REVIEW ARTICLE

Agricultural Reviews, Volume Issue : ()

Potential Impact of using Genetically Modified Crops in Ethiopia: A Review

Ashebir Seyoum Feyisa

10.18805/ag.R-213

ABSTRACT

Agriculture in Ethiopia is reliant on the poor farmer's income. Crop production in the country is hampered by a variety of factors, among them subsistence farming, inefficient use of farm inputs, climate change, poor export performance, policy uncertainty and low interest in agricultural credit are the major ones. Plant pests also pose a threat to food crops, resulting in significant losses for smallholder farmers and jeopardizing food security. Thus, Ethiopian policymakers recently recognized genetically engineered crops as a viable method of increasing food productivity and quality. A thorough empirical review had conducted, focusing on the status, potential benefits and drawbacks of genetically modified crop production in Ethiopia. Descriptive statistics had used, followed by raw data interpretation. Genetically modified crop production is an option for addressing food insecurity, malnutrition and the production of low-cost feedstock. However, as genetically modified crops become more prevalent in Ethiopian agriculture, humans, wildlife and the environment must all be considered. As a result, GM crops can help poor farmers improve their agricultural livelihoods if better national biosafety regulations had implemented.

Key words: Biotechnology, Food security, Gene flow, GM crops, Seed sovereignty.

Humans have been breed plants to improve desirable characteristics for thousands of years. Selective breeding methodologies have been using to enhance traits since the discovery of Mendel's Law in 1990 (Fehr, 1991). Most of such techniques improve viability against disease, pests and climate change. Crop yields boost because of the green revolution, but the benefits were limited to improved farm input usage and the adoption of strains that responded better to fertilizer.

However, biotic and abiotic constraints such as drought conditions, soil problems, a lack of agricultural land and the advent of new pests have inhibited more yield increases.

The ever-growing human population, which is estimated to hit 9.8 billion by 2050 (UN, 2017), along with climate change, increased demand for the agricultural product for industries, natural resource scarcity and the percentage of arable land per capita on the earth, is nearing capacity will intensify the struggle for food (UN, 2017). According to the (FAO) report year 2019, 820 million peoples suffered from hunger and malnutrition (FAO, 2019). Farm production would need to more than double by 2050 (Ray *et al*., 2013). Thus, the world must look for a new way to improve productivity in line with improving the efficiency of supply chains and reducing wastage.

Plant breeding has been a crucial technique in agricultural production improvement; the application of hybrid vigor via cross-breeding has resulted in significant productivity advantages in global food crops (Kempe *et al*., 2014). Plant breeding has been a crucial technique in agricultural production improvement; the application of hybrid vigor *via* cross-breeding has resulted in significant productivity advantages in global food crops (Kempe *et al*., 2014). Convectional breeding is based on the introduction of new genes into current cultivars through sexual crossings. It also leads to the transmission of the entire set of genes from both parents, which may not be desired and may result in a lower yield. Traditional plant breeding programs are also limited to what genetic variation available in the gene pool of the crop or close relative that is sexually compatible. It is a time-consuming and labor-intensive method. Thus, researchers are switching towards biotechnological approaches for crop improvement (Saurabh *et al*., 2014).

According to the Secretariat of the Convention on Biological Diversity (2000), Biotechnology has defined as any technological application that uses biological systems, living organisms, to make or modify products or processes for specific use. Since their introduction, GM crops have been reported beneficial in crop yield, economic growth and environmental impacts (Zhang *et al*., 2020). However, advancement in GM crops has raised several concerns regarded to their safety. Naturalness, transfer of genes between species, ecological, economic and trade impact issues are some of the questions that arose in the technology.

Department of Plant Science, College of Agriculture and Natural Resource, Bonga University P.O. Box 334, Bonga, Ethiopia.

Corresponding Author: Ashebir Seyoum Feyisa, Department of Plant Science, College of Agriculture and Natural Resource, Bonga University P.O. Box 334, Bonga, Ethiopia.
Email: ashebirseyoum20@gmail.com

How to cite this article: Feyisa, A.S. (2022). Potential Impact of Using Genetically Modified Crops in Ethiopia: A Review. Agricultural Reviews. DOI: 10.18805/ag.R-213.

Submitted: 26-06-2021 **Accepted:** 26-03-2022 **Online:** 18-05-2022

In Ethiopia, agriculture is the dominant sector of the economy (Diriba, 2018). It's contributing to 37% of the GDP and 73% of employment opportunities (FAO, 2019). Although the agriculture sector accounts for more than half of the country's GDP, changes in the industry are uncommon. Our world, including Ethiopia, is currently suffering climate change, which will impact agriculture, the environment and health. This transformation may also result in new insect pests, illnesses and weeds challenged to manage through prior technology (Bale *et al*., 2002).

Recently, global food security faced challenges due to an ever-increasing population, increases in food prices owing to severe climatic effects, agricultural input costs and agricultural policy. In addition, environmental sustainability issue also becomes serious agenda because of rapid industrialization, urbanization and population growth. Furthermore, with the rapid industrial revolution, globalization and population growth, environmental sustainability is becoming a big problem. As a result, farmers would have better necessity accessibility to other crops that use new, environmentally sustainable technology to ensure food security and environmental sustainability. Africa is the center of origin and also a producer of several cereal crops. But, yield gaps are high due to climate change, population growth, poor mechanization, poor soils and weak agricultural policies (Kolawole *et al*., 2010).

