



Cereal Crops Research Achievements and Challenges in Ethiopia

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Abstract: Cereals are the principal class of crops in Ethiopia in terms of area coverage (10.22 million ha), volume of grain production (25.38 million metric tons), engaging 16.24 million smallholder Ethiopian farmers for their livelihood, and economic importance with respect to food security in the country. In spite of this, the production and productivity of cereals in Ethiopia has been seriously challenged by a multitude of biotic and abiotic stresses resulted the national average grain yield has been very low (2.45 t/ha). Despite of this fact, a total of 391 improved cereal varieties which comprises 36 tef, 66 maize, 35 rice (15 upland, 11 lowland and 9 irrigated), 106 bread wheat, 35 durum wheat, 47 sorghum, 53 barley (37 foods and 16malt) and 13 finger have been released/registered up to date. These are accompanied as a package by a number of improved crop management agronomic/cultural practices, soil and water management, pest management, farm implement, and utilization and processing technologies. This paper presents an overview of the historical milestones, the major achievements recorded and challenges of cereal research in Ethiopia with special focus on the major cereals including tef [*Eragrostis tef* (Zucc.) Trotter], maize (*Zea mays* L.), bread wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), rice (*Oryza sativa* L.), and finger millet (*Eleusine corocana* L.).

1. INTRODUCTION

Ethiopia is endowed with diverse agro-ecologies suitable for different crops such as cereals, pulses, oil crops, vegetables, fruits, and root crops. The major cereals grown in Ethiopia include tef (*Eragrostis tef*), maize (*Zea mays* L.), bread wheat (*Triticum aestivum* L.), durum wheat (*Triticum durum* Desf.), barley (*Hordeum vulgare* L.), sorghum (*Sorghum bicolor* L.), rice (*Oryza sativa* L.), and finger millet (*Eleusine corocana* L.). All of these cereals belong to the family of grasses, *Poaceae* (formerly Graminae).

Cereals are the principal crops in Ethiopia in terms of both the area coverage and volume of production. Of the total arable land cultivated annually, cereals occupy the greatest proportion of area coverage accounting for about 81.27 % of the total acreage of all grain crops (cereals, oilseeds, and pulses) (CSA, 2017) (Table 1). Among the major cereals, tef accounts for the largest acreage followed by maize, sorghum, barley, wheat, millet and rice. Likewise, the annual production of cereals consistently exceeds all other food crops and contributes about 87.42% of the total annual production. The highest proportion of annual grain production of the country comes from maize which makes up to 27.02 % followed by tef (17.29 %) of the total produce. Maize also gives the highest yield per unit area (3.7 t/ha), followed by rice (2.8 t/ha), wheat (2.6 t/ha), sorghum (2.5 t/ha), barley (2.1 t/ha), and tef (1.7 t/ha), respectively (CSA, 2017).

Cereals, with the largest distribution and huge production potential across the country, have engaged majority of small-scale farmers for their livelihood. In terms of farm households involved in field crop production, cereals make up the highest proportion. Nearly, more than 90% of the total 14 million farm households engaged in grain crops are involved in cereal production. Cereal accounts for roughly 60% of the rural employment, 80% of total cultivated land, more than 40% of a typical household's food expenditure, and more than 60% of total caloric intake. The contribution of cereals to the national income is also large. According to the available estimates, cereal contribution to agricultural gross domestic product (GDP) is about 65% (Diao *et al.* 2005).

Table1. Area, production and yield of cereals for private holdings for 2016/17 (2009 E.C.) main (meher) season in Ethiopia

Crop	Area		Production		Average yield (t/ha)	No. of farmers (million)
	Million ha	% of gain crops	Million (Metric tons)	% of grain crops		
Tef	3.017	24.000	5.020	17.290	1.664	6.999
Barely	0.959	7.630	2.024	6.970	2.111	4.170
Wheat	1.696	13.490	4.537	15.630	2.675	4.996
Maize	2.136	16.980	7.847	27.020	3.675	10.863
Sorghum	1.882	14.970	4.752	16.360	2.525	5.987
Finger millet	0.456	3.630	1.017	3.500	2.230	1.735
Oats/Emmer	0.024	0.190	0.049	0.170	2.046	0.223
Rice	0.048	0.390	0.136	0.470	2.809	0.150
Cereals	10.218	81.280	25.382	87.410	2.467	16.236
Pulses	1.550	12.320	2.815	9.700	1.681	6.062
Oil seeds	0.805	6.400	0.839	2.890	1.284	3.544
Grain crops	12.573	100.000	29.036	100.000	1.811	17.441

Source: CSA, 2017

Research on major cereals have been going on since the early 1950 initially by higher learning institutions and then aggressively by the national research establishment in collaboration with international research centers. However some commodities like rice has been started sing late 1980s. Since then, a number of technologies enhancing productivity and production of the crops have been generated in different research disciplines to benefit small-scale farmers and the country as a whole. Economically, all of the cereals are of great importance in Ethiopia in terms of ensuring food security and food self-sufficiency, serving as means of household income and livelihood (employment opportunity) especially for smallholder farmers.

