American Journal of Environmental and Resource Economics
2022; 7(3): 68-71
http://www.sciencepublishinggroup.com/j/ajere
doi: 10.11648/j.ajere.20220703.11
ISSN: 2578-7861 (Print); ISSN: 2578-787X (Online)

Performance Evaluation and Adaptation Trial of Hybrids Maize for Highland Areas of Southeastern Ethiopia

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To cite this article:
Shimelis Tesfaye, Abiy Balcha. Performance Evaluation and Adaptation Trial of Hybrids Maize for Highland Areas of Southeastern Ethiopia. *American Journal of Environmental and Resource Economics*. Vol. 7, No. 3, 2022, pp. 68-71. doi: 10.11648/j.ajere.20220703.11

Received: June 20, 2022; **Accepted**: July 15, 2022; **Published**: July 28, 2022

Abstract: A significant proportion of maize in Ethiopia is produced in the highland zones, which represents very favorable maize growing environments but highland maize improvement research in Ethiopia lagged behind that in the other ecologies. The objective of this study was to identify adapted and high yielding hybrids for each environment and to recommend a suitable one for the local maize growers of the area. Four maize hybrids and one local check were evaluated using randomized complete block design with three replications for grain yield and yield related traits within 2019/2020 cropping season at three woredas. Analyses of variances showed significant differences among the hybrids for grain yield, days to silking and number of ears per plant. In the combined analysis of Kofale and Kersa woredas, kolba variety gave, higher yield (7.86 t ha^{-1}) followed by Jibat (6.77 tha^{-1}). Although, Kolba and Jibat variety are the highest yielder at locations it is below its potential. Generally, the study indicated kolba and jibat varieties were promising varieties for Kofale and Kersa districts.

Keywords: Adaptation, Highland, Hybrid, Yield

1. Introduction

A significant proportion of maize in Ethiopia is produced in the highland zones, which represents very favorable maize growing environments. In highland areas maize is the first crop grown and is a popular “hunger breaking crop” when it is harvested and consumed green [1]. However, highland maize improvement research in Ethiopia generally lagged behind that in the other ecologies. A program geared to developing improved maize genotypes is facilitated by the use of locally adapted and introduced germplasm with genetically divergent gene pool and population. Any breeding work where selection method is employed requires having genetic variation in the population on which the improvement work is to be done [2].

A plant species is likely to show a greater variation in a region with varied climatic and other ecological conditions such as mountains and valleys, which show considerable variation in the prevalent conditions i.e., Plants of species growing in different environments are likely to be different, i.e., diverse. Therefore, plant species would show a great variation in such areas [3]. Under natural environmental influence, cross pollinated population are relatively fluid in which gene favoring adaptation and increased seed production tends to increase at expense of gene unfavorable for adaptation or fitness to reproduce. The shift toward more adaptive genotypes may be accelerated by selection and environmental stress to which the breeding population is subjected [2].

In Ethiopia, maize growing agro-ecologies are broadly classified into four major categories: mid-altitude sub-humid (1000-1800m.a.s.l.), highland sub-humid (1800-2400m.a.s.l.), lowland moisture stress areas (300-1000m.a.s.l.) and lowland sub-humid (<1000 m.a.s.l.) [4]. Maize research and development was started in 1952 in the country to enhance its productivity targeting the needs of small-scale farmers who produce more than 90% of maize [5]. In the 1970s and 1980s, locally developed improved open pollinated varieties (OPVs) were released for wide area production at different agro-ecologies of the country. In the late 1980s, the first locally developed non-conventional hybrid was released for the mid-altitude sub-humid maize growing areas. Since then, several improved OPVs and hybrids with pest and disease resistance were released for large-scale production across different agro-ecologies..

Currently, the National Maize Research Project has three main breeding stations located in the above three major agro-ecologies excluding the lowland sub humid agro-ecology [6].

The mid-altitude sub-humid agro-ecology is a high potential area for maize production in Ethiopia. It is the leading maize growing agro-ecology contributing the largest share of maize produced in the country [5]. However, production and productivity of maize in this and other agro-ecologies is constrained by several factors. These include unavailability of improved varieties, limited access to improved seeds, diseases such as gray leaf spot caused by *Cercospora zeae-maydis*, *Turcicum* leaf blight (*Exserohilum turcicum*) and common rust (*Puccinia sorghi*), field and storage insect pests (e.g., maize stalk borers and the maize weevil), low soil fertility and poor market development [7]. Therefore, there is a need to develop improved maize varieties and their production packages for sustainable maize production in the country.

The low land moisture stress agro-ecology is the other maize producing agro-ecology of Ethiopia. This agro-ecology encompasses drought-affected areas occupying over 40% of the area in the country and contributes 20% of the total maize production [8]. In addition to the above constraints, recurrent drought is the most important challenge for maize production and productivity in this agro-ecology [9].

