrimination later in life because they do not have the same education levels as their peers, leading to further economic discrimination. The situation is circular, of course: The reason for the lack of education is the lack of significant family income.

The gender roles of Colombian citizens vary by class. In the upper and middle classes, women hold a more familial role and men are the breadwinners. The women of the upper and middle class also dedicate their time to church and social issues. However, lower class women hold jobs outside the home to help contribute to the total income of the home (“Colombia” *Countries and Their Cultures*). About 25% of maternal deaths in rural areas are due to self-inflicted abortions outside of a hospital because these women cannot receive adequate health care due to their location.

Other rural deaths can be attributed to tropical diseases as well as guerilla attacks (“Colombia” *Countries and Their Cultures*). The availability of healthcare varies by class and region of the country. The middle and upper classes of urban Colombia have easier access to healthcare than those from the lower class or rural areas due mainly to location (“Colombia” *Countries and Their Cultures*). Healthcare itself is relatively affordable and of high quality. The primary issue for the citizens of Colombia is getting to an adequate healthcare facility.

In the poorest rural communities of Colombia, clean water and toilets can be hard to come by. It is estimated that every one in three people does not have access to a clean toilet and every one in four people do not have access to safe drinking water (“Colombia” *WaterAid*). In Colombia, nearly 99% of the country’s population had access to electricity as of 2016 (“Colombia - Access to Electricity (% of Population)”). In major cities such as Bogotá, telephones and cell phones are common, but in rural areas, they are not (“Colombia 2017 Crime & Safety Report: Bogotá”). Roads are in poor condition all around the country; this poor infrastructure leads to accidents, increased travel time, and violent crimes. Poor road conditions can also make it difficult to access local markets that provide nutritious food.

Another recent issue for Colombia has been the surge in Venezuelan refugees. These refugees are looking for food, jobs, money, education and a better life. Since the country of Colombia is already struggling to provide for its own residents, the displaced persons increase the number of people struggling to make ends meet with limited resources.

The Colombian drug crisis has also played a large part in holding the country back. Colombia is responsible for nearly half of the world’s cocaine supply. The government has tried to decrease drug trafficking by destroying the coca plants from which cocaine is derived (“Drug Trafficking in Colombia”). However, the guerillas continue to steal agricultural land for drug related crimes.

Political instability, low wages, access to education, a divide in social class, gender, and location have all contributed to the struggles of everyday Colombian citizens, thus making the challenge for solving other issues the country faces even more strenuous. Among these other issues, a severe crop problem for coffee farmers is a disease caused by the *Hemileia vastatrix* fungus, commonly known as coffee rust. The fungus develops as a brown powder on the leaves of a coffee bush or small tree. Over time, the plant loses its leaves, produces a significantly smaller yield, and eventually dies after it has lost the ability to produce cherries (“Coffee Rust”). From 2008 to 2011, the production of coffee decreased 31% due to coffee rust (Wight).

Coffee rust is an issue found in other places around the world as well. For example, Sri Lanka used to be a major coffee exporting country. In the late 19th century, coffee rust infected their crops. After a few decades, coffee was no longer grown in Sri Lanka because all of the plants were destroyed. Shortly after, they switched to producing tea, and the main purchaser of their product, Britain, switched to drinking tea.

There are two main types of coffee plants grown in Colombia: the *Coffea arabica*, also known as arabica, and the *Coffea canephora*, also known as robusta. Arabica coffee is known for its sweet taste; it sells well in international markets. Robusta is known for its bitterness and a higher caffeine content. The two plants vary greatly on a biological and physical level as well. Arabica beans grow on a bush: The cherries mature between seven and nine months, the plant thrives between fifteen and twenty-four degrees celsius, and it is normally grown in hilly areas. Robusta grows as a tough tree to be about ten meters tall: Its cherries mature in eleven months, the plant thrives between twenty-four and thirty degrees celsius, and it produces seeds that are smaller than arabica seeds. However, the biggest difference between these two varieties is that arabica plants are susceptible to coffee rust, while robusta is resistant.

Coffee is grown in the northern part of South America within the Zona Cafetera, or the Colombian coffee growing axis, between the ranges of mountains that make up the Andes (“History of Coffee in Colombia”). The topography of Colombia is significantly varied; it includes many features such as the mountains of the Colombian Andes and the Sierra Nevada de Santa Marta ranges and the plains of Los Llanos. The majority of farmland is located at a level lower than the mountains or in the Atlantic lowlands (Garavito). Because Colombia is very hilly and mountainous, machinery cannot be used; therefore, each cherry is picked by hand. An average coffee tree contains about two to four kilos of cherries per tree, and a skilled picker can collect between forty-five and ninety kilos per day. This amount produces nearly eighteen kilos of coffee beans (“All About Coffee”).

