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Nigeria: Defeating Drought and Malnutrition with Bio-Fortified Sorghum

Worldwide food quality, efficiency, and sustainability have increased over the past fifty years due to the adoption of high-yielding hybrids, fertilizers, and improved land practices. However, these advancements have largely excluded developing nations, which have seen far less agricultural productivity than developed ones (FAO). Progression towards food security demands a greater focus on the ignored situation of developing nations.

While many view Nigeria as one of Africa's most advanced countries, the deceptively impoverished nation still faces major issues in food security. Nigeria is the most populous nation in Africa—seventh in the world—with a population of approximately 190 million. The population is on pace to grow to 392 million by 2050, but a population boom could inspire unprecedented suffering in a nation already struggling with food security ("Africa: Nigeria"). The crisis largely remains a "silent one", receiving little international attention, even though millions are threatened by severe malnutrition and famine (Bloemen).

The typical diet for Nigerians consists mainly of maize, sorghum, millet, cassava, yam, and beans. Unfortunately, many families are struggling to put these staple foods on the table. Hunger grips the northern region, where 90,000 children are at risk of dying of severe malnutrition within the upcoming months. In total, the UN has identified 15 million people in the region as in need of humanitarian assistance (Bulman). Ironically, in a nation devastated by famine, the agricultural industry comprises 70% of the workforce ("Nigeria at a Glance"). Roger Thurow of the Chicago Council on Global Affairs accurately describes the current condition as a ridiculous and shameful oxymoron.

Nigeria's food insecurity is a direct result of the region's arid climate and inability to resist to drought, collectively leading to poor and innutritious harvests. The Sub-Saharan area of northern Nigeria within the Sahel and Sudan ecological zones produces most of the nation's grain products and consists of small-scale subsistence farming and nomadic herding (Abubakar and Yamusa). While this region is the breadbasket of Nigerian agriculture, it also suffers the most from drought, exhibiting many of the signs conducive to drought. For example, the region continues to suffer from low rainfall and reduced cloud coverage, which worsens the effects of high evaporation rates (Abubakar and Yamusa).

In recent years, drought has caused sorghum yields to decrease by 16-20% and variability in harvests to steadily increase in the Sahel region (Sultan and Gaetani). Meanwhile, the land surrounding Lake Chad has suffered a severe drought over the last few decades—depleting nearly 90% of the lake's water content since 1963—which has brought about sharp decreases in crop yields in the surrounding area and left the many families vulnerable (Juma). Further, on the national scale, farming constitutes the largest sector of its economy at 40% of its GDP ("Nigeria at a Glance"). The severity of drought can be seen in the economy from 1971 and 1972, where a water scarcity reduced agriculture's role in the nation's GDP from 18.4% to 7.3% (Abubakar and Yamusa).

For decades, the Nigerian government heavily relied on oil as the crux of its revenue. Though, because of the decline in oil prices and the resulting economic recession as of 2016, the nation is beginning to see a greater reliance on the agricultural industry. Farming now contributes 40% of the national GDP, but most farmers still live in marginal rural areas, cannot afford standard irrigation systems, and are forced, to practice rain-fed agriculture (Juma). While the national relevance of agriculture is on the rise, the largely subsistence-farmers continue to severely suffer from poverty.

Poverty presents a serious plight for the Nigerian people. Currently, 70% of the population live below the national poverty line ("Africa: Nigeria"), on the equivalent of under one U.S. dollar per day (Adetayo). Over 62% are characterized as in extreme poverty and in need of considerable humanitarian aid ("Africa: Nigeria"). The impoverished sector of Nigeria is almost exclusively represented by the rural population, which mainly practices smallholder farming (Adetayo). Worsened by the effects of drought, the marginal yields of farmers literally represent the difference between life and death. Further, because water scarcity presents such a precarious situation for farmers, they often oppose introducing new practices, which inhibits any potential economically-secure future. In a study conducted by the Keffi Local Government of Nasarawa, ten random villages were sampled, and 58.9% of farmers in the area were characterized as risk averse (Yusuf). The agriculture industry must begin to adopt innovations in the field, but any approach to long-term security must recognize the economic situation of the native people.

