The Release and Registration of High Yielding Maize Hybrid Cultivar-AMH854 (“Ambo”) for the Transitional-Highland to Highland Agro-Ecologies of Ethiopia

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Abstract

‘Ambo’ is the common name given to the new maize (Zea mays L.) hybrid with the breeders’ name AMH854 after its official release from the highland maize research sub-program based at Ambo Agricultural Research Center. The name ‘Ambo’ is given to mark the change of name of the Ambo Plant Protection Research Center (which had been dedicated to excellence in only plant protection research) to the Ambo Agricultural Research Center of the Ethiopian Institute of Agricultural Research. ‘Ambo’ is a three-way cross hybrid developed from the combination of three parental inbred lines. So far, a number of improved maize cultivars that have increased the yield gains in the maize production system, were released by the national maize breeding programs. As part of the national maize research system, the highland maize breeding program has been developing and releasing high yielding cultivars, of which ‘Ambo’ (or AMH854) is the latest addition in the list. Better grain yield potential with acceptable plant stature plus good husk cover than previous releases of the program are desirable characters of this hybrid. It has up to 22 % of yield advantage over the check. For these reasons, ‘Ambo’ was released for commercial production in the transitional-highland to highland maize growing agro-ecologies of Ethiopia in 2022.

Key words: - Highland maize cultivar, Maize hybrid, Tropical highlands, Variety registration,

Introduction

Maize (*Zea mays* L.) is a widely cultivated grain that is a staple food in many countries, including the United States, Africa, and other areas of the world (Abbas et al., 2022). In Ethiopia, maize is an important staple crop ranking first among cereals in total grain production (27.43%) and second in area coverage (16.79%) (CSA, 2018). It is cultivated in all of the major agro-ecological zones in the country mainly for food consumption. Recent reports of the Central Statistical Agency of Ethiopia showed that maize was produced on about 2.53 million hectares of land and total production of

10.55 metric tons (MT) with an average national yield of 4.18 t ha^{-1} (CSA, 2021). The national average maize yield is lower than the international average (5.75 t ha^{-1}) (FAOSTAT, 2017) due to various production and productivity constraints caused by several biotic and abiotic stresses in all agro-ecologies. The constraints vary within and across agro-ecologies. Strong efforts have been exerted to curb maize production constraints by the national maize research and coordination programs since 1940s and 1950s up to the present time through development and release of various maize production technologies.

The Bako National Maize Research Program of the Ethiopian Institute of Agricultural Research (EIAR) has three major sub-programs coordinated from three different breeding centers, *viz*, Bako, Ambo and Melkassa. The breeding centers have been developing maize germplasm targeting specific constraints of the four major maize agro-ecologies, which in recent years were restructured into five product concepts through a project called Modernizing Ethiopian Research on Crop Improvement (MERCI) (Abiy et al., 2019) as: Intermediate-maturing (500 series) hybrids adapted to mid-altitude sub-humid to moist maize growing areas (1000-1800 meters above sea level – masl); Late-maturing (600 series) hybrids adapted to mid-altitude and transitional highland moist maize growing areas (1750-2000 masl); Early to intermediate maturing (300-400 series) varieties/hybrids adapted to low moisture stress areas (<1700 masl); Intermediate-late maturing (700-800 series) hybrids adapted to the highland areas (>1850 masl) and High yielding nutritious maize (high pro-vitamin A; QPM + high Zn) adapted to different agro-ecologies of Ethiopia.

The objectives and research focus of the three maize breeding programs is to develop high yielding stress tolerant maize cultivars together with their full production packages that fit the diverse maize agro-ecologies to ensure food, nutrition and income security of maize farmers and other end-users within the maize value-chain. As part of the national maize research system, the highland maize breeding program has been developing and releasing high yielding maize cultivars. AMH854 (or ’Ambo’) is the latest addition in the list. The objective of this paper is to report the result of trials that led to the approval of AMH854 for commercialization in the highland agro-ecology of Ethiopia.

