International Journal of Advanced Multidisciplinary Research
ISSN: 2393-8870
www.ijarm.com
(A Peer Reviewed, Referred, Indexed and Open Access Journal)
DOI: 10.22192/ijamr Volume 9, Issue 6 -2022

Research Article

DOI: http://dx.doi.org/10.22192/ijamr.2022.09.06.005

Wheat breeding, Major Achievements and Challenges in South and Southwestern Part of Ethiopia

Tegegn Belete
Ethiopian Institute of Agricultural Research, Jimma Research Center, P.O.Box 192, Jimma, Ethiopia
Email: *tegegnbelete2011@gmail.com*

Keywords

Challenges,
Production,
Variety,
Wheat,
Southwestern

Abstract

Agriculture is the largest sector of employment and main source of livelihood in Ethiopia. Nearly 85% of the population depends directly on farming. Grain production constitutes the major share of the domestic agricultural production. Nearly 98% of cereals are produced by small holder farmers. In Ethiopia, South and Southwestern part of Ethiopia was one of major coffee growing regions and have climatic and edaphic factors that combine well to meet the requirements of both coffee and cereals thereby strengthening the linkage between the two crops. This linkage has, in turn, enhanced the role of cereals in diversifying the coffee based farming system and the coffee industry as well. Currently, regional states of Oromia and Southern Nations, Nationalities and Peoples Region (SNNPR) are high potential coffee growing regions also having tremendous potential for cereal production.

Wheat is an important staple food crop in Ethiopia and since 2005 the country has been the largest producer of wheat in sub-Saharan Africa. It is grown in the highlands at altitudes ranging from 1500 to 3000 m.a.s.l. Yem special district,Jimma and Buno Bedele zones, are among major wheat producing areas of south and southwestern part of Ethiopia. Jimma research center was conducting wheat breeding experiments in collaboration with national bread wheat program to identify high yielding and adaptable varieties for main and irrigation potential areas of South and Southwestern part of Ethiopia for five years and identified promising wheat genotypes. Soil acidity, diseases, weeds and insects are major causes for productivity reduction in south and southwestern part of Ethiopia. Therefore, the objective of the paper was to review major achievements and challenges of wheat breeding in South and Southwestern part of Ethiopia. In future, the team planned to develop wheat varieties broadly adapted and tolerant to biotic and abiotic stresses, popularization and dissemination of the improved technologies, conducting crossing activities to identify diseases resistant and high yielding wheat genotypes, capacity building and creating more linkages.

1. Introduction

Agriculture is the largest sector of employment and main source of livelihood in Ethiopia. Nearly 85% of the population depends directly on farming. Grain production constitutes the major share of the domestic agricultural production. Nearly 98% of cereals are produced by small holder farmers (USDA, 2014).

Wheat is an important staple food in the diets of several Ethiopian, providing about 15% of the caloric intake for the country's over 90 million populations (FAO 2017), placing it second after maize and slightly ahead of teff, sorghum, and enset, which contribute 10-12 percent each (Minot *et al.*, 2015). Bread wheat (*Triticum aestivum* L. Thell) and durum wheat (*Triticum*. *turgidum* L. var. durum) are the two wheat species cultivated in Ethiopia.

In sub-Saharan Africa, Ethiopia ranks second to South Africa in terms of total wheat area and production and with annual production of more than 4 million tons of grain on 1.6 million hectares of land which accounted for 13% of total land allotted to cereals (CSA, 2014; USAID, 2014).In Ethiopia, wheat ranks fourth in total crop area and production. It is grown in the highlands at altitudes ranging from 1500 to 3000 m.a.s.l, situated between 6-16^{o}N and 35-42^{o}E; however, the most suitable agro-ecological zones for wheat production fall between 1900 and 2700 m.a.s.l. (Hailu, 1991). Major wheat production areas are located in the Arsi, Bale, Shewa, Ilubabor, Western Harerghe, Sidamo, Tigray, Northern Gonder, and Gojam regions.

