

Achieving food security in Ethiopia by promoting productivity of future world food tef: a review

Abstract

Tef is an endemic tropical cereal crop of Ethiopia and it has been cultivated for thousands of years in Ethiopian high lands. The grains is a daily food staple for about 50 million inhabitants (60% of the total population) accounting for 14% of all calories consumed. Based on morphological, biochemical and biosystematics data and DNA sequencing, tef has been grown in Ethiopia since before recorded times. Tef has been introduced to different parts of the world through various institutions and individuals since 1866. The crop is highly adapted to diverse growing condition and its adaptability has resulted in its cultivation as an important crop in 10 of the 18 agroecological zones of the country. Tef grain does not contain gluten and is an increasingly important dietary component for individuals who suffer from gluten intolerance. The nutritive value of tef compares well with some of the major cereals such as wheat, barley, maize and sorghum, and in fact, it is better than some of these crops in mineral content specially zinc, copper, and manganese. Annual tef production has been increasing year after year on average by about 10%. Annual increased in productivity is believed to contribute about 6% of the 10% growth with 4% attributed to expansion in total area. It is the second most important cash crop after coffee and generating almost 500million USD incomes per year for local farmers. Compared to other staples, the price of tef has increased at faster rate in recent years and hence the price gap between tef and other staples is widening. The volume of export has fluctuated and relatively a larger quantity was exported in 1995-97, 2001 and 2005 but export has declined since January 2006, mainly due to high domestic prices and government export ban on unprocessed tef grain. The benefits of keeping an export ban in place to favor Ethiopian consumers and protect smallholder farmers in certain respects are significant. Currently, tef research in Ethiopia has mostly focused on breeding and improvement of backward agronomic practices with little emphasis on the Mechanization and processing of the crop. There is a need to develop comprehensive strategy at country level for large scale production, adoption, adaption and maintenance of farm implements. An immense contribution is needed from researchers in production and adaptation of prototype models grainer to boost production and reduced quantity of seed rates. Putting in place mechanisms for tef seed standardization, packaging, labeling and distribution that are capable of meeting farmers' demands would help to ensure a sustainable supply of high quality improved tef seeds. It is necessary to develop site specific recommendations for organic and inorganic fertilizers that are most suitable for tef production. Development of Mechanical harvesters and threshers offers potential to increase efficiency, minimize yield loss, time and cost saving. Increasing farmers' access to price information increase transparency of the market and would enable farmers make better selling decisions and provide increased bargaining power to begin the value chain. Here, I present both the benefits and drawbacks of major tef production, the efforts being made to improve tef, and suggestions for some future directions.

Keywords: tef, production, use, drawback, market opportunity

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Introduction

Tef [*Eragrostis tef* Zucc. Trotter] is an endemic tropical cereal crop of Ethiopia and it has been cultivated for thousands of years in high lands Ethiopian.^{1,2} It is an unidentified specific cereal crop in the world while in Ethiopia; it is the major staple grains primarily used to make injera a delicious traditional fermented pancake. Tef has a robust vegetative growth habit and has an advantage of being harvested multiple times in a growing season. The above depicted nature of the crop draws attention of growers outside of its origin and cultivated principally as forage for livestock feed in countries like Australia, South Africa, and United States.³ Tef is a fine stemmed,

tufted annual grass characterized by a large crown, many shoots and a shallow, diverse root system. Its inflorescence is a loose or compact panicle.⁴ The seed sizes are quite small, ranging from 1–1.7mm long and 0.6–1mm diameter with 1000 seed weight averaging 0.3–0.4grams and 150 grains of tef has equivalent weight with almost one seed of wheat.⁵ With the exception of finger millet, tef has the smallest seed size among the grain crops in the world.⁶

*Shahidur*⁷ indicated that tef has strong inseparable traditional and cultural ties for second African population nation of Ethiopia with more than 90million people. The grains are a daily food staple for about 50million inhabitants (60% of the total population) accounting

for 14% of all calories consumed. Agricultural sample survey of CSA⁸ indicated that 6.3 million households are engaged in the growing of tef including both male and female headed households. Tef is produced by small holder farmers in most productive agricultural lands available in 30 of the 83 districts found in Ethiopia.⁹ Based on land use, tef is dominant among cereals but second to maize in terms of production and consumption.⁸ Even though, tef has enormous potential for growth, it has been neglected for centuries in research, development and promotion compared to major cereals. The very low productivity of the crop is as a result of the limitations in the full exploitation of the existing potential of the crop.²

During the dictatorial military regime of Mengistu (former Ethiopian military ruler), there was a strong campaign and enforcement of farmers for shifting of tef with other high productive staple crops. Similarly, the late prime minister of Ethiopia Meles Zenawi also said, if something miracles will not happen, tef will disappear from Ethiopian dish. The exerted political pressures were not totally abandon farmers from growing of tef. The persistence of tef in cultivation was partly commence through its socio-economic benefit gained from both grains and straw compared to other cereals. Tef has become the principal component and largely consumed diet in north east Africa and Asian regions by millions of house hold.¹⁰ Currently, the crop has received worldwide recognition by consumers for its best nutrient quality in relation to major staple crops and its health benefits for those suffering from celiac and diabetes.⁴ In Ethiopia, both the demand and price of the crop has skyrocketed and it has become a luxury for the Ethiopia masses.¹¹

