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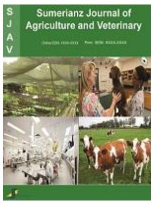

Original Article Open Access

Performance Evaluation of Maize (*Zea mays L.*) Varieties in Low Moisture Stress Area of Southern Ethiopia

Gobeze Loha*
Hawassa Agricultural Research Centre, Ethiopia

Legesse Hidoto
Hawassa Agricultural Research Centre, Ethiopia

Abstract

Maize is priority crop to farmers because it is a stable food in many rural communities of southern region. It is widely grown in the various parts of southern region from lowland to mid-highlands. On the other hand, moisture stress is one the most critical production constraints of maize in low to intermediate agro-ecology. Hence, screening maize varieties tolerant to moisture stress is of paramount important in order to sustain maize production in moisture areas. In this context, field experiment was conducted at Amaro, Halaba and Inseno testing sites of Hawassa Agricultural Research Center during 2012/2013 cropping season inorder to select adaptable maize varieties for moisture stress with reasonable grain yield. Treatments consisted of eleven maize varieties (Gibe I, Gibe II, Guto, Mlekasa I, Melkasa II, Melkasaa IV, Melkasa VI, Shalla, BH-540, BH-543 and Aba raya) released for variable agroecologies. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Analysis of variance revealed that plants had higher plant height, ear height, number of rows per cob, seeds per row, seeds per cob, biomass, grain yield, HI and prolificacy at Inseno and Halaba as compared to Amaro. Generally, almost all maize varieties exhibited superior performance at Inseno followed by Halaba for agronomic traits whereas their performance was poor at Amaro. Based on this result that BH 540, BH 543 could be used at Inseno and Halaba with specific inclusion Shalla for Halaba and Abaraya for Inseno. Further more , varieties Gibe II, Melkasa II and Shalla can be recommended for Amaro environment.
Keywords: Maize; Varieties; Moisture stress.

1. Introduction

Maize (*Zea mays* L.) has become the third most important cereal crop in the world, because of its high adaptability and productivity [1]. Globally maize is grown under diverse climatic conditions but yields best under moderate temperatures with sufficient water [2]. However, on the African continent, it is the most important food crop and mainstay of rural diets in the eastern and southern regions [3-5]. Maize has a higher carbohydrate production potential per unit land than other cereals and was the first major cereal to undergo rapid and widespread technological transformation in its cultivation [6]. In developed countries, maize is grown mainly for animal feed and as raw materials for industrial products, such as starch, glucose, and dextrose and bio fuel. Therefore, maize occupies an important position in Africa and on the global economy where it is traded as a food, feed and industrial grain crop [7].

Many factors affect grain yield of maize such as genetic constitution, fertilization, moisture and plant density. Successful and sustainable maize production depends on the correct application of production inputs. These inputs are, inter alia, adapted cultivars, plant density, soil tillage, fertilization, irrigation, herbicides, pesticides, harvesting, marketing and financial resources. From this list, water is regarded as the most important constraint to increase food production. Considering water, the balance between the incessant demand for water by crops and its sporadic supply by precipitation that even short-term dry spells often reduce production significantly, and prolonged droughts can cause total crop failure and mass starvation [8].

Rainfed agriculture is confronted with unreliable or erratic rainfall and recurrent drought with subsequent production failures [9]. The water requirements associated with producing food for the future world population are huge and almost certain to increase. Drought is one of the most important stresses threatening maize production, food security and economic growth in the Ethiopia. Maize is priority crop to farmers because it is a stable food in many rural communities of southern region. It is widely grown in the various parts of southern region from lowland to mid-highlands. Moisture stress is one the most critical production constraints of maize in low to intermediate agro-ecology. However, the extent of yield reduction due to moisture stress varies with genotypes. Developing maize varieties tolerant to moisture is of paramount important in order to sustain maize production in moisture areas. Hence, this study was initiated with objective to select adaptable maize varieties for moisture stress with reasonable grain yield.