Since Ethiopia is one of the world's most food-insecure countries, the government has attempted to formulate and execute various economic growth strategies, with agricultural development taking precedence (Tenaye, 2020). According to Pender *et al*. (2001), cereal crops provide food for Ethiopians, so most agricultural transformation plans prioritize increasing cereal crop productivity. Minten and Dorosh, 2019; Tenaye, 2020) found that cereal prices have increased significantly during the last two decades. As a result of worldwide price increases and reduced production due to climate change, this inflation rate would worsen. Inflation has aggravated food insecurity in Ethiopian cities.

Increasing agricultural productivity and tackling such problems need innovation and the use of productivity-raising technologies Spielman and Pandyalorch (2009). Genetically engineered crops may be an option to increase agricultural productivity in developing countries like Ethiopia. Like other technological interventions, genetic engineering may not eliminate all agricultural production restrictions, but it may be especially effective in tackling productivity restrictions that conventional methods haven't yet addressed. Thus, Ethiopia is needed to take part in new agricultural technologies like GM crop production to feed the ever-increasing food insecure citizens. Nevertheless, policymakers should have a strategy regarding farmers' choices and the future export market. Keeping the above argument in mind, the objective of this paper is to discuss the potential influence of genetically modified crop production on Ethiopia's subsistence-based agricultural system.

An extensive review of both published and unpublish documents had done. As a result, the information gathered, organized, interpreted and evaluated comes from secondary sources. Various authors and researchers have written on this topic; all available sources had used to assess current production and the beneficial and adverse effects of producing genetically modified crops in Ethiopia. As a result, descriptive statistics, followed by interpretation of raw data obtained from organizational sources, were used to justify the results.

Ethiopian agriculture

Ethiopia's agriculture relies on the livelihoods of poor farmers. These farmers' scarcity of agricultural land and the backwardness of their production methods are challenges to the sector's lack of growth. The agricultural sector, despite many challenges, is still the backbone of the country's economy. Despite this, the government and non-governmental organizations have conducted numerous studies on what needs to be changed to improve the lives of impoverished farmers. However, no solution was found that can permanently enhance the quality of life of poor farmers. It is because the strategies are imaginary and cannot solve the problem in the long run.

Ethiopian agricultural productivity is affected by a subsistence-oriented production system, minimal use of purchased farm inputs, unstable weather conditions, low output prices and policy uncertainty and a lack of interest in agricultural loans (Urgessa, 2015). Additionally, waterlogging, salinity and parasitic weeds are also crucial challenges for Ethiopian crop production. Plant pests and diseases also affect food crops and causing significant losses to smallholder farmers and impact food security. Plant breeding combined with chemical fertilizers, pesticides, irrigation and other yield-enhancing inputs has helped raise food production. Even though chronic hunger is still widespread in many developing countries, the global proportion of hungry people was reduced from over 50% in the first half of the twentieth century to around 11% today (Qaim, 2020). However, intensified agricultural production reached its limit. Therefore there is a need for new technology which could contribute to higher crop yields, lower use of chemical fertilizers and pesticides, better crop resilience to climate stress, reduced postharvest losses and more nutritious foods. New plant breeding technologies (NPBTs), including genetically modified and gene edited crops, offer significant potentials for sustainable agricultural development and food security while addressing shortcomings of the Green Revolution (Qaim, 2020). In line with this, Ethiopia has approved the commercial cultivation of genetically modified (GM) insect-resistant cotton (Bt-cotton), confined field trials on GM maize and disease-resistant enset (*Ensete ventricosum*) (Sida, 2021).

What are genetically modified organisms?

It is challenging to get the universally accepted definition for the term genetically modified organisms. The European Commission and the Food and Agriculture Organization, on the other hand, define genetically modified organisms

(GMOs) and their products like plants or animals produced through techniques in which the genetic material has altered in a way that does not occur naturally through mating or natural recombination (Oliver, 2014).

Before we talk about recombinant DNA technology, we first need to know what DNA is. In the early 1800s, it was unthinkable for the leading scientists and philosophers that a chemical molecule could hold enough information to build a human being. In 1928, Frederick Griffith demonstrated a transmission process of genetic information by transforming Pneumococcus (Malago, 2009). In Avery *et al*. (1944) have proven that Griffith's transforming principle was DNA. The next step after the discovery of DNA was the idea of how DNA structure might look. A race between various lab groups ensued and in 1953 James Watson and Francis Crick published a model of DNA structure. The demonstration that the genetic code was (almost) universal and the advent of gene cloning and DNA sequencing in the 1970s led to an explosion of activity in the new field of molecular genetics and was a spur to the development of new methods for genetic transformation of animals and plants (Wang *et al*., 2017). *In vitro* production of a recombinant *DNA* molecule has four basic steps.

(1) Obtain different DNA fragments using restriction endonucleases for specific target sequence DNA sites using enzymatic cleavage.
(2) joining the desired gene in vector.
(3) Introducing the vector in the host organism, which is grown to produce multiple copies of the incorporated DNA fragment in culture.
(4) finally clones containing a relevant DNA fragment are selected and harvested. The first recombinant DNA molecule was discovered in Paul Berg's lab in 1972. This pioneering work formed the basis of the recombinant DNA revolution.

Importance and use of gMO crops

In 2050 the global population will reach an estimated nine billion people. Presently the yields of most major crops are decreases, while the demand is growing. However, the productivity of major crops should be double by 2050. According to the FAO consensus study, the global yield increases necessary to satisfy future demand must be acquired from the same amount of land now under cultivation (FAO, 2012). This scenario does not consider additional needs on farmlands for bioethanol production, animal feed production, inappropriate land-use problems, water resource problems and climate change problems (Alexandratos and Bruinsma, 2012). Therefore, attaining a high yield must come from genetic improvement or increase agricultural inputs. Conventional breeding cannot keep pace with what is required. So to meet the target, genetically modified crops might fill the gap (Oliver, 2014).

