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Analyzing yield variability of introduced and locally developed malt barley varieties in Ethiopia

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ABSTRACT

The study examined yield potential variability of introduced and locally developed malt barley varieties in the breeding program. The study included 31 malting barley varieties released and registered in Ethiopia from 1976-2022. Primary and secondary data was used for the study. Primary data related to the genealogy of malting barley varieties released and registered were collected through interviews with key informants. Secondary data on production capacity was obtained from the Ethiopian Agricultural Authority. The data were analyzed using descriptive analysis and inferential statistics. Descriptive statistical analysis using ratios and percentages was used to analyze the average contribution of introduced malting barley varieties to the development of entire improved malting barley varieties in the country. The ratio compares the number of malting barley introduced to the total number of varieties released or registered. An inferential statistic called "Welch's unequal variances t-test" or "unequal variances t-test" was used to analyze the impact of introduced malting barley varieties on yield increases. The average contribution of introduced malting barley varieties found in the analysis was 42%. These improved varieties came from donor organization and private companies for direct release through adaptation research. The combined analysis of Welch's unequal variances t-test across years showed average yield of 39.6 and 40.6 quintal per hectare for introduced and locally developed malting barley respectively. The results show that the country's agricultural research institutes have locally yielded one quintal more per hectare than the introduced and registered varieties under research management. However, no statistical significance was observed in yield potential between introduced and locally developed malting barley varieties. This indicates that the existing varieties have not proven the need for introduction of varieties except for quality parameters. A major push factor promoting introduction of new and improved malting barley varieties for registration is the misconception that local varieties have low productivity. This also increases the vulnerability of private companies to introducing new varieties from foreign sources. In addition to providing new crop varieties, plant introduction saves time and effort in breeding programs. However, the replacement of local landraces can lead to genetic vulnerability and erosion. Therefore, the introduction of new varieties requires strong control and regulatory measures.

Key words: Genetic source, Varieties, Breeding program, Malt barley, Impact, Ethiopia.

1. INTRODUCTION

Agriculture is an important sector for economic sustainability and social security in developing countries around the world [1]. Ethiopia's economy is dependent on agriculture, which accounts for 40-50 percent of the country's gross domestic product (GDP) and more than 80 percent of exports [9, 20, 22-23]. In addition, 80% of the country's population depends on the agricultural sector for their livelihood, which is one of the main occupations [15, 23].

With a population of about 123 million (2022), Ethiopia is the second most populous country in Africa after Nigeria and the fastest growing economy in the region, showing 6.4 percent growth in 2021/22. However, it remains one of the poorest with a per capita gross national income of $1,020 [25].

Over the past 100 years, plant breeding has expanded food and nutrition security, provided suitable crops for changing climates, and helped alleviate poverty in the aspect of expanding human populations. However, only five percent is irrigated, and crop yields from small farms are below the regional average [23]. If we are to meet the growing demand for food without demanding more land from nature, crop yields will have to increase dramatically. High-yielding varieties and new agrochemicals with improved appearances will be important pillars. Improved crop varieties combined with better agricultural practices can help reduce environmental degradation and prevent agro-climate change.

Improved crop varieties are the key outputs of agricultural research and have contributed to a significant increase in agricultural production and productivity [7, 13, 16]. Plant breeders apply knowledge to continue improving crop varieties, making them more productive and more adaptable to climate extremes, insects, drought and disease.

Improvements in field crops through plant breeding are numerous [17]. About 940 field crops have been recommended or released for major agricultural crops (cereals, pulses and oil crops) in Ethiopia by 2022. Since the beginning of the barley improvement program, 31 malting barley varieties have been released or registered for production (Figure 1).

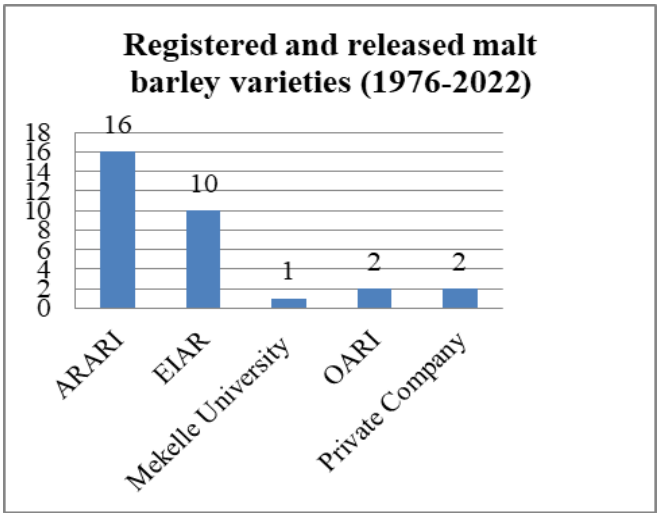

Figure 1: Registered and released malt barley varieties (1976-2022)
Source: Ethiopian Agricultural Authority

In general, plant breeding is a key science to improve crop production, with an estimated contribution of 50% to increase productivity, as mentioned by [5, 18]. However, improved cultivars that crop breeders report outperforming landraces under experimental conditions may yield significantly less under farmers' conditions due to genotype-by-environment interactions [12].