Tef is cultivated similarly like other cereals in Ethiopia depending on agro-ecology of the area and growing period of the variety that mostly takes place once in a year but it can rarely produce twice a year in areas receiving bimodal nature of rain. It is usually grown in pure stands at normal density but occasionally carried out under a multiple cropping system.¹² In such cases it is usually grown as an intercrop with rape, safflower, and sunflower or relay-cropped with maize and sorghum,¹³ sequentially in a crop-rotation system in the mid- and high-altitude areas after chickpea, field pea, faba bean and grass pea; while at low and some mid-altitude areas it is grown after common bean. Usually a 4-5 year rotation cycle is practiced. The 4-year rotation cycle of tef sequence followed would be: pulse/tef/ tef or another cereal.¹³

Origin, diversity and distribution

Ethiopia is endowed with diverse agro-ecological zones with diversified soil fauna and flora. This suited condition favors the country to be become the major diversity and center of origin for several economically important crops like the prominent *Eragrostis tef*.¹⁴ Tef is an indigenous C₄, self-pollinated, chasmogamous annual warm season grass and taxonomically, it belongs to the grass family, Poaceae, and genus *Eragrostis*.¹³ The genus *Eragrostis* is found everywhere in the world with 43, 18, 12, 10, 9, 6 and 2% of their origin in Africa, South America, Asia, Australia, Central America, North America and Europe, respectively.¹⁵ Out of the total available 54 confirmed *Eragrostis* species in Ethiopia, 14 species are endemic.¹⁶

Ethiopia is one of the richest centers of crop origin contributing numerous important crops to the world such as *Eragrostis tef* and other related species.¹⁶ This botanist has further confirmed diversity of tef only in Ethiopia along with several other indigenous, exotic crops and wild relatives. Variability of the crop has not existed anywhere in the world except in Ethiopia indicated with its origin and domestication.¹⁷

This was later confirmed by the well-known US plant geneticist Jack Harlan ‘the Noble Cereal of Ethiopia’, who called tef as a semi-endemic crop originated in a defined centre with very limited dispersal. Harlan furthered also noted that tef has had some dispersal to other countries such as India but has less importance elsewhere than in Ethiopia, then included Eritrea. Whereas, tef is typically grown in the Ethiopian highlands and has centre of diversity, it is also grown in Eritrea, according to both experts.^{18,19}

Since before recorded times, tef has been grown in Ethiopia.²⁰ Based on morphological, biochemical and biosystematics data and DNA sequencing, the most likely direct wild progenitor is believed to be *Eragrostis pilosa*, a weedy species that can be found in both temperate and tropical regions throughout the world and which is very common in Ethiopia.²¹

The name tef is said to have probably originated from the Amharic word “tefa”,²² which means lost because of small seed size that is difficult to find once it is dropped. However, other more credible sources state that it was derived from the Arabic word tahf, a name given to a similar wild plant used by Semites of south Arabia during the time of food insecurity.²³ The existing accumulated evidences derived from cultural and historical heritage, linguistic source, and its limited geographical area of production is more sounds about the place of origin of the crop to be in northeastern Africa.¹³

All cultivated plants were domesticated from their wild species but the exact time and place of origin and the true ancestry of many crops are still highly speculative as the origin of man. Similar to other crops, exact time and place of tef first brought in to cultivation was debatable but it is believed that it is a very old crop in Ethiopia where its cultivation begun before the birth of Christ.¹³ The major production areas of today are not probably the early place of domestication rather it probably took place in the western part of Ethiopia.

Tef was introduced in to new areas far from its center of origin by various agents in recent times. It was first imported to Britain from Ethiopia in the 19th century with the aid of the Royal Botanical Garden and from then to India, Australia, USA and South Africa.¹³ The distribution of the crop got intensified through time in the world and now it is produced in Malawi, Zaire, India, Sri Lanka, Australia, New Zealand and Argentina.¹² It is also grown in some African countries with very limited volume mainly in Kenya, Uganda, Zimbabwe and Mozambique by Skyes in 1911 and Horwitz in 1940 to Palestine. According to Costanza et al.,²⁴ tef is cultivated principally for livestock feed than its grain in these countries because of its limited utilization for human consumption.

The recent rationale for distribution of tef outside Ethiopia was the government imposed ban on export exerted due to recurring food insecurity and roar price in domestic market beyond consumers’ affordable level.²⁵ Therefore, this triggers immense interest in growing of tef outside Ethiopia to become enormously increased. The production of tef in United States was started 1984 and the amount of production got boosted enormously with increasing demand for the nutritious grain primarily by Ethiopian descendants and secondly by Americans and for its supper quality animal hay.¹⁰ It was also recently introduced in north-western Europe particularly Netherland.²⁶

Agro-ecology and production environments

Tef is a C₄, self pollinated, chasmogamous annual grass whose plants range from 30 to 120cm in height.^{13,27} It is adapted to a wide

range of environmental conditions and its adaptability has resulted from its cultivation as the main cereal crop in 10 of the 18 broad agro-ecologies found in Ethiopia.²⁸ It is widely cultivated both in high potential production areas receiving adequate rain sufficient for growth and marginal production areas receives inadequate rain difficult to complete life cycle of most other staple crops.¹³ Most of these production areas are located in vertisols that possess much water on surface during main growing season and brought physiological drought to non-vertisol area that has limitations with water holding capacity for long period. These characteristics of tef has resulted from its reasonable tolerance for excess and shortage moisture in growing season compared to maize, wheat and sorghum, making it a preferred crop for growers.²⁹ It is often considered as a rescue crop in seasons when early planted crops such as maize fail as a result of moisture deficit.³⁰