*Corresponding Author

2. Materials and Methods

2.1. Experimental Site

Field experiments were conducted during 2012/13 cropping season at three locations namely; Amaro (Clay loam textured soil with a pH of 6.5, 0.26% total Nitrogen (N), 39 ppm available phosphorous (P), 40.4 ppm available potassium (K) and altitude of 1400masl), Halaba (Clay loam textured soil with pH 6.8 =, EC = 0.08 ds/m, total N (%) = 0.44, available P = 37.6 ppm) and altitude of 1800 masl) and Inseno (Clay loam textural class soil with pH = 5.9, EC = 0.085 ds/m, CEC = 21.8 me/100 g soil, total N(%) = 0.118, available P 6.4 ppm, available K 48.2 ppm and OC (%) = 2.7) testing sites of Hawassa Agricultural Research Center.

2.2. Treatments and Experimental Design

Treatments consisted of eleven maize varieties (Gibe I, Gibe II, Guto, Mlekasa I, Melkasa II, Melkasaa IV, Melkasa VI, Shalla, BH-540, BH-543 and Abaraya) released for variable agroecologies. The treatments were laid out in a randomized complete block design (RCBD) with three replications. Planting was carried out following the onset of rainfall and planting time of respective areas. A 4 x 4 m plot size used and maize was planted at inter and intra row spacing of 80 and 25 cm, respectively. Two seeds were placed per hill and after emergence seedlings were thinned to maintain 80 plants per plot. The recommended phosphate in forms DAP was applied at planting whereas N fertilizer applied in split where the first half at planting and second half applied 40 days after planting. Weeding and cultivation were carried out as desired during growing season.

2.3. Data Collection and Analysis

Data recorded were plant height, ear height, prolificacy, ear length, ear diameter, number of seeds per row, seeds per cob, thousand seed weight, biomass, grain yield and harvest index (HI). Plant height, ear height, ear length, ear diameter, number of rows per cob and number of seeds per row were measured for five randomly selected plants per plot. Seeds number per cob was determined multiplying the number of rows by the number of seeds per row. Thousand seed weight (TSW) was measured by counting a thousand seeds with a seed counter and weighing it with sensitive balance. Grain was manually harvested from central rows and converted to kg ha^{-1} after adjusting the moisture content to 12.5%. Biomass yield was estimated as the sum of stover weighed and grain yield. Harvest index (HI) is the ratio of grain yield to the total biomass yield which was estimated by dividing grain yield by total biomass. Prolificacy is the property of producing more than one ear per plant and was estimated by dividing the number of ears by the number of plants harvested. Data were combined over locations after carrying out the homogeneity test of variances [10] and subjected to analysis of variance using the general linear model SAS version 9.1 [11]. Treatment means were compared using the least significant difference (LSD) at 5% level of significance.

3. Results

3.1. Plant Height and Ear Height

Main effect of location and varieties had significant differences on plant and ear heights (Table 1). Plants attained higher plant and ear heights at Inseno and Halaba as compared to Amaro. The highest plant height (210 cm) and ear height (106 cm) were observed for variety Gibe I followed by BH 543. The lowest plant and ear heights were observed for Melkasa I. Location by variety interaction resulted significant difference on plant heights. The highest plant height (241 cm) was recorded for BH 543 at Halaba followed by Gibe I at Inseno with mean plant height of 238 cm. The lowest plant height (115 cm) was observed for Melkasa I at Amaro. In contrast, location by variety interaction did not have significant effect on ear heights.

3.2. Rows per Cob, Seeds per Rows and Seeds per Cob

Location and varieties had significant differences on number of rows per cob, seeds per row and seeds per cob (Table 1). Number of rows per cob, seeds per row and cob were higher at Halaba and Inseno as compared to Amaro. Regarding varieties, the highest number of rows per cob (15.3), seeds per row (36) and seeds per cob (545), averaged over locations, were obtained from Guto. The lowest number of row per cob (12.8) for BH 540, seeds per row (25) and seeds per cob (329) recorded for Melkasa I. Moreover, location by variety interaction resulted in significant differences on seeds per row and cob. The highest number of seeds per row (39) was achieved from variety Guto at Inseno followed by Shalla and BH 540 (36) at Inseno. There was also similar number of seeds per (36) was recorded for varieties Shalla and Gibe II at Halaba. The lowest number of seeds per row (22) was seen for variety BH 543 at Amaro.