Barley is the fifth most important cereal crop with 2.34 million tons of grain produced annually on 0.93 million hectares [14]. The share of malted barley is estimated to be less than 7% of the total annual barley production. In recent times, two-thirds of the barley was used for feed, one-third for malt, and about 2% for food [2]. The average yield of barley in Ethiopia is low (2.18 tons/ha) compared to the world average (2.89 tons/ha) and the potential yield of 6 t/ha [19].

Malt barley varieties were evaluated based on malt quality characteristics and parameters such as grain size, germination energy, moisture content, thousand kernel weight, malt protein content, friability, extract content of malt, PH of wort, Color of wort, soluble protein, kolbach index according to European brewery convention specification and Ethiopian malt quality standard requirement. Due to poor quality of locally produced malt barley, domestic production of malt grain covers only 38% of total national demand [3].

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 [4]. Correspondingly, more than 1800 for wheat, more than 4500 for sorghum, around 2500 for barley and more than 900 for chickpea, lentil and finger millet accessions of Ethiopian origin have been introduced to various international and foreign national crop improvement programs and seed companies [8]. Moreover, Ethiopian barley has been used to protect Californian barley from dwarf yellow virus, saving estimated $160 million damage annually [11].

The average crop genetic resource dependence among different regions of the world is over 50% and in some regions it can be as high as 100% for the most important crops [10]. To enrich and improve the germplasm base, exotic germplasm of both food and malt species have been introduced by Ethiopian breeding program from ICARDA and other sources. This type of plant breeding is expected to replace local landraces with improved varieties and narrow genetic base, resulting in genetic erosion and lower genetic diversity [21, 24].

One of the main objectives of germplasm exploration and collection are to reduce the risk of genetic erosion of important genes and genetic stocks as well as to increase the stability of crop varieties by utilizing the useful genes in crop breeding and thereby reduce the risk of yield loss.

For this reason, the understanding of the dynamics of the introduced and locally enriched varieties in malt barley production believed important. Therefore, this study provides empirical evidence for potential yield differences between introduced and domestically enriched malting barley varieties released or registered in Ethiopia.

2. OBJECTIVES

The main objective of this study is to analyze yield potential variability of introduced and locally developed malt barley varieties in the breeding program.

Specifically,

- To examine the level of contribution of malting barley varieties introduced to the development of entire improved malting barley varieties.
- To analyze the impact of introduced and locally developed malt varieties on yield growth

3. METHODOLOGY

3.1. Data

Primary and secondary data was used for the study. Primary data related to the ancestry of 31 malt barley varieties released and registered were collected through interviews with key informants. Secondary data related to yield potential was obtained from Ethiopian Agricultural Authority crop variety register issue number (1-25) [6].

3.2. Data Analysis

The data were analyzed using descriptive analysis and inferential statistics. Descriptive statistical analysis using ratios and percentages was used to analyze the genetic interdependence of the country. The ratio compares the number of malting barley varieties introduced to the total number of varieties released or registered.

"Welch's unequal variances t-test" or "unequal variances t-test" inferential statistics was used to analyze the impacts of the introduced malting barley varieties on yield increases.

The Welch t-test statistic is defined by the following formula.

$$t = \frac{\Delta \overline{X}}{s_{\Delta \bar{X}}} = \frac{\overline{X}_1 - \overline{X}_2}{\sqrt{s^2_{\bar{X}_1} + s^2_{\bar{X}_2}}}$$

$$s_{\bar{X}_i} = \frac{s_i}{\sqrt{N_i}}$$

Where,
$\overline{X}_i$ = the sample mean
$S_{\bar{X}i}$ = the standard error
S_i = the corrected sample standard deviation and,
N_i = the Sample size

4. RESULT AND DISCUSSION

4.1. The contribution of introduced malt barley varieties in the development of entire improved malt barley varieties

In addition to financial investment, a large proportion of the malting barley varieties grown in Ethiopia today can be traced their ancestry from germplasm received from international donors, mainly ICARDA.

As shown in Table 2 below, since 1976, a total of 31 varieties of malting barley have been produced by breeders and 18 (58%) of them have been developed and released locally. The findings show that the average contribution of introduced malt barley varieties in Ethiopia was 42%. These improved varieties came from donor organization and private companies for direct release through adaptation research not as a parent material.

For this type of crop, the number of malt varieties introduced was high for Ethiopia, which has a reach crop accessions and high gene variability.