The high altitude sub-humid agro-ecology, including the highland transition and true highlands, is next to the mid-altitude agro-ecology with greater maize area and production in Ethiopia. The Ethiopian highland maize breeding program is situated at Ambo to coordinate maize research and technology development for the highland agro-ecologies. This program was initiated in 1998 in collaboration with the International Maize and Wheat Improvement Center (CIMMYT) and National Agricultural Research Systems (NARS) of east and central African countries including Ethiopia, Kenya, Tanzania, Uganda, Rwanda, and Burundi. Research and variety development of highland maize has generally lagged behind other agro-ecologies before the launch of this breeding program [10. In the region, maize varieties commonly grown beyond 2000 m.a.s.l. have been local varieties with low yield potential [11]. Consequently, the breeding program was initiated to develop a pool of both the regional highland maize breeding activities have been conducted at Ambo, Ethiopia while germplasm evaluations have been done across different environments of the member countries. Each partner country funds germplasm evaluation and development in their specific environments in addition to grants secured from partner organizations.

In the past, small cereal crops such as tef, wheat and barley were the most widely grown food crops in the highlands of Ethiopia, especially in the West Shoa and East Arsi zones, where maize used to be considered a homestead crop of minor importance. To date maize has become the most important cereal crop of the highland farmers in Ethiopia [12].

Farmers in the highland zones of Ethiopia with an elevation of 1,800 m above sea level generally grow tropical-highland adapted local varieties originally sourced from the mid- and low-altitude areas [6]. These varieties are often tall and have long maturity period, which make them vulnerable to frost damage and lodging [12]. In addition, most of the varieties grown in the region are low yielding [13]. with susceptibility to various leaf diseases such as northern leaf blight (NLB), gray leaf spot (GLS) and common rust (CLR), and are very tall in plant and ear height that result into root and stalk lodging, and also are late in physiological maturity [14].

Grain yield is the combined outcome of genetic potential and environment interaction. Variability in genetic potential among varieties is a major component of variable yield. Average maize yield in Ethiopia as well as in Southern region is low because of insect pest damage, lack of high yielding cultivars and poor crop management practices. Another problem expressed by the farmers is lack of appropriate seed varieties at planting time. Available seed varieties are usually not well adapted to the local conditions and this leads to very low yields [4]. Therefore, the main objective of this study was to identify adapted and high yielding hybrids for each environment and to recommend a suitable one for the local maize growers of the area.

2. Materials and Methods

Description of Experimental Sites

The experiment was conducted at Kersa, Arboye and Kofale woredas in 2019-2020 main growing season. These locations are different in soil type, altitude and mean annual rainfall. Hence, each location was considered as an individual environment.

Experimental Material

The experiment was consisted of four highland maize hybrids and one local check. Descriptions of genotypes are listed in Table 1.

Table 1. *Lists and descriptions of experimental materials.*

Variety	Year of release	Area of Adaptation		Maturity Date	Potential Yield (t/ha)	
		Altitude (masl)	Rainfall (mm)		Research Site	On farmers field
Arganne	1995	1800-2500	1000-1200	175	70-80	55-65
Jibat	2009	1800-2600	1000-1200	178	80-120	60-80
Kolba	2016	1800-2600	1000-1200	184	90-120	60-80
BH661	2011	1600-2200	1000-1500	160	95-120	65-80
Local check						

Experimental design and trial management

Five Varieties were planted at each location in a randomized complete block design (RCBD) with three replications. Each plot had four rows of 5.25-meter length. Each genotype was planted at 75 cm between rows and 30 cm within row spacing. Two seeds were planted per hill and then thinned to one plant per hill providing a uniform stand of about 53,333 plants/ha. To reduce border effects, data was recorded from the two central rows of each plot. Other management practices were done as recommended for each location.

Data collected

Data collection the middle two rows were used for data collection and harvested at maturity. Individual plant base data as well as plot base data were collected on five traits. Data collected on individual plant basis from five randomly selected plants were, days to tasseling and days to silking. The randomly selected plants were carefully uprooted at physiological maturity to measure growth parameters. Data collected on plot basis were numbers of ears, days to maturity and grain yield (t/ha).

Statistical data analysis

Analysis of variance for the design was carried out using SAS 9.0 software for the parameters studied following the standard procedures outlined by [5]. The level of significance used in 'F' and 't' test was P=0.05. When the treatment effects were found to be significant, the means were separated using the Fisher's protected least significant.

3. Results and Discussion

The combined analysis of variance (ANOVA) revealed that significant ($P \leq 0.001$) variations among the five hybrids for grain yield and days to silking and ($P \leq 0.05$) for number of ears.