The socioeconomics of poverty greatly influence the livelihood of Nigerians beyond agriculture, too. The dynamics between drought, poverty, and living standards have been studied at great lengths. Poverty in the arid northern regions greatly exceeds their southern counterparts, seeing about 65-75% characterized as poor as opposed to 25-35% (Adetayo). Access to education in Nigeria is strictly dictated by wealth. In poor households, 34% receive no education, 24% attend primary, 21% secondary, and only 15% post-secondary. On the other hand, only 27% of the wealthy receive no education, 40% attend primary, 48% secondary and 52% post-secondary (Adetayo). Similarly, the impoverished regions receive considerably less than adequate access to medical services. Despite millions suffering from malnutrition, only 3.7% of Nigeria's GDP is spent on health expenditure, mostly for non-rural settings ("Africa: Nigeria"). Worsened by drought, poverty dictates the lives of an agriculture-reliant society.

Poorer households often lack the means to deal with food shortages, leading to millions suffering from hunger and malnutrition. Currently, 8.1 million Nigerians face acute food insecurity ("Nigeria at a Glance"), 462,000 suffer from acute malnutrition, and 450,000 children are malnourished in northeast Nigeria (Olawoyin). The large masses of insecure families will continue to suffer and see further drastic hardships without international intervention. According to UNICEF, malnutrition stunts the growth of 40% of Nigeria's children under the age of five, putting 1.4 million children at risk from dying from food insecurity in the Sahel region alone (Bloemen).

Drought poses a serious detriment to food security for millions in Nigeria and branches into many diverse areas of its people's livelihood. Water scarcity directly affects socioeconomics on the national scale and acts as the major force in countless issues: human migration, political conflicts over scarce resources, starvation, and destruction of critical biodiversity.

Thus, promoting food security in Nigeria will require a multipronged solution. The National Biotechnology Development Agency (NBDA) of Nigeria will develop a more drought-tolerant and nutritional breed of sorghum by utilizing advanced breeding and gene-modifying biotechnology. Ultimately, the modified sorghum must be affordably distributed among the largely smallholder farms of the northern region.

The NBDA works towards making biotechnology an engine of socio-economic growth in Nigeria. Established in 2001, they have promoted the development of science in response to issues of food security and sustainability. This agency operates on the international level while ensuring the well-being of Nigerians at the local level.

Sorghum offers unique advantages for combating drought and micronutrient deficiencies. The crop already plays a prominent role in farming and consumption in Nigeria, so implementing improvements would not require broad behavioral changes for farmers. Further, sorghum already possesses genetic markers for partial and natural drought tolerance, making it the most viable option for future development (Che et al.). Lastly, the Nigerian government has already conducted preliminary trials on GM sorghum, opening the gateway for national distribution (Cerier). Sorghum's opportune status makes it the prime solution crop.

Hybrid crops remain underutilized in developing countries, such as Nigeria, despite their unmatched potential in agricultural advancement in both stressed and optimal conditions (Gaffney). In hybrid production, breeders first create inbred, or parental, lines with a vast gene pool to later produce offspring ≤hybrids from. Breeders evaluate the effectiveness of the offspring in multiple environments, and after each season, only the preferred hybrids are retained for further use. Hybrid crops utilize natural means to develop ideal breeds and are key to maintaining long-term food security.

Establishing an organization of trained breeders in Nigeria under the NBDA is essential for effective hybrid production. Currently, Nigeria's lack of skilled breeders and biotech infrastructure hinders its ability to develop viable sorghum hybrids. While outdated sorghum hybrids have previously been released in Nigeria, they have proved ineffective for farmers and resulted in unprofitable yields (Pixley). Without the value promised by hybrids, smallholder farms will choose not to adopt preferable sorghum breeds in the future, forever locking the nation in food insecurity.

To optimize the success of hybrids, breeders must attentively develop and adapt them for specific environmental conditions. Previous attempts by seed companies lacked the means to focus on individual locations, and attempted to universalize generic breeds among adverse conditions; thus, they provided little improvement over farmers' traditional crops at a premium price (Pixley). The most effective methodology for breeders would be to cross and self-pollinate through extensive inbred lines, allowing for the most genetic variations and recombinants among offspring (Gaffney et al.). Inbred lines pass on the desired genes among numerous offspring. Comprehensive variation among breeds allows scientists to select the ideal genetic sequence for local adaptation.