The adaptability of tef to wide ranges of environmental conditions enables its adaptability to a varied range of altitudes reaching up to 3000 meters above sea level under various climatic and soil regimes but performs better in between 1800 and 2100 m.a.s.l.³¹ Tef usually grows from heavy black to light red soils and chemically adapted from acidic to alkaline soils but better agronomic performance is obtain when grown under light sandy to heavy clay soils, and under moderate acidic to low alkaline conditions.³² According to Seyfu,¹³ tef performs very well with an annual rain-fall of 750-850mm and growing season rain-fall of 450-550mm.

It is a long day crop that requires long duration of exposure to radiation energy and this implies that length of the day is more important than light intensity for tef. Abundant light is found in the area where the crop is cultivated for centuries than elsewhere in the world. Light is one of the most important factors influencing many vital plant processes like seed germination, leaf expansion, growth of stem and shoot, production of tillers, branches, flowering, fruiting, root development, growth movements in plants. This significant role of light poses picky challenges when the crop is grown outside its domestication center of Ethiopia and Eritrea, as the normal physiological function of the crop is affected. Different varieties, varies in terms of number of days required to maturity and most varieties completed their life cycle within of 60-180days depending on the agro-ecology but the optimum length of growing the crop is between 90-130 days.³³

The first plowing for tef production in most part of the country starts immediately after the previous crop is harvested. In less weed prone areas, it is done either after the onset of the small (belg) or main (kiremt) rainy seasons.³⁴ The small seed size nature of tef requires more repetitive disking and harrowing plot to meet the proper fine, firm, level seed bed demand of tef relative to other crop cultivated in Ethiopia for germination and vigorous vegetative growth.³³ It requires more frequent plowing on Vertisols reaching up to 12times due to larger clod formation during plowing compared to Nitosols.³³

The Research recommendation by Kenea et al.,³⁵ on the number of tillage required in Nazareth and western Wellega was about 3times and 12times respectively. Many tillage trials were conducted in Ethiopia in different locations and indicated that the grain yield of tef is increased with increasing of number of tillage.³⁶ Melesse³⁷ reported that 3-5times of tillage is advisable to enhance yield of tef whereas,³⁸ recommended more frequency of 5-9times particularly important to adequate rain fall areas and³⁹ argued that 4-times of tillage could produce adequate yield. The soil phyco-chemical and biological

difference, inerratic rain distribution and farmers economic problem causes the tillage frequency not to be consistence from region to region in Ethiopia.

Importance of Tef

Tef has own agronomic and food qualities that make it the most important crop to the farm household compared to other crop enterprises.¹³ Tef is a better choice and provides some harvest when it grows in moisture stress agro-ecology where other crops face potential starvation that leads to total production loss.³¹ The other quality of tef is its storability in various locations without infected by storage pests compared to other staples and making it an alternative cereal cash crop for most farmers.⁴⁰ It is also the most desirable crop because of its straw quality for livestock feed, best *Enjera* quality, and the ability to provide more satisfaction from a small weight of the grain, locally known as Bereket.⁴¹

Tef is produced in Ethiopia with limited application of chemical inputs for 600years and still the agronomic practices engaged are similar in harvesting of qualitative nutritious grains.⁵ The modern techniques employed in crop improvement have positive influence on production but have negative impacts on the final nutrition quality of grains due to dilution effect. Tef is not yet exposed to modern breeding techniques and it has not been genetically manipulated so far thus its grains are pure as nature itself.⁴²

Tef is gluten free crop which makes it suitable for peoples with celiac diseases.^{10,43} It contains important nutrients and from total aggregate of chemicals 60% is starch with 20% of it is rapidly digestible that convert in to blood glucose within about half an hour. Whereas the remaining 50% of the starch is slowly digestible that changes into blood glucose within 3 to 5hours while 30% is resistant starch that cannot be converted in to glucose, but use as substrate for the bacterial flora in the colon.⁴² Tef products are not only gluten free but might help consumers to control their weight. Different than the modern grains tef helps the body to be fit for life. Products made out of tef, including *Enjera*, help Ethiopian sport men and women to break international records over and over again. This is possible because tef has a high content of iron. This made that the haemoglobin in the blood is higher, so more oxygen can be transmitted, and sportsmen can attain better sport results.

Use of the crop

In Ethiopia, tef is principally cultivated to harvest the economic part of the grain for own consumption. The grains are used to bake injera after milled, a type of Ethiopian bread which are the most beloved national dish.⁴⁴ Tef is one of the least famous yet most nutritional grains in the world and injera make from it has excellent flavor, aroma, texture and durable quality.³¹ It is known for its nutrient quality and 99% high return quality after milling compared to 60-80% from wheat.⁴⁴ The grains can also be ground into flour which is used to make porridge and alcoholic beverages such as *tela* and *katikala*.³¹ Cooked tef can be mixed with herbs, seeds, beans or tofu, garlic, and onions to make grain burgers. The grains can also be sprouted and the sprouts used in salads and on sandwiches.