3.3. Ear Length, Ear Diameter and Thousand Seed Weight

Main effects of location and varieties had significant differences on ear length and diameter (Table 1). Maize varieties had relatively higher ear length and diameter at Halaba and Inseno as compared to Amaro. The highest ear length (14.66 cm) and ear diameter (4.60 cm) were recorded for variety Shalla followed by BH 540 with mean ear length and diameter of 14.47 and 4.45 cm, respectively. The lowest ear length (11.29 cm) and ear diameter (3.87 cm) were observed fro variety Melkasa I. Similarly, location and varieties resulted significant differences on TSW where Halaba and Inseno showed superiority in TSW as compared to Amaro. Regarding varieties, averaged over locations, the greatest TSW (444 gm) was recorded for variety BH 543 followed BH 540 with mean TSW of 439 gm. The least TSW (270 gm) was seen for variety Melkasa II.

3.4. Biomass, Grain Yield, Harvest Index and Prolificacy

Analysis of variance revealed that maize varieties were significantly reacted to locations (Table 2). The highest biomass yield (17833 kg/ha) was recorded at Inseno followed by Halaba with mean biomass yield of 16552 kg/ha. The lowest biomass yield (9563 kg/ha) was seen at Amaro.

Maize varieties, averaged over locations, exhibited differences significantly for biomass yield with respective of their genetic variability. The greatest biomass yield (17823 kg/ha) was obtained from variety Abaray followed by Gibe II with mean biomass yield of 17458 kg/ha. The lowest biomass yield (9896 kg/ha) achieved from variety Melkasa I. Similarly, location by variety interaction had significant effect on biomass yield. The highest biomass yield (21635 kg/ha) for variety Abaraya at Halaba followed by Melkasa II at Inseno with mean biomass yield of 20135 kg/ha. The lowest biomass yield (5552 kg/ha) was obtained from Melkasa I at Amaro. In line with this, grain yield and HI were significantly differed in response to locations (Table 2). The greatest grain yield (7563 kg/ha) and HI (0.42) were observed at Inseno followed by Halaba with mean grain yield of 7021 kg/ha and HI of 0.41. Both parameters were lowest at Amaro. Significant difference were detected for maize varieties with respect of grain yield. The highest grain yield (7365 kg/ha) was obtained from variety BH 543 followed by BH 540 with mean grain yield of 7177 kg/ha. The lowest grain yield (2667 kg/ha) was achieved from variety Melkasa I. Significant differences were detected due to effect of location by variety interactions for biomass and grain yield (Table 2). The greatest biomass yield (21635 kg/ha) was recorded for variety Abaraya at Halaba followed by Melkasa II with mean biomass yield of 20135 kg/ha. The lowest biomass yield (5552 kg/ha) was obtained from Melkasa I at Amaro. In line with this, the highest grain yield (10792 kg/ha) was obtained from variety BH 540 followed by BH 543 with mean grain yield of 10615 kg/ha at Inseno. The lowest grain yield (948kg/ha) was seen for variety Gibe I at Amaro.