To understand how genetically modified crops can support Ethiopian agriculture, we must first examine the country's main crop problems and the efforts made to resolve them.

Maize

Maize is one of the most important cereal crops in production volume, area coverage and household consumption. It occupies about 2 million ha, the second largest production area next to teff (Abate *et al*., 2015). Despite its rise in total production, the national average yield of maize (3.6 tons/ha) was still lower than the world average (5.8 tons/ha) and potential yield (12.5 t/ha) in the 2018 production period (van Dijk *et al*., 2020). The main reason for this yield gap is related to biotic and abiotic stresses concerning climate change. In addition, the spread of insect pests, plant diseases and invasive weeds are also a threat to farmers in Ethiopia (Yirga *et al*., 2020).

The Ethiopia Institute of Agricultural Research, in collaboration with international research institutes, has been actively engaged in the development of better maize technologies suited for the country's different maize producing environments (Yirga *et al*., 2020). Over 60 improved maize varieties (hybrids and open-pollinated varieties) with associated agronomic and crop protection practices have been released or registered in the country since the 1970s (Fig 1). Nevertheless, on average, 80 percent of maize varieties cultivated in Ethiopia were developed from germplasm that had not been enhanced for drought tolerance (Ertiro *et al*., 2019). However, different agro-ecological zones and maize-producing areas are affected by droughts of varying intensity (Table 1). To address these issues and boost agricultural productivity, the Ethiopian government approved a field trial of drought-tolerant and pest-resistant TELA corn, marking Ethiopia's first GMO food crop planting.

Cotton

Cotton is one of Ethiopia's main cash crops and it is widely grown in the lowlands on large and small-scale farms using both irrigation schemes and rain-fed agriculture. Ethiopia has excellent cotton-growing conditions and a large amount of land that could use to grow cotton (Bayrau *et al*., 2014). However, only about 3% of the country's total potential cotton production areas had utilized. To transform the country's agricultural-based economy into a manufacturing-based economy, the government has built industrial parks in most country's regions, focusing on agro-processing sectors. The government paid prior attention to the textile and clothing sectors to attain this goal. Cotton is a raw material in this industry. The continuous supply of high-quality raw materials at a fair price is critical for the textile and garment industry's continued development (Addis *et al*., 2021).

Cotton varieties and production system in ethiopia

Cotton is grown in a range of areas throughout Ethiopia. It is estimated that approximately 3 million hectares of land are suitable for cotton cultivation. With the current global scenario favoring food crops over other crops, Ethiopia's vast potential advantages make it adopt its cultivation. Though Ethiopia has a long history of cotton cultivation, it only cultivates about 3% of the total land suitable for its

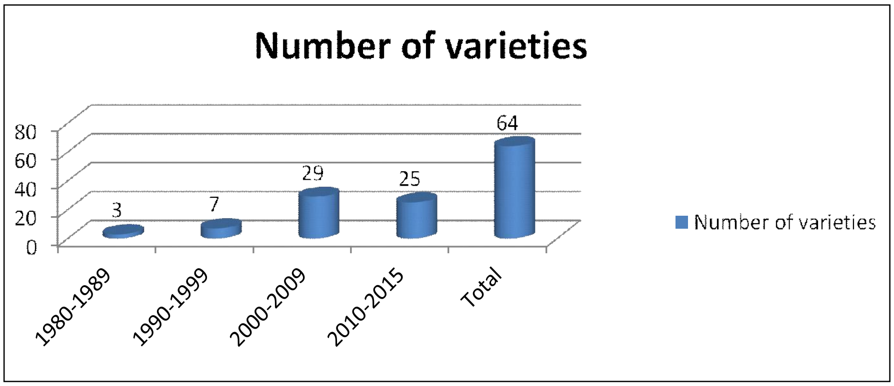

Fig 1: Maize varieties released in Ethiopia.
Source: (Gissa, 2016).

Table 1: Causes of yield damage on maize plots by region, percentage.

	Tigray	Afar	Amhara	Oromia	Somali	Benishangul	SNNP	Gambella	harari	Dire Dewa
Number of plots	(204)	(8)	(384)	(449)	(126)	(56)	(494)	(40)	(128)	(48)
Too much rain	1.0	0.0	5.5	6.5	0.0	1.8	3.2	5.0	0.0	0.0
Too little rain	74.0	12.5	63.5	61.3	96.8	25.0	84.2	72.5	96.1	100.0
Insects	3.9	0.0	3.1	3.8	0.8	3.6	2.0	0.0	3.9	0.0
Crop diseases	1.0	0.0	1.0	12.3	0.0	7.1	0.6	2.5	0.0	0.0
weeds	2.5	12.5	1.3	0.7	0.0	17.9	0.8	7.5	0.0	0.0
Hail	9.8	12.5	5.5	1.1	0.0	0.0	2.4	0.0	0.0	0.0
Flood	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Frost	0.0	0.0	0.0	0.9	0.0	0.0	0.4	0.0	0.0	0.0
Wild animals	0.5	12.5	3.4	4.0	0.0	10.7	1.8	10.0	0.0	0.0
Birds	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
Shortage of seeds	0.0	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Depletion of soil fertility	4.4	0.0	0.5	4.2	0.0	10.7	2.4	0.0	0.0	0.0
Security problems	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Spoiled seeds	0.0	0.0	8.3	0.9	0.0	1.8	0.8	0.0	0.0	0.0
Others	2.5	50.0	6.5	3.8	2.4	21.4	1.2	2.5	0.0	0.0
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Source: (Yirga *et al*., 2020).

production (Adiss *et al*., 2021). Ethiopia's cotton production system is diverse, with about 25% of the production area benefiting from irrigation facilities and producing 35-40% of national output. The national average yield is estimated to be 2.5 tons/ha under irrigation and 1.5 tons/ha under rain fed conditions (Lançon and Woldu, 2020). Generally, this yield per hectare is low compared to the main cotton producing countries in the world.