Nutrient enriched tef injera has used with variety of stews placed on it prepared from pulses and meat.⁵ Injera is consumed with taking a piece of it torn to grasp the stew and salad for eating. Fermentation of cereals or their blend with legumes is a potentially important

processing method that can be expected to improve the nutritive value such as availability of proteins and amino acid profiles. It could also decrease certain anti nutritional factors like phytates, protease inhibitors and flatulence factors. The traditional consumption of injera with stew from pulse enhances the balance of the food.⁴⁴ New alternative dishes are started to appear in the western world in the form of breakfast like tef waffles, tef banana bread.³¹

The straw which remains after separation of grains is equally important nationally in keep ruminants during off seasons. Teklu³¹ reported that straw quality of tef is ranked first nationally compared to other cereal crop residues and better performance of animals was obtained on growth and fattening those treated with tef residue contrast to native grass hay. Understanding of this value growers are usually feeding the straw to most productive animals like draught ox and milking cow. In addition to cherished livestock food, the straw is used to reinforce mud used for plastering of local houses and grain containers.

Nutritional status

Compared to common cereals crops growing in the globe, much research was not conducted to understand the chemical composition of Ethiopian orphan tef and its associated health and nutritional benefits. These further limit the development of production and post harvest processing technologies in value adding the product.³ Because of this the crop has long been restricted only in Ethiopia where it was originated in terms of cultivation and consumption. Although tef is one of the preferred crop for wider health consumption but due to lack of familiarity by consumers and limited interests in tef causes Ethiopian to think for centuries their crop is lesser in quality.⁴⁵ On the other hand, for the last ten years the discovery of the gluten-free of tef has encouraged researchers in agronomy, breeder, nutrition, and food science to exert more endeavors to improve the historically neglected crop. Consequently, numerous research has been done on the composition of tef nutrition and its post harvest values. Currently, the development of new tef-based products has accelerated out of its center of origin initially in Denmark.

The nutritive value of tef grain compares well with some of the major staple crops and in fact, it is better than some of these crops in mineral content specially zinc, copper, and manganese.²² The nutritional profile of tef indicated highest quantity of protein compared to usually consumed staples in Ethiopia and its caloric content is solely exceed by maize. The grain has a high concentration of different nutrients with very high calcium content, and significant levels of the minerals phosphorus, magnesium, aluminum, iron, copper, zinc, boron, barium, and thiamin. It is considered to have an excellent amino acid contents, and it also said to have higher lysine levels than wheat and barley and a little lower than rice and oats.⁴⁶

The tiny size of the grain is the major contributor and secret behind the nutritional value of tef due to the flour contain both the bran and the germ.²⁰ Difficult in husking of the bran and germs during milling from the grain are rationales in high nutrient value of tef flour because the bran and germs are main nourishing part of any grains. The difficulty of isolating the bran and germs enables the whole grains to be milled and entirely consumed latter. The gluten freeness of tef is an alternative compatible grain to address people allergic to the gluten in wheat and considered saves to for patients with celiac diseases and healthiest food for those not suffering from celiac.⁴⁷ Furthermore, with addition of other ingredients it is possible to enrich tef flour

artificially during milling. This practice will help to produce value added products having diversified nutrient augmented with injera, cookies and cakes.

Tef production trend in Ethiopia

Crop production is composed of the largest share in cultivated area, production and consumption as well as in contribution of gross domestic product of the country. Boosting productivity is the major means to produce and provide adequate raw material to booming domestic industries and supports the effort to ensure food security in Ethiopia.⁴⁸ Among the total grain products, 98% of cereals are harvested with the help of small holder growers whereas the remaining 2% is produced by state and commercial farms primarily for seed purpose.⁸ Thus production of cereals contributes half of the caloric intake by standard households.⁴⁸ In addition, cereal crop production plays crucial roles in employment opportunity for 60% of the rural poor and coverage of 80% of total arable land in Ethiopia.⁸

According to the survey data of Central Statistical Agency,⁴⁹ tef production has expanded by 124.5 percent in between 2003/2004 and 2012/2013 cropping years (Figure 1), (Figure 2). This growth was achieved mainly due to 37 percent expansion in area under cultivation and 64 percent increase in yield levels per hectare. Annual tef production has been increasing year after year on average by about 10%. Annual increased in productivity is supposed to contribute about 6% of the 10% growth with 4% attributed to increase in net cropped area allotted to tef (Figure 1). This situation is continuing in the farming community without deliberate promotion of tef culture. According to CSA,⁸ tef is among economically important cereals being cultivated in Ethiopia and it was estimated that 3.5 million tons was produced from 2.73million hectares of arable land. This is comparable to 22.14% of the total area and 15.28% of the total grain production of the staples cultivated in the country, making tef the leading crop among cereals and other annual crops by area.

