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Full Length Research

Adaptation study of Haricot bean (*Phaseolus vulgaris* L.) varieties in moisture stress areas of Abergelle, Northern Ethiopia

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ABSTRACT: The haricot bean (*Phaseolus vulgaris* L.), locally known as 'Boleqe' also known as a dry bean, common bean and kidney bean is an important source of protein, calories and cash for smallholder farmers of Ethiopia. The national and regional research institutions in the country have released many varieties for commercial production. However, these improved varieties have not been tested for their adaptability potential under the Abergelle condition. Therefore, a field experiment was conducted during the 2013 and 2014 main cropping seasons using a randomized complete block design with three replications. The objectives of the study were to evaluate the performance and select the best and well-adapted haricot bean varieties. The data of 12 different agronomic traits subjected to combined analysis of variance revealed significant ($p \leq 0.05$) differences among the common bean varieties for most of the characters (days to 50% emergence, flowering, seed filling period and 90% physiological maturity, pod length, plant height, number of pods per plant, number of seeds per pod, seed yield, biomass yield, harvest index and thousand seed weight) studied. In conclusion, the present study entails the presence of significant variations among common bean varieties. Awash melka had better performance than the other varieties for yield (1.9 t ha^{-1}) and yield related traits. Therefore, it is recommended as a promising variety to increase the source of cash crops for farmers in the study area and foreign currency as the export crop of the country, Ethiopia.

Keywords: Adaptation, agronomic traits, moisture stress, *Phaseolus vulgaris* L.

INTRODUCTION

The common bean (*Phaseolus vulagris* L) is an annual crop belonging to the family *Fabaceae.* It is a very important legume crop grown in a range of cropping systems and environments in regions as diverse as Latin America, Africa, the Middle East, China, Europe, the United States, and Canada. The leading bean producer and consumer is Latin America, where beans are a traditional, significant food, especially in Brazil, Mexico, the Andean Zone, Central America, and the Caribbean (Gepts, 2010). Beans grow best in well-drained, sandy loam, silt loam or clay loam soils, rich in organic content. Common beans are adapted to the low and mid-altitude areas at an altitude 900 -2100 meters above sea level, optimum temperature of 24°C and average rainfall of 200 - 600 mm per annum. It is grown best in warm climates at temperatures of 18 to 24°C (Assefa *et al*., 2005). As it is quickly maturing and can be easily intercropped, bean serves as a key component in intensifying production in smallholder farmer systems.

In Ethiopia, the common bean is consumed as traditional dishes. The crop is produced more for consumption than export. Dry beans are mostly prepared as '*nifro'* (boiled whole grains), mixed with sorghum or maize and '*wat'* (local soup) and also with '*kocho'*. Fresh beans (mature, whole non-dried grain) are popular for their taste and crack ability (MoARD, 2009). It is well known that dry seeds represent an affordable source of proteins despite being deficient in sulphur amino acids. In addition, common bean seeds are rich in complex carbohydrates, dietary fibre, starch, minerals and vitamins. Like other legumes, common bean seeds contain several bioactive compounds including enzyme inhibitors, lectins, phytates, oligosaccharides and phenolic compounds, which play metabolic functions in humans or animals (Piergiovanni and Lioi, 2010).

Although the crop has been cultivated in different parts of the country, the major common bean production regions are the central, eastern, and southern parts of the country. Common bean is considered the main cash crop and protein source for smallholder farmers in many lowlands and mid-altitude zones of Ethiopia. The crop is usually grown by subsistence farmers as the sole crop and/or intercropped with either cereals or tree crops. In the semi-arid to sub-humid highlands of the Hararghe region, including the area where this study was conducted, common bean is grown mostly intercropped with sorghum (*Sorghum bicolor* L), chat (*Catha edulis* Forsk.) and maize (*Zea mays* L.) and seldom as a sole crop (CSA, 2015).

Its ability to fix nitrogen also means that it can encourage much-needed, even longer-term improvements in soil fertility. In a nutshell, the versatility of the bean crop and its contribution to a household's food income, diet, health and even environmental security is remarkable. Despite the importance of common beans for farming households and in the national economy, the productivity of beans in Ethiopia is low (ECEA, 2010). Its area of production is increasing and according to the CSA (2015/6) report common bean was produced on about 323,327.27 ha of land and 513,724.81 tons produced in (2015) main cropping season with a productivity of 1.5 t ha^{-1}; which is low as compared to the world average of 3.5 t ha^{-1} obtained in research centres. This low yield is attributed to various constraints such as moisture stress, the absence of improved high-yielding varieties, low soil fertility, and losses due to insect pests and disease (Ferris and Kaganzi, 2008; ECEA, 2010).