Cotton production and productivity are affected by biotic, abiotic, social and economic factors. Among biotic factors, bacterial blight, Flea Beetle, Pink Bollworm and Mealybug are the major ones. Meanwhile, cotton bollworm is one of the pest challenges farmers struggle to manage. It cause about 36- 60% yield loss and on irrigated cotton production (Gudeta and Egziabher, 2019). In addition to this, losses associates with unfavorable weather conditions (Zeleke *et al*., 2019). According to National Planning Commission (2016), the lack of quality seeds and poor supply chain affects both cotton producers and textile mills. Informal seed sector is by far the largest seed supply chain. In major cotton production areas, small scale farmers are using massively fuzzy seed from more informal channels, like own source, bought from ginneries, local markets and fellow farmers. Despite numerous research efforts by Worer Agricultural Research Center to improve cotton genotypes, Deltapine 90, Stam 59A and Acala SJ2 varieties are still widely grown commercially throughout Ethiopia. However, Deltapine 90 and Acala SJ2 varieties had passed 30 years. According to research results, these varieties no longer correspond to the current standards (Lançon and Woldu, 2020).

In 2015, a change in the Biosafety regulation had allowed the importation of Genetically Modified Organisms (GMOs) for a confined experiment. Several hybrid and GMO cotton varieties from India have been introduced and approved by the national variety release committee (NVRC). However, they did not perform well enough compared to the cost of the seed (Lançon and Woldu, 2020; Adiss *et al*., 2021). In line with this, the cotton production system in the country should be economical, socially beneficial and environmentally friendly.

According to various research findings, the majority of cotton production constraints were related to a lack of improved varieties, a seed system, inputs, mechanization and a value chain and marketing. These constraints may be altered by the conventional production system. However, because the country's cotton production areas were close to the border, there was a risk of GMO cotton seed spreading from neighboring countries. Thus, it is still necessary to implement national research programs so that biotechnology and plant breeding advances can be used in the development of cotton varieties adapted to Ethiopia's specific environmental conditions, as well as in the control of regionally important insect pests.

Enset

Enset, a member of the Musaceae family and the species Ensete, is a popular home garden food crop in Ethiopia. It resembles a single-stemmed, large banana plant (Sahle *et al*., 2018). Enset is one of the most important crops in Ethiopia, contributing to food security and rural livelihoods for approximately 20 million people (Olango *et al*., 2014). It increases soil fertility and has high productivity, drought tolerance and environmental sustainability. Despite its importance, Ethiopian enset production is hampered by a variety of pests and diseases. Enset Xanthomonas Wilt is the most severe of these pests and pathogens, according to farmers (Yemataw *et al*., 2020). Numerous researches have been done to solve the issue. Cultural practices, sanitation control measures, use of disease-free sucker for planting material, crop rotation and the use of resistant clones are all viable management options for bacterial wilt. However, no complete resistant clone has been discovered (Hunduma *et al*., 2015). However, research on host-pathogen interactions revealed that disease susceptibility or tolerance levels differed between genotypes (Table 2). Furthermore, many tissue culture-based propagation procedures have been established to provide disease-free planting material, which will help to prevent the spread of bacterial wilt disease on a large scale (Table 3). Furthermore, the lack of any effective chemicals has placed farmers under stress. As a result, new technology is required to produce disease-resistant plant material where conventional breeding methods have failed.

Production of GMO crops

According to James (2015), genetically modified crops were planted on 191.7 hectares of land in 2018. The top five biotech crop producers in the world are the United States, Brazil, Argentina, Canada and India. North America produces 44.4 per cent of the world's biotech crops, with the United States leading the pack (James, 2018). Soybean (92.1 Mha) was the most widely planted biotech crop in 2015, followed by maize (53.6 Mha), cotton (24 Mha) and oilseed rape (canola) (8.5 Mha). This indicates that soybeans and cotton are the most widely cultivated genetically modified crops in the world. South Africa, Burkina Faso and Sudan are the top three GMO-producing countries in Africa, with GM cotton as the main crop.

Ethiopia has not yet begun growing genetically modified food grains; nevertheless, the permission to cultivate genetically-modified cotton would advance the country forward in this industry. In addition, ongoing maize and enset research initiatives indicate the country's potential competitiveness in the sector.

Seed sovereignty and food security

Ethiopia is one of the African countries struggling to feed its growing population, despite the agriculture sector is the

Table 2: Mean disease incidence of Xanthomonas wilt-tolerant enset landraces.

Collection zone	Name of landrace	Mean disease incidence (%)	References
Dawro	Maziya	19.31	Hunduma *et al*., 2015
Dawro	Halaa	22.50	McKnight, 2013, Annual report
Gurage	Nechuwe	11.00	Welde-Michael *et al*., 2008
Gurage	Dere	11.00	Welde-Michael *et al*., 2008
Gurage	Bezeriyet	11.00	Welde-Michael *et al*., 2008
Gurage	Lemat	22.00	Welde-Michael *et al*., 2008
Gurage	Anikefiye	33.00	Welde-Michael *et al*., 2008
Kembata-tembaro	Hiniba	33.00	Welde-Michael *et al*., 2008
Kembata-tembaro	Sorpie	33.00	Welde-Michael *et al*., 2008
Kembata-tembaro	Dirbo	35.00	McKnight, 2013, Annual Report
Kembata-tembaro	Onjamo	18.75	McKnight, 2013, Annual Report
Sheka	Noba	6.70	Haile *et al*., 2014
West and southwest shewa	Badadiat	34.26	Hunduma *et al*., 2015
West and southwest shewa	Hiniba	30.18	Hunuduma *et al*., 2015
Wolaita	Halla	33.00	Welde-Michael *et al*., 2008

Source: (Yemataw *et al*., 2018).