Training skilled breeders offers a practical solution for an underdeveloped nation suffering from food insecurity. Through education, Nigeria's native scientists will be able to internally develop hybrids and evaluate their performance in multiple areas. A related expenditure called the Program for Africa's Seed Systems previously invested in educating plant breeders in small seed businesses and ultimately developed 464 favorable varieties of fifteen different popular crops, amounting to 80,000 metric tons of seed (Gaffney et al.). In a similar undertaking by DuPont Pioneer through their product AQUAmax, the agribusiness company managed to natively breed 80 hybrid maize crops, locally adapted to produce heightened yields in drought stress conditions. The AQUAmax hybrids offer top-end characteristics to combat water scarcity, such as advanced stomata control, strengthened kernels, and efficient root systems, ultimately requiring less water per bushel ("Bred to Shine Rain or Shine"). Under the NBDA, trained breeders will adopt a similar approach to minimize drought's devastating effects through sorghum. Focusing on training native breeders offers a grassroots movement that establishes the essential infrastructure for future hybrid production and allows for specific adaptations among breeds.

In addition to breeding hybrids, the NBDA organization will adopt gene-modifying and gene-editing biotechnology to further improve sorghum drought tolerance and nutritional value. Training geneticists to identify and manipulate specific genes known to contribute to specific deficiencies establishes the infrastructure in Nigeria to tackle both current and future agricultural difficulties. Through gene-modifying and gene-editing technology, scientists can overexpress specific genes involved in drought tolerance and micronutrient synthesis. Overexpression entails increasing the transcription rate for the specified genes. Thus, geneticists can improve sorghum yields and quality during drought by either increasing the rate at which natural counter-measures occur or by introducing foreign counter-measures. Further, genetic variants developed through gene-editing can be integrated into geographic specific inbred lines for hybrid production.

The plant hormone ethylene regulates many aspects of plant development, including the abiotic stress drought (Shi et al.). It is well-documented in literature that inhibitors of ethylene synthesis mitigate yield loss by enhancing the plant's drought tolerance. In recent research, scientists have determined the negative regulators for ethylene production are encoded by the ARGOS gene family in grain crops such as sorghum. Studies have concluded the overexpressing of certain genes reduces the effects of ethylene on plant development. In an experiment by DuPont Pioneer, geneticists discovered the ARGOS8 gene to be specifically linked to the negative regulators in maize crops. Using CRISPR-Cas9 breeding technology, they replaced the gene's native promoter with a stronger GOS2 promoter to increase the expression of the ARGOS8 gene. As a result, the modified maize saw increased grain harvests by over five bushels per acre under drought or even well-watered conditions (Shi et al.). In addition to the ARGOS family, other gene-silencing approaches have also been used to modify ethylene synthesis. AMINOCYCLOPROPANE-1-CARBOXYLATE SYNTHASE (ACCS) catalyzes the rate-limiting step in its production. Modified maize plants with reduced ethylene synthesis via knocking down the enzyme ACCS6 have shown increased yields under water-deficient conditions (Shi et al.). Identification of the ARGOS8 and ACCS6 homologs in sorghum will provide the tools to confer similar drought-tolerances.

Gene-modifying technology can be further applied to solve micronutrient deficiencies in status quo sorghum. While sorghum presents an excellent source of calories, it has major nutritional drawbacks in micronutrients and protein quality. Currently, 250 million people suffer from vitamin A deficiencies and a half-million children annually develop blindness; of these deficiencies, over 50% prove mortal for children within months (Sommer and West). About 300 million families in Nigeria rely on sorghum as their staple diet, but the crop presents serious deficiencies in vitamin A (Che et al.). However, geneticists can account for these defects and fatalities by stabilizing β-carotene, a precursor for constructing vitamin A. By using sorghum seed-specific promoters to drive expression of phytoene synthase 1 and carotene desaturase genes, geneticists can increase β-carotene synthesis (Mantey). One step further, by introducing the homogentisate geranylgeranyl transferase gene, they can mitigate the negative effects of oxidation, recognized as the main contributor to β-carotene degradation (Che et al.). In addition to vitamin A, gene-modifying technology can also target amino acid deficiencies within sorghum. Sorghum protein quality is limited by low contents of certain essential amino acids: lysine, threonine, and tryptophan ("Sorghum and Millets in Human Nutrition"). In the absence of these key amino acids, it provides poor protein quality when consumed. Through gene-modification, seed-specific promoters can be introduced to drive the expression of feedback insensitive enzymes such as dihydrodipicolinate synthase (DHPS), threonine synthase (TS), and anthranilate synthase (AS). Only through manipulation of these rate-limiting enzymes can the amino acid levels of lysine, threonine, tryptophan, and ultimately protein quality increase (Sands et al.). By adopting gene-modification and gene-editing practices, the NBDA organization will produce nutritiously sustainable sorghum with increased micronutrients and protein quality.