Materials and Method

Experimental materials and design

Thirty promising hybrids selected from previous years’ preliminary variety trials (PVT) were promoted to Highland Advanced National Variety Trial (AVT) in 2020. The hybrids were organized and evaluated in five highland representative locations (Table 1). Seven genotypes included in the AVT were also organized and evaluated in replicated on-farm trials to generate additional data. The AVT genotypes were arranged using row-column design, while the on-farm trials were laid out in randomized complete block (RCB) design. The genotypes involved in both trials were replicated three times and planted in two-rows of 5.25m long plots. Intra - and inter- row spacings were 0.25m and 0.75m, respectively. Fertilizer applications were at the rate of 200 kg ha^{-1} Urea and 150 kg ha^{-1} of NPS. Urea was applied in split, the first half at 40 days after planting and the remaining half after 70 to 80 days immediately before tasseling. The trials were managed following appropriate research recommendations. The hybrids were evaluated across years and locations for yield performances, reaction to pests and other important agronomic traits.

Table 1. Descriptions of locations used for AVT in 2020

Site	Geographic position			Annual	Temperature (°c)		Soil type
	Longitude	Latitude	Altitude †(m.a.s.l.)	rainfall (mm)	Min.	Max.	
Ambo	38°07' E	8°57' N	2225	1115	11.7	25.4	Heavy- Vertisol
Holetta	38°30' E	9° 00' N	2400	1065	6.4	22.1	Nitosol
Kulumsa	39°13' E	8°13' N	2180	824	10.0	23.0	Eutric- Vertisol
Jimma (Dedo)	36°70' E	7°39' N	2310	1650	-	-	Nitosol
Debre-Markos	37°46'E	10°16'N	2460	1200	11.0	20.0	Nitosol

†= (m.a.s.l.) = meters above sea level; The rainfall and temperature values are long-term mean weather data.

Description of experimental sites

The most superior highland maize three-way cross hybrid, selected based on results of more than ten environments of field evaluations under PVT and NVTs, was promoted to a variety verification trial (VVT) which was conducted on-station and farmers' field in 2021. Based on the proposal submitted by Ambo Agricultural Research Center to Plant Variety Release, Protection and Seed Quality Control Directorate of the Ministry of Agriculture (MoA) in 2021, the selected candidate hybrid was planted along with a standard check on a plot size of 10 m x 10 m both on-station and on-farm across nine highland agro-ecology representative sites, i.e., three on-station each having two on-farm trials. Trial management practices were as described for AVT. When the maize plants in the VVT reached at dough stage, the technical committee (TC) under the National Variety Release committee (NVRC) of the MoA was invited to visit and evaluate the candidate hybrid under VVT.

Statistical analyses

The data collected from the AVT for grain yield and other desirable traits were analysed using Spatial META-R statitical software version 2.0 (2018-05-24) (CIMMYT, 2016) while the on-farm trial was analyzed using PROC GLM procedure in SAS 9.3 (SAS, 2002). The across locations data of AVT were first subjected to individual and then to combined anlyses of variance (ANOVA) in order to test the significance of genotype by environment interaction (GEI) and also generate means for specific genotype performances prior to subsequent analyses. Heritability in the broad sense was computed for different traits. The variation due to genotypes and genotype by environment for grain yield was further examined using GGE biplot based on the principal component analysis (PCA) of environment centred data (Yan et al., 2000). The GGE biplots were generated using GenStat® Release 17 (Payne et al., 2007) statistical software using the model based on singular value decomposition (SVD) of the first two principal components (Yan, 2002). An average environment coordinate (AEC) was also drawn on the genotype-focused biplot to visualize the mean and stability of the hybrids (Yan and Kang, 2003). Yan's (2002) model was used for GGE biplot: $Y_{ij} - \mu - \beta_j = \lambda_1\xi_{i1}\eta_{j1} + \lambda_2\xi_{i2}\eta_{j2} + \varepsilon_{ij}$, where Y_{ij} is the mean yield of i^{th} hybrid in j^{th} environment, μ is the grand mean, β_j is the main effect of environment j, $\mu + \beta_j$ is the mean yield across all hybrids in environment j, λ_1 and λ_2 are the singular values (SV) for the first and second principal component (PC1 and PC2), respectively, ξ_{i1} and ξ_{i2} are the Eigen vectors of hybrid *i* for PC1 and PC2, respectively, η_{j1} and η_{j2} are the Eigen vectors of environment *j* for PC1 and PC2, respectively and ε_{ij} is the residual associated with hybrid *i* in environment *j*.

