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Democratic Republic of the Congo, Factor 1: Plant Science

Democratic Republic of the Congo: Tapping the Potential of Biotechnology and Traditional Plant Breeding to Alleviate Food Insecurity

By 2050 the world population is projected to reach 9.9 billion, which is an increase of 33% from the current 7.4 billion (PRB, 2016). With arable land area expected to decrease, the challenge of providing food for everyone is going to be significant. With increasing population and decreasing resources, the existing problem of food insecurity is only going to increase. In Sub-Saharan Africa alone the population is projected to increase from the current 974 million to 2.5 billion by 2050. This is a very worrisome situation as there are currently around 239 million undernourished people in Sub-Saharan Africa (FAO, 2010). One such country in the Sub-Saharan region where population is projected to increase by around 125%, by 2050, is the Democratic Republic of the Congo (DRC) (PRB, 2016).

Geography and Demographics

Central Africa houses the Democratic Republic of the Congo (DRC), which is the second largest country in Africa, and covers around 2.3 million square kilometers. The DRC's 10,481 km border is shared with 9 other countries. Majority of the land (68%) is forest while only about 11% is agricultural land. DRC has an estimated 750,000 square kilometers of arable land of which only around 100,000 square kilometers is used for cultivation (Smoes, 2012). A major reason for the small percentage of arable land under cultivation is the conflict that DRC has faced over the years and the insecurity that has arisen because of it. The Congo river flows through the country from east to west, but due to waterfalls and rapids is only partly navigable. The DRC has a wealth of natural resources, fertile soil, and hydroelectric power potential (CIA, 2017). There are over 81 million people living in the DRC, of which 45% belong to around 200 ethnic groups (CIA, 2017). The population structure is not balanced with 42% falling in the 0-14 years age group, 21% falling in the 15-24 years category, 30% in the 25-54 years group, 4% in the 55-64 years, and only 3% in the 65 years or above group. The mean size of a family in the DRC is about 6.8 members (CFSVA, 2014). As seen from the population structure above, most of these members are children. In rural areas, large extended families are normal, living under the same roof or in a tight group of homes.

Economy and Agriculture

The annual economic growth rate for 2016 is 4.3%, which has decreased from 7.7% during the 2010-2015 period (World Bank, 2016). The major economic sectors are the mining industry, which represents around 28% of the gross domestic product (GDP), and agriculture, which contributes to less than 50% of the GDP (Smoes, 2012). The agricultural industry is divided into a "traditional" and a "modern" sector. The traditional agriculture sector is primarily for subsistence. From 1970 to 1990, the DRC's population has doubled, but with that growth the average farm size decreased from 1.5 acres to 0.5 acres. DRC has a fairly high population density of 1124 people per square kilometer of arable land (PRB, 2016). Decreasing farm size makes it harder for farmers to support their families. However, small-scale farmers use very basic equipment, often only a simple hoe and watering cans. Agriculture is mainly rain-fed, relying on rainfall for irrigation. Shifting cultivation is the dominant form of agriculture in the DRC where land is cleared, cultivated, and then fallowed in a cyclical manner (Ickowitz et al., 2015). Commonly cultivated plants are tubers, sycamore trees, maize, rice, peanuts, beans and oil palms. The modern agriculture sector consists of a few large agricultural businesses, which use modern production

methods. However, the production is mostly for export and consists of sugar cane, coffee, cocoa, palm oil, cinchona bark, and rubber (Smoes, 2012).

Life in the DRC

In the DRC, there is no difference in food security between male and female-headed households. The better educated the household head was, the better was the household's food security status. Only 13% of households headed by a member who attended primary school were severely food insecure, while 41% belonged to moderately food insecure households, and 46% to food secure households (CFSVA, 2014). Nationally, 87% of boys and 83% of girls attend a primary school between 6 to 12 years. There were significant differences in that only 4% of boys were not attending any school, compared to the 12% of girls that were not attending any school at all. The most common reason (>50%) for children not attending school was their parents' inability to fund their schooling, with sickness of the child (around 20%) being the second. The constitution of the DRC, through Article 43, guarantees free and compulsory primary education. However, parents continue to pay the majority of the school fees that include the teachers' salaries, construction and maintenance fees, school promotion fees, printing costs, examination fees, insurance fees, and the national school tax, all of which add up to more than 50% of the total public education expenditure (Seymour et al., 2011). Another barrier to schooling could be the 200-400 different dialects spoken by various ethnic groups throughout the DRC (Smoes, 2012). Displacement due to the years of conflict is also playing a role in the poor enrollment of children in school (Seymour et al., 2011).