2. FOOD SECURITY CONTRIBUTIONS OF CEREALS

Cereals are the major food crops for ensuring food security in Ethiopia as they constitute the major component of staple diet for majority of the population and contribute approximately 70% of the average Ethiopian calorie intake (Haward *et al.* 1995, Solomon, 2011). Consumption levels of cereals are slightly higher in rural areas (152 kg) compared to urban areas (137 kg) (Bart *et al.*, 2012). Among the major cereals, maize is the most important staple in terms of calorie intake in rural Ethiopia. The 2004/5 national survey of consumption expenditure indicated that maize accounted for 16.7% of the national calorie intake followed by sorghum (14.1%) and wheat (12.6%) in descending order (Berhane *et al.*, 2011).

Cereals are important for meeting basic needs and income for small-scale farmers. Of the total annual production of cereals, it is estimated that about 45% is utilized as food expenditure for an average household (Xinshen and IFPRI, 2010) and the remaining is for seed, sales, animal feed and as in-kind payment for labor.

The uses of cereals in Ethiopia are numerous. Of the total Ethiopian population involved in agricultural production, over 90% of the households are engaged in cereal cultivation of which around 70% rely on it as a means of employment directly or indirectly.

3. MAJOR CONSTRAINTS OF CEREAL PRODUCTION

3.1. Relatively Low Productivity of Cereals

The national average grain yield of cereals in Ethiopia is relatively low amounting to about 1.7 t ha⁻¹ for tef 2.1 t ha⁻¹ for barley, 2.7 t ha⁻¹ for wheat, 3.8 t ha⁻¹ for maize, 2.5 t ha⁻¹ for sorghum, and 2.8 t ha⁻¹ for rice in 2016 (CSA, 2017). This, amongst others, is due to the widespread use of low yielding

varieties coupled with unimproved traditional practices that ultimately contribute to the low national average yield of major cereal in the country.

3.2. Diseases

Several pests (weeds, diseases, and insect and other pests) are constraining cereal production and productivity in different parts of Ethiopia. The impact of these biotic factors on the general performance, yield and grain quality varies depending upon the genetic, environmental, management condition and the interactions of these factors.

Diseases are amongst the most important constraints in cereal production in Ethiopia. The magnitude of yield loss associated with various diseases varies with varieties, location, season and planting date.

3.3. Insect Pests

Large numbers of insect pests attacking cereals under field and storage conditions have been identified (Table 3). Depending on the incidence and damage, some insect pests have been known to be economically important in Ethiopia.

Table2. Important diseases of major cereals in Ethiopia

Crop	Major diseases
Barley	Scald (<i>Rhynchosporium secalis</i>), net blotch (<i>Helminthosporium</i> spp.), stripe rusts (<i>Puccinia</i> spp.) powdery mildew (<i>Erysiphae graminis</i>), head blight (<i>Fusarium heterosporium</i>), covered smut (<i>Ustilago hordei</i>), barley yellow dwarf virus (BYDB)
Maize	<i>Turcicum</i> leaf blight ((<i>Exserohilum turcicum</i>), gray leaf spot (<i>Carpospora zea-maydis</i>), common leaf rust (<i>Puccinia sorghi</i>), maize streak virus (MSV), Maize Lethal Necrosis Disease (MLND)
Rice	Rice blast (<i>Pyricularia oryzae</i>), brown spot (<i>Cochliobolus miyabenus</i>), Sheath rot (<i>Sarocladium oryzae</i>) and sheath blight (<i>Thanatephorus cucumeris</i>).
Sorghum	Anthraxnose (<i>Colletotrichum sublineolum</i>), grain mold (<i>Fusarium</i> spp, <i>Alternaria</i> spp., <i>Helminthosporium</i> spp., <i>Curvularia</i> spp.), gray leaf spot (<i>Cercospora sorghi</i>), rust (<i>Puccinia purpurea</i>), smut (<i>Sphacelotheca</i> spp), ergot (<i>Claviceps sorghi</i>), downy mildew (<i>Peronosclerospora sorghi</i>) and leaf blight (<i>Helminthosporium turccium</i>
Teff	Teff rust (<i>Uromyces eragrostidis</i> Tracy), head smudge (<i>Helminthosporium miyakei</i> Nisikado), leaf spot (<i>Helminthosporium</i> spp.), damping-off (<i>Drechslera</i> spp., and <i>Epicoccum nigrum</i> Link.)
Wheat	yellow/stripe rust (<i>Puccinia striiformis</i> Westrnd), stem/black rust (<i>P. graminis fsp. tritici</i>) leaf/brown rust (<i>P. riondite fsp. tritici</i>), <i>Septoria tritici</i> (<i>Microsphearelia graminicola</i>)
Finger millet	Finger millet blast (<i>Pyricularia grisea</i>)