Results and Discussion

Background of the New Hybrid

The new hybrid designated as MH9807005-1-2-2-1-1-1-2-##-#-#-#-B-B/HLM0011//HLF0012 is a three-way cross hybrid locally developed from three tropical highland adapted inbred parents. The source germplasm for the early generation lines, which had further undergone rigorous selections (for diseases, combining ability and adaptation) and now constituted as inbred parents of the new hybrid, had initially been introduced from CIMMYT-Zimbabwe in 1998 (Twumasi et al., 2002). The first inbred parent designated as MH9807005-1-2-2-1-1-1-2-##-#-#-#-B-B and with full pedigree of [POOL9Ac7-SR(BC2)]FS222-1-2-2-1-1-1-2-##-#-#-#-B-B-B is a derivative of CIMMYT transitional highland population known as Pool9A, while the second and third inbred parents designated as HLM0011 and HLF0012 with pedigrees SRSYN95[ECU//SC/ETO]F1-##(GLS=3.5)-20-2-1-1-#-#-#-#-# and SRSYN95[KIT//N3/TUX]F1-##(GLS=2)-22-2-2-2-2-#-#-#-#-#-#-B-B-B, were derived from Ecuador and Kitale heterotic group populations, respectively. All the three parental inbred lines were developed through the collaborative efforts between the Ethiopian Institute of Agricultural Research (EIAR) and CIMMYT at Ambo Agricultural Research Center.

Agronomic and Morphological Characters

The hybrid 'Ambo' has an intermediate plant stature. It has relatively large leaf width, pendent orientation, and both the stem and leaf are green in colour. The hybrid has a deep kernel depth which are flat-shaped and large in size. The average 1000 kernels weight of Ambo is 435 grams with semi-dent kernel texture. More detailed agro-morphological features of this new hybrid are presented in Table 2 below.

Table 2. Agronomic and morphological characteristics of AMH854 (or "Ambo")

Characters	Values or specific description
Adaptation area:	Transitional-highland to highland agro-ecologies
- Altitude (m.a.s.l.)	1800 – 2600
- Rainfall (mm)	900 – 1500
Seed rate (kg ha^{-1})	25 kg ha^{-1}
Planting date	Mid-May to Late-May (immediately after the onset of the rainy season)
Fertilizer rates:	
- DAP (Kg ha^{-1})	150 kg ha^{-1}
- UREA (kg ha^{-1})	200 kg ha^{-1}
Days to flowering:	
- Male flowering (days)	93
- Female flowering (days)	94
Days to maturity (days)	190
Plant height (cm)	245
Ear height (cm)	145
Cob length (cm)	20
Cob width (cm)	5.2
Grain size	Large
1000 kernel weight (gm)	435
Seed color	White
Yield potential (t ha^{-1}):	
- Research field	8.5 – 12.5 t ha^{-1}
- Farmers' field	8.0 – 9.3 t ha^{-1}
Year of release	2022
Breeder/ Maintainer	EIAR – Ambo Agricultural Research Center

Yield Performance

The new hybrid ('Ambo'), designated as "3XH1900432" in the trial, significantly out yielded both standard checks (AMH853-Kolba and AMH851-Jibat) in many of the locations in both AVT as well as on-farm trials in 2020 (Table 3 and 4). Considering all on-station trials across locations, the yield advantage of the proposed hybrid over the standard check varied from 10 % to 63 %. However, the average yield advantage of the new hybrid over the first standard

Table 3 Individual and combined analyses of selected traits from National Variety Trials in 2020