The plot of land allotted to tef production is extended due to the adaptable quality of tef to Ethiopian farmers (Figure 2).⁵⁰ Initially, both the grain and straw achieve relatively higher value in the market in contrast to those of other produced crops.⁵¹ This is due to the crop becomes exportable commodity and it is expected to enhance the farmers income in the future. Additionally, it is an excellent versatile crop to the diverse climatic conditions that exist in Ethiopia.^{35,41} Tef production has been increasing from year after year and so does the demand for its staple grain in both rural and urban areas of Ethiopia (Figure 1).⁵²

Despite the aforementioned importance and coverage of large area, its productivity is very low when it is compared with cereal crops like maize and wheat. The national average yield is 1.38tha⁻¹ for tef which is 77.97% below the national average maize yield and 39.86% below the national average wheat yields (Figure 3).

This is mainly due to limited use of improved seeds resulted from inconsistent production of sufficient seeds both in quality and quantity along with greater delays in distribution, supply and storage problems. An inefficient agronomic practice due to technical incapability and cost inaccessible of inputs for farmers and fragmented farm plots further aggravates farmers' production capacity. The application of Lime, which is used to treat highly acidic soil in Ethiopia, is limited in access and costly to afford for subsistence farming households. presented farm equipment exploited by growers are the traditional

ones used for centuries without slight modification and the available improved tools like row planters, broad-bed makers, and ploughs are also not enough and not readily available to farmers nationwide. The available pesticides are very costly and are not extensively reachable to farmers. The recent devaluation of Ethiopian Birr against dollar will also further escalate the price of imported agricultural inputs. Fertilizer is not domestically manufactured for local consumption but import from out of the country and the prices is expect to stay roar for growers, partially due to importation and many bottlenecks in domestic delivery practice.

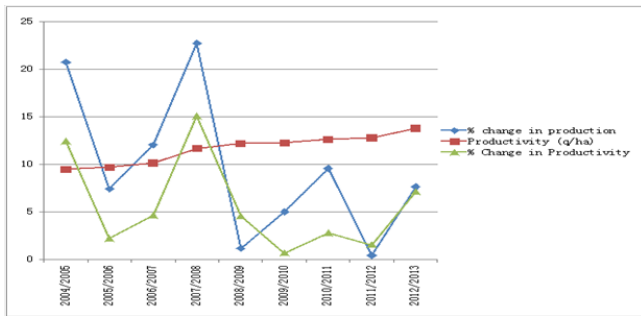


Figure 1 Trends of % changes in Production and productivity of tef (q ha⁻¹). Source: Author's calculation based on various Central Statistical Agency (CSA, 2005-2013) publications

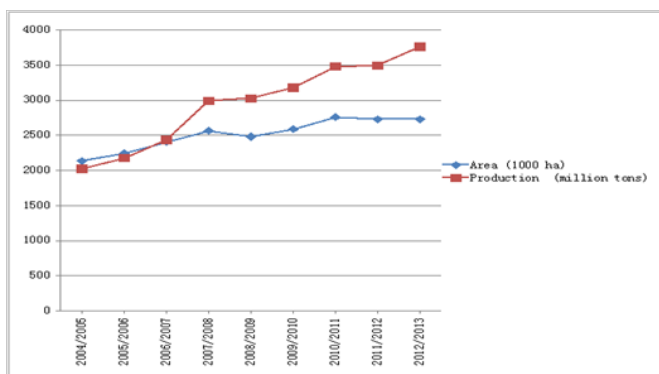


Figure 2 Trends in land use and production of tef. Source: Author's calculation based on various Central Statistical Agency (CSA, 2005-2013) publications

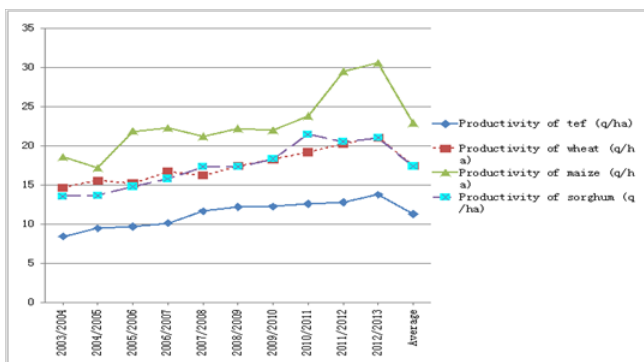


Figure 3 Trends of productivity in major cereals grown in Ethiopia. Source: Author's collection from various Central Statistical Agency (CSA, 2004-2013) publications

The minute seed size of tef create troubles in the time of sowing and in some way during rouging of other plants growing in the field and threshing operations. Tiny natures of the seed, exposed to wind when broadcast in time of sowing creates difficulty in maintaining the recommended plants per unit area and even distribution. Farmers usually use higher seeding rates than those recommended by researchers, which may be due to their unclean seed with lower germination rate, and apparently also to minimize weed infestation.⁵³

Tef has dominated the top position as compared to major cereals produced in Ethiopia in marketable price. Tef is now showing more attraction to producers as profitable marketed crop with high production cost and high labour intensive in tillage, sowing, weeding, harvesting and threshing activities. Even though, the production cost is roared, but production is also steadily increasing at around 10% per year for the last ten years (due to increased in net cropped area and raise in productivity with high underlying demand derived from increasing in price (Figure 1). It is important crop to indigenous Ethiopian peoples and it also becomes the potential healthy crop for the rest of the world.