In the DRC, how households access food is determined by the livelihood of the family. Most households across all livelihoods obtain the dominant portion of their food through market purchases. However, this is not true of food crop producers and fishermen, who generate most of the food that they consume. In addition to the source, the frequency of food consumption also varies greatly by food type. Nationally, tubers, such as cassava, are eaten daily (6.5 days per week), followed by a high consumption of oil (6.1 days), followed by vegetables (5.7 days), cereals, such as maize, (4.3 days), legumes and nuts (3.8 days), and animal protein and eggs at only 2.5 days a week (CFSVA, 2014). This diet, though high calorific in nature, can also contribute to malnutrition due to the very little amount of animal protein eaten. Thus, 15% of the population in the DRC suffers from protein deficiency, while 50% of the population suffers from a variety of other deficiencies including iron, riboflavin, and vitamin B12. In the DRC, access to health care is very poor for children as only 39% receive treatment for fever, 42% for pneumonia, and 39% for diarrhea. In some provinces, more than half the children seek treatment for pneumonia and diarrhea (CFSVA, 2014). According to the World Health Organization, there is only about 1 physician per 10,000 population, and around 10 nursing and midwifery personnel per 10,000 population (WHO, 2017). In addition, the physical distance between the patients and doctors is also a significant barrier to treatment. For the treatment of congenital malformations, patients and surgeons may have to travel an average of 178.4 km (111 miles) to undergo/perform surgery, with limited infrastructure in the rural areas making the travel difficult (Kalisya et al., 2015).

The poverty rate in DRC is quite high. It is amongst the poorest countries in the world. Seven out of ten households are poor with rural areas having 8 out of 10 households being poor. 62% of the total expenditure of households in the DRC is on food (IMF, 2013). According to the Global Hunger Index (GHI) that tracks and measures hunger globally and by country based on the percentage of population that is undernourished, for the proportion of children under 5 years of age who are underweight, and mortality rate of children younger than 5 years of age, DRC's score rose by around 63% (IFPRI, 2011). Around 53% of children under the age of 5 years show stunting and/or wasting (IFPRI, 2015a). The DRC ranks 176 out of 188 countries on the United Nations 2015 Human Development Index report that measures three basic dimensions of human development, access to knowledge, long and healthy life, and a decent standard of living (UNDP, 2015). A major barrier to the development of the quality of human life is the

prevalence of corruption, brought along by the several years of conflict, violence and instability leading to repeated political crises, weak governance, and mismanagement of natural resources (Chêne, 2013).

Food Security Status

Food security is measured by a combination of three different indicators: (i) the food consumption score (FCS), (ii) the wealth index, based on asset ownership, and (iii) the coping strategy index (CSI). Using the 3 indicators, households have been categorized into 3 food security groups. These are severely food insecure, moderately food insecure, and food secure. Severely food insecure households have very poor food consumption and low wealth with the most severe CSI score, while moderately food insecure households have marginal to acceptable food consumption but the most severe CSI score. The food secure households have adequate food consumption (CFSVA, 2014). In the DRC, 54% of rural households (around 28 million people) nationally are food insecure. Of that, 7.5 million people are severely affected. Of the food insecure households in the DRC, 55% took part in only 1 livelihood activity, while 30% households had 2 livelihood activities. 11% of households had 3 livelihood activities to survive (CFSVA, 2014). Food crop farmers and agricultural wage laborers are reliant mostly on one single income activity. Fishermen, at 70%, made up the biggest portion of poorest households in the DRC, followed by food crop farmers (57%), artisans (46%), and cash crop and livestock farmers (36%). In rural DRC, agriculture (including fishing) generated income to 97% of households (CFSVA, 2014). Food crop farmers and fishermen contribute 50% and 48%, respectively, to their food source. Nationally, of the household's income, 67% is spent on food. The most (20%) is spent on eggs, fish, meat, etc., followed by cereals (16%), tubers (12%), and legumes and nuts (7%). 6% of a DRC family income is spent on health, while education and energy round out the top three at 5%. Poor households spend 72% of their income on food, while rich households spend 62%. Similarly, severely food insecure households spend 73%, while moderately food insecure and food secure households spend 68% and 66% of their income on food, respectively (CFSVA, 2014). However, not all poor households are automatically food insecure. Around 47% of poor households were found to be food secure at a national level, in the DRC (CFSVA, 2014).