Table-1. Growth and yield parameters as affected by locations and varieties

Location	Variety	Plant height (cm)	Ear height (cm)	Rows per cob	Seeds per row	Seeds per cob	Ear length (cm)	Ear diameter (cm)	TSW (gm)
Amaro	Gibe I	166j-m	87	13.1	23l-n	306m	8.88i	3.85	328m
	Gibe II	155l-o	72	13.6	29h-k	388h-l	11.29h	4.25	326m
	Guto	152m-p	74	16.0	33b-h	522a-c	11.97gh	4.29	273t
	Melkasa I	115r	38	13.3	27j-m	369j-m	11.12h	3.58	295p
	Melkasa II	152m-p	65	13.5	30d-j	397g-k	12.07f-h	4.17	282rs
	Melkasa IV	120qr	61	12.8	29f-j	378i-m	12.32d-h	4.07	240x
	Melkasa VI	135o-r	55	15.3	29f-j	447c-i	12.23e-h	3.99	232y
	Shalla	154m-o	59	14.8	28i-l	407f-j	12.93b-h	4.31	314o
	BH 540	168j-m	80	12.8	29f-j	368j-m	12.94b-h	4.11	285r
	BH 543	159k-n	85	15.2	22n	328k-m	7.91i	4.39	319n
	Abaraya	171i-m	94	14.5	27i-l	418d-j	11.23h	3.87	312o
Halaba	Gibe I	226a-d	114	14.3	34b-e	480b-f	14.30a-e	4.61	432f
	Gibe II	193e-g	95	13.5	36ab	480b-f	15.86a	4.59	375h
	Guto	190f-i	95	15.4	35a-c	547ab	14.11a-f	4.40	328m
	Melkasa I	139n-q	53	12.8	25k-n	316im	11.32h	3.93	280s
	Melkasa II	193f-h	93	13.6	34b-e	458c-h	14.59a-c	4.67	270u
	Melkasa IV	179g-k	83	14.3	34b-e	491b-d	14.42a-c	4.45	350j
	Melkasa VI	171h-m	69	14.8	30d-j	437d-j	14.73ab	4.31	245w
	Shalla	191f-i	78	14.7	36ab	546ab	15.44a	4.30	473d
	BH 540	211c-f	114	13.1	34bc	447c-i	15.01ab	4.50	502b
	BH 543	241a	115	15.2	33b-f	485b-e	14.67ab	4.57	480c
	Abaraya	217b-d	106	14.3	33b-f	474b-f	15.81a	4.54	366i
Inseno	Gibe I	238ab	117	13.1	35bc	480b-e	14.48a-c	4.45	423g
	Gibe II	215c-e	100	13.5	34bc	462c-h	14.92ab	4.47	429f
	Guto	209d-f	110	14.4	39a	568a	13.87a-g	4.21	343k
	Melkasa I	131p-r	47	13.5	23mn	303m	11.43h	4.10	276t
	Melkasa II	186g-j	86	14.0	33b-f	463c-h	15.12a	4.50	261v
	Melkasa IV	177g-l	78	13.3	31c-i	413e-j	14.34a-d	4.25	291q
	Melkasa VI	179g-k	67	14.9	29f-j	431d-j	12.55c-h	4.52	239x
	Shalla	210d-f	92	13.6	36ab	491b-d	15.60a	4.62	335l
	BH 540	232a-c	104	12.4	36ab	446d-i	15.47a	4.37	530a
	BH 543	217b-d	111	13.3	35bc	464c-g	14.69ab	4.85	532a
	Abaraya	219a-d	114	13.2	34bc	435d-j	14.76ab	4.33	458e
	LSD	22.2	NS	NS	4.0	75.0	2.08	NS	4.0
Variety mean	Gibe I	210a	106a	13.5e-g	30c-e	424c	12.55de	4.30b	395c
	Gibe II	189b	89cd	13.5e-g	33bc	443bc	14.02a-c	4.44ab	377d
	Guto	184b	93bc	15.3a	36a	545a	13.32b-e	4.30b	315f
	Melkasa I	128d	46g	13.2fg	25f	329d	11.29f	3.87c	384h
	Melkasa II	177b	81de	13.7d-f	32b-d	439bc	13.92a-c	4.41ab	270i
	Melkasa IV	158c	74e	13.5e-g	32b-d	427c	13.69a-d	4.26b	294g
	Melkasa VI	162c	63f	15.0ab	29e	438bc	13.17c-e	4.28b	239j
	Shalla	185b	76e	14.4b-d	33bc	481b	14.66a	4.60a	374e
	BH 540	204a	101ab	12.8g	33bc	420c	14.47ab	4.45ab	439b
	BH 543	206a	105a	14.6a-c	30de	426c	12.42ef	4.33b	444a
	Abaraya	202a	103a	14.0c-e	31b-e	442bc	13.93a-c	4.25b	377d
	LSD	12.8	10.1	0.8	3.0	43.0	1.20	0.26	2.0
Location mean	Amaro	150b	70b	13.6b	28b	393b	11.35b	4.08b	291c
	Halabs	196a	92a	14.1a	33a	469a	14.57a	4.44a	373b
	Inseno	201a	93a	14.2a	33a	451a	14.29a	4.43a	374a
	LSD	6.7	5.3	0.4	1.0	22.0	0.62	0.1	1.0
	CV (%)	7.5	12.6	5.8	8.7	10.6	9.5	6.6	11.8

NS= not significant

Table-2. Biomass, grain yield, harvest index and prolificacy as affected by location and varieties