At Kofale, the highest yield obtained were (6.25) t/ha^{-1} from Kolba followed by jibat and BH661 with grain yield of 5.82 and 3.46 tha^{-1}, respectively (Table 3). At Kersa, the highest grain yield was obtained from Kolba (9.47 tha^{-1}) followed by Jibat (7.73 tha^{-1} (Table 3). In the combined data kolba gave higher yield (7.86tha^{-1}) then Jibat (6.77 tha^{-1}) and BH661 (5.09 tha^{-1}) (Table 2). Although, Kolba (AMH853) and Jibat variety are the highest yielder at locations it is below its potential. The releasing organization reported that Kolba has potential of 9-12 tha^{-1} on research field and 8.9 tha^{-1} on farmer's field (Crop Variety Registry, 2016). Similarly, Jibat gave yield of 7.2 tha^{-1} at Bule Hora district of Borena [6], which varies with this finding due to difference in experimental locations. Due to cold stress during the growing season all varieties were not performed Well at Arboye woreds. Maize Growth under Temperature Extremes Crop plants usually experience different biotic and abiotic stresses simultaneously that cause many morphological and physiological perturbations, resulting in stunted plant growth and reduced grain yields [7].

Table 2. *Combined mean performances of five varieties (4 hybrids and 1 Check) for traits in 2019/20.*

Variety	DA	DS	NE	GY t/ha	DM
Jibat	88.11	89.86	27.87	6.77	198.38
Kolba	87.61	88.81	19.84	7.86	198.54
Argene	88.61	90.47	21.05	2.82	198.45
BH661	95.64	104.63	21.24	5.09	199.42
local check	102.53	108.40	14.51	2.22	199.21
Grand Mean	92.50	96.43	20.90	4.95	198.80
LSD	14.70	11.96	16.89	3.72	4.63
CV	6.13	1.64	37.93	12.01	1.55

DA= days to Anthesis, DS= days to silking, NPP= number of ears per plant, GY= grain yield, DM= days to maturity.

At Kofele, kolba was the earliest to shade pollen (85.7 days) and all varieties were earlier than this check in days to anthesis (Table 3). Although at kersa all varieties were earlier than check (95 days) and the earliest to shade pollen was kolba (88 days) (Table 3). Days to 50% silking showed a similar pattern to days to anthesis and varied from 87 to 110 days for jibat and check, respectively at kofele and 87 to 103 days for kolba and checks, respectively at kersa. (Table 3).

The highest number of ears was 27 for jibat at kofele and 35 at kersa and 27 across the two locations. Days to Maturity ranged from 196 days (Argene) to 205 days (Check) with a mean value of 202 days at kofele (Table 3). At kersa kolba was the earliest to mature (193 days) (Table 3). Across locations, both kolba and jibat were the earliest maturing varieties than others and the checks (table 2).

Table 3. *Mean performances of five varieties (4 hybrids and 1 local Check) for traits at kofale, Kersa and Arboye in 2019/20.*

Variety	Kofale					Kersa					Arboye
	DA	DS	NPP	GY t/ha	DM	DA	DS	NE	GY t/ha	DM	GY t/ha
Jibat	86.02	87.72	26.82	5.82	198.00	88.81	90.72	35.47	7.73	194.67	4.85
Kolba	85.69	88.38	21.91	6.25	201.16	88.36	87.77	17.97	9.47	193.76	5.70
Argene	87.02	90.37	12.70	1.66	196.56	88.96	89.41	28.72	3.97	196.49	4.95
BH661	105.64	110.61	12.70	3.46	209.51	88.96	100.24	29.22	6.73	195.58	4.39
local check	110.63	115.25	10.55	3.09	205.77	94.93	103.86	12.97	1.36	196.49	4.00
Grand Mean	95.00	98.47	16.93	4.06	202.20	90.00	94.40	24.87	5.85	195.40	4.78
LSD	1.97	3.03	6.74	1.22	7.01	10.01	2.88	17.24	0.96	2.64	1.85
CV	1.10	1.64	22.03	16.38	1.98	8.83	1.64	42.52	8.82	0.87	20.53

DA= days to Anthesis, DS= days to silking, NPP= number of ears per plant, GY= grain yield, DM= days to maturity.

4. Conclusion and Recommendation

This study was conducted to identify adapted and high yielding hybrids for each environment and to recommend a suitable one for the local maize growers of the area 2019/1920 main cropping season. Location-specific evaluation of maize hybrid is crucial for the hybrid maize program. Two promising varieties kolba and jibat that had higher yield as compared to others varieties and the checks were identified based on their mean performance that can improve the production and productivity of maize yield in Kofale and kersa districts. Considering their high yield, these varieties were recommended to be used in kofele and kersa districts and similar agro ecologies of southeastern Ethiopia. Trial conducted at Arboye woreda cannot performed well due to cold stress during the growing season, so it is possible to repeat the trail to identify the promising varieties to specific location.

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