Table 3: In vitro propagation studies of Ensete for disease free planting material in Ethiopia.

Name of clones	Initial explant	Reference
Yanbule, Mesena and endale	Shoot tip	Zinabu *et al*., 2021
Bedadeti	Corm discs	Tripathi *et al*., 2017
Arkiya, Digomerza and Mazia	Shoot tip	Gezahegn and mekbib, 2016
Adoo, Agadae, Aginae, Astara, Badedeaet, Beresae, Beshoutae, Bofaro, Boseredae, Botae, Derae, Feresae, Gembela-Besha, Gemeticha,Gwarae, Kantcho, Keberae, Lemat, Moondorarae, Netcho, Seskael, Swetae, Tuzuma and Wenadae	Shoot tip	Birmeta and welander, 2004
Choro, Ketano and nobo	Zygotic embryos	Negash *et al*., 2001

Source (Author)

driving force of the economy. According to Devereux (2000), food insecurity is a situation that resulted from failing to produce enough food in good season and incorporates low food intake, variable access to food and vulnerability to shocks. Among many reasons are contributing to food insecurity in the country, subsistence agricultural production and rapid population growth are the main challenges to food insecurity in Ethiopia. FAO (2012) reported that over 800 million peoples were suffering from hunger and malnutrition, among a quarter populations is found in Sub-Saharan countries. Thus, a novel technology that sustains agricultural productivity should develop to feed the malnourished millions.

The choice of a national food security strategy is contingent on a country's development resources, the structural and institutional state of its political, economic and social life. There are three main types of agri-food policy solutions aimed at food security in this context. Food self-reliance, food self-sufficiency and food sovereignty are the three primary forms of agri-food policy strategies ensuring food security (Baer-Nawrocka, 2019). The assumption of the first strategy is to produce and export goods in which the country has a comparative advantage. Food sovereignty and food self-sufficiency, on the other hand, are focused on increasing the domestic production of vital agricultural products, even though the country has no comparative advantage in this region (Baer-Nawrocka, 2019). Food sovereignty is the right of nations to decide their food production, consumption and save safe and nutritious food to ensure food security. Seed is the most fundamental and vital agricultural unit, which is the basis for food security and biodiversity conservation. It also serves as a vehicle for bringing new technologies and support services to rural areas (Chand and Kc, 2020).

For the farmer, the seed is more than just a source of future plants and food; it is also a repository of culture and history. The ultimate symbol of food security is the seed. The free exchange of seeds between farmers has been the foundation for preserving biodiversity and food security. Farmers' free exchange extends beyond seed exchange to include exchanges of ideas and knowledge (Shiva, 2001). In recent decades, Agriculture has turned to genetically engineered crops as the only hope for solving the chronic food shortage. GMO production and usage are increasing, which is incompatible with long-term sustainability. It is highly uniform and promotes the development of monocultures and intensive production technologies.

Large companies that grow GM seeds purchase rivaling smaller seed growing companies to raise the prices of planting materials and take control over farmers. Farmers are compelled to purchase patented genetically modified seeds, which are significantly more expensive than traditional seeds (Schlett and Beke, 2015). Farmers' freedom will decline, traditional planting materials will fade away and GM seeds will succeed and eliminate diversity. Patented GM seeds jeopardize seed sovereignty and, thus, food sovereignty, because farmers can no longer save their seeds for the following season (Schlett and Beke, 2015). Burkina Faso, Sudan and South Africa are the only African countries that have allowed commercial cultivation of genetically modified (GM) crops. Only South Africa grows a genetically modified food crop, while Burkina Faso has banned the cultivation of GM cotton following a massive failure for farmers and seed companies (AFSA, 2020).

Ethiopia has one of the world's most diversified agricultural systems and is the origin and diversification center for several important food and fiber crops. For thousands of years, Ethiopia's small-scale small farmers have cultivated and managed such diversity in agricultural development. There is little evidence that genetically modified organisms enhance production, reduce pesticide usage, or alleviate environmental concerns in the long run. As a result, GMO experiments are ongoing on enset and maize, which are vital crops for nearly 20 million and nine million Ethiopians, respectively, which is concerning (Abate *et al*., 2015; Borrell, 2019). Therefore, there should be a way to maintain farmers' rights. FAO Resolution 5/89 officially endorsed farmers' rights as the 'rights arising from the past, present and future contributions of farmers in conserving, improving and making available plant genetic resources, particularly those in the centers of origin/diversity (FAO 1989). For instance, If you plant a transgenic crop while your neighbor opposes GMOs and only grows heirloom varieties, your populations will inevitably cross-pollinate, resulting in DNA from your plants in your neighbor's seeds (and vice versa). As a consequence, your neighbor's field will have contaminated with the patented seed. Thus, for seed lines to stay really "pure," improved agricultural planning and open seed storage technologies must be used and involves adopting effective measures to conserve biodiversity while also ensuring public access to landrace seeds.