Barriers to Food Security

As we have seen, food security is defined by access to sufficient food for dietary needs and food preferences. However, low crop yields are common in many developing countries including DRC. Several complex factors contribute to low food productivity, such as lack of clean planting material, disease, insect pests, weeds, abiotic stresses like drought, heat, nitrogen deficiency, and poor yield or nutritional content (Johanson and Ives, 2001). Drought can be compounded with poor soil fertility that requires expensive chemical fertilizer inputs. In addition, the effect of pests and diseases on African agriculture can be devastating. With plant health being a major factor, 30-40% losses annually are commonly reported in literature and any solutions addressing food insecurity will have to take plant health into account (Flood, 2010). At the national level, in the DRC, 51% households recognized the lack of access to improved varieties of seeds as one of the major challenges to agriculture, with 45% facing constraints accessing even traditional seeds. A second important factor is the lack of modern farming equipment. The government of the DRC has created National Services for agricultural mechanization, motorization, and technology to increase agricultural production. However, the acquisition of agricultural equipment such as tractors, covers barely 5% of the 8 million hectares cultivated annually (CFSVA, 2014). Pests and diseases contribute significantly to the challenges of agriculture, followed by poor soil quality. Mineral fertilization is rarely used, even if recommended, the high cost being a major factor in this decision (CFSVA, 2014).

The proportion of undernourished people is high for the DRC and has risen from 26% in 1990-92 to 69% in 2014 (FAO, 2010). A lot of this is attributed to conflict and war. Conflicts change farmer perceptions and cropping behavior, and better market access helps them adapt more towards conflict resistant

cropping systems (Kibriya et al., 2016). In eastern DRC, agriculture-based livelihoods were a victim of the war that caused displacement of households and decrease in local productivity, such as bean productivity went down by 72%, manioc by 53%, and bananas by 45% (FAO, 2010). In cases of food insecurity due to protracted crises, livelihood promotion can serve to support food security by improving livelihood strategies and assets, and supporting key policies and institutions that boost livelihoods. In the DRC, the NGO Action contre la Faim is providing agricultural services such as seed multiplication and crop protection as well as agricultural extension to improve farming practice (FAO, 2010).

Role of Plant Science and Agriculture in Food Security

In 2014, an assessment for change in the food security policy of the DRC carried out by the United States Agency for International Development (USAID) identified the key systems, processes and relationships that influenced the food security policy development process. It next assessed whether the DRC had the capacity to undertake policy change, and finally, looked at the key challenges of the Agricultural Law that is currently considered to be an obstacle to increased investments in agriculture (USAID, 2014). The Government of the DRC has developed a National Agricultural Investment Plan with a budget of $5,730 million. However, since 2012, the government of the DRC has disbursed a total of only $40 million on agriculture, research and training, which is not sufficient to reach the 2020 target of increasing public agriculture expenditure by 10%. In addition, the state agricultural institutions are extremely weak in technical capacity or expertise to implement the work plans of the National Agricultural Investment Plan. Another major problem is the lack of quality agricultural statistics that makes the development of policy very difficult (USAID, 2014). Even though agriculture is considered as one of the priority sectors in government programs, the human capacity is characterized by older staff at retiring age at one end and very junior staff with only bachelor's degrees or lower on the other (Ragasa et al., 2014).