Wheat is grown >1500 m.a.s.l. in mid and highland areas as a rain-fed crop in Ethiopia. Irrigation contributes 1.1% of the total cultivated land (Girmay, 2017). At mid and highlands between 1900 m.a.s.l. and 2700 m.a.s.l., wheat was grown in 1.696907 million hectares during 2017-18 and produced about 46.429657 million tonnes with average productivity of 27.3 qt/ha in Ethiopia (Anonymous, 2018); whereas the world average productivity was 33 qt/ha (EIAR, 2020). Wheat serves as both a food crop and an important source of income for Ethiopian small-holders. Demand for wheat is growing rapidly in Ethiopia, reflecting population growth and shifting dietary patterns linked to urbanization that are mirrored across other eastern and southern African countries (Mason,2015).Ethiopia remains a net importer of wheat, meeting just over 70% of demand from domestic production (Shiferaw *et al*.2015). There is a shortage of wheat production in the country for meeting the demand. According to Gebre *et al*. (2017), about 1.0 million tons of wheat is being imported annually since 2008 in Ethiopia at the cost of 500 million US dollars. Lately, Ethiopia imported 1.7 million tonnes of wheat (EIAR, 2020). Ethiopia remains one of the largest recipients of food aid in Africa, receiving around 27% of the global food aid given to sub-Saharan Africa (USDA, 2014).

In Ethiopia, South and Southwestern part of Ethiopia was one of major coffee growing regions and have climatic and edaphic factors that combine well to meet the requirements of both coffee and cereals (Paulos,1994) thereby strengthening the linkage between the two crops. This linkage has, in turn, enhanced the role of cereals in diversifying the coffee based farming system and the coffee industry as well. Currently, regional states of Oromia and Southern Nations, Nationalities and Peoples Region (SNNPR) are high potential coffee growing regions also having tremendous potential for cereal production. Wheat is one of the major cereal crops grown in Ethiopia. The South and Southwestern highland part of the country,Yem special district,Jimma and Buno Bedele zones, are among major wheat producing areas that cover 2823.3,29,257 and 1751 ha and with the productivity of 29.2,31.4 and 28.5qt/ha respectively (CSA,2020).Jimma research center was conducting wheat breeding experiments at highlands of south and southwestern Ethiopia in collaboration with national bread wheat program to identify high yielding and adaptable varieties for main and irrigation potential areas of South and Southwestern part of Ethiopia. Therefore, the objective of the paper was to review major achievements and challenges of wheat breeding in South and Southwestern part of Ethiopia.

2. Materials and Methods

Table 1: Site descriptions of main season trials

Site	Altitude	Coordinates	RF (mm)	Temp	Soil type
Dedo	>2400	7^0 25'N 37° 00' E	1850	18.6	Nitosol
Gechi	2087	8^0 27′N 36^0 21′E	1700	18	Nitosol
Yem special district	2413	$7^0$57′N 37° 61′E	1800	19	Nitosol

Table 2: Location and descriptions of weather condition for two locations (irrigation trials)

Locations	Latitude	Longitude	Altitude (m.a.s.l.)	Soil type	Remark
Seka chekorsa	7^0 35’ 54’’	36^0 44’52’’	1733	Nitosol	
Tiro Afeta	7^0 53’ 42’’	37^0 15’ 38’’	1753	Nitosol	

2.1. Experimental Materials (main season)

Twenty five nationally released bread wheat varieties (Table 1) were obtained from the National Bread Wheat Research Coordinating Center (NBWRCC) based at Kulumsa Agricultural Research Center (KARC) for use in this study. The genotypes were evaluated in six environments, over two growing seasons, in the highlands of Southwestern Ethiopia.

2.1.1. Trial Management

The experiments were laid out in a randomized complete block design with 3 replications at all environments. Each plot had six rows in a plot size of 3 m × 1.2 m (3.6 m^2) with spacing of 20 cm between rows and 5 cm between plants. Fertilizer was applied at the rate of 150 kg Diammonium phosphate (DAP) and 200 kg urea/ha. Both urea and DAP were given through split application, half dose at planting and the remaining half at full tillering stage. At planting the portions of both DAP and urea were mixed and drilled into the rows and mixed with soil before planting. Seeds were drilled into the rows at the rate of 150 kg/ha. The remaining half doses of both fertilizers were applied at full tillering through top dressing. Weeds were controlled by 3 to 4 times hand weeding. Data were recorded on all agronomic characters and grain yield. However, only grain yield was considered for stability analysis. The central four rows were hand harvested and threshed separately to determine grain yield. The moisture content of the grain was adjusted at 12.5% and grain yield was converted to qt/ha.

2.2. Experimental materials (Irrigation trials)

Twelve bread wheat and durum wheat genotypes were obtained from national wheat breeding program to evaluate the performance and identify adaptable and high yielding varieties at Jimma in irrigation condition.