Genotype	Entry	Individual location analysis for GY (t ha^{-1})					Combined analyses of 10 traits for five locations										
		Ambo	Holetta	Kulumsa	Debre-Markos	Jimma	DA (days)	PH (cm)	CLR (1-5)[#]	TLB (1-5)	GLS (1-5)	SL (%)	RL (%)	HC (%)	EA (1-5)	GY (t ha^{-1})	Yield Rank
SXH180033	1	7.4	5.4	11.4	3.2	5.0	108.5	235.4	2.3	2.3	4.0	11.1	1.9	11.1	4.2	6.3	8
SXH180098	2	6.5	6.6	10.1	3.2	3.7	104.8	225.1	2.0	2.6	3.0	2.5	0.8	3.0	5.1	5.9	13
SXH180165	3	6.5	5.6	7.4	1.5	3.4	105.0	222.5	3.0	2.0	3.0	5.9	0.0	2.3	5.3	4.5	31
SXH180179	4	5.7	5.5	9.8	3.2	4.6	109.8	211.8	1.8	1.8	3.5	12.3	1.6	2.0	4.9	5.8	17
SXH180192	5	6.9	6.5	9.5	1.8	3.1	102.5	211.9	1.5	3.0	2.5	8.1	0.0	3.8	5.5	5.2	25
SXH180197	6	7.6	6.0	9.1	3.1	4.3	112.5	240.9	1.8	1.9	2.5	8.3	2.2	0.0	4.6	5.6	20
SXH180226	7	5.4	6.7	8.8	2.8	3.9	105.5	213.4	1.5	2.1	4.5	4.3	1.1	9.8	5.8	5.5	21
SXH180227	8	7.1	7.2	10.8	1.9	3.3	109.8	229.4	1.8	2.4	3.5	4.6	1.8	10.3	4.9	5.8	18
3XH180029	9	7.9	7.1	10.9	2.1	5.2	101.2	216.4	1.5	3.0	3.0	6.1	3.2	8.5	4.7	6.3	9
3XH180032	10	5.5	6.1	8.2	2.1	4.0	107.2	200.6	2.0	2.0	2.0	6.0	2.6	6.7	5.3	5.1	27
3XH180070	11	8.2	7.2	10.7	2.9	5.1	100.7	232.0	2.3	1.9	2.0	1.2	0.5	7.6	5.4	6.5	6
3XH180130	12	8.5	5.0	11.8	3.5	5.1	101.3	221.4	1.8	2.1	3.0	6.0	2.9	11.0	4.9	6.3	10
3XH180213	13	6.5	5.2	11.4	3.7	5.3	102.5	216.5	1.8	2.6	2.0	9.0	4.1	9.1	4.7	6.4	7
3XH180366	14	6.6	5.9	9.9	3.1	4.9	100.7	225.4	1.5	2.4	4.5	4.6	1.4	4.2	4.6	5.9	14
3XH180402	15	6.7	6.7	11.5	3.1	5.4	99.8	225.6	1.8	1.9	3.5	4.3	1.2	13.7	4.9	6.7	4
3XH180424	16	5.9	5.5	10.9	2.5	4.5	107.2	217.0	3.0	3.1	2.5	22.2	0.4	2.4	5.5	5.9	15
3XH180431	17	5.8	3.2	8.9	1.7	3.1	107.2	218.3	5.3	4.3	3.0	13.3	0.9	0.7	5.6	4.2	32
3XH180477	18	5.6	7.0	10.3	2.8	3.6	110.3	211.6	2.0	2.5	2.5	24.7	5.5	3.8	6.5	5.9	16
3XH180478	19	6.8	5.1	10.1	2.8	3.9	111.8	226.5	2.8	2.8	2.5	7.4	0.9	3.5	5.2	5.5	23
3XH180553	20	6.6	5.9	10.6	3.4	4.8	112.0	219.6	3.3	2.3	3.0	5.3	0.4	23.7	6.2	6.2	12
3XH180544	21	6.3	5.1	10.7	1.8	3.1	108.0	220.5	3.3	4.6	2.5	21.7	1.7	8.4	6.5	5.2	26
3XH180559	22	5.5	5.1	10.8	1.3	4.5	112.8	215.4	2.3	2.4	3.0	4.2	0.9	4.7	5.2	5.4	24
3XH180622	23	6.1	7.1	11.6	3.0	4.7	109.0	227.0	2.8	3.5	3.0	12.8	1.2	3.7	5.6	6.6	5
3XH180627	24	7.1	3.6	9.6	1.5	2.2	106.2	209.4	3.5	4.5	3.5	4.8	0.8	4.1	5.5	4.2	33
3XH180636	25	7.0	5.4	11.2	2.8	3.6	109.0	216.9	3.5	3.1	2.5	8.1	0.8	1.8	5.7	5.7	19
Table 3 Cont'd….																	
3XH180637	26	5.7	4.2	9.9	2.1	3.7	111.7	201.1	4.8	3.4	3.5	4.1	0.9	2.9	5.6	5.0	28
3XH180641	27	6.1	4.4	9.5	1.8	3.2	105.7	205.0	4.0	4.1	3.0	3.3	0.8	7.7	5.5	4.7	29
3XH180644	28	6.8	3.5	10.5	1.2	3.1	107.2	212.6	4.3	4.5	2.5	8.5	0.0	2.1	5.9	4.6	30
3XH1900432 (Ambo)	29	9.1	8.7	11.7	3.3	7.0	106.2	235.9	1.5	2.1	2.5	4.1	1.7	2.9	4.7	7.7	1