Gene flow and genetic diversity

Gene flow is a natural phenomenon that alters the gene frequency in populations (Mallet, 2001). There are three methods of gene flow: seed dispersal, horizontal transfer and pollen movement. All techniques result in gene flow, or more accurately, the transfer of transgenes that results in genetic exchange (Ellstrand, 2003). Crop-to-wild, crop-to-weed and crop-to-crop gene flow and contamination are the main issues with pollen movement and seed dispersal. Crop-to-wild and crop-to-weed gene flow have received attention (Ellstrand, 2003). The main concern here is that an influx of genes from domesticated crops would alter the fitness (ability to reproduce and leave viable offspring) of wild and weedy populations. Coexistence and identity preservation among transgenic and non-transgenic cropping systems at the field level are becoming the main issues in the current agricultural scenario, where 189.8 million ha of GM crops were planted in 2017 with a global market value of US$ 17.2 billion (ISAAA, 2017).

To reduce transgene escape, numerous techniques have been suggested, including the use of a buffer zone around the GM crop in a field with barren areas and genetic methods to reduce the fitness of transgenic hybrids (Daniell, 2002). However, Cotton, maize, soybean, oilseed rape, rice and wheat have all been found to have convincing evidence of transgene escape (Dong *et al*., 2016).

The introduction of GM crops in developing countries which are centers of diversity of specific crops may in some cases be problematic. Ethiopia is one of the richest genetic resource centers in the world in terms of crop diversity. This is due to a variety of farming systems, socioeconomics, cultures and agro-ecologies. Coffee (Coffea arabica), safflower (Carthamus tinctorius), tef (Eragrostis tef), noug (Guizotia abyssinica), anchote (Coccinia abyssinica) and enset (Ensete ventricosum) are examples of crop plants that originated in Ethiopia (IBC, 2012b).

It is recommended that in the case of vulnerable areas such as centers of diversity, the introduction of genetic material from GM crops into related species should be controlled. According to the European Food Safety Authority (EFSA), specific risks related to "persistence and invasiveness, including plant-to-plant gene flow," must be assessed in the risk assessment of GE plants (EFSA, 2010).

CONCLUSION

Ethiopia is one of the African countries struggling to feed its growing population, despite the agriculturae sector is the driving force of the economy. It contributes to 46% of the GDP, over 90% of exports and 83% employment opportunities. Ethiopia's agriculture is based on the livelihoods of poor farmers. These farmers' scarcity of agricultural land and the backwardness of their production methods are some of the challenges to the sector's lack of growth. Thus, Ethiopia is needed to take part in new agricultural technologies like GM crop production to feed the ever-increasing food insecure citizens. However, GM crops pose questions about possible threats to living things and the environment. As a result, extensive risk evaluations of genetically modified plants and strict adherence to national biosafety rules are necessary.

Conflict of interest: None.

REFERENCES

Abate, T., Shiferaw, B., Menkir, A., Wegary, D., Kebede, Y., Tesfaye, K., Kassie, M., Bogale, G., Tadesse, B. and Keno, T. (2015). Factors that transformed maize productivity in Ethiopia. Food Security. 7(5): pp.965-981.

Addis, T., Kachi, A. and Wang, J. (2021). A review of current state and future directions of cotton production in Ethiopia. Cogent Food and Agriculture. 7(1): p.1880533.

AFSA- Alliance for Food Sovereignty in Africa. (2020). Seeds of neo-colonialism – Why the GMO promoters get it so wrong about Africa [online]. Available at: https://afsafrica.org/seeds-of-neo-colonialism-why-the-gmo-promoters-get-it-so-wrong-about-africa/ [accessed: April 8, 2021].

Alexandratos, N. and Bruinsma, J. (2012). World agriculture towards 2030/2050: the 2012 revision.

Avery, O.T., MacLeod, C.M. and McCarty, M. (1944). Studies on the chemical nature of the substance inducing transformation of pneumococcal types: induction of transformation by a desoxyribonucleic acid fraction isolated from pneumococcus type III. The Journal of Experimental Medicine. 79(2): 137-158.

Baer-Nawrocka, A. and Sadowski, A. (2019). Food security and food self-sufficiency around the world: A typology of countries. PloS one. 14(3): e0213448.

Bale, J.S., Masters, G.J., Hodkinson, I.D., Awmack, C., Bezemer, T.M., Brown, V.K. and Whittaker, J.B. (2002). Herbivory in global climate change research: Direct effects of rising temperature on insect herbivores. Global change biology. 8(1): 1-16.

Bayrau, A., Bekele, F., Assefa, B. and Mihiretu, M. (2014). An Institutional Assessment of the Cotton and Sugarcane Commodities in Ethiopia: The Climate Change Perspective. Addis Ababa, Ethiopia.

Berg, P., Baltimore, D., Brenner, S., Roblin, R.O. and Singer, M.F. (1975). Asilomar conference on recombinant DNA molecules. Science. 188(4192): 991-994.

Birmeta, G. and Welander, M. (2004). Efficient micropropagation of *Ensete ventricosum* applying meristem wounding: A three-step protocol. Plant Cell Reports. 23(5): 277-283.

Borrell, J.S., Biswas, M.K., Goodwin, M., Blomme, G., Schwarzacher, T., Heslop-Harrison, J.S. and Wilkin, P. (2019). Enset in Ethiopia: a poorly characterized but resilient starch staple. Annals of botany. 123(5): 747-766.

Briefs, I.S.A.A.A. (2017). Global status of commercialized biotech/GM crops in 2017: Biotech crop adoption surges as economic benefits accumulate in 22 years. ISAAA brief. 53: pp.25-26.

Chand, H. and Kc, B. (2020). Quality seeds for food security and food self-sufficiency during havoc of covid-19 in Nepal. Tropical Agroecosystems (TAEC). 1(2): 80-87.

Committee, I.C.A. (2016). International cotton advisory committee production and trade policies affecting the cotton industry october 2016.