Table3. Important insect pests of major cereals in Ethiopia

Crop	Major insect pests
Barley	Barley shootfly, (<i>Delia arambourgi</i> Seguy, <i>D. flavibasis</i> Stein.), Russian aphid (<i>Diuraphis noxia</i> Mordvilko),, chafer grub (<i>Melolontha</i> spp.)
Maize	Stalk borer (<i>Busseola fusca</i>) Spotted stalk borer (<i>Chile partellus</i>), termites (<i>Macrotermes</i> and <i>Microtermis</i> spp) Maize, weevils (<i>Sitotroga zeamias</i>) Large grain borer (<i>Postephanus turncatus</i>)
Rice	Termites, stem borer (Pyraliae), stalked-eyed flies (<i>Diopsis thoracica</i>)
Sorghum	Stak borer (<i>Chilo partellus</i>), shootfly (<i>Atherigona soccata</i>), midge (<i>Contarinia sorghicola</i>), weevil
Teff	Shtfly (<i>Atherigonia</i> spp.), red teff worm (<i>Mentaxya ignicollis</i> Walker), Wello bush cricket (<i>Decticoides brevipennis</i> Rage.), black tef beetle (<i>Erlagerius niger</i> Weise), grasshoppers (<i>Ailopus</i> spp. and <i>Eyprepcnemis</i> spp.)
Wheat	Shoot fly <i>D. steiniella</i> Emden, , Russian aphids (<i>Diuraphis noxia</i> Mordvilko)

3.4. A Biotic Constraints

The most important abiotic stresses in cereals production are drought, cold, water logging, low soil fertility, soil acidity and salinity, hail and frost. In the coastal lowland and rift valley areas, moisture stress is significantly limiting maize production and productivity. Late onset and early cessation of rainfall are predominant phenomena in this area, and occasionally across the country. Also rainfall

distribution is often erratic resulting in shortage of precipitation during critical growth stage of the plants. Sorghum is critically affected by recurrent drought due to its inherent adaptation to warmer lowlands, and the erratic nature of rainfall in such agro-ecologies of the country is frequent particularly in arid and semi-arid lowland areas where over half of sorghum in the country is produced under severe to moderate drought stress conditions. The most important abiotic stresses in barley farming system include low soil fertility, low soil pH, poor soil drainage, frost and drought.

Likewise, the major abiotic stresses in teff and rice husbandry include drought, soil acidity, waterlogging, cold and frost. Wheat is severely affected abiotic factors such as low and poor distribution of rainfall in lowland areas, and water logging in half of the highlands, and soil erosions are perceived as causes for significant wheat yield losses in the country. Recent estimates indicate that low rainfall and poor distribution problems and plant lodging can cause a 10-30 percent of yield losses (Lemma *et al.*, 2008).

4. CEREAL RESEARCH FOCUS AREAS

4.1. Development of Improved Varieties

The major characteristics sought for in the genetic improvement of cereals have been high yield, diseases and insect pest tolerance/resistance, wide adaptation, yield stability, adaptation to varied agro-ecologies and farming systems with suitability to optimum rainfall and drought-prone (especially terminal drought) areas, various types of maturity (early, intermediate and late), quality (mainly seed color and tolerance/resistance to major biotic and abiotic stresses).

The variety development, among others, involves: germplasm enhancement through collection/acquisition and evaluation/characterization of germplasm accessions, population improvement, hybridization (inter-and inter-specific) and generation advancement, and induced mutation techniques and generation advancement; screening of selected genotypes in observation nurseries; evaluation of promising materials initially in preliminary variety trials; undertaking series of multi-environment variety trials over locations and years/seasons; and finally, verification and release of variety.