3XH1900434	30	6.8	8.0	11.9	3.4	6.3	107.2	219.1	2.3	1.9	2.0	1.2	0.4	1.8	4.3	7.4	2
JIBAT (Check2)	31	6.2	5.6	8.6	2.8	5.2	103.3	215.9	2.3	2.1	2.5	3.4	1.5	10.0	5.5	5.5	22
KOLBA (Check1)	32	5.6	6.2	10.6	3.3	5.1	101.8	213.1	1.5	2.0	2.5	5.7	1.2	5.3	5.1	6.3	11
BH661	33	7.8	8.1	11.3	3.1	6.3	111.5	237.4	1.5	2.0	3.5	11.4	0.8	16.7	4.2	7.2	3
Heritability (H^2)		_	_	_	_	_	0.88	0.58	0.79	0.80	_-	0.30	0.27	0.70	0.83	0.80	
Grand Mean		6.6	5.9	10.3	2.6	4.4	104.1	219.7	2.5	2.7	2.9	7.9	1.4	6.3	5.2	5.80	
$LSD_{(0.05)}$		3.1	2.5	2.1	0.9	2.0	2.6	17.9	1.3	1.1	1.9	13.6	2.9	6.6	0.7	1.10	
$CV_{(\%)}$		22.9	20.9	10.1	16.8	22.1	2.0	7.3	29.0	32.8	32.0	118.3	175.6	86.3	12.5	16.6	
% yield advantage*		62.5	40.3	10.4	-	37.3										22.20	

Key: DA= Days to 50%anthesis; PH= Plant height; CLR= Common leaf rust; TLB= Turcicum leaf blight; GLS= Gray leaf spot; SL= Stalk lodging; RL= Root lodging; HC= Husk cover; EA= Ear aspect; GY= grain yield; * Yield advantage over the recently released check1; # Diseases severity scores were recorded based on 1-5 scale (where 1= no disease and 5= highly diseased)

Table 4. Combined analysis of desirable traits from six on-farm sites in west Shewa zone in 2020

Entry	Genotype	GY	DA	PH	TLB	PA	EA
3	3XH1900432 (Candidate)	10.21	94.75	270.50	1.50	3.80	3.50
2	3XH180636	8.92	96.33	257.50	2.50	4.10	4.30
1	SXH180083	8.46	95.50	274.00	2.75	5.10	4.10
4	3XH1900434	8.15	93.42	242.00	1.75	4.30	6.80
6	Kolba (check1)	8.28	89.33	269.00	1.75	4.80	5.30
5	Jibat (check2)	7.38	90.42	262.00	2.25	4.60	6.40
7	BH661	9.68	98.25	285.50	2.00	4.50	3.90
	Grand Mean	8.73	94.00	265.79	2.07	4.46	4.90
	LSD $_{(0.05)}$	1.03	2.07	12.14	1.85	0.66	2.95
	CV $_{(\%)}$	12.08	1.77	4.16	37.98	7.58	34.75

Key: GY = Grain yield (t ha^{-1}); DA = Days to anathesis (days); Plant height (cm); TLB = Turcicum leaf blight (1-5 scale, where 1=no disease & 5=highly diseased) PA and EA = Plant and Ear aspects (1-9 scale, where 1=excellent performance and 9=poor performance).

check hybrid (AMH853 -'Kolba') across five locations was 22.2 % with average grain yield of 7.7 t ha^{-1} as compared to 6.3 t ha^{-1} for the standard check-1. The Detailed advantage in terms of grain yield and other desirable traits of the newly released hybrid AMH854 over the checks are presented in Table 3 and 4.