Abergelle Agricultural Research Center mandate area is part of the dry lowland areas of the Tigray region, northern Ethiopia. The rainfall is unpredictable in amount and distribution; moreover, the duration is very short. As a result, crops are frequently exposed to moisture stress at critical stages of growth which results in either low yield or total crop failure. The national and regional research institutions in the country have released many varieties for commercial production. However, these improved varieties have not been tested for their adaptability potential under Abergelle areas and did not reach the smallholder farmers living in that area.

Hence, this study was intended to select the best, well-adapted and high-yield Haricot bean variety/varieties.

MATERIALS AND METHODS

Description of the study area

The field experiment was carried out under rain-fed conditions at Abergelle Agricultural Research Center on station during the 2013 and 2014 main cropping seasons. Abergelle is located in the central zone of Tigray region, Northern Ethiopia at about 903 km north of Addis Ababa and 120 km southwest of 'Mekelle' and situated at 13°14'06" N latitude and 38°58'50" E longitude (Figure 1). The area is agro-ecologically characterized as hot warm sub moist lowland (SMl-4b) located at an altitude below 1500 m.a.s.l. Plains, hills and river valleys, characterize the topography of the district and it is highly exposed to soil erosion. The soil analyses indicated that the proportion of sand, silt and clay was 94, 1 and 5%, respectively, indicating that the textural class of the experimental site is sandy. Besides, the pH value of the soil was 7.05, indicating the site is ideal for common bean production. The average annual rainfall varies from 350 to 650 mm and the temperature ranges from 21 to 41°C. The distribution of rainfall is erratic and variable, which results in strong variation in crop, yields (Dereje *et al*., 2007). The rainfall distribution is unimodal, concentrated during the summer (July to August) leading to one cropping season per year (Belay *et al*., 2017).

Experimental design and crop management

Five export-type Haricot bean varieties (Table 1), sourced from Melkasa Agricultural Research Center (MARC) were evaluated in this study. These varieties were planted under field conditions in a randomized complete block design (RCBD) replicated thrice. The plot size was 4 x 3.2 m (12.8 m^2) having 8 rows with a harvestable plot area of 1.6 x 4 m (6.4 m^2) with four rows and spacing 40 cm between rows and 10 cm between plants was maintained. The spacing between plots and blocks was 0.50 and 1 m, respectively. Di-ammonium phosphate (DAP) fertilizer was applied at a rate of 100 kg ha^{-1} at planting. Livestock were excluded by fencing. No irrigation was applied. Weeds were controlled periodically by hand weeding and other management practices like pest or disease control was done as required.

Data collection and sampling techniques

An agronomic, phenological and morphological trait of each variety was collected following *Phaseolus vulgaris* L. descriptor (Debouck and Hidalgo, 1986). The data recording for each trait was carried out as follows.

Phenological traits

Days to 50% emergence: The number of days recorded when 50% of the seedlings emerged from the soil in each plot.

Days to 50% flowering: This was determined by counting the number of days from emergence to the time when 50% of the plant starts flowering through visual observation.