Tef Market

Production and selling of staple crops is the principal way of living for Ethiopian masses.⁴⁸ Tef is largely produced for market mainly because of its high price and absence of alternative cash crops (such as coffee, tea or cotton) in the major tef producing areas of the country.⁵⁴ It is the second most important cash crop after coffee and generating almost 500 million USD incomes per year for local farmers.⁵⁵ Compared to other staples, the value of tef grain has increased at faster rate in recent years and hence the price gap amid tef and other staples is widening. In particular, the price gap between tef and maize has widened considerably since 2000 (Figure 4).⁵⁶ The incentive to grow tef as a cash crop has improved further. Poor farmers growing tef have benefited in recent years as the relative price of tef (which they sell) has increased while that of other staple crops such as maize and sorghum (which they buy for consumption) has declined (Figure 4).

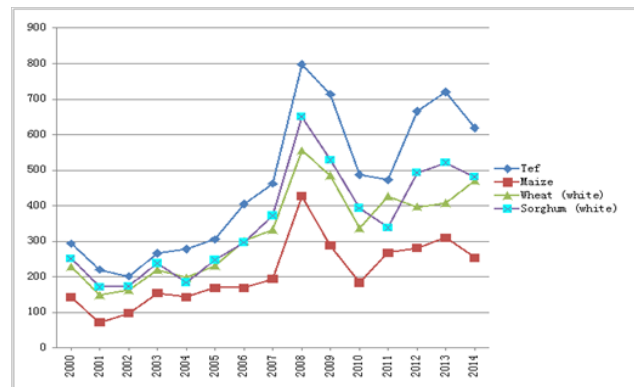


Figure 4 Trends of cereal crops whole sale prices at Addis Ababa market USD per ton.

Source: EGTE-<http://www.egte-ethiopia.com/en/2014-04-07-05-30-44/market-statistics.html>

Exporting tef has recently begun and the crop has become a means of generating foreign exchange earnings for the country.⁵⁷ It is exported to different countries, mainly to the Arab world, North

America and too numerous European nations primarily for Ethiopian Diasporas. Tef was not well known as food crop outside Ethiopia and Eritrea previously but this trend has changed and changed forever through higher recognition in different parts of the world both in terms of production, consumption and export. Out of its original cultivation area many countries are involved in the production and marketing of tef around the globe. These countries include South Africa, Cameroon, Canada, Netherlands, British, India, USA, china and Uganda.² Even though, the total volume of production is very high in Ethiopia but the country is not benefitting from the selling of its own crop.

The volume of export has fluctuated and relatively a larger quantity was exported in 1995-97, 2001 and 2005 but export has declined since January 2006, mainly due to high domestic prices and government export ban on unprocessed tef grain (Figure 5).⁵⁸ The rationale behind the government on export ban was to bring domestic inflation price into consumers' affordable level and meet local food security demand. However, the imposed ban averts the Ethiopia government particularly farmers from engaging and benefiting in the raising world trade, which could increase GDP and change the livelihood of growers. There are report that suggest that tef is being smuggled (after the ban) through the port of Djibouti to the port of Ashdod in Israel, where some 80,000 Ethiopian Jews live. Demand is thought to be very high in the USA where huge number of Ethiopians and people of Ethiopian origin live.

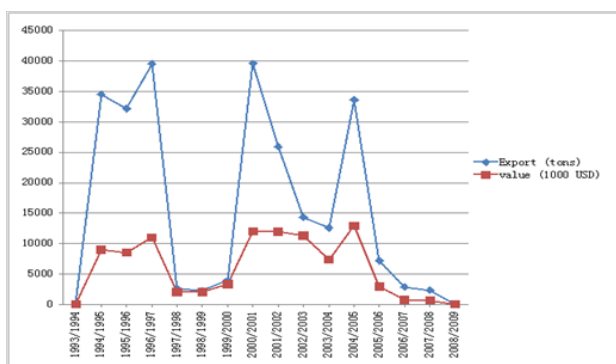


Figure 5 Trend of tef export in Ethiopia. Source: FAOSTAT (tef is considered as cereal, nes (not elsewhere specified))

Keeping the ban is the right measure temporarily in stabilizing the crop price for the benefit of millions of Ethiopians and guarding smallholder farmers in certain respects are significant. However, this resolution has negative alarms on producers to boost their production and limits their participation in the global tef grain market. From the very beginning the aim of the ban was to impose the trouble of consumers on growers who could benefit considerably more from engaging in the international market. If the ban is removed, the domestic price will rise to the international price, causing production to expand and consumption to contract in the next agricultural season. Because removing the ban will cause prices to rise, producers (farmers) gain while consumers lose. The only lasting solution is to provide price incentives to farmers to produce much more product and making the market more predictable and transparent.

Tef is the most value added crops compared to other cereals growing in the country. Following the imposing ban on raw grain export, selling of processed form of tef product is started to mount nationwide and benefited many stake holders involved in the process. Currently, pancake (*Enjera*) is found for sale in private houses, shops, super markets and hotels like the commonly available bread

from wheat in Ethiopia. Similarly good initiation also observed by super markets located in Addis Ababa through supplying of tef flour to their clients and it is also expected to expand in the near future in to regional super markets. Today, the raw grain export is totally shifted with exporting of millions of processed injera daily to different destinations mainly to Ethiopian in the Diasporas. But this condition is changing with the increasing number of non Ethiopian costumers who regularly visit Ethiopian restaurant in Europe, America and Asia. This is a very good opportunity to the government of Ethiopia in general and tef grower in particular in boosting the GDP and improvement of the livelihood of the farming community.