Table 2. Lists of introduced and locally developed malt barley varieties in Ethiopia (1976-2022)

Variety	Gene Source	Year of release	Potential Yield	Average potential Yield
Beka	Introduced and registered	1976	24-38	31
Holker	Locally developed and released	1979	24-31	27.5
HB-120	Locally developed and released	1994	24-53	38.5
HB-52	Locally developed and released	2001	24-47	35.5
HB-1533	Locally developed and released	2004	26-30	28
Kiflu-B (Miscal-21)	Locally developed and released	2006	19-52	35.5
Haruna Nijo /specific for northern region/	Introduced and registered	2006	48	48
CDC Select	Introduced and registered	2006	36	36
ፍሬ ገብስ (EH1609-F5-B 3-10)	Locally developed and released	2010	28-42	35
Bekoji-1 EH1293/ F2-18B-11-1-1 4-18)	Locally developed and released	2010	50	50
Sabini	Introduced and registered	2011	49	49
Bahati	Introduced and registered	2011	48	48
EH1847/F4.2p. 5.2 (BEA/IBON64/ 91)	Locally developed and released	2011	44.23	44.23
IBON 174/03	Locally developed and released	2012	30-57	43.5
Traveler	Introduced and registered	2013	25-45	35
Grace	Introduced and registered	2013	20-40	30
HKBL 1512-5	Introduced	2015	26-38	32

Variety	Gene Source	Year of release	Potential Yield	Average potential Yield
(Fanaka)	and registered			
HB1963	Locally developed and released	2016	35-60	47.5
HB1964	Locally developed and released	2016	33-56	44.5
Singitan (IBON-MRA)	Locally developed and released	2016	31-41	36
Explorer (Marine x Beatrix)	Introduced and registered	2017	26-41	33.5
Fatima Pedigree: Sunshine x Tamtam	Introduced and registered	2018	25-42	33.5
Raya 1 Pedigree: MU-MB 1440/L94	Locally developed and released	2018	36	36
MOATA Pedigree: LEGACY/ 4/TOCTE// GOB/HUMA11 0/3/ ATAH92 /ALELI/ 5/ARUPO/ K8755// MORA	Locally developed and released	2018	51	51
RGT Planet (Pedigree: Tamtam x Concerto)	Introduced and registered	2019	44	44
Henrike (Pedigree: Marnie x Bolina)	Introduced and registered	2019	45	45
Waro (LIBRA T95/DIMALT)	Locally developed and released	2019	21-40	30.5
Iftuu (Mn Brite)	Locally developed and released	2020	49.38-64.65	57.02
Suba (Bekoji-1xGrace)	Locally developed and released	2021	40-50	45
MBF5P#26 (Ras) HB1533XDrummond	Locally developed and released	2021	41-50	45.5
Focus (GracexZeppelin)	Introduced and registered	2022	35-65	50

4.2. The impact of introduced and locally developed malt varieties on yield increases

The genetic source was an important basis for increasing grain yield potential. As shown in the table 3 below, potential yield ranges from 30-50 quintal per hectare for introduced and 27.5-57 quintal per hectare for locally developed malt barley varieties. The average yield is 39.6 and 40.6 quintal per hectare for introduced and locally developed malt barley respectively.

The result showed that the country's agricultural research institutes had locally developed quality malt barley varieties which had the average potential of giving up to one quintal per hectare more yield as compared to introduced and registered varieties under research management. However, no significant effect on yield potential was observed between introduced and locally developed malt barley varieties. This indicates that the existing varieties have not justified the need to introduce or develop them locally. In spite of the fact that other malt quality characteristics and wort quality characteristics parameters are also mandatory for decision making.

Table 3. Two-sample t test with unequal variances

ttest potentialyield, by (geneticsource) unequal welch

Group	Obs.	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval]	
Introduced	13	39.6	2.2	7.74	34.94	44.29
Locally developed	18	40.6	1.9	8.25	36.50	44.70
Combined	31	40.2	1.4	7.92	37.28	43.09
diff		-1.0	2.9		-6.90	4.09

diff=mean (Introduced) - Mean (Locally developed) t = -0.3390

Ho:diff= 0 Welch's degrees of freedom = 29.0125

Ha: diff < 0 Ha: diff!= 0 Ha: diff > 0
Pr(T< t)=0.3685 Pr(|T|> |t|)=0.7371 Pr(T>t)=0.6315

The main barrier to introducing new and improved malt barley varieties through introduction for registration is the misconception that local species have low productivity. This also increases the vulnerability of the private companies to rely on introducing new varieties from external sources. In the same strain, several developing countries have lost ancient knowledge about resistant species.

5. CONCLUSION

There is no simple solution to increasing crop productivity while improving resource use efficiency and protecting environmental quality. Science-based agricultural technologies developed through agricultural research are important in increasing productivity while maintaining or improving the sustainability of natural resources and the environment.

Growing high-yielding varieties is critical to successful crop production and increasing farmers' net income. Improving

crop plants using traditional plant breeding programs can be costly, time consuming and labor intensive. Moreover, the budget allocated to agricultural research is low over time to carry out important activities. To overcome these important challenges, plant breeders are introducing improved varieties. The introduction of improved varieties replaces local landraces by narrowing the genetic base leading to genetic vulnerability and genetic erosion. This limitation of genetic diversity directly affects the input materials for new breeding programs.

Therefore, policies and regulations are needed to promote locally developed malt varieties with a view to reducing dependence on introduction of new varieties.

CONFLICT OF INTEREST

The author declares no competing interests

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