Cereal research apart from the generation of improved technologies and information, it is also involved in the generation of basic knowledge. The generation of basic information on the biology, genetics, physiology, socio-economics, food technology and other aspects of the crops rests heavily upon the domestic research in Ethiopia.

4.2. Development Improved Management Practices

This involves the development of appropriate cultural or agronomic practices, as well as other crop, soil and pest (weeds, diseases and insect pests) management options that promote productivity and sustainable cereal production in various agro-ecologies and farming systems. This also includes development and modification of improved farm machinery and implements.

4.3. Multiplication and Provision of Source Technologies

This involves multiplication of adequate quality and quantity of nucleus and foundation (breeder, pre-basic and rare case basic) seeds of improved varieties and proto-types of other technologies for provision to seed and technology multipliers.

4.4. Promotion of Improved Technologies

This entails the creation of awareness and subsequent demand by users for proven improved technologies through field demonstrations and limited level scaling up activities

5. ACHIEVEMENTS AND IMPACTS

5.1. Major Cereal Technologies

5.1.1. Released Varieties

Over the years of research on cereals, commendable achievements have been made in the generation of technologies and information useful for boosting the productivity and production of cereals in Ethiopia.

As one of the components of the package of improved technologies, to-date a total of 391 varieties of major cereal crops has been released and registered in the country. These include 36 teff, 66 maize, 35 rice (15 upland, 11 lowland and 9 irrigated), 106 bread wheat, 35 durum wheat, 47 sorghum, 53 barley (37 foods and 16 malt) and 13 finger millet varieties.

Variety development has also been targeted to addressing the needs of different maturity groups (early, medium and late), adaptability under different agro-ecological conditions, quality and farming systems like irrigation. In rice there are three major growing ecosystems (rain fed upland, rain fed lowland and irrigated) to which varieties are developed and recommended for adaptability. For maize, there are three maize growing ago-ecologies (high-altitude sub-humid, mid-altitude sub humid, low altitude sub humid). Likewise others cereals breeding program also have their agro ecologies and technologies are generated and recommended based on agro ecologies.

5.1.2. Genetic/Productivity Gain in Cereals

The overall national mean grain yield productivity of the major cereals (teff, maize, rice, wheat, sorghum and barely) in Ethiopia showed a constant increase except a sharp drop in 2003. However from 2004 till 2017 a constant and progressive increase was recorded. It indicated that the overall cereal grain yield productivity increased from 1.2 t/ha in 2001 to 2.5 t/ha in 2017 rising by 108.3%. Considering the individual commodity, the productivity over the past 17 years (2001-2017) increased by 112%, 105.6%, 85.7%, 108.3%, 90.0% and 100% for teff, maize, wheat, sorghum, barley and rice, respectively. (Figure 1)

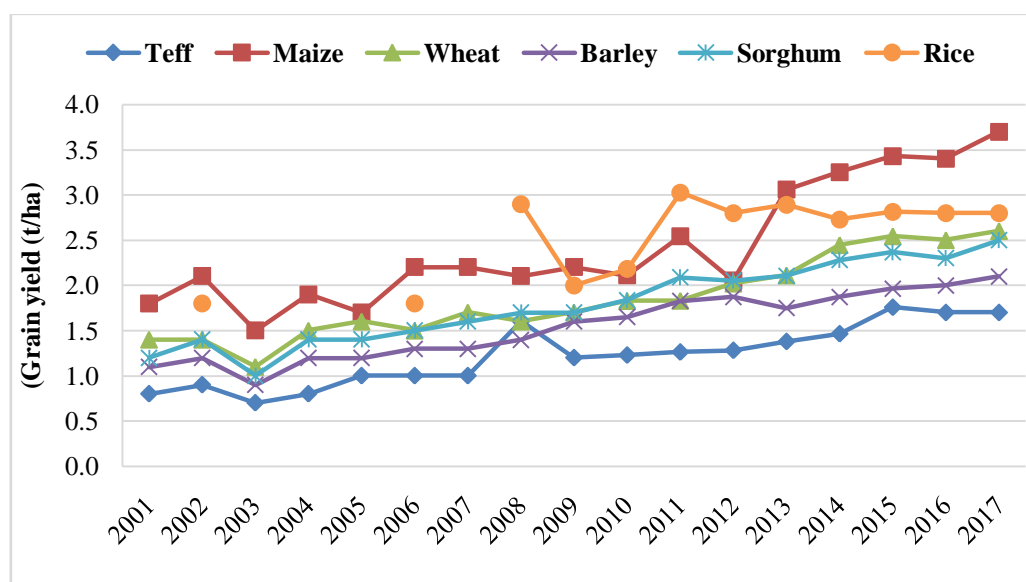


Figure1. Mean grain yield productivity of individual cereals (2001- 2017) in Ethiopia