Location	Varieties	Biomass (kg/ha)	Grain yield (kg/ha)	HI	Prolificacy
Amaro	Gibe I	7635kl	948k	0.21	0.7
	Gibe II	11979g-j	2948hi	0.24	0.9
	Guto	10760i-k	1698i-k	0.13	0.4
	Melkasa I	5552l	2604h-k	0.33	1.0
	Melkasa II	10240jk	2875hi	0.22	0.8
	Melkasa IV	7292kl	2365h-k	0.22	0.6
	Melkasa VI	7990j-l	2313h-k	0.23	1.0
	Shalla	11458h-k	2740h-j	0.27	0.8
	BH 540	10594i-k	2292h-k	0.27	0.8
	BH 543	9552j-l	1604i-k	0.23	0.7
	Abaraya	12156f-j	1115jk	0.31	0.9
Halaba	Gibe I	17156b-e	8333cd	0.47	1.0
	Gibe II	19198a-d	8365cd	0.35	1.1
	Guto	15729c-g	7604d	0.52	1.3
	Melkasa I	9552j-l	2156h-k	0.29	0.9
	Melkasa II	18927a-d	4969e-g	0.34	1.1
	Melkasa IV	15281d-h	5177ef	0.47	1.1
	Melkasa VI	14583e-i	3854f-h	0.40	1.1
	Shalla	16385b-f	10344ab	0.44	1.0
	BH 540	15344d-h	8438cd	0.47	1.0
	BH 543	18302a-e	9865a-c	0.37	1.0
	Abaraya	21635a	8156cd	0.43	1.1
Inseno	Gibe I	19479a-d	8625b-d	0.43	1.1
	Gibe II	18052a-e	8531cd	0.38	1.4
	Guto	17052b-e	8375cd	0.52	1.3
	Melkasa I	148583e-i	3250g-i	0.31	1.3
	Melkasa II	20135ab	4948e-g	0.36	1.2
	Melkasa IV	15802c-g	5635e-g	0.46	1.2
	Melkasa VI	17708a-e	4719e	0.42	1.2
	Shalla	18260a-e	8271cd	0.42	1.2
	BH 540	17708a-e	10792a	0.49	1.3
	BH 543	17708a-e	10615a	0.45	1.2
	Abaraya	19688a-c	9427a-c	0.39	1.4
	LSD	4250	1731	NS	NS
Variety mean	Gibe I	14760b-d	5969c	0.37	0.9
	Gibe II	17458ab	6615a-c	0.32	1.1
	Guto	14510b-d	5896c	0.39	1.0
	Melkasa I	9896e	2667e	0.31	1.1
	Melkasa II	16438ab	4260d	0.31	1.0
	Melkasa IV	12492d	4396d	0.38	1.0
	Melkasa VI	13427cd	3625de	0.35	1.1
	Shalla	15375a-c	7125ab	0.38	1.0
	BH 540	14552b-d	7177ab	0.41	1.0
	BH 543	15188b-d	7365a	0.35	1.0
	Abaraya	17823a	6229bc	0.38	1.2
	LSD	2456	999	NS	NS
Location mean	Amaro	9563b	2135c	0.24b	0.8
	Halabs	16552a	7021b	0.41a	1.1
	Inseno	17833a	7563a	0.42a	1.3
	LSD	1282	521	0.07	NS
	CV (%)	17.8	19.0	39.4	22.0

NS= not significant

3.5. Correlation between Selected Parameters and Grain Yield

The relationship between selected agronomic traits with grain is depicted in Table 3. The correlation coefficient (r) values of selected agronomic traits with grain yield ranged from -0.05 to 0.82. Plant and ear height were positively significantly ($P \leq 0.05$) correlated which might suggest that the traits are closely associated with grain yield. Similarly, number seeds per row, seeds per cob, ear length, ear diameter, biomass, TSW and prolificacy had positively significantly associated with yield. In contrast, number or row per cob with grain yield correlation was not significant.

Table-3. Correlation of growth and yield components with grain yield

Parameter	Grain yield
Plant height	0.82*
Ear height	0.68*
Number of rows per cob	-0.05^{NS}
Number of seeds per row	0.72*
Number of seeds per cob	0.60*
Ear length	0.72*
Ear diameter	0.56*
Biomass	0.78*
Thousand seed weight	0.77*
Prolificacy	0.53*