In the DRC, cassava is not only a source of food, but also income for about 70% of the population. It is a major staple crop grown in more than 50% of arable land, but only 15% of cultivated areas are covered by improved varieties (CFSVA, 2014). Cassava production is affected by various diseases, which cause enormous yield losses in the field. Prominent among these are the cassava mosaic disease (CMD) (Muengula-Manyi et al., 2012) and cassava brown streak disease (Mulimbi et al., 2012). Promotion of agricultural innovation will help the National Institute for Agronomic Research (INERA) in the DRC to increase its capacity to assist farmers in targeted areas. Screening of the vast natural biodiversity of the DRC should be able to identify species that show natural resistance to different pests and diseases and to use traditional plant breeding techniques to create high yielding, disease resistant crop varieties.

Plantain and banana are considered the second most important staple crop after cassava. However, a decade of civil unrest, underinvestment, social and technological constraints have led to declining productivity. In addition, viral and bacterial diseases, such as Banana bunchy top virus, *Fusarium* and *Xanthomonas* wilt, and pests such as nematodes and weevils, have contributed to the problem (Mobambo et al., 2010). Making use of clean seed systems to prevent bacterial and viral diseases, improving access of farmers to information on new technologies, efficient use of fertilizers, increasing road infrastructure, and having good marketing organizations will help in stabilizing the banana industry (Mobambo et al., 2010).

Solutions for Alleviating Food Insecurity

A primary approach to resolving food insecurity could be through understanding of the economic issues that face the DRC. The understanding of food availability and prices in different parts of the country will be a key element in making strategies to address food insecurity. The differences in access to food play a role in the type of prevalent diet. There are five types of diet that can be identified in the DRC: cassava based, maize based, bread and rice based, multicolored beans based, and cassava and palm oil based

(Marivoet, 2016). There is high variation in food prices across the DRC with prices being very high in Kinshasa, making the capital highly dependent and vulnerable to food imports from abroad. On the other hand, some provinces such as Equateur and North Kivu are among the most competitive food producers that can be leveraged to formulate strategies to address food insecurity (Marivoet, 2016). Another barrier faced by the government in their effort to solve the food insecurity problem is distance. The people of the DRC are widely dispersed while the transportation infrastructure is dilapidated and crumbling. Some rural areas are so isolated that they are not accessible via roads (Kalisya et al., 2015). With the transportation infrastructure being highly inadequate, the transport of food as well as agricultural technology to rural areas is significantly hindered (Ragasa et al., 2016).

Secondly, considering that only around 10% of the DRC's agricultural potential is currently being utilized, there could be more attention given to acquiring agricultural land. This could be through clearing of forests to create agricultural fields. However, it is important that deforestation is done through some controlled means so as to not damage the ecosystem, as is happening currently (Ickowitz et al., 2015). An increase in productivity can lead to increased deforestation, since productivity growth will increase profitability of agriculture and thus increase the value of agricultural land, making land clearing a profitable activity (Ickowitz et al., 2015).

Yet another important factor in the resolution of food insecurity is the education of farmers in the application of scientific research and knowledge through agricultural extension. Without appropriate access of farmers to information, crop yields decrease significantly as revealed in a recent study. Lufuluabo et al. (2016), collected data on climate change over a 30-year period and correlated that with farmers' perception of the change and their agricultural practices. They found that farmers were not using any inputs even though 67% of the farmers felt the effects of climate change. This resulted in a significant decrease in average yield of maize grains from 1.6 t/ha in 1999 to 0.75 t/ha in 2004 (Lufuluabo et al., 2016). Another study carried out recently to assess the performance of the agricultural extension systems in the DRC revealed that despite having one of the highest extension agent-to-farmer ratio, there was a lack of coordination, policy and mandate, funding, incompetent and aging agents, and a lack of interaction of the agents with the farmers, that has led to the failure of the government in delivering knowledge and technologies to the rural areas. The study found that significant factors that would lead to the success of agricultural extension systems were external funding, making sure performance target were met, rewards and sanctions, and development of skills (Ragasa et al., 2016). Citizens should also help spread the newly acquired knowledge and technologies, because the government alone would not be able to disseminate it across the country. If citizens help, the modernization of the DRC will happen much faster.

Spending on agricultural research in the DRC is around $11.4 million, which is 0.21% of the agricultural GDP for the country (IFPRI, 2015b). In addition, several international agencies and countries are committed to the development of DRC's agriculture and rural sector. For the period 2008-2016, the African Development Bank (AFDB) will invest $176 million, USAID $128 million, World Bank $120 million, Belgium $88 million, South Korea $11 million, Netherlands $6 million, Sweden $5 million, and Spain $3 million (AFDB, 2013).

