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Yield and Agronomic Performance of Food Barley Varieties in Southern Ethiopia Highlands

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ABSTRACT

Background and Objective: Barley (*Hordeum vulgare* L.) is one of the major cereal crops grown in Ethiopia. The objective of this study was to select and recommend the best adapted and high-yielding late-maturing food barley varieties for the Sidama and Gedeo Zones of Southern Ethiopia. **Materials and Methods:** Fourteen late maturing food barley varieties and the local check were laid out in RCBD with three replications at three Research Sub Centers at Bule in 2013 and 2014 whereas at Gedeb and Abera Gelede in 2014 only. **Results:** Mean grain yield across locations indicated that six varieties were significantly yielded the local check *viz* variety HB 1307, Cross 41/98, HB 42, EH 1493, Dimtu and Ardu 1260B which gave 6273.1, 5690.8, 5540.6, 5181, 5067.9 and 5047.3 kg ha^{-1}, respectively. These high-yielding varieties gave a yield advantage of 39.07, 26.16, 22.92, 14.86, 12.35 and 11.90%, respectively compared to the local check. **Conclusion:** High-yielding and widely adaptable varieties across locations would be popularized and scaled up for production in the tested areas and similar agro-ecologies of Southern Ethiopia's highlands. For specific adaptation, those varieties can be recommended for production in their niche where they are best-suited areas.

KEYWORDS

Adaptability, barley varieties, scaling up, *Hordeum vulgare*, productivity, yield component

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INTRODUCTION

Barley (*Hordeum vulgare* L.) is one of the five major cereal crops grown in Ethiopia's highlands for thousands of years[1]. It is the fifth most important crop after tef, maize, sorghum and wheat both in area coverage and total production[2]. It has grown from 1800 to 3400 m above sea level in different seasons and production systems[3]. In the extreme highlands, barley is the only source of food, homemade drinks, animal feed and cash. In Ethiopia, barley is generally grown in two different planting seasons per year: During the long rainy season (*Meher*) and the short rainy season (*Belg*)[4]. Barley is a dependable source of food in the highlands as is produced during the main and short rainy seasons as well as under residual moisture[3]. The late-barley production system is dominant in the highland areas of Ethiopia and is practiced during *Meher*, or the main rainy season (June to October). More than 47 food barley varieties have been released nationally. Despite releasing many varieties extension work on the promotion of improved varieties in the country has been very poor compared with that of bread wheat and maize[3]. Barley productivity is limited by poor soil fertility, frost, water logging, insect and leaf diseases, moisture stress, low-yielding varieties and, adequate agronomic practices[5]. These produce poor yields and have been practiced for centuries. Despite releasing many barley varieties in the country few have been accessed by

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farmers with their agronomic practices, this is accompanied by low productivity. The objective of this study was to select and recommend the best adapted and high-yielding late-maturing food barley varieties for the Sidama and Gedeo Zones of Southern Ethiopia.

MATERIALS AND METHODS

Description of the experimental area: The study was conducted for two years (2013 to 2014) at Bule Agricultural Research Sub Center (06°18'02.5"N, 38°24'18.2"E, Elevation 2842 meters above sea level) and one year (2014) at Abera Gelede (06°41.5"N, 38°704E, elevation 2697 m.a.s.l.) and Gedeb (06°57'41.5"N, 38°15'35.56"E) in main cropping season (July to January). Bule and Gedeb are in Gedeo Zones and Abera Gelede is the then Sidama Zone (Now Sidama Regional State).

