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Mali, Plants

Using the Neem (*Azadirachta indica*) Tree and Bitter Leaf (*Gymnanthemum amygdalinum*) Shrub As Pesticide Alternatives to Improve Agricultural Productivity in Mali

It is not going to be easy to feed nearly 9 billion people by 2050, or even the projected 43 and a half million people in Mali (Population Pyramid). Mali is a country suffering from the effects of climate change-related weather patterns, poor infrastructure, post-harvest losses, and low agricultural productivity (USAID). Ranking 79th of the 113 countries in the Global Food Security Index, Mali needs innovation to ensure a sustainable food system in which future generations have enough healthy and nutritious food to eat.

Mali is a landlocked country in Western Africa revolving around the agricultural industry. In a population of over 20 million, about 55.3% of the population inhabits rural areas, with about 34.1% of the land devoted to agriculture. As agriculture makes up a significant 39% of Mali's GDP, about 80% of jobs are related to agriculture, supporting the average family size of 5.8 people (Chutel). The terrain is varied with plains in the North, savannahs in the South, and hills in the Northeast. Most farms are of a smaller scale, producing crops such as maize and rice (CIA Factbook). The Malians' cereal-rich diet includes rice, sorghum, and maize, along with cowpeas, and starchy vegetables such as cassava and yams. The lack of diversity in Malians' cereal-rich diets remains one of the greatest barriers a typical family faces as their diets often lack certain micronutrients such as vitamin A (UNICEF). 49% of the population lives under the global poverty line with over half of both men and women uneducated (66% and 53% respectively). 49% of the population lacks access to electricity, often disproportionately affecting rural communities (U.S. Agency for International Development). A multi-faceted approach is needed to ameliorate the current conditions facing communities in Mali.

As agriculture is one of the largest industries in Mali, the continued usage of obsolete pesticides demands reform to create a more sustainable future for farming. About 4 million tons of pesticides are sprayed every year in Mali, including obsolete pesticides, with around 50,000 obsolete pesticides across the country (World Bank). Obsolete pesticides have been responsible for the death of around 200 people every year from toxic pesticide poisoning, an additional toll on rural communities. 80% of these obsolete pesticides are used for cotton, one of Mali's major export crops (World Bank). Not only are these pesticides harmful to human and soil health, but are pollutants to water and the cause of health issues in livestock who graze on sprayed crops. Insufficient safety training for farmers and an overall lack of community awareness of the dangers of these toxic pesticides are a few of the many reasons why obsolete pesticides continue to be utilized to this day. In 2007, the Africa Stockpiles Program was set up to tackle this issue, regulating pesticide use (World Bank). Further efforts and/or solutions could aid the program in handling the thousands of obsolete pesticides still in existence in Mali.

Just as unsustainable agricultural practices continued to be used, the poverty issue in Mali remains unaddressed. With a 12% unemployment rate nationwide, and a whopping 32% unemployment rate in Bamako, the nation's capital, change is desperately needed in the job sector (International Labor Organization). To put this into perspective, the United States had an overall unemployment rate of just 3.5% in January of 2020 before the Covid-19 pandemic (U.S. Bureau of Labor Statistics). This high unemployment rate in Mali can be attributed to a "lack of funding" and "poor governance," according to a survey given out by TheVoice4Thought foundation to youth in Mali. The youth in the study explained that the lack of government guidance in helping people to find jobs is the leading cause of the country's high unemployment rate. A solution is needed to not only make farming practices more sustainable but to revitalize Mali's economy and secure jobs for the next generation.

A major problem with agriculture in Mali is a lack of environmentally-friendly alternatives to battle pests such as the fall armyworm (*Spodoptera frugiperda*), cotton bollworm (*Helicoverpa armigera*), and desert locust. The fall armyworm is the larval form of the invasive moth and can travel up to 62 miles in one night, affecting staple Malian crops: maize, sorghum, fruits, vegetables, and more. Across the African continent, the fall armyworm has led to losses of \$4.6 billion annually (Jerving). The cotton bollworm is an invasive moth, but is most destructive in its larval form. In just 15 days, a couple larvae can completely ruin all the bolls on a cotton plant. Other affected crops include tomatoes and maize ("*Helicoverpa armigera* (Cotton Bollworm)").

Locusts are yet another threat to the future of Mali's agricultural systems, forming damaging swarms. The heavy rains in 2012 helped to bolster locust hatching in northern Mali. Locusts, specifically desert locusts, are a type of grasshopper that travels in swarms, damaging and consuming crops along the way. While Mali is not among the countries most severely affected by locusts, the country could very well encounter more in the future as climate change increases the number of cyclones, and weather patterns that nourish the locusts with water and the necessary heat for breeding (Eos). Oftentimes, areas affected by locusts don't have sufficient resources to battle them, leading to crop loss and food insecurity. By reducing the effects of locust swarms, agricultural livelihoods in not just Mali, but around the East African and Indian region can be benefited. Currently, chemical pesticides are utilized, but this measure is insufficient to prevent desert locusts from severely damaging crops.