Production problem

Currently, tef research in Ethiopia has mostly focused on breeding and improvement of backward agronomic practices with little emphasis on the mechanization and processing of the crop. Lack research in many critical areas like, reducing lodging, water-logging, drought resistance, and improved blended fertilizers limits the quantity of production. The adoption rate of improved seed by growers is very limited in the country emanating from shortage of supply, accessibility, suitability of available varieties to all agro-ecological conditions and unaffordable price. The employment of ineffective agronomic practices limits production in diversified ways which comprises poor land preparation and inefficient method of sowing. The accumulation of much water in the growth media at early vegetative state restricts good field stand and vigorous growth resulting from withdrawal of oxygen in the soil root system which causes to anaerobic condition to prevail.

Additionally, repetitive tillage, removal of crop residues, and failure to apply manure lead to degradation of nutrient store house organic matter and removal of top fertile soil through erosion. The row sowing method and minimum seed rate are not properly exploited. The current traditional method of broadcasting causes unevenly scattering of seeds in the field and brought abnormal stand establishment which causes difficulty in agronomic practices. The high losses occurs during post-harvest operations additionally limits the volume of production and aggravates the marketable price. These losses are resulted from poor threshing practices and constraints in use of mechanical harvesters. The existing value chain of tef is very fluctuated that leads to seasonal variation in consumers' price.

Farmers are forced to sell crops at harvest time, when price is low, because of a need for immediate income to compensate for fertilizer, seed, and stationary fee for their school children and lack of storage options. Currently, there is very limited value addition processes of grains in to flour and flour in to injera by small number of urban dwellers. The nutrient packed small grains of tef have not gotten the opportunity to be exploited as an industrial crop. A comprehensive effort to plant higher quality tef has been reduced by partial value addition and export restrictions on the crop.

Harvesting

The harvesting activity of tef has starts when the growing crops in the field completely change their colour to straw or yellowish.⁵⁹ This phenological stage of the crop occurs 60-120days after sowing depending on growing period of the varieties and environmental conditions.¹³ The major indicators of maturity are changing of the panicle which holds the spikelet in to straw colour.⁶⁰ Early harvesting is advisable before the crop gets too dry and exposed to sever shatter

which leads to high yield losses.¹³ The amount of losses during mowing of the crop is not yet determined through research but it is believed that much the volume of grains is lost through shaking when handling by hand for cutting. The safest moisture for storage is not specifically determined through research but as like other staples it is estimated to be 12%. It usually dries naturally while in the field and does not require artificial heat for harvest. Tef is harvested after the seeds are physiological mature and dried. The seeds do not have dormancy right after harvest and if there is adequate moisture it can be germinate immediately after harvest.

Mowing is done by holding the bundle of plants in the left hand and cutting them on the right hand with sickle 5cm above the ground. The bundles in the hand after mowing are placed collectively in the ground. One man can harvest around 200m² in one working day and then to cover a hectare an average of 50 persons are required. Mostly in Ethiopia farmers are harvesting tef in *debo* (labour sharing) and lending of tools needed to harvest. In the time of harvesting men are responsible in mowing and dropping of the piles in the ground while elderly women, and children engages in heaping of the piles (*Nodo*) lied on the ground. Tef plants have bundles in the range of 14-18cm in diameter but the clusters get larger when sorghum stalks are there. Farmers are usually left the bundles without tied in the ground until harvesting is finalized on the entire field and following completion of harvesting, all bundles scatter in the field are heaped together until threshing.

Threshing is done traditionally with an ox feet trampling in clean circle plaster with cow dung or sprayed with water called *Awudema*. The cleaning and threshing activities brought both quantity and quality loss in the field. In the threshing yard, incorporation of impurities high particularly on the first threshing is not uncommon. The chaffs and other broken tef plant parts are separated through winnowing are either used for livestock feed or allowed to decompose naturally as manure.

Conclusion

Tef is a priority cereal crop for 6.4million farmers in Ethiopia, but as most farmers still use traditional agronomic practices it still has very low productivity. Increment of tef demand across Ethiopia and the expansion of its horizon as popular ingredient outside of Ethiopia require heavy investment on the improvement of production to satisfy the ever increasing demand. Just like white bread has been a status symbol in the United States, white tef was reserved for the wealthiest and most prestigious families in Ethiopia. Its nature of cultivation in harsh conditions coupled with its consumption by prestigious families, cost of white tef production is significantly increased. There is also believed that, the shelf life of injera is prolonged with the use of white tef.

Tef is the most labour intensive crop and its cost of production is relatively high compared to other staples. There is a need to develop comprehensive strategy at country level for large scale production, adoption, adaption and maintenance of farm implements. Development and distribution of farm technologies can effectively address the most pressing backbreaking work of tef cultivation and its cost of production. The research conducted should focus on the suitability of the technologies to the economic condition of growers and adapting approaches to Ethiopian. Thereby, the strategies can be conducted in collaboration with relevant stakeholders including farmers, cooperatives, regional and local administrators and other concerned private sectors.