Stability Analysis

Figure 1 shows the GGE biplot based on the principal component analysis (using genotype-focused scaling). It provided the best means for recognizing the performance and stability of adaptable hybrids simultaneously (Yan and Kang, 2003). Visualization of the mean and stability of the hybrids was achieved by drawing an average environment coordinate (AEC) on the genotype-focused biplot (Yan and Kang, 2003). The ideal hybrid in Figure 1 is represented by the small circle located on the AEC abscissa and with an arrow pointing to it. It had the highest yield of all cultivars under evaluation and considered to be stable. Hence, hybrid 29 ('Ambo') has close proximity to the ideal genotype, and therefore, most desirable in terms of mean yield and stability of all the tested hybrids (Figure 1).

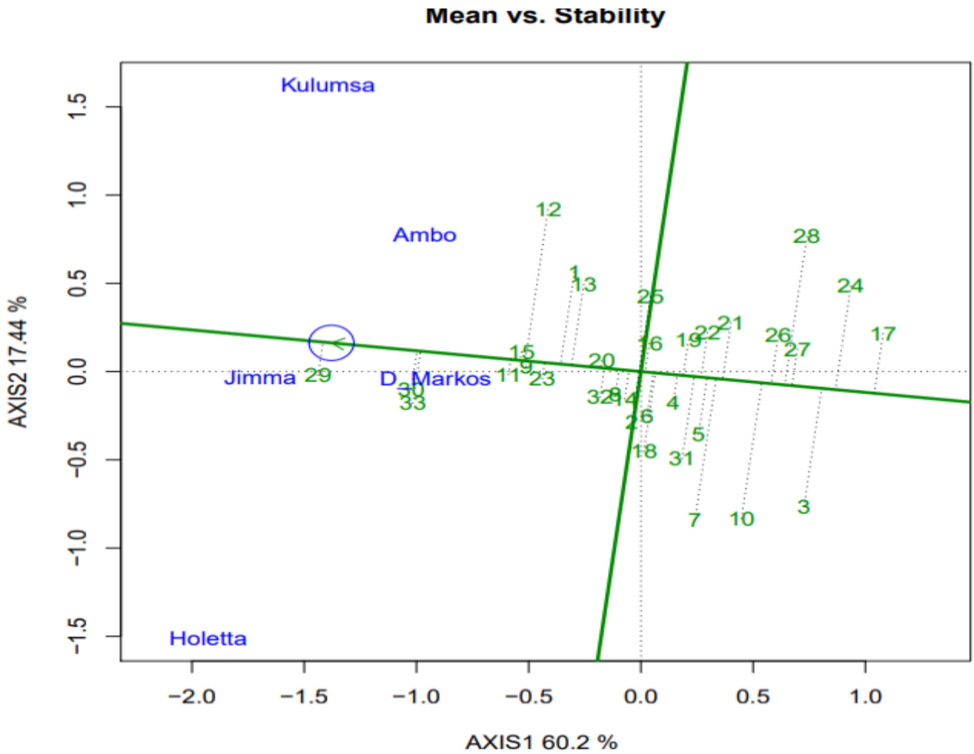

Figure 1 GGE biplot analysis of 2020 AVT data; the number codes are entry numbers of genotypes in Table 3.

Conclusion and Recommendation

The new three-way hybrid is a stable and well-adapted intermediate maturing hybrid suitable for transitional-highland to highland agro-ecologies of Ethiopia with altitudinal ranges of 1800-2600 m.a.s.l. The high yield with acceptable plant stature plus good husk cover characteristics of the new hybrid would make it preferable by farmers, while the high yielding ability of the female parent (or single-cross seed parent) is also an additional positive attribute that would further interests seed producers involved in maize seed business. Therefore, smallholder farmers and maize commercial seed producers can grow and multiply the seed of ‘Ambo’ hybrid with the recommended agronomic and other management practices in the highland sub-humid agroecology of Ethiopia.

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