My recommendation involves the possible incorporation of two different antifungal plants with a multitude of uses, allowing for job growth and revitalization of rural livelihoods in Mali. Information concerning pesticide instruction utilizing these plants would be disseminated via the radio and other forms of mass media, including cartoon images in newspapers.

Neem oil derives from the neem tree (*Azadirachta indica*), native to Burma, Sri Lanka, and India (University of New Hampshire). It was introduced to Mali in the 1960s, reaching up to 30 meters tall and 20 meters wide. It grows well in hot, dry climates, making it suitable for growing in Mali. The neem tree produces a deep, robust root system, allowing it to survive wear and tear very well. The up to 2 cm neem fruit originates from white, bisexual, clustered flowers, which bees are fond of (Fig. 1). Interestingly, the tree gives off a scent resembling that of honey! When ripe, the fruit is yellow and sweet tasting,

enveloping a seed made up of a shell and a few kernels. The kernel has the strongest pesticidal properties out of all parts of the tree and is made up of the compound Azadirachtin. Azadirachtin interferes with the hormones of insects, preventing them from developing and reproducing properly when ingested ("Effects on Insects"). The oil itself can be incorporated into dust, powders, and concentrates. The neem tree does not disappoint in production, bearing fruit within 3-5 years, and developing into full production capability at 10 years of age. About 50 kg of fruit can be harvested every year, and better yet, the tree can survive a few centuries (University of New Hampshire).

Neem oil is less toxic than many pesticides and is a popular option for organic home gardeners to control diseases and insects. While protective equipment is required during the application, exposure to neem oil has not been shown to increase cancer risk (Environmental Protection Agency). Neem oil has been used for thousands of years to aid in the healing of wounds, as skincare, and as fertilizer. The main compound Azadirachtin disintegrates very quickly by microbes in the environment, with a half-life of 1-2.5 days on the plant (The National Academies Press), making it more sustainable than current pesticides used, which have lasting impacts on soil health and on many farmers who lack the PPE (personal protective equipment) needed to spray conventional pesticides safely (Jerving).

Thus far, the Food and Agriculture Organization of the United Nations has encouraged farmers in Mali to utilize 41 different alternatives to obsolete chemical pesticides as part of their project, "Elimination of Obsolete Pesticides including Persistent Organic Pollutants and Strengthening Pesticide Management." One of the pesticide alternatives tested was a combination of neem oil and Solsain, an organic fertilizer. It was found based on demonstration plot testing that the neem oil and Solsain regimen was effective against phyllophagous caterpillars ("Alternatives to pesticides").

Azadirachtin has been shown to reduce the chance of locusts forming their notorious swarms, as it blocks the production of the hormones needed. When locusts ingest crop material sprayed with neem oil, they can become lethargic, although still alive (NCBI).

One of the ways in which the neem tree has the potential to change livelihoods in Mali dramatically is through the possible number of jobs and new industries it could create. People in the Ancient Indian civilization noticed the neem tree's many uses (Fig. 2), and the neem tree has, as a result, been a sacred plant for the country for hundreds of years. People used it as a source of shade, ate the fruit, used it as herbal medicine, and improved storage conditions for "grains and pulses" with it (Neem Foundation). The neem tree was prized for its versatility in its uses in the case study of Ancient India. Taking advantage of a plant known to be used for a variety of uses could spur new industries in Mali, creating new jobs which could lessen the severity of the country's poverty.

The cost of neem oil is a factor to consider as alternatives to standard pesticides must be affordable for farmers to use them. In a video by *Deutsche Welle*, Diarra Agriculture, an orange farm outside of Bamako, Mali, was facing white termite infestations. A man who works at the farm explained how the standard pesticides were not effective against the termites. When the farm tried using neem oil, the neem oil worked better than other pesticides used and was cheaper too. The price of a liter of neem oil from one

company 200 km from Bamako is 15 euros, enough to spray about 1/3 of a soccer field. With a cheaper price and greater efficacy than conventional pesticides, neem oil is a viable option for use in Malian farms, especially as farmer profits will increase from lower pesticide costs.

Increased crop output efficiency for fruits and vegetables grown in Mali could occur with the widespread use of neem oil. With better control of diseases and pests and the ability to reduce postharvest losses, more crops can be produced within the same amount of land. Better vegetable crop efficiency could help to allow for possibly more vegetables to be grown than before to support the population. This will not only increase farmer profits but allow for more sustainable farming practices.

While neem oil seems like it is a perfect solution, there are some challenges to its implementation, which have prevented it from being used on a larger scale in the agricultural industry. Neem oil can only be applied at night since it is sensitive to light, and farmers need to be educated on the exact formula mixture for proper use (Deutsche Welle). Standard pesticides are easier to apply, and farmers are already familiar with them. In addition, the process to purify the neem oil is lengthy manual labor. Only neem fruit that has already fallen to the ground may be used, and a mere few neem oil processing operations currently exist in Mali. After being handpicked, the fruit must be dried, crushed, and processed. The oil is then distilled to get rid of its odor. The solid remains of the process, or “neem cake,” can be used for fertilizer, or extracted even further for lower-quality oil for soaps (Deutsche Welle). The lengthy manual labor, convenience, and education barriers have thus far hindered the neem tree’s potential to transform agricultural livelihoods in Mali. My recommendation seeks to promote the widespread use of neem oil in Malian agriculture and to account for the education barrier hindering its use on a large scale through a multi-faceted mass media approach.