Daniell, H. (2002). Molecular strategies for gene containment in transgenic crops. Nature biotechnology. 20(6): 581-586.

Devereux, S. and Sussex, I. (2000). Food insecurity in Ethiopia (p. 7). Institute for Development Studies.

Diriba, G. (2018). Agricultural and rural transformation in Ethiopia. Ethiopian Journal of Economics. 27(2): 51-110.

Dong, S., Liu, Y., Yu, C., Zhang, Z., Chen, M. and Wang, C. (2016). Investigating pollen and gene flow of WYMV-resistant transgenic wheat N12-1 using a dwarf male-sterile line as the pollen receptor. PLoS One. 11(3): p.e0151373.

EFSA Guidance for those carrying out systematic reviews European Food Safety Authority. (2010). Application of systematic review methodology to food and feed safety assessments to support decision making. EFSA Journal. 8(6): 1637.

Ellstrand, N.C. (2003). Current knowledge of gene flow in plants: implications for transgene flow. Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences. 358(1434): 1163-1170.

Ertiro, B.T., Azmach, G., Keno, T., Chibsa, T., Abebe, B., Demissie, G. and Worku, M. (2019). Fast-tracking the development and dissemination of a drought-tolerant maize variety in Ethiopia in response to the risks of climate change. In The Climate-Smart Agriculture Papers (pp. 79-86). Springer, Cham.

FAO, IFAD, UNICEF, WFP and WHO. (2019). The State of Food Security and Nutrition in the World 2019. Safeguarding against economic slowdowns and downturns [online]. Rome, FAO. [Cited 7 April 2021]. http://www.fao.org/state-of-food-security-nutrition.

FAO, WFP and IFAD. (2012). The State of Food Insecurity in the World 2012. Economic Growth is Necessary But Not Sufficient to Accelerate Reduction of Hunger and Malnutrition. Rome, FAO.

FAO. (1989). Resources phytogenetiques: Leur conservation in situ au service des humains, Rome: FAO.

FAO. (2019). National Gender Profile of Agriculture and Rural Livelihoods-Ethiopia. Country Gender Assessment Series, Addis Ababa. 84 pp.

Fehr, W. (1991). Principles of cultivar development: Theory and technique. Macmillian Publishing Company.

Gezahegn, G. and Mekbib, F. (2016). *In vitro* regeneration of disease free enset [*Ensete ventricosum* (Welw) Cheesman] planting materials from bacterial wilt diseased plants using shoot tip culture. African Journal of Biotechnology. 15(40): 2192-2201.

Gissa, D.W. (2016). Maize Varieties and Seed Value Chain Challenges in Ethiopia.

Gudeta, B. and Egziabher, A.G. (2019). Cotton production potential areas, production trends, research status, gaps and future directions of cotton improvement in Ethiopia. Greener Journal of Agricultural Sciences. 9(2): 163-170.

Haile, B., Adugna, G. and Handoro, F. (2014). Physiological and pathogenicity of *Xanthomonas campestris* pv. musacearum strains collected from enset and banana in southwest Ethiopia. Afr. J. Biotechnol. 13: 2425-2434

Hunduma, T., Sadessa, K., Hilu, E. and Oli, M. (2015). Evaluation of enset clones resistance against enset bacterial wilt disease (*Xanthomonas campestris* pv. musacearum). Journal of Veterinary Science and Technology. 6(3): pp.1-7.

IBC. (2012b). Ethiopia: Third country report on the state of plant genetic resource for food and agriculture to FAO, Addis Ababa, Ethiopia.

ISAAA. (2017). Pocket K No.16: Biotech Crop Highlights in 2017. Manila: International Service for the Acquisition of Agri-biotech Applications (ISAAA).

James, C. (2018). Brief 44: Global Status of Commercialized B iotech/GM Crops: 2012. ISAAA Brief. (44).

James, C., Teng, P., Arujanan, M., Aldemita, R.R., Flavell, R.B., Brookes, G. and Qaim, M. (2015). Invitational essays to celebrate the 20th Anniversary of the commercialization of biotech crops (1996 to 2015): progress and promise. ISAAA Brief. (51).

Judit, O., Péter, L., Péter, B., Mónika, H.R. and József, P. (2017). The role of biofuels in food commodity prices volatility and land use. Journal of competitiveness. 9(4): pp.81-93.

Kempe, K., Rubtsova, M. and Gils, M. (2014). Split-gene system for hybrid wheat seed production. Proceedings of the National Academy of Sciences. 111(25): pp.9097-9102.

Kolawole, P.O., Agbetoye, L. and Ogunlowo, S.A. (2010). Sustaining world food security with improved cassava processing technology: The Nigeria experience. Sustainability. 2(12): 3681-3694. https://doi.org/10.3390/su2123681.

Lançon, J. and Woldu, B. (2020). The Ethiopian Cottonseed System-Description, Analysis and Recommendations.

Malago Jr, W., Soares Costa, A. and Henrique Silva, F. (2009). DNA as genetic material: Revisiting classic experiments through a simple, practical class. Biochemistry and Molecular Biology Education. 37(5): pp. 290-295.

Mallet, J. (2001). Gene flow. Insect movement: Mechanisms and consequences. pp. 337-360.

McKnight, C. (2013). Integrated Management of Bacterial Wilt of Enset [Ensete ventricosum (Welw.) Cheesman] caused by Xanthomonas campestris pv. musacearum in Ethiopia.

Minten, B. and Dorosh, P.A. (2019). Rising cereal prices in Ethiopia: An assessment and possible contributing factors (Vol. 73). Intl Food Policy Res Inst.