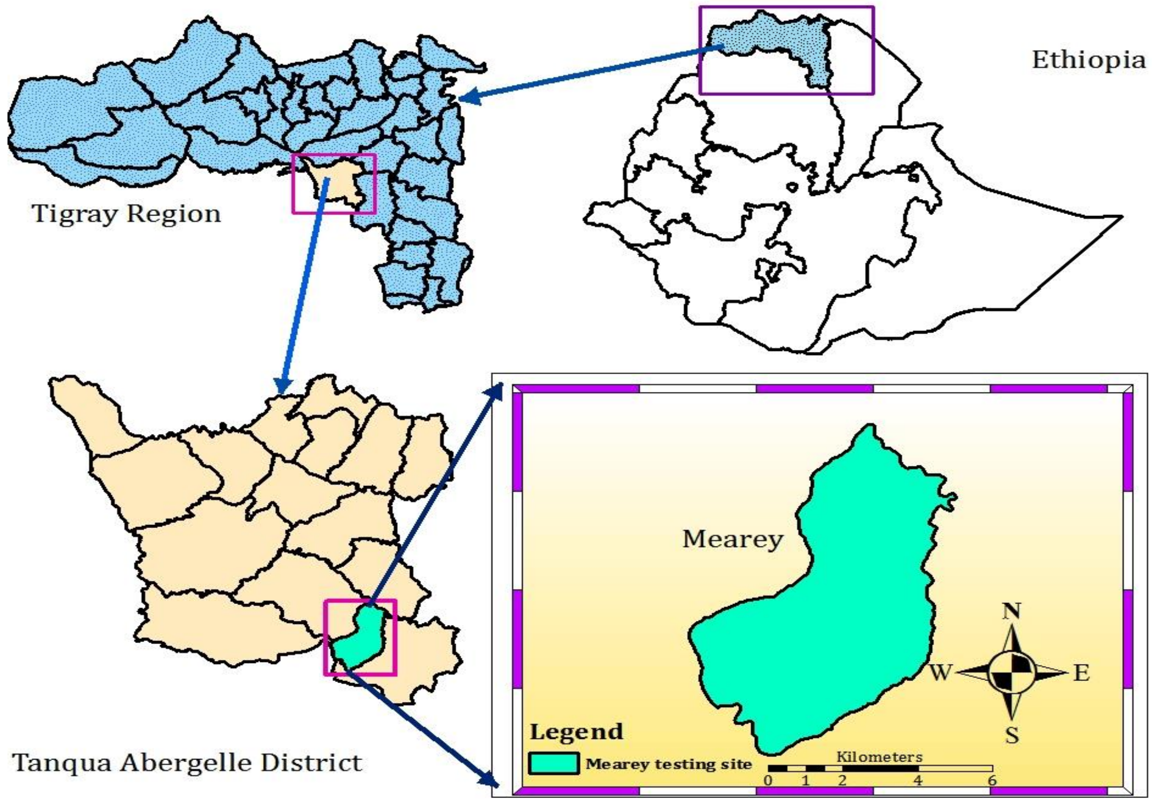

Figure 1. Map of the study area.

Table 1. Description of common bean varieties

Genotype	Seed color	Seed size	Adaptation masl	Year of release	Breeder/Maintainer
Awash melka	White	Small	1400-2200	1999	MARC/EIAR
Awash-1	White	Small	1400-2200	1990	MARC/EIAR
Akos red	Red	Medium	1400-1850	2007	MARC/EIAR
Mexican-142	Creamy	Small	1400-1850	1973	MARC/EIAR
Argene	White	Small	1400-1850	2005	MARC/EIAR

MARC = Melkasa Agricultural Research Center, EIAR= Ethiopian Institute of Agricultural Research.

Days to 90% physiological maturity: This was recorded as the number of days from emergence to the stage when 90% of the plants in a plot had mature pods in their upper parts with pods in the lower parts of the plants turning yellow.

Seed filling period: It was recorded as days from flowering to maturity.

Morphological traits

At the pod setting stage, five plants were randomly selected from each plot and carefully tagged. These plants were used to measure traits like:

Pod length: The exterior was measured for 5 pods from five plants in centimetres.

Plant height: The height of the plant measured at physiological maturity from the ground surface to the tip of the main stem was recorded in centimetres from 5 plants.

Yield and yield related traits

Five plants were randomly selected from the four central rows to determine the yield-related traits as given below.

Number of pods per plant: Fertile number of pods from 5 sampled plants were counted and recorded.

Number of seeds per pod: It was determined from the average number of seeds per 10 pods per 5 sampled plants.

Thousand seed weight: It was determined from the 1000-seed weight at (10%) moisture content of the seed randomly selected from the plot and expressed in grams.

Seed yield: The central four rows were threshed from each plot and seeds obtained from them were adjusted to standard moisture level (10%) per plot in grams and converted into tons per hectare.

Biological (**biomass) yield**: The weight in grams of sun-dried above-ground parts of the plants was recorded from the central four rows. Since the common bean plants start shedding leaves at the late pod setting stage, five plants were tagged from destructive rows at the late pod setting stage and then the old leaves, *i.e.* the leaves that lose their pigmentation were collected each day and stored in polythene bag up to the crop reaching the exact date of physiological maturity in order to estimate above-ground dry biomass yield including leave parts. At physiological maturity, the aboveground dry biomass of five pre-tagged plants from the destructive rows was measured after oven-drying the harvested produce at constant weight at 70$^{°C}$ for 24 hours. For obtaining the total aboveground dry biomass, the dry biomass per plant, thus, obtained was multiplied by the total number of plants in the net plot area and converted into ton ha^{-1}. This was used to calculate the harvest index.