My second recommendation is to take advantage of the bitter leaf tree (*Gymnanthemum amygdalinum*), an antifungal plant native to Malian woodlands and bodies of water. A herb added to soup dishes, bitter leaf is commonly sold in markets across Mali, Zimbabwe, Mozambique, and more. When the branches of the bitter leaf shrub are burnt, the ashes contain properties that inhibit seed-borne fungi (“Uses Of Bitter Leaf Plant: Growing Bitter Leaf Vegetable Greens”). In this way, the bitter leaf shrub can act as a pesticide-alternative to conventional environmentally-harmful chemicals. The bitter leaf shrub forms a multitude of white flowers and yellow fruit called achene. When the leaves of the bitter leaf shrub are chewed, pests are drawn away due to their bitter taste (Tlankka, Nicodemus S.). I would recommend using the leaves of the bitter leaf shrub to form a liquid form: bitter leaf oil. This oil could be sprayed, perhaps in addition to neem oil as pesticide alternatives. However, bitter leaf oil has not been tested as of yet on a large scale.

There are 373 different radio channels in Mali (Media Landscapes). Radio is the largest method of mass media spread in Mali- more than phones and newspapers. Community radios such as the Union of Free Radios and Televisions of Mali are an integral part of the community and an important source of information (Media Landscapes). The radio can address one of the major challenges of widespread commercial agricultural use of neem oil and bitter leaf oil in Mali: the education barrier. The radio is the most popular and the most efficient way of spreading mass media in Mali and can be accessible to those

in rural areas as well as urban areas. Already integrated into communities, this recommendation is easier to implement. There is no need to download an app or access a website people are not familiar with, which can be burdensome as many, especially in rural communities, don't own cell phones, have secure internet connection, or have electricity. My recommendation to tackle the education barrier preventing widespread use of neem and bitter leaf oil is to create a radio program or radio station, educating the people and spreading awareness of agricultural alternatives and innovations, such as neem oil. A radio or radio program could also help to train or recruit farmers on the proper uses of techniques, and how neem oil and bitter leaf oil should be properly applied. My recommendation could have the most influence on a government radio channel so that the information will be spread to as many people as possible. Therefore, this radio portion of this approach should be funded and run by the government to be most effective. To cater messages to women, information should be focused on the health benefits of using safer pesticides, such as prevention of toxic pesticide poisoning. To cater messages to men, information should be focused on the cost benefits and overall greater efficacy against pests, as men are the ones usually caring for the fields. In order to disseminate information on the benefits of neem and bitter leaf oil among Malian youth, social media might be helpful, although rates of illiteracy among youth remain high. A government-influencer campaign could be impactful as youth often look up to influencers they view online on Instagram, Youtube, Twitter, etc. A transformation to sustainable agriculture could be catalyzed by youth to the older generation.

A visual component is the other portion of this multi-faceted approach to tackle the education barrier discouraging the use of neem oil on a larger scale. There is a limit to the depth of information that can be presented via radio. The African Cartoon Magazine *Katakata* has created comics to spread awareness of the dangers of obsolete pesticides ("How Mali Is Eliminating Hazardous Pesticides"). The purpose and intentions of the cartoonists are understandable to even the illiterate, and newspapers are already an existing news medium in Mali. Therefore, this medium of mass media would be best catered to the uneducated. This magazine is helping to tackle the lack of awareness of the dangers of obsolete pesticides (World Bank). A similar type of magazine could be created to help spread awareness of the potential usage of neem oil and bitter leaf oil in farms. Cartoons could be used as a visual component on how to use neem oil in a variety of different situations and in greater depth than what radios can present. However, as the radio is more accessible to most of the population and is utilized more frequently, it is the best option in combination with comics to "sell" neem as a potential crop pesticide alternative.

My recommendation to promote the widespread use of neem oil and bitter leaf oil in agriculture through a multi-faceted approach of radio and comics could be a promising method to improve agricultural livelihoods in Mali. Widespread use of the neem and bitter leaf plants could spur the creation of new jobs, which can tackle Mali's poverty challenge, improve insect and pest prevention, raise farmer incomes, and allow for a more sustainable world. While more convenient access to neem and bitter leaf oil and the lengthy manual process to produce neem oil remain challenges, tackling the education barrier could lead to increased community demand for broader usage of neem and bitter leaf oil as a pesticide alternative, which could have the effect of a push for more neem processing operations and greater distribution in stores. These plants have the potential to allow us to secure a better future for generations to come in Mali if we take advantage of mass media to promote it.

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