6. PROSPECTS OF CEREAL RESEARCH IN ETHIOPIA

6.1. Challenges

6.1.1. Food Security

Currently, the population of Ethiopia is estimated at about 100 million, and considering the rate of 2.6% population growth rate per annum. Under the existing situations, ensuring food security will be a scary challenge unless the rate of cereal productivity is lifted-up twice than the current one. Development of high yielding and widely adapted varieties under rain fed conditions and technologies suitable for irrigated farming system are given considerable focus to ensure food security and sustainable development.

The majority of Ethiopian population relies on cereals to meet its nutritional requirements particularly with regard to calories. However, most cereals are deficient in major micro nutrients and on the other side animal products rich in the essential nutrients for human being are unaffordable to low income

classes of the community. Development and incorporation of nutritious rich cereal varieties with respect to essential amino acid, pro-vitamin A, Zn & Fe, etc which are also equally important with high yield potential should be given due research consideration

6.1.2. Shortage of Varieties with Specific Trait and Adaptability

Despite the *availability of diverse wealth of genetic resources*: maintained by major cereals in this country to improve phenologic, agronomic, morphologic, nutritional, biotic and abiotic stress tolerance traits, it is not yet fully exploited. The wealth of diversity in the species offers ample opportunities for genetic improvement of the crop and to develop varieties suitable for different agro-ecologies, cropping systems and purposes.

6.1.3. Diseases and Insect Pests Threat

Crop production and productivity are mainly affected by biotic factors. Among the biotic factors economically important endemic diseases and insects pests which result in huge losses of yield are common problems in cereals. The effects of climatic variability which has currently threatened global environmental condition also favors the evolvement of unknown deadly diseases, insects and also result into frequent outbreak of disease causing microorganisms. The main focus of cereal research is thus to identify and/or isolate genotypes with good level of resistance to the economically important diseases and pests in a regular and proactive bases. Continuous surveillances of newly emerging disease and insect pest should be undertaken in order to design and generate integrated control mechanisms.

6.1.4. Drought Stress Threats

Cereal production and productivity are intermittently and regularly suffering from drought, erratic rainfall and high heat intensity. Identification of genotypes (climatic resilience varieties) withstanding drought and tolerate high heat intensity is the area of focus is, thus, of paramount significance to mitigate the problem.

6.1.5. Crop Management Aspects

Among other issues in crop production and productivity, agronomic management practices are indispensable along with improved varieties. Most of the technologies are out dated and there is a lack of crop husbandry recommendation specifically developed for different cropping system and/or agro-ecological conditions. Therefore, the research system should be geared to revitalize and /or generate package of technologies that should go with improved varieties.

7. SUMMARY AND CONCLUSIONS

Cereals crop production is widely distributed in different regions of the country starting from sea level to as high as 3000 meters above sea level. Among the well know cereals, Ethiopia is center of diversity for teff, sorghum barley and durum wheat. While bread wheat, maize and rice are by introducing with substantial years of adaptation. These crops due to their earlier domestication and introduction in different parts of the country have been widely adopted by the farmers. Consequently, they are the major staples of large majority of Ethiopian population and occupy the largest portion of cultivated land and account to the highest portion of annual grain production in the country. They also constitute nearly 90% of farm households engaged in food crop production and serve as source of income and employment. Despite their importance as top priority crop to ensure food security, the productivity in per unit area bases is far behind the world average. Some of the factors that inhibited their production and productivity over the years include biotic, abiotic and socio economic constraints.

Over the years, numerous cereal production technologies and their respective management mechanisms has been developed and for use by the farming community. So far a total of 391 varieties of teff, wheat, maize, barley, sorghum, finger millet and rice varieties have been released. There were also crop husbandry practices, soil fertility management, methods of tillage operations, pest control at field and storage level and value addition of some crops have been developed and recommended for use. Along this line maintenance and multiplication of early generation seeds of improved varieties recommended for commercial production have been done for further multiplication of certified seed by private and public seed companies.

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