The use of varieties that have high grain yield, resistance to local disease and pests, and better protein qualities would significantly contribute to increased grain production and alleviation of malnutrition and food insecurity. One such example of the screening of better varieties of crop plants comes from a study to develop quality protein maize lines in the DRC. In this study 137 maize lines were developed and screened for breeding applications (Mbuya et al., 2012). Similarly, studies have evaluated several wheat varieties for productivity (Ndjadi et al., 2016). According to the Agricultural Science and Technology Indicators (ASTI), in 2009, around 48% of the cultivated area was estimated to have been planted with improved cassava varieties. In fact, according to the Alliance for a Green Revolution in Africa (AGRA),

agricultural authorities from the DRC's Service National des Semences have released 3 new varieties of maize, 1 variety of cassava and 10 varieties of an assortment of beans in February of 2017, that will be available to farmers immediately. Availability of improved seed varieties will help the farmers in producing crops that will not only meet their dietary needs but will also result in added income through selling and marketing of their crops.

The development of agricultural biotechnology is another potential solution for tackling the problem of food insecurity. The current process of biotechnology makes use of recombinant DNA technology to improve plants. So far, in Africa, commercial genetically modified crops are grown only in 4 countries, Egypt, Sudan, Burkina Faso, and South Africa (Arthur and Yobo, 2014). With the advent of genetically modified crops there have arisen several concerns such as the potential toxicity of the novel genes and their products, the potential to become antigens and allergens, the potential of alterations of metabolic pathways leading to unintended effects, and the potential spread of harmful traits to weeds and non-genetically modified crops. To safeguard against potential risks of biotechnological applications most African countries have signed and ratified important legally binding international instruments such as the Convention on Biological Diversity and the Cartagena Protocol on Biosafety (Karembu et al., 2009). The countries are developing functional National Biosafety Frameworks (NBF) to oversee the development of policies, laws, regulations, administrative systems for permits, and public participation in biosafety decision making processes. The DRC NBF is considered a work-in-progress, as a national biosafety law and a Biosafety Bill is still being drafted (Karembu et al., 2009). Biotechnology in the DRC is limited to conventional technologies such as production of beers and soft drinks, transformation and conditioning of dairy products, and traditional production of fermented foods. Only a few experimental trials have been carried out by some research and teaching institutes such as universities and colleges, that include trials on transgenic bananas, and transformation of cassava for reducing the levels of cyanide (Mtui, 2011).

Despite the obvious advantages of biotechnology, there is a poor public awareness and participation in modern biotechnological matters, and a lack of a biotechnology policy. Like several other African nations, the DRC is also taking a mostly precautionary approach towards regulation of genetically modified (GM) foods and crops. Some primary reasons for this are that most of the developmental assistance for DRC comes from Europe, rather than the United States. Thus the European donors can influence the direction the country can take towards accepting biotechnology. Because the largest of Africa's farm exports are to Europe, it is the European regulatory systems that have to be followed. Another source of influence are advocacy campaigns against GM crops from organizations that are mostly active in Europe and indulge in fear-mongering that such crops might cause allergies, chronic toxic effects, and cancers (Paarlberg, 2013). With cultural ties of DRC and other African nations being closer to Europe than to the United States, they are more inclined to believe the European practices as the best ones.

International Agencies and Projects in Aid of the DRC

Several international agencies and countries are involved in projects to bring about food insecurity relief in the DRC, such as, the World Food Programme's Protracted Relief and Recovery Operation to provide food assistance for internally displaced people and refugees in conflict affected areas, nutritional support to children aged 6-59 months, access to markets and education, Special Operation to Strengthen the Food Security Cluster Coordination for bringing food to displaced people through collaboration with UN agencies, NGOs, donors and other stakeholders, strengthening smallholder farmers value chains in the DRC that focuses on reviving agricultural commodity markets (WFP, 2016). In addition, other agencies such as the USAID's Office of Food for Peace (FFP) are awarding cooperative agreements with the goal of improving food and nutrition security and economic well-being in vulnerable populations in the DRC. The awards total $150 million for a 5-year period from 2016-2020. The World Bank is sponsoring the Agriculture Rehabilitation and Recovery Support Project for the DRC to increase agricultural productivity