Most coffee is grown in developing countries such as Colombia. Since these countries are still developing, the practice of food and crop science is significantly underdeveloped. Colombia’s National Federation of Coffee Growers, also known as Fedecafe, was determined to change this before Colombia’s coffee production reached a state of crisis. Fedecafe created a research facility called Cenicafe that opened in 1938 to prepare for the arrival of coffee rust and serve as a scientific research facility for coffee. The coffee industry has provided Cenicafe with an annual budget of nearly 10.7 million dollars to fight the coffee rust epidemic (Wight). Cenicafe has conducted many years of research with the purpose of finding ways to change the coffee plant and prevent the spread of coffee rust. One of Cenicafe’s first projects was to find a way to combine the great taste of arabica coffee with the resistance of robusta to create the perfect coffee plant. However, it was not as simple as creating a hybrid between the two plants. These two plants do not normally interbreed. After years of research, a new variety of coffee, called Timor, was found in nature. Timor seemed to be a near perfect hybrid of arabica and robusta and could have been the perfect solution to all issues relating to coffee rust, except it did not taste good. Next, the researchers attempted to breed Timor with Caturra, the dominant species of arabica plants, to improve the taste, maintain resistance, and produce a shorter tree that would be better for productivity. The scientists bred this combination for five generations. After each generation was harvested, the coffee was tasted and the best plants were selected to attempt to bring out the flavor. Finally, the hybrid reached a satisfactory taste and the Colombia hybrid was born. Unfortunately, the resistance did not last forever, and coffee rust is an issue once again: This is a pitfall of monoculture. Current solutions for battling coffee rust include pruning the plants down to their roots or spraying fungicides which can be potentially harmful to plants, soil, and the water supply.

Coffee rust attacks the leaves of the coffee plant first; therefore, the epidermal tissue of the leaves provide the first line of defense. If the spores from the coffee rust succeed in entering the plant through the openings in the stomata (pores in the epidermis of leaves, stems, and other organs), pathogen-associated molecular pattern (PAMP)-triggered immunity is provoked. PAMP-triggered immunity allows for the plant to strengthen its cell walls, slowing the penetration of the spores. If, however, proteins from the fungus are detected, the hypersensitive response will occur, allowing the plant to initiate localized necrosis and attack the spores. This defense will stop the spread of spores completely by producing enzymes and chemicals to hinder the reproduction of spores. It is at this stage of development that genetic modification could take place using Clustered Regularly Interspaced Short Palindromic Repeats (CRISPR), a method used to edit genes. However, before CRISPR can be used, the genes related to controlling the hypersensitive response need to be identified. Because these defensive responses include a large number of proteins, transcription factors and communication signals, identifying one or two key components is cumbersome and would not necessarily yield a perfect fix. It should be noted that the controversy surrounding the use of genetically modified organisms is not a concern for Colombia.

Spectrophotometers can be used as a way to identify coffee rust in a plant before the plant is completely infected. This technology uses a color sensor that detects light variations in leaves. Interpreted data from

this instrument can alert a farmer about a potential coffee rust attack before it completely destroys the crop. Once coffee rust is identified, a farmer would continue to follow their previous protocols for spraying fungicides, but use CR-10 instead. CR-10 is a biodegradable fungicide that has been proven to be effective in coffee rust outbreaks located in Costa Rica and Guatemala (“Biofungicide CR-10 Keeps Winning Battles Against Coffee Rust In Guatemala And Costa Rica”). Because this fungicide is biodegradable, the farmers would not destroy their land or their plants.

These solutions could be carried out using resources from Cenicafe and a local university. Cenicafe could implement the techniques necessary to modify the seeds while a university extension program could teach farmers better growing methods and how to use spectrophotometer technology. Providing incentives for farmers to buy the modified seeds would also encourage the change. Because planting new seeds would likely result in a low yield the first year, incomes would reduce as well. Therefore, Fedecafe could continue to offer subsidies and loans to farmers (Penarredonda).

Other considered solutions include ideas such as augmenting the export of robusta coffee, moving the location of coffee farms, and changing the types of arabica seeds used. However, all of these ideas have proven to be ineffective or unrealistic. Robusta coffee cannot be planted instead of arabica because Colombia only exports arabica coffee and the country has no intent to change that due to fear of losing buyers. Farming at a higher altitude and increasing plant diversity in a plantation could theoretically work because coffee plants are less susceptible to coffee rust when grown at a lower temperature or among other plants. This solution fails for two main reasons: It would be temporary due to global warming, and changing the area that is being farmed could mean potentially relocating a village or town. However, if this relocation were tested in a controlled setting and yields promising results, it could be implemented in an unpopulated area of the country in the future. Changing the types of arabica seeds being used could, in theory, aid in finding a resistant variety of arabica. This solution would have a very difficult time being carried out. Many farmers keep the trees they have planted for around eight years; this would mean that the effects of changing seeds would be extremely delayed. Farmers may also have a difficult time convincing their buyers to stay in business with them due to a possible shift in price.

The only way to prevent coffee rust from taking over the coffee industry is to use multiple methods for a combined solution. These methods consist of pre- and post-planting methods, as well as improving the overall well-being of the Colombian people. To control coffee rust, the combined efforts of gene identification, gene editing, spectrophotometer use, and fungicides must be implemented. If this is accomplished, the health of the coffee plants and the welfare of the Colombian people will be improved.

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