Row planters

Recently row sowing with appropriate seed rate have shown significant yield advantages and reducing input costs over broadcasting method. However, currently there is no readily available mechanized row sowing implements in Ethiopia, especially for tef in association with its minute seed size. Although, there are some trials carried out by Agricultural transformation agency and Ethiopian Institute of Agricultural Research in production of row seeder but so far no functional seeder was emanated. An immense contribution is needed from researchers in production and adaptation of the prototype models seeder to boost production and reduced the quantity of seed rates. There is also need to scale-up production and distribution of seeders for tef farmers across the country with very fair price that grower can adopt.

Seeds

The main limitations associated with tef improvement are availability, quality, sustainability in emanating seed technologies and agronomic production packages. Therefore, it is advisable to work with federal and regional seed projects, growers associations, farmer cooperative unions, and seed producing farmers with participating of private sectors in harmonized way to ensure adequate supply of locally suitable certified seeds. Conduction research on-farm to improve tef seed across the nation in different agro-ecological conditions will ensure stability before supplying to final growers. The main strategies to create enabling environment for popularization of improved varieties, is increasing farmer awareness and access to inputs. Lastly, creating of favorable conditions for tef seed standardization like packaging, labeling and distributing are expected to meet the demands to ensure consistent provision of improved qualitative seeds.

Fertilizers

Currently, much of the fertilizers applied in tef fields are industrially fixed artificial fertilizers with no or limited application of natural fertilizers to replenish the soil. The agricultural input supply enterprise is the sole importer and distributor of chemical fertilizers in Ethiopia. Many claims have risen by farmers regarding accessibility, timely distribution and costly to afford the existing fertilizer. The domination of the government run organization in input supply limits the participation of other players and avoids competition in the fertilizer market along with its supply, access and distribution. The dose of fertilizers applied in the country is based on blanket recommendation. Thus, development of site specific recommendation for both organic and organic fertilizers is highly significant for each tef growing areas. The recommendation of fertilizers should be based on the fertility status of the soil derived from soil analysis and crop response treatments to determine the adequate balance of blended and organic fertilizers.

Lodging

Lodging is the state of permanent displacement of the stems from their upright position. All high yielding factors like variety, fertilizers, population and irrigation affect lodging. Careful management of the factors like selection of resistant genotypes, development of resistance varieties, following raised bed cultivation, proper N fertilizer application, irrigation at right time and quantity, pest and disease management and growth regulator application will reduce lodging and improve yield and quality of the crop.

Harvesters

Tef was harvested for a century manually using sickle and this traditional method still exists without any modification. Ethiopian farmers are suffering a lot with untimely rain during harvest season that causes significant yield loss. Development of mechanical harvesters also offers a potential to increased efficiencies, prevent yield loss, time and cost savings for Ethiopian farmers. Using mechanized harvesters can reduce the amount of days of labor needed to harvest one hectare by 70-80%. Distributions of feasible harvester technologies have multiple advantages in the livelihood of the farmer.

Threshers

Post-harvest mechanization is another limitation for tef growing small holders that brought threshing costs and production losses. Mechanical threshers have been developed for maize but not yet for the rest of other cereal crops including tef. Adopting small scale thresher from other countries and adapting and multiplying them locally is advisable to address the demand.

Marketing

As noted earlier, tef has a wider market opportunity domestically with increasing and ever changing client demand. There is also an increasing export demand, which can be met with research and development efforts towards increasing yield, setting up grain supply schemes and improving quality through processing industries. Even though, the price of tef is boosted both domestically and globally still farmers are not benefitting much because of involvement of brokers in the process and government ban on grains export. Strengthening and advertising of farmers' associations and establishment of grains storages in the proximity of residence of the farmer with the introduction of warehouse system will avoid the most pressing problem with marketing. This will create opportunity for growers to increase profit by protecting them from the most deceive brokers in the system. There is a need to start exploring idea of promoting farmers association in grains market to increase the size and quality of the market and finally enhance bargaining power of farmers in the possibility of collusion and deceiving price. Generally, providing of timely market information to growers will enhance transparency of the market and increased the bargaining power of the farmer to make better decision in transaction.

Value addition

Tef is the most value added crop relative to other cereal crops growing in the country. The processed forms like injera and flour have started booming in the market but still this recent development is little as compared to the nutritional value and demand of tef. The current value chain that exists in tef is at its initial stage of development. Most of the post harvest processing activities are carried out by consumers only without involvement of other stake holders. The establishment of strong linkage among producers, suppliers, consumers, processors, whole sellers, and retailers is inevitable to begin the value chain. In the future, there is a need for development of product patents to infiltrate the world market without degradation of export ban on raw grain.

Extension

Currently the extension program in Ethiopia primarily focuses on the dissemination of a package of technologies mainly improved varieties and fertilizer. The measure of extension performance is

mainly based on the number of farmers taking part in the package program. Yet the most important aspect which is related to the efficient use of technologies and the application of appropriate crop management practices on farmers field have little attention. Improving crop management practice such as appropriate planting date, seed bed preparation, weed and pest management, rate and method of fertilizer application, crop rotation, manure, etc and resource management technologies like soil and water conservation technologies greatly influences the magnitude and sustainability of crop productivity growth. Moreover, given the increasing input price such as fertilizer, the use of improved crop management practices minimizes the production cost by improving the efficiency of input use. In general, improving the provision of extension service could significantly enhance adoption and intensity of improved technologies.

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Conflict of interest

The author declares no conflict of interest.

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