Harvest index (HI): It was calculated as the ratio of seed yield to total above-ground biomass yield (biological yield).

$$\text{HI} = \frac{\text{Seed yield}}{\text{Total above ground biomass}}$$

Data analysis

Homogeneity of error variance was tested prior to combined analysis using Bartlett's test (Steel and Torrie, 1980) and statistical analyses were performed using the Statistical Analysis System (SAS) software version 9.1 program (SAS Institute, 2004). Means were separated using Fisher's Least Significant Difference (LSD) test at a 5% level of probability as stated in Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Phenological traits

A significant difference was observed between varieties for days to emergence, flowering, seed filling period and physiological maturity (Table 2). Even though, Akos red was late to emerge (8 days), it was flowered 37 days and matured 64 days earlier than the other varieties. However, Awash melka filled its seeds in a short period (17 days), thus, making it more adaptable in drought-prone areas. The observed difference in earliness traits (days to flowering, seed filling period and days to physiological maturity) were due to varieties' differences in genotypic makeup, as common bean show variability in growth habit, seed characteristics, maturity and adaptation. It could be also due to better local adaptation to the Northern Ethiopia environments (Murut *et al*., 2014; Gereziher *et al*., 2017). The obtained result was in line with the works of Agza *et al.* (2012), Sisay (2015) and Belay *et al*. (2017) in cowpea, who reported that legumes can do well on sandy loam soils which can help in producing extensive root system that extracts moisture from lower depth of soil.

Morphological traits

Highly significant (p≤0.01) difference was observed between varieties for plant height (Table 3). The highest plant height (56.90 cm) was recorded for Mexican-142, whereas, the shortest plant height (26.90 cm) was recorded for Argene. In line with the finding, the existence of genotypic variation in plant height (Awan *et al*., 2014; Zelalem, 2014 and Gereziher *et al*., 2017) has been reported for common bean.

In terms of pod length there was a significant (p≤0.05) varietal difference. Akos red had scored the tallest pod length (12.30 cm) while Argene had scored the shortest pod length (6.91 cm).

Yield and yield related traits

Number of pods per plant (PPP)

Highly significant differences (p<0.01) were exhibited among Haricot bean varieties for the number of pods per plant. Relatively more numbers of pods per plant were recorded from the Mexican-142 variety with 31.4 pods per plant. On the contrary, Akos red followed by Argene had a lower number of pods per plant with 11.8 and 11.9, respectively (Table 3).

Number of seeds per pod (SPP)

Haricot bean varieties exhibited variation in number of seeds per pod. The variety Awash melka produces more seeds per pod (5.29) compared to the other varieties, while, Akos red produces the lowest number of seeds per pod about 4 seeds per pod.

Seed yield (SY)

A significant variation was observed among Haricot bean varieties in their response to seed yield. The highest seed

Table 2. Mean values of phenological traits of Haricot bean varieties tested at Abergelle on station.

Variety	DE			DF			DM			SFP		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Mexican-142	5.0^{d}	6.0^{c}	6.0^{c}	58^{a}	56.13^{b}	57^{b}	79.13^{a}	80.0^{a}	80.0^{a}	21.0^{d}	24.0^{c}	23.0^{c}
Akos red	8.0^{a}	8.0^{a}	8.0^{a}	37^{d}	36.8^{e}	37^{e}	65.0^{d}	62.60^{c}	64.0^{c}	28.0^{b}	26.0^{b}	27.0^{b}
Argene	6.0^{c}	6.0^{c}	6.0^{c}	50^{b}	51.13^{c}	51^{c}	74.13^{c}	75.0^{b}	75.0^{b}	24.0^{c}	24.0^{c}	24.0^{c}
Awash melka	7.0^{b}	7.0^{b}	7.0^{b}	60^{a}	58.13^{a}	59^{a}	75.5^{bc}	76.0^{b}	76.0^{b}	16.0^{e}	18.0^{d}	17.0^{d}
Awash-1	6.0^{d}	6.0^{c}	6.0^{c}	44^{c}	45.63^{d}	45^{d}	75.0^{bc}	75.0^{b}	75.0^{b}	31.0^{a}	29.0^{a}	30.0^{a}
LSD (5%)	0.89	0.94	1.0	2.25	2.0	1.5	3.05	5.1	7.0	2.5	2.0	3.0
CV (%)	3.9	4.78	5.71	2.50	2.31	1.8	1.78	3.6	5.1	5.6	1.24	4.0

Means with the same letter are not significantly different at $P \leq 0.05$. DE=Days to 50% emergence, DF=Days to 50% flowering, SFP=seed filling period, DM= days to 50 % maturity, LSD=least significance difference, CV (%) = coefficient of variation in percent.

Table 3. Mean values of morphological traits of Haricot bean varieties tested at Abergelle on station.