Treatments, experimental design and cultural practices: For this study, 14 late-maturing varieties were collected from Holetta Agricultural Research Center and the local checks collected from the farmer's stock around the experimental sites were evaluated in the main rainy season (July to January). One hundred farmers from five villages 20 from each village visited the experiments during the physiological maturity period. Those farmers were appreciated especially for late-maturing varieties than other experiments of early maturing and malt barley varieties in the sub-center. Fourteen late-maturing food barley varieties and, the local check (Table 1) were tested for two years in 2013 and 2014 using Randomized Complete Block Design (RCBD) with three replications. The experiment was sown at a seed rate of 100 kg ha^{-1} during the main cropping season (July to January) at Bule, Abera Gelede and Gedeb Sub Centers. Each plot has six rows of 2.5 m in length. Each row was separated by 20 cm. The adjacent plots were separated by a blank row in both years. Nitrogen and phosphorus fertilizers were applied at the rate of 41 N and 46 P_2O_5 at planting, using urea and DAP (Di-ammonium phosphate) as a source of N and P_2O_5. One-third of the total amount of nitrogen was applied at planting in the form of urea and 2/3 after the first weeding. But the whole DAP was applied at planting as a source of phosphorus and nitrogen. Broadleaf weeds were controlled using 2,4-D herbicide applied four weeks after planting at the rate of one liter per 200 L of water ha^{-1} followed by two hand weeding with an interval of 15 days after herbicide application.

Data collection and statistical analysis: Days to heading and maturity, grain filling period, plant height (cm), spike length (cm), spikelet per spike, 1000 kernel weight (g) and grain yield were collected from the four central rows. Days to heading were recorded as when the spikes of 50% of the culm in a plot had fully extruded out. Physiological maturity was recorded when the plants had almost lost their green color from both vegetative and reproductive tissues. Plant height was measured from the ground level to the tip of the spike excluding the owns after physiological maturity. Grain yield was estimated after adjusting 12.5% seed moisture content. Analysis of Variance (ANOVA) was conducted using SAS as described by researchers[1,6] and mean separation was done using Duncan Multiple Test Range Test (DMRT).

Table 1: Description of plant materials

Variety	Year of release	Productivity quintal ha^{-1}	Altitude meter above sea level
HB 1307	2006	35-50	2000-3000
Shege	1985	23-51	2300-2800
HB 42	1984	32-55	2000-2800
Ardu 1260B	1986	36-50	2200-2800
Dimtu	2001	20-40	2300-2800
Cross 41/98	2012	25-56	2000-2600
EH 1493	2012	25-61	2300-2800
Yedogit	2005	23.5	2600-3000
Estayish	2004	19.6	2600-3000
Tiret	2004	23	2600-3000
Shedeho	2003	15-26	2600-2900
Harbu	2004	15.5-44.9	2300-2600
Agegnehu	2007	29	2600-3000
Abdane	2011	15-32	2300-2600
Local check			

One quintal: 100 kg and Source: Crop variety registry from 1984 to 2012

RESULTS

A combined analysis of variance showed that there was a significant difference ($p<0.0001$) for all agronomic, yield and yield component traits (Table 2). On the other hand, the ANOVA exhibited the presence of significant interaction of location by treatment for all agronomic, yield and yield component traits.

Agronomic characters: Barley varieties have differed for days to heading, maturity, grain-filling period and plant height ranging from 70 to 88 days, 57 to 65 days and 95.8 to 118.6 cm for days to heading, maturity, grain-filling period and plant height, respectively (Table 3). Varieties Ardu 1260B, HB 42 and the local check took longer days to head 88, 87 and 87 days, respectively, while variety Harbu was earlier to head (70 days) (Table 3). Variety Ardu 1260B took longer days to reach physiological maturity (148 days). But regarding grain filling period variety, HB1307 had a longer grain filling period (65 days). Variety Ardu 1260B was the tallest (118.6 cm) of all the rest of the varieties including the check.