2.2.1. Trial management

The trials (both bread and durum wheat) were conducted using randomized complete block design (RCBD) with two replications at both locations under irrigation conditions. Sowing was done manually. A seed rate was based on the recommendation which was 120kg/ha.Spacing between blocks and rows was 1m and 0.3m respectively with total plot size of 3m width x 5m length. As per the recommendations, plots were fertilized with 150 kg of UREA and 100 kg of NPS per hectare. All NPS was applied at planting, while urea one-third at sowing and two-third at

tillering stage of the crop was applied in split half at planting and the remaining half at tillering stage. All other relevant field trial management practices were carried out throughout the experimentation period across all locations as per the recommendations for the respective locations. All plots were irrigated at 8-10 days interval and Nativo chemical was applied one time at the occurrence of rust.

3. Major Achievements

3.1. Bread wheat trials (Main season)

Jimma Research Center evaluated twenty five released bread wheat varieties in the highlands of southwestern Ethiopia in 2016-2018 cropping seasons and identified Tay,Ga'ambo,Gassay and King bird as stable and high yielding varieties. But, the identified varieties were showed yield reduction and fluctuation and affected by different diseases. (Leta and Addishiwot, 2019).

Table 3: Mean grain yield and other traits of identified bread wheat varieties tested across locations of Jimma and Buno Bedele zones

Variety name	Days to heading	Days to maturity	Plant height (cm)	Number of fertile Tillers	Grain yield (qt/ha)
King bird	65.1	117.5	77.4	8.1	32.6
Gassay	67.8	119.5	71.8	9	33.7
Tay	69.7	121.6	84.4	9.5	38.03
Ga'ambo	64.9	118.5	77.3	8.5	34.3

3.2. Irrigation trials

Currently, cereal crops breeding team started screening of wheat genotypes (bread and durum wheat) in collaboration with wheat program coordinating centers and Oromia regional state government to identify high yielding and stable varieties for irrigation potential areas of Jimma zone. The study will be carried out to determine suitable genotypes for cultivation in the southwestern Ethiopia under irrigation condition by taking into account the responses of genotypes to these different conditions and the effects on grain yield, quality, yield, and yield components. The promising genotypes of both bread and durum wheat were evaluated in the coming seasons.

Table 4: Mean performance of grain yield (qt/ha) and yield related traits of bread wheat varieties tested different locations during 2020 in irrigation condition

Varieties	DH	DM	PH (cm)	FT	TSW (g)	BY (qt)	GY (qt)
Deka	61	93	84.2	8.5	41.1	95.8	46.7
Hibist	54	94	84.7	8.5	41.75	121.25	48.5
Shorima	64	96	83.35	10.35	39.05	120.7	46
Liben	62	93	80.5	6.35	33.05	123.75	46.9
ETBW9554	62	93	82.65	6.35	43.4	119.55	49.55
Kakaba (c)	62	93	85.2	7	32.4	104.2	40.65
Wane	51	93	85.35	7.8	35.9	106.25	44.8
Ogolocho	58.5	91.5	76.35	6.15	36.85	98.75	40.8
obora	72.5	91.5	79.65	7.5	35.05	120.85	41.35

Sofumar	61.5	97.5	85.65	7.35	39.45	100	46.1
Balcha	62	91.5	87	7.7	37.95	139.6	48.8
Danda'a	63.5	91.5	98.5	5.85	42.1	134.15	48.25
Mean	**61.2**	**93.2**	**84.4**	**7.5**	**38.2**	**115.4**	**45.7**
F test	**0.0001**	**0.0298**	**0.0078**	**0.293**	**0.003 3**	**0.0041**	**0.0008**
CV (%)	**2.8**	**1.6**	**4.1**	**20.4**	**5.5**	**7.4**	**3.4**
LSD at 5%	**3.7**	**3.2**	**7.6**	**3.3**	**4.6**	**18.7**	**3.5**

DH=days to heading, DM=days to maturity,PH=plant height,FT=fertile tillers,TSW=thousand seed weight, BY= biomass yield,GY= grain yield,CV=Coefficient of variation,LSD= least significant difference

Table 5: Mean performance of grain yield (qt/ha) and yield related traits of durum wheat varieties tested at different locations during 2020 in irrigation condition