*= Significant at 5% probability level, NS= not significant

4. Discussion

Maize varieties reacted differently for agronomic traits measured in response to location with respect of their genetic variability (Table 1 & 2). Generally almost all maize varieties exhibited superior performance at Inseno followed by Halaba for agronomic traits. The grain yield differences recorded were 5428 kg/ha between Inseno and Amaro while 4886 kg/ha between Halaba and Amaro. Thus, relatively the performances of varieties were poor at Amaro. .This probably suggests that Inseno and Halaba was relatively better environment with plant growth conditions. Moreover, this illustrated that subjecting plants to favorable growing conditions increased the ability of varieties for capturing resources which was reflected as evident in their increased agronomic performance. The significant effects of environments indicated that the genotypes performed differently across locations. Thus, the mean yield of genotypes differed from location to location. Similarly, maize varieties, averaged over locations, showed significant differences on plant height, ear height, rows per cob, seeds per row, seeds per cob, ear length, ear diameter and TSW (Table 1). Relatively higher plant height (≥ 200 cm) and ear heights (≥ 100 cm) were recorded for varieties Abaraya, BH 543, BH 540 and Gibe II. Variety Guto gave the highest number of row per cob, seeds per row and seeds per cob. The greatest ear length was recorded for Shalla whereas ear diameter and TSW for BH 543. Maize varieties, averaged over locations, tended to express a wide range of their genetic variability for grain yield. Grain yield variations ranged from 2667 to 7365 kg/ha. Variety BH 540 out yielded which was followed by BH 543. Melkasa I was least in respect to grain yield performance. The significant difference among the genotypes showed vitiations in their response (yield potential) to different locations.

Location by variety interactions resulted in significant differences on plant height, seeds per row, seeds per cob, ear length, TSW, biomass and grain yield (Table 1 & 2). For aforementioned parameters, varieties had superiority at Ineno followed by Halaba. In general the performance of varieties was poor at Amaro with the grain yield variability ranged from 948 to 2948 kg/ha. At Amaro varieties Gibe II, Melasa II and Shalla gave relatively higher grain yield with HI (Physiological efficiency and ability of converting total dry matter into economic yield) values were 0.24, 0.22 and 0.27, respectively. At this location the prolificacy (Character of plants to produce more than one ear per plant) of plants were nearly below unity (Table 2). Hallauer and Troyer [12] suggested that genotypes which produce two ears per plant in a favourable environment may produce only a single ear per plant or even develop a barren plant in an un-favorable environment. This variability might be attributed to varietal differences in maize genotypes in response to the prevailing environmental conditions. Hence, Amaro location could be considered as a stressful environment with profound limitation in potential performance of maize varieties. At Halaba maize varieties expressed relatively better performance with respect to grain yield. Grain yield variability ranged from 2156 to 10344 kg/ha from lowest to the highest with the prolificacy value of nearly more than unity where most of plant had more than one ear per plant. At this location varieties with superior performance with sounding grain yield were Shalla, BH 543 and BH 540. This probably indicates that genotypes describe the complete set of genes inherited by an individual that is important for the expression of a trait under consideration in a particular environment. Therefore, this necessitates the need to select and recommend maize genotypes at higher plant density to attain the maximum potential yield with optimum integration of spatial arrangement of row spacing and plant density. On the other hand, maize varieties at Inseno performed best to their potential as compared to Halaba and Amaro. Mean grain yield was varied from 3250 to 10792 kg/ha with HI from 0.31 to 0.52. Maize varieties with economically sounding grain yield were BH 540, BH 543 and Abaraya with the highest grain recorded for BH 540. Abay and Bjornstad [13] indicated that genotype by environment (G x E) interactions is a differential genotypic expression across environments which affect the genotypes rankings within each environment and hence relevant for identifying mega environments and targeting genotypes. Moreover, the significant of G X E indicates the presence of fluctuation of genotypes performance across environments or testing sites with inconsistency performance. Similar results were recorded by Akcura, *et al.* [14], Acura and Kaya [15], Asfaw [16], Dagne [17], Abdurhaman [18] and Muluken [19]. The correlation of almost all agronomic traits with grain yield was relatively strong indicating that their contribution towards grain yield was considerable.

5. Conclusion

Maize varieties reacted differently for agronomic traits measured in response to location with respect of their genetic variability. Generally almost all maize varieties exhibited superior performance at Inseno followed by Halaba for agronomic traits whereas their performance was poor at Amaro. Based on this result that BH 540, BH 543 could be used at Inseno and Halaba with specific inclusion Shalla for Halaba and Abaraya for Inseno. On other hand, varieties Gibe II, Melkasa II and Shalla can be recommended for Amaro environment.

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