Yield and yield components: Variety Dimtu exhibited a longer spike length (7.3 cm) (Table 3). This variety also had more spikelets per spike (21.3) than all the improved varieties and the local check. Variety Shege had a heavier and significant thousand seed weight (48.8 g) than the local check. The mean grain yield across locations indicated that variety HB 1307 gave high grain yield (6273.1 kg ha^{-1}) and bit all the varieties studied. Generally, mean grain yield across locations indicated that six varieties were significantly

Table 2: Combined analysis of variance for late maturing food barley varieties

		Mean square							
Source of variation	DF	Days to heading	Days to maturity	Grain filling period	Plant height (cm)	Spike length (cm)	Spikelet per spike	1000 kernel weight (g)	Grain yield (kg ha^{-1})
Loc	3	2600.69***	7245.45***	10093.63***	1710.74***	18.28***	231.69***	2256.91***	119110846.0***
Rep (Loc)	8	8.66ns	5.76ns	3.06ns	7.77ns	0.19ns	0.28ns	20.81**	966069.0**
Trt	14	393.20***	452.66***	53.47***	447.09***	1.06***	18.92***	67.23***	3972262.4***
Loc*Trt	42	59.89***	57.81***	57.64***	66.20***	1.47***	10.22***	28.04***	967425.2***

DF: Degree of freedom, ***Very highly significant at $p<0.001$, **Highly significant at $p<0.01$, *Significant at $p<0.05$ and ns: Not significant

Table 3: Combined mean performance of agronomic, yield and yield component traits of late maturing food barley varieties across locations in Southern Ethiopia

Variety	DH	DM	GFP	PH	SL	SPS	TKW	GY	YA
HB 1307	82^{b}	147^{ab}	65^{a}	103.0^{d-f}	7.0^{a-c}	20.6^{b}	47.9^{ab}	6273.1^{a}	39.07
Shege	84^{b}	142^{e}	58^{b-e}	103.2^{d-f}	6.9^{a-c}	19.9^{cd}	48.8^{a}	4222.8^{g}	-6.38
HB 42	87^{a}	146^{b}	58^{b-e}	103.0^{d-f}	6.6^{c-e}	19.6^{de}	47.3^{a-c}	5544.6^{bc}	22.92
Ardu 1260B	88^{a}	148^{a}	60^{b-d}	118.6^{a}	7.0^{a-c}	19.4^{e}	47.0^{a-d}	5047.3^{de}	11.90
Dimtu	83^{b}	143^{c-e}	59^{b-e}	114.2^{b}	7.3^{a}	21.3^{a}	46.2^{b-f}	5067.9^{de}	12.35
Cross 41/98	82^{b}	139^{f}	57de	103.9^{de}	7.2^{ab}	20.3^{bc}	45.2^{d-g}	5690.8^{b}	26.16
EH 1493	84^{b}	145^{bc}	61^{b}	101.0^{gh}	7.1^{ab}	20.2^{bc}	44.7^{e-g}	5181.1^{cd}	14.86
Yedogit	83^{b}	142de	59^{b-e}	109.9^{c}	6.7^{b-d}	18.2^{g}	45.5^{c-g}	4832.3^{d-f}	7.13
Estayish	75^{cd}	132^{hi}	56^{e}	97.8^{j}	6.2^{e}	17.6^{h}	44.5^{fg}	4387.6^{fg}	-2.73
Tiret	77^{c}	135^{g}	58^{c-e}	101.8^{g-h}	7.0^{a-c}	17.4^{h}	42.5^{hi}	4630.6^{e-g}	2.66
Shedeho	77^{c}	134^{gh}	56^{e}	100.2^{hi}	6.4^{de}	18.7^{f}	41.5^{ij}	4631.0^{e-g}	2.67
Harbu	70^{e}	130^{i}	61^{b-d}	104.6^{d}	6.5^{c-e}	17.5^{h}	43.9^{gh}	4300.4^{g}	-4.66
Agegnehu	73^{d}	134^{gh}	61^{b}	98.6^{ij}	6.6^{c-e}	17.6^{h}	46.7^{b-e}	4709.6^{d-g}	4.41
Abdane	73^{d}	133^{g-i}	59^{b-e}	102.5^{e-g}	6.8^{a-d}	18.5^{fg}	40.4^{j}	4498.4^{fg}	-0.27
Local check	87.0^{a}	145^{bc}	57de	113.2^{b}	6.6^{c-e}	18.5^{fg}	46.0^{b-f}	4510.7^{fg}	0
Mean	80.32	139.71	59.39	105.05	6.82	19.05	45.23	4901.88	
CV	3.13	2.06	5.65	1.92	7.62	2.70	4.95	10.98	
F test	***	***	***	***	***	***	***	***	

DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height (cm), SL: Spike length (cm), SPS: Spikelets per spike, TKW: Thousand kernel weight (g), GY: Grain yield (kg ha^{-1}), YA: Yield advantage (%), ***Significant at $p<0.001$ and Alphabets: Similar letters in each trait indicates no statistically different among varieties whereas different letters showed statistically different

yielded the local check *viz* variety HB 1307, Cross 41/98, HB 42, Eh 1493, Dimtu and Ardu 1260B which gave 6273.1, 5690.8, 5540.6, 5181.1, 5067.9 and 5047.3 kg ha^{-1}, respectively (Table 3). These top yielder varieties gave yield advantages of 39.07, 26.16, 22.92, 14.86, 12.35 and 11.90%, respectively compared to the local check.

The mean grain yield of each specific location indicated that improved varieties bit the local check ranged from one at Gedeb, 2014, five at Bule, 2014 and nine at Abera Gelede, 2014 (Table S1-S4). This indicates that there are potential varieties of those given above the local check in each specific location.

Table S1: Mean performance of agronomic, yield and yield component traits of late maturing food barley varieties at Bule, 2013

Variety	DH	DM	GFP	PH	SL	SPS	TKW	GY	YA
HB 1307	74^{g}	161^{b}	87^{a}	100.4^{g}	6.9^{de}	21^{c}	55.0^{a-d}	6273.1^{a}	39.07
Shege	80^{e}	157^{cd}	77^{f-h}	107.3^{d}	8.4^{a-c}	24^{b}	62.0^{a}	4222.8^{g}	-6.38
HB 42	85^{b}	160^{b}	75^{h}	107.3^{d}	7.7^{bd}	24^{b}	57.3^{a-d}	5544.6^{bc}	22.92
Ardu 1260B	86^{a}	167^{a}	81^{cd}	118.8^{ab}	8.1^{a-c}	20^{d}	58.0^{a-c}	5047.3^{de}	11.90
Dimtu	75^{f}	157^{d}	82^{bc}	118.3^{b}	8.8^{a}	27^{a}	53.0^{b-d}	5067.9^{de}	12.35
Cross 41/98	81de	151^{e}	70^{i}	103.2^{f}	8.7^{ab}	22^{c}	54.3^{a-d}	5690.8^{b}	26.16
EH 1493	84^{c}	160^{b}	77^{f-h}	107.6^{d}	6.4^{e}	19de	53.0^{b-d}	5181.1^{cd}	14.86
Yedogit	64^{k}	144^{gh}	80^{c-e}	100.8^{g}	6.9^{de}	17^{f}	56.7^{a-d}	4832.3^{d-f}	7.13
Estayish	67^{i}	145^{fg}	78^{d-g}	104.4^{e}	6.1^{e}	18^{e}	58.3^{a-c}	4387.6^{fg}	-2.73
Tiret	71^{h}	142^{h}	71^{i}	104.0^{ef}	8.2^{a-c}	21^{c}	48.7^{de}	4630.6^{e-g}	2.66
Shedeho	66^{j}	142^{h}	76^{gh}	100.8^{g}	6.9^{de}	17^{f}	50.0^{cd}	4631.0^{e-g}	2.67
Harbu	63^{l}	147^{f}	84^{b}	112.4^{c}	7.8^{a-d}	19^{d}	57.7^{a-c}	4300.4^{g}	-4.66
Agegnehu	67^{i}	147^{f}	79^{c-f}	92.8^{h}	7.5^{cd}	19^{d}	55.3^{a-d}	4709.6^{d-g}	4.41
Abdane	66^{j}	148^{f}	82^{bc}	107.7^{d}	8.2^{a-c}	22^{c}	41.7^{e}	4498.4^{fg}	-0.27
Local check	82^{d}	159^{bc}	78^{e-g}	119.5^{a}	6.3^{e}	20^{d}	60.0^{ab}	4510.7^{fg}	0
Mean	74.0	152.5	78.5	107.0	7.5	20.6	54.7	4901.88	
CV	0.60	0.95	1.9	0.46	7.4	2.8	8.3	10.98	
F test	***	***	***	***	***	***	**	***	

DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height (cm), SL: Spike length (cm), SPS: Spikeltes per spike, TKW: Thousand kernel weight (g), GY: Grain yield (kg ha^{-1}), YA: Yield advantage (%)., ***Significant at p<0.001, **Significant at p<0.01 and Alphabets: Similar letters in each trait indicates no statistically different among varieties whereas different letters showed statistically different

Table S2: Mean performance of agronomic, yield and yield component traits of late maturing food barley varieties at Bule, 2014

Variety	DH	DM	GFP	PH	SL	SPS	TKW	GY
HB 1307	92^{b-d}	147^{ab}	54^{a-c}	93.3^{hi}	5.5^{c-e}	22^{b}	50.7^{b}	7104.0^{a}
Shege	96^{bc}	142^{a-c}	46^{c}	98.9^{e}	6.5^{ab}	20de	49.3^{c}	5347.1^{fg}
HB 42	98^{b}	147^{ab}	49^{bc}	95.5^{f}	5.4^{e}	20de	46.0^{ef}	6161.7^{b-d}
Ardu 1260B	96^{bc}	147^{ab}	51^{a-c}	113.9^{a}	5.5^{de}	19^{ef}	46.7^{e}	5490.3^{d-g}
Dimtu	93^{b-d}	137^{bc}	44^{c}	107.2^{b}	6.3^{a-c}	21^{d}	48.0^{d}	6740.0^{ab}
Cross 41/98	87^{c-e}	137^{bc}	50^{a-c}	93.9^{gh}	6.5^{ab}	22^{b}	46.0^{ef}	6500.6^{a-c}
EH 1493	90^{b-e}	144^{ab}	54^{a-c}	87.2^{j}	6.6^{ab}	24^{a}	44.7^{gh}	5408.4^{e-g}
Yedogit	107^{a}	150^{a}	43^{c}	101.1^{d}	7.0^{a}	22^{bc}	42.7^{i}	5198.4^{g}
Estayish	90^{b-e}	140^{a-c}	50^{a-c}	92.7^{i}	6.2^{a-d}	21^{cd}	45.3^{fg}	5941.3^{c-f}
Tiret	81^{e}	142^{a-c}	61^{a}	94.9^{fg}	5.6^{c-e}	18^{g}	48.0^{d}	5939.0^{c-f}
Shedeho	96^{bc}	140^{a-c}	44^{c}	95.0^{f}	6.6^{ab}	22^{bc}	42.0^{i}	5928.4^{c-f}
Harbu	81^{e}	132^{c}	51^{a-c}	92.5^{i}	6.0^{b-e}	19^{f}	44.7^{gh}	5817.4^{c-g}
Agegnehu	84de	144^{ab}	60^{ab}	94.6^{fg}	5.3^{e}	17^{h}	52.7^{a}	6070.1^{b-e}
Abdane	81^{e}	132^{c}	51^{a-c}	93.8^{gh}	6.4^{ab}	22^{b}	46.0^{ef}	6627.8^{ab}
Local check	98^{b}	142^{a-c}	44^{c}	104.6^{c}	6.0^{a-e}	20de	44.0^{h}	5421.7^{e-g}
Mean	91.3	141.5	50.2	97.3	6.1	20.8	46.4	5979.74
CV	5.29	3.67	11.68	0.61	6.72	2.67	0.91	6.10
F test	***	**	*	***	***	***	**	***

DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height (cm), SL: Spike length (cm), SPS: Spikelets per spike, TKW: Thousand kernel weight (g), GY: Grain yield (kg ha^{-1}), ***Significant at p<0.001, **Significant at p< 0.01, *Significant at p<0.05 and Alphabets: Similar letters in each trait indicates no statistically different among varieties whereas different letters showed statistically different