However, establishing a hybrid breeding infrastructure and adopting advanced biotechnology alone will not solve the food security issues in Nigeria. Increasing crop yields through the drought-tolerant seed requires its fair distribution among the low-income farmers of Northern Nigeria. Already suffering from poverty, many subsistence farmers lack the revenue to fully adopt any future breed. As a result, the established NBDA organization must integrate a ten-year program that facilitates the supply of seed in the agricultural industry. In Malawi, the Targeted Farm Inputs Program (TFIP) distributed vouchers to the low-income farmers, which allowed them to acquire the seeds at a reduced cost from distributers (Rubyogo et al.). Similarly, the NBDA organization will subsidize seed costs initially, requiring the government to assume the financial responsibilities.

To sustain the distribution program, the Nigerian government will require international funding. Specifically, the government can target foundations such as the Gates Foundation, which recognizes the agricultural plight in Africa and actively funds multinational biotechnology development projects. They financed Uganda's National Research Agricultural Organization to develop a solution to a devastating banana-crop disease. Since 2013, the foundation has granted about 22% of its $1.8 billion global development expenditures towards agricultural projects (Lopatto). Further, the Nigerian government can pursue assistance from intergovernmental organizations such as the United Nations.

The ten-year time frame allows NBDA to respond to the current drought-induced crises through the development of savior-seeds. However, a fully subsidized distribution program will ultimately be economically unsustainable (Rubyogo et al.). In ten years, the NBDA organization must additionally transition the seed-development industry from the government to the private sector to ensure long-term food security. The NBDA will enable the private sector to produce effective hybrid crops and use biotechnology. Moreover, this will promote farmer independency and allow for the development of more environmentally specific crop varieties in the future. Transitioning from a government-sponsored distribution to the private sector ensures access to improved seeds among smallholder farmers.

Upon distribution, the farmers will be quick to adopt the new sorghum breed as well as other developed breeds in the future. African nations have empirically opposed the commercial use of genetically-modified (GM) crops, because many European markets ban GM crops. However, hybrid crops do not require gene-modification, but rather utilize natural processes. Moreover, many African nations are already choosing to adopt biotechnology practices. For example, Zambia's Higher Education Minister Michael Kaingu informed parliament he planned to embrace GM crops, saying, "We recognize that modern biotechnology has advanced worldwide and, as a nation, we cannot afford to ignore the benefits of this technology" (Cerier). Many African countries such as Ethiopia, Kenya, Uganda, Malawi, Swaziland, Nigeria and Ghana are also conducting trials on genetically-altered crops, forever changing agriculture on the continent.

Low food productivity and micronutrient deficiencies plague the people of Nigeria. These plights directly stem from the water-scarce conditions of drought in the Northern region. Thus, the solution is to establish a hybrid breeding infrastructure and utilize gene-editing biotechnology to develop a drought-tolerant breed of sorghum which contains high amounts of micronutrients. In an agriculture-reliant society, the ability to cultivate harvests despite drought will be the difference between life and death. Nigeria will see multigenerational prosperity from a renovated agricultural industry and approach. It will ultimately prevent severe malnutrition, increase political stability, and solve the socioeconomic problems such as poverty. The international community has long neglected Nigeria, leaving its continuous struggle a "hidden hunger". There exists a humanitarian imperative to right this wrongdoing and to ensure children do not die of starvation. The time to act is now.

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