and improve marketing of crops and animal products by smallholder farmers in targeted areas, with a commitment amount of $120 million by November 2017 (World Bank, 2017). The International Fund for Agricultural Development is financing $183 million for several projects in the DRC to improve smallholder farmers' access to effective production services, appropriate technologies and local markets, and to make farmers' organizations more professional so that they can become economic partners with private enterprises in rural areas (IFAD, 2017). The OPEC Fund for International Development is committed to spending $68 million on various projects in the DRC of which around $25 million are for the agricultural sector (OFID, 2017).

Conclusion and Recommendations

With conflict over the last few years creating a sense of insecurity, the small subsistence farmer in the DRC is the one who has suffered the most. Farming has not been able to spread even though there is ample arable land. In fact, over the years farm sizes are decreasing. Poverty is rampant in the DRC making it one of the poorest countries in the world. More than half of rural dwellers in the DRC are food insecure. Several factors have contributed to this food insecurity. By far, one of the most important factors is the lack of education of farmers in the application of scientific research and knowledge. In addition, the lack of availability of seeds or even a decent transportation system has added to the problem of agricultural technology not reaching the farmers, or produce from the farmers not reaching the market. Diseases and pests of the staple crops of the DRC have caused the condition of the food insecure farmers to worsen even more. With not enough governmental support to alleviate the problem of food insecurity, it would seem that the resolution of food insecurity in the DRC is not possible. However, this endeavor, though difficult, is not impossible. Listed below are some of the recommendations that will help tackle this problem.

1. One of the foremost requirements is the development of a good agricultural extension program for education of farmers in the application of scientific research and knowledge. This will require the hiring of many more qualified personnel in the agricultural research institutes in the DRC. This should also encourage the exposure of farmers to knowledge about modern biotechnology. The education of farmers will help to spread that education to other citizens. In addition, any progress made by researchers in the field of technology development should be widely publicised so that it can reach the intended target faster and effectively.
2. The second most important need is the availability of high quality improved seed varieties that should be managed through the governmental agencies and establishment of agricultural cooperatives.
3. Modern farming tools and equipment will go a long way in the production of crops in shorter time with less labor. The government needs to step up its efforts to mechanize agriculture. Mechanization will also allow women to pursue other skills, instead of spending most of their time laboring in the fields. A key point here is to ensure that any technological support that is provided should be affordable to the farmers.
4. There is rich biodiversity in the DRC. A scientific program should be developed to screen this biodiversity for crop varieties that are naturally resistant to different viral, fungal, and bacterial diseases, as well as pests. Traditional plant breeding methods should be developed to transfer these desired features into crop varieties that are high yielding to create superior varieties. Increased yields will play a major role in decreasing food insecurity.
5. Improvement of the road infrastructure and transport should have a significant contribution in alleviating food insecurity. This will lead to motivation for bringing more land under cultivation. This can be achieved through projects from various organizations, including the government of the DRC. If the government is not doing enough, citizens should form groups and pressurize their elected officials through peaceful protest, if necessary, until changes are made.
6. The use of modern biotechnology tools to genetically engineer crops for higher yield, resistance to pests and diseases, and other stresses will greatly improve the situation of food insecurity. A primary

requisite for this will be the drafting and passing of regulations for biosafety by the government of the DRC.

7. Finally, it will be imperative to involve global agencies and organizations such as the WFP, FAO, World Bank, and the USAID, along with developed countries to formulate plans to effectively implement these above-mentioned solutions in the DRC. The United States should use its wealth, global influence and power to spread awareness of the food insecurity problems in struggling countries like the DRC. Its wealth and power would not only help the DRC, but would also benefit the United States itself. The DRC would be a future ally, trading partner, as well as a partner to improve national security. Making the rest of the developed world aware of the food insecurity that exists in the developing world, would be the key to harness the support of people around the world, by gathering not only donations for the cause, but also by groups volunteering their time and efforts.

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