Table S3: Mean performance of agronomic, yield and yield component traits of late maturing food barley varieties at Gedeb, 2014

Variety	DH	DM	GFP	PH	SL	SPS	TKW	GY
HB 1307	78^{d}	129^{b}	51^{b}	108.3^{d}	8.0^{a}	18^{a}	43.3^{c}	6838.1^{a}
Shege	77^{de}	120^{d}	43^{ef}	100.0^{gh}	6.3^{c}	16^{bc}	44.7^{a}	3716.4^{fg}
HB 42	82^{c}	128^{c}	46^{d}	100.3^{g}	6.0^{c}	15^{de}	44.0^{b}	4462.9^{cd}
Ardu 1260B	86^{a}	133^{a}	47^{cd}	13.7^{b}	6.7^{bc}	18^{a}	44.0^{b}	4631.4^{c}
Dimtu	82^{c}	129^{b}	48^{c}	115.7^{a}	6.7^{bc}	17^{b}	43.3^{c}	3779.6^{fg}
Cross 41/98	77^{de}	121^{d}	44^{e}	103.7^{f}	6.3^{c}	16^{bc}	42.0^{d}	5470.7^{b}
EH 1493	77^{de}	129^{b}	52^{b}	97.7^{i}	7.7^{a}	18^{a}	40.0^{e}	4693.7^{c}
Yedogit	76^{e}	130^{b}	53^{a}	115.7^{a}	6.3^{c}	16^{bc}	44.0^{b}	4693.3^{c}
Estayish	72^{h}	109^{j}	38^{i}	87.7^{j}	5.7^{c}	14^{e}	34.0^{j}	3455.1^{gh}
Tiret	77^{de}	118^{e}	41^{h}	106.7^{e}	7.3^{ab}	14^{e}	36.0^{i}	4291.0^{c-e}
Shedeho	73^{g}	114^{f}	42^{gh}	100^{gh}	6.3^{c}	15^{de}	38.0^{g}	3716.1^{fg}
Harbu	68^{i}	112^{h}	43^{ef}	99.7^{gh}	6.0^{c}	15^{de}	37.3^{h}	3266.3^{h}
Agegnehu	71^{h}	113^{g}	42^{fg}	99.3^{h}	6.3^{c}	16^{bc}	38.7^{f}	3957.9^{ef}
Abdane	75^{f}	119^{e}	43^{ef}	97.7^{i}	5.7^{c}	13^{f}	38.0^{g}	3303.4^{h}
Local check	85^{b}	128^{c}	44^{e}	112.7^{c}	6.3^{c}	17^{b}	42.0^{d}	4120.0^{d-f}
Mean	77.1	122.2	45.1	103.9	6.5	15.9	40.6	4293.06
CV	0.72	0.40	1.51	0.52	7.93	2.97	0.82	5.31
F test	***	***	***	***	***	***	***	***

DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height (cm), SL: Spike length (cm), SPS: Spikelets per spike, TKW: Thousand kernel weight (g), GY: Grain yield (kg ha^{-1}), ***Significant at $p<0.001$ and Alphabets: Similar letters in each trait indicates no statistically different among varieties whereas different letters showed statistically different

Table S4: Mean performance of agronomic, yield and yield component traits of late maturing food barley varieties at Abera Gelede, 2014