Negash, A., Krens, F., Schaart, J. and Visser, B. (2001). *In vitro* conservation of enset under slow-growth conditions. Plant Cell, Tissue and Organ Culture. 66(2): 107-111.

Olango, T.M., Tesfaye, B., Catellani, M. and Pè, M.E. (2014). Indigenous knowledge, use and on-farm management of enset [Ensete ventricosum (Welw.) Cheesman] diversity in Wolaita, Southern Ethiopia. Journal of Ethnobiology and ethnomedicine. 10(1): pp.1-18.

Oliver, M.J. (2014). Why we need GMO crops in agriculture. Missouri Medicine. 111(6): p.492.

Pender, J., Gebremedhin, B., Benin, S. and Ehui, S. (2001). Strategies for sustainable agricultural development in the Ethiopian highlands. American Journal of Agricultural Economics. 83(5): 1231-1240.

Qaim, M. (2020). Role of new plant breeding technologies for food security and sustainable agricultural development. Applied Economic Perspectives and Policy. 42(2): pp.129-150.

Ray, D.K., Mueller, N.D., West, P.C. and Foley, J.A. (2013). Yield trends are insufficient to double global crop production by 2050. PloS one. 8(6): p.e66428.

Sahle, M., Yeshitela, K. and Saito, O. (2018). Mapping the supply and demand of Enset crop to improve food security in Southern Ethiopia. Agronomy for Sustainable Development. 38(1): 1-9.

Saurabh, S., Vidyarthi, A.S. and Prasad, D. (2014). RNA interference: concept to reality in crop improvement. Planta. 239(3): pp. 543-564.

Schlett, A. and Beke, J. (2015). Food security and GMOs. Studia Mundi-Economica. 2(1): 95-103.

Shiva, V. (2001). Protect or Plunder?: Understanding Intellectual Property Rights. Zed Books.

Sida, T.S. (2021). Will Ethiopia be a springboard or a stonewall for GM crops in Africa?. Nature Biotechnology. 39(2): 147-148.

Spielman, D.J. and Pandya-Lorch, R. (2009). Millions fed: Proven successes in agricultural development. Intl Food Policy Res Inst.

Tenaye, A. (2020). Technical efficiency of smallholder agriculture in developing countries: The case of Ethiopia. Economies. 8(2): 34.

The Cartagena Protocol on Biosafety to the Convention on Biological Diversity. Secretariat of the Convention on Biological Diversity (ISBN: 91-807- 1924-6) Montreal, 2000.

Tripathi, J., Matheka, J., Merga, I., Gebre, E. and Tripathi, L. (2017). Efficient regeneration system for rapid multiplication of clean planting material of *Ensete ventricosum* (Welw.) Cheesman. *In vitro* Cellular and Developmental Biology-Plant. 53(6): 624-630.

UN (United Nations, Department of Economic and Social Affairs). Population Division. (2017). World Population Prospects: The 2017 Revision, Key Findings and Advance Tables working paper No.ESA/P/WP/248

Urgessa, T. (2015). The determinants of agricultural productivity and rural household income in Ethiopia. Ethiopian Journal of Economics. 24(2): 63-91.

Van Dijk, M., Morley, T., van Loon, M., Reidsma, P., Tesfaye, K. and van Ittersum, M. K. (2020). Reducing the maize yield gap in Ethiopia: Decomposition and policy simulation. Agricultural Systems. 183: 102828.

Wang, P., Meyer, T.A., Pan, V., Dutta, P.K. and Ke, Y. (2017). The beauty and utility of DNA origami. Chem. 2(3): 359-382.

Watson, J.D. and Crick, F.H. (2010). 1953. A Structure for Deoxyribose Nucleic Acid University of Chicago Press. (pp. 82-84).

Welde-Michael, G., Bobosha, K., Addis, T., Blomme, G. and Mekonnen, S. (2008). Evaluation of enset landraces against bacterial wilt. Afr. Crop Sci. J. 16, 89-95.

Yemataw, Z., Borrell, J.S., Biswas, M.K., White, O., Mengesha, W., Muzemil, S., Darbar, J., Ondo, I., Heslop-Harrison, P.S., Blomme, G., Wilkin, P. (2020). The Distribution of Enset Pests and Pathogens and a Genomic Survey of Enset Xanthomonas Wilt. bioRxiv. 2020 Jan 1.

Yemataw, Z., Bekele, A., Blomme, G., Muzemil, S., Tesfaye, K. and Jacobsen, K. (2018). A review of enset (*Ensete ventricosum* (Welw.) Cheesman] diversity and its use in Ethiopia. Fruits. 73(6): 301-309.

Yirga, C., Nin-Pratt, A., Zambrano, P., Wood-Sichra, U., Habte, E., Kato, E., Komen, J., Falck-Zepeda, J.B. and Chambers, J.A. (2020). GM maize in Ethiopia: An ex ante economic assessment of TELA, a drought tolerant and insect resistant maize. Intl Food Policy Res Inst. 1926. DOI: 10.2499/p15738coll2.133714.

Zeleke, M., Adem, M., Aynalem, M. and Mossie, H. (2019). Cotton production and marketing trend in Ethiopia: A review. Cogent Food and Agricxdulture. 5(1): 1691812.

Zhang, Y.M., Zhang, Y. and Xie, K. (2020). Evaluation of CRISPR/Cas12a-based DNA detection for fast pathogen diagnosis and GMO test in rice. Molecular Breeding. 40(1): 1-12.

Zinabu, D., Gebre, E. and Asfere, Y. (2021). Genotype and plant growth hormone interaction effect on In vitro propagation of early maturing enset (*Ensete ventricosum* (Welw.) Cheesman) cultivars. Plant Cell Biotechnology and Molecular Biology. 89-102.