Varieties	DH	DM	PH (cm)	FT	TSW (g)	BY (qt)	GY (qt/ha)
Utuba	61.0	95.5	79.7	8.5	53.1	124.9	42.5
Ude	60.5	94.5	76.5	10.2	43.9	115.8	39.9
Fetan	62.5	100.5	79.5	11.4	42.9	118.5	48.5
Alemtena	57.5	99.0	80.5	11.4	44.5	115.5	42.0
Werer-1 (check)	63.0	96.5	75.5	9.7	50.8	149.5	41.0
Yerer	67.5	102.0	75.5	8.8	45.0	133.0	31.5
D2018	62.5	100.0	75.0	11.8	51.2	113.7	44.2
Denbi	59.0	99.0	84.9	11.4	41.8	102.4	37.2
Bulala	53.0	109.0	75.2	11.4	46.5	116.7	44.6
Toltu	58.0	99.5	70.4	14.8	44.4	119.0	46.4
Dire	64.0	100.5	74.3	14.2	38.8	102.6	29.5
Mukiye	51.0	99.5	75.8	13.7	48.5	101.0	32.0
Mean	**60.0**	**99.6**	**76.9**	**11.4**	**45.9**	**117.7**	**39.9**
F test	**0.003**	**0.004**	**0.423**	**0.001**	**0.003**	**0.013**	**0.001**
CV (%)	**4.5**	**2.2**	**6.4**	**9.2**	**5.2**	**8.1**	**7.9**
LSD at 5%	**5.9**	**4.8**	**10.9**	**2.3**	**5.3**	**20.9**	**6.9**

DH=days to heading, DM=days to maturity,PH=plant height,FT=fertile tillers,TSW=thousand seed weight, BY= biomass yield,GY= grain yield,CV=Coefficient of variation,LSD= least significant difference

4. Challenges

4.1. Soil Acidity

Worldwide, acidic soils are one of the most important limitations to agricultural production (Von Uexküll,1995). In Ethiopia, acid soils account for about 34% of agricultural land area that range from slight to strongly acidic soils (Wayima,2019).Acid soils generally occupy the western part of the country extending from southwest to northwest, although strongly acidic soils occur mainly in the western part of the country including the lowlands. Acid soils are particularly prevalent in the highlands of Ethiopia Kidanemariam (2012) and the application of lime commonly results in improved yields of various crops (Kidanemariam, 2013).The productivity of wheat over acidic areas of Ethiopia is low as compared to parts of the country where soil acidity is absent. For instance, in areas with strongly acidic soils, which occur widely in the western and southwestern parts of the country, the productivity of wheat is as low as 0.8–2.0 t/ha.

These areas include Jimma ,Illu-Ababora,West Wellaga, Gamo Gofa, Asosa, and Metekel zones.

4.2. Diseases

The major biotic factors that limit wheat production in the country include diseases, pests and weeds (Abebe *et al.,* 2012). Among the diseases, rusts (stem rust (*P. graminis f.sp.* tritici), leaf rust (*P. triticina* Eriks) and stripe rust (*P. striiformis* Westend. f.sp. tritici) are the most important diseases reducing wheat production in Ethiopia. From the three rusts, stem rust has been the most important disease of wheat in main wheat growing regions of Ethiopia (Admassu *et al.,* 2009; Denbel *et al.,* 2013).

4.3. Weeds

Among the biotic factors weeds are one of the major constraints in wheat production as they reduce productivity due to competition, allelopathy and by providing habitats for pathogens as well as serving as alternate host for various insects, fungi and increase harvest cost (Abbas *et al*.,2009).Studies indicated that crop losses due to weed competition throughout the world are greater than those resulting from combined effects of insect pests and diseases (Amare *et al*.,2014).The yield loss caused by weed infestations in wheat ranges from 10-65% depending up on the weed species, their density and environmental factors(Gezu and Soboka,2001).

5. Future line of work

5.1. Developing wheat varieties broadly adapted and tolerant to biotic and abiotic stresses
5.2. Popularization and dissemination of the improved technologies
5.3. Conducting crossing activities to identify diseases resistant and high yielding wheat genotypes
5.4. Capacity building
5.5. Creating more linkages at national and international

6. Summary and Conclusion

Wheat is an important staple food crop in Ethiopia and since 2005 the country has been the largest producer of wheat in sub-Saharan Africa. It is grown in the highlands at altitudes ranging from 1500 to 3000 m.a.s.l. Yem special district,Jimma and Buno Bedele zones, are among major wheat producing areas of south and southwestern part of Ethiopia. Jimma research center was conducting wheat breeding experiments in collaboration with national bread wheat program to identify high yielding and adaptable varieties for main and irrigation potential areas of South and Southwestern part of Ethiopia for five years and identified promising wheat genotypes. Soil acidity, diseases, weeds and Insects are major causes for productivity reduction in south and southwestern part of Ethiopia.

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Quick Response Code	Website: www.ijarm.com Subject: Agriculture
DOI:10.22192/ijamr.2022.09.06.005	

How to cite this article:
Tegegn Belete. (2022). Wheat breeding, Major Achievements and Challenges in South and Southwestern Part of Ethiopia. Int. J. Adv. Multidiscip. Res. 9(6): 40-47.
DOI: http://dx.doi.org/10.22192/ijamr.2022.09.06.005