Variety	DH	DM	GFP	PH	SL	SPS	TKW	GY
HB 1307	83^{a}	150^{a}	67^{a}	110^{c-f}	7.5^{a-c}	20^{bc}	42.7^{a}	7765.1^{a}
Shege	82^{a}	149^{a}	67^{a}	106.7^{eg}	6.5^{cd}	20^{bc}	39.3^{a-e}	5093.0^{c}
HB 42	84^{a}	148^{a}	64^{a-c}	108.9^{c-g}	7.4^{a-c}	19^{d}	42.0^{ab}	7938.9^{a}
Ardu 1260B	84^{a}	147^{a}	63^{a-d}	128.3^{a}	7.7^{ab}	21^{ab}	39.3^{a-e}	7245.6^{ab}
Dimtu	83^{a}	149^{a}	66^{a-c}	115.5^{bc}	7.4^{a-c}	21^{ab}	40.7^{a-d}	6790.5^{a-c}
Cross 41/98	83^{a}	148^{a}	66^{a-c}	115.0^{b-d}	7.4^{a-c}	22^{a}	38.7^{b-e}	7869.6^{a}
EH 1493	85^{a}	147^{a}	63^{a-d}	111.6^{c-f}	7.9^{a}	21^{ab}	41.3^{a-c}	7188.1^{ab}
Yedogit	84^{a}	146^{a}	63^{a-d}	122.2^{ab}	6.9^{a-d}	18^{e}	38.7^{b-e}	6564.2^{a-c}
Estayish	71^{cd}	134^{c}	63^{a-d}	106.6^{e-g}	7.1^{a-c}	17^{ef}	40.7^{a-d}	5693.3^{bc}
Tiret	79^{b}	137^{b}	58^{d}	101.6^{g}	6.7^{b-d}	15^{h}	37.3^{de}	5683.2^{bc}
Shedeho	73^{c}	138^{b}	65^{a-c}	105^{fg}	5.9^{d}	21^{ab}	36.0^{e}	6115.2^{a-c}
Harbu	68^{e}	131^{c}	64^{a-c}	113.9^{ce}	6.5^{cd}	17^{ef}	36.0^{e}	5404.5^{bc}
Agegnehu	71^{d}	133^{c}	62^{b-d}	107.8^{d-g}	7.4^{a-c}	18^{e}	40.0^{a-d}	6451.1^{a-c}
Abdane	71^{d}	132^{c}	61^{cd}	111.1^{c-f}	6.9^{a-d}	16^{gh}	36.0^{e}	5449.1^{bc}
Local check	84^{a}	149^{a}	65^{a-c}	116.1^{b-c}	7.7^{ab}	18^{e}	38.0^{c-e}	5377.6^{bc}
Mean	78.9	142.5	63.7	112.0	7.1	18.9	39.1	6441.94
CV	1.79	1.25	3.74	3.61	7.80	2.36	4.52	16.17
F test	***	***	**	***	**	***	**	*

DH: Days to heading, DM: Days to maturity, GFP: Grain filling period, PH: Plant height (cm), SL: Spike length (cm), SPS: Spikelets per spike, TKW: Thousand kernel weight (g), GY: Grain yield (kg ha^{-1}), ***Significant at $p<0.001$, **Significant at $p<0.01$, *Significant at $p<0.05$ and Alphabets: Similar letters in each trait indicates no statistically different among varieties whereas different letters showed statistically different

DISCUSSION

In the present study, the results indicated that barley varieties have differed in a wider range of agronomic characteristics. In this study, two improved varieties Ardu 1260B, HB 42 and the local check took longer days to head from tested varieties while the variety Harbu was 17 days earlier to head than the local check. In line with this finding Abera *et al.*[7] found varieties Harbu and Dafo were earlier to head than the local check at West and Kellem Wellega Zones. In disagreement with study[8,9] reported that the local check was early to head to the improved varieties at Diko Tsida Sub Center of Gamo and Limo Districts of Hadiya Zone highlands respectively. Similarly, as days to heading variety, Ardu 1260B also took longer days to reach physiological maturity than most of the varieties and local checks too. In disagreement with this

finding[9] found the local cultivar matured later compared to other varieties while Lema *et al.*[8] and Maggo[10] reported that variety HB 42 was later to reach physiological maturity 126 and 144 days, respectively than the rest of the barley varieties and local check. But regarding grain filling period variety, HB1307 had a longer grain filling period than the check. In disagreement with this result, an experiment done in West Shewa showed the local check had more grain filling periods than improved varieties[9]. A longer grain filling periods allow photosynthetic components to remain green improving grain filling and leading to good grain yield of post-anthesis assimilates which is important in cereals[11]. Variety Ardu 1260B was the tallest of all the rest of the varieties including the check. Not in line with the study, Lema *et al.*[8] and Maggo[10] found that HB 1307 (116.6 cm) and Dimtu (125.8 cm) were the tallest varieties in an experiment done in Kaffa and Gamo highlands respectively. Similarly, the study done in the Arsi Zone of the Oromia Region reported that variety HB 1307 had a plant height par with the other two tallest improved food barley varieties[12]. Generally, varieties tested in different agro-ecologies responded differently to agronomic characters.

Regarding yield characteristics variety, Dimtu exhibited a longer spike length and more spikelets per spike than the local check. In disagreement with this study, Lema *et al.*[8] reported variety Tiret had the longest spike length than both the improved and local check. The older improved variety Shege had a heavier and significant thousand seed weight than the local check but was par with HB 1307, HB 42 and Ardu 1260B. This result was supported by Maggo[10] who found the highest mean value of a thousand kernel weight recorded from HB 42 (47.7 g). The mean grain yield across locations indicated that variety HB 1307 gave high grain yield (6273.1 kg ha^{-1}) and bit all the varieties studied. In line with this study, Lema *et al.*[8], Shimeles *et al.*[5] and Birhanu *et al.*[13], reported that the highest mean grain yield was recorded from HB 1307 (2427.8, 5143 and 6764 kg ha^{-1}) respectively and similarly variety Ageghehu was reported among the low yielders in both authors. This variety HB 1307 was also found to be among the high-yielder varieties in an experiment done in the Central Highlands of Ethiopia[14]. In disagreement with result of Maggo[10], found variety Dirbe exhibited the highest grain yield (4.6 tons ha^{-1}) followed by HB 42 (3.5 ha^{-1}). Generally, in this study, the mean grain yield across locations indicated that six varieties significantly outyielded the local check *viz* variety HB 1307, Cross 41/98, HB 42, EH 1493, Dimtu and Ardu 1260B which gave 6273.1, 5690.8, 5540.6, 5181.1, 5067.9 and 5047.3 kg ha^{-1}, respectively. These top yielder varieties gave yield advantages of 39.07, 26.16, 22.92, 14.86, 12.35 and 11.90%, respectively compared to the local check.

The six high-yielding and widely adaptable varieties would be popularized and scaled up for production in the tested areas and similar agro-ecologies of Southern Ethiopia's highlands. Those four varieties for specific adaptation are recommended for production in their niche where they are best-suited areas. Despite releasing many food barley varieties in the country few have been accessed by farmers with their improved agronomic practices, this is accompanied by low productivity. Promotions of recently released barley varieties are important for barley-growing farmers to easily access them and to increase production and productivity. So participatory evaluation of recently released varieties by researchers and farmers is important for easy adoption of the varieties which leads to increased production and productivity.

CONCLUSION

In this study, six wide and four specific adaptable varieties were identified and the evaluated barley varieties showed variation in phenological, yield and yield component traits. These adapted and top yielder varieties gave yield advantages of 39.07, 26.16, 22.92, 14.86, 12.35 and 11.90%, respectively compared to the local check. These varieties are high yielding and widely adaptable across locations and would be popularized and scaled up for production in the tested area and similar agro-ecologies of Southern Ethiopia highlands. For specific adaptation, the four barley varieties can be recommended for production in their niche where they are best-suited areas.

SIGNIFICANCE STATEMENT

In this study, from the 14 evaluated food barley varieties select and recommend at least one adapted and high-yielding variety to farmers of Southern Ethiopia. In this regard six wide and four specific adaptable varieties were identified. These high-yielding varieties gave a yield advantage between 11.9 and 39.07% compared to the local check. Therefore, these high-yielding and widely adaptable food barley varieties across locations would be popularized and scaled up for production in the tested areas and similar agro-ecologies of Southern Ethiopia's highlands. This increases the production and productivity of barley-growing farmers. But the four specific adapted varieties can be recommended for production in their niche where they are best-suited areas.

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