Variety	PH			PL			PPP			SPP		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Mexican-142	53.47^{a}	60.34^{a}	56.9^{a}	7.6^{bc}	7.93^{b}	7.76^{bc}	30.18^{a}	32.7^{a}	31.4^{a}	4.8^{ab}	4.72^{b}	4.76^{b}
Akos red	31.80^{b}	21.96^{e}	26.9^{d}	12.2^{a}	12.36^{a}	12.3^{a}	9.68^{b}	13.9^{d}	11.8^{d}	4.13^{b}	3.95^{c}	4.04^{b}
Argene	37.20^{b}	33.0^{d}	35.1^{c}	6.5^{c}	7.35^{b}	6.91^{d}	7.33^{b}	16.4^{cd}	11.9^{d}	5.27^{a}	5.0^{ab}	5.13^{a}
Awash melka	33.87^{b}	46.4^{b}	40.2^{b}	8.1^{b}	8.85^{b}	8.49^{b}	22.07^{a}	28.7^{ab}	25.4^{b}	5.0^{a}	5.58^{a}	5.29^{a}
Awash-1	32.93^{b}	37.94^{c}	35.4^{c}	7.1^{bc}	7.66^{b}	7.4^{cd}	18.9^{ab}	23.4^{bc}	21.1^{c}	5.3^{a}	5.2^{ab}	5.21^{a}
LSD (5%)	7.57	4.71	4.16	1.59	2.0	1.12	11.90	9.05	5.4	0.80	0.7	1.0
CV (%)	7.2	4.32	4.1	10.6	1.29	7.6	27.11	21.62	5.5	8.57	7.14	3.5

Means with the same letter are not significantly different at $P \leq 0.05$. PH= plant height, PL= pod length, SFP=seed filling period, SPP= number of seeds per pod, PPP= number of pods per plant, LSD=least significance difference, CV (%) = coefficient of variation in percent.

yield was recorded from the variety Awash melka (1.9 t ha^{-1}) while the lowest yield was recorded from Argene (0.58 t ha^{-1}). The trial site is characterized by less moisture and low soil fertility conditions; hence varieties which tolerate these stresses perform best. Successful cultivars must have good yield and other essential agronomic characters. Awash melka had a significantly higher yield (performed well and gave better yield) than the other Haricot bean varieties and this variety required less number of days to fill its seeds, thus, making it more adaptable in drought-prone areas. The greatest yield of this variety could be due to its inherent genetic potential. It could be also due to better local adaptation to the study area. Moreover, Murut *et al*. (2014) reported that the Awash melka variety gave a seed yield of 1.9 to 2.07 t ha^{-1} in Northern Ethiopia environments which is in agreement with the current finding.

Biomass yield (BY)

The genotype Mexican-142 had the maximum biological yield with a value (4.46 t ha^{-1}) while Argene had a minimum biological yield with a value (2.18 t ha-1). This result agrees with the findings of Singh (2001) who reported the maximum and minimum mean value for biological yield, 1000 seed weight, and seed yield of common beans.

Harvest index (HI)

Significant varietal difference was observed for the harvest index (Table 4). Awash melka had the maximum harvest index with a value of 0.46 while Argene had a minimum harvest index with a value of 0.28. The range and mean values in this study suggest the existence of sufficient variability among the tested varieties for the majority of the traits studied and their considerable potential for improvement of common bean.

Thousand seed weight (1000SW)

The varieties tested had a significant variation among each other for thousand seed weight. Akos red produces the highest seed weight (358 g) while Argene was the lowest (117 g) followed by Mexican-142 (130 g). Overall, the large seeded bean type showed the highest thousand seed weight while for small seeded bean type was lowest.

Generally, the range of variation was wide for most of the yield and yield-related traits such as biological yield, seed yield, harvest index, 1000-seed weight and number of pods per plant while other traits showed low to fairly high range values (Table 5). The current variations in yield and yield-related traits among varieties consent with previous reports of Alemu *et al.* (2014), Tadesse *et al.* (2014), Murut

Table 4. Mean values of yield and yield related traits of Haricot bean varieties tested at Abergelle on station.

Variety	SY			BY			HI			1000SW		
	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean	2013	2014	Mean
Mexican-142	1.18^{ab}	1.24^{b}	1.21^{b}	5.1^{a}	4.24^{a}	4.67^{a}	0.24^{b}	0.338^{b}	0.29^{b}	126.0^{d}	133.9^{c}	130^{b}
Akos red	1.19^{ab}	0.97^{c}	1.08^{b}	2.7^{cd}	2.24^{b}	2.48^{d}	0.43^{a}	0.428^{a}	0.43^{a}	329.3^{a}	386.5^{a}	358^{a}
Argene	0.47^{c}	0.68^{c}	0.58^{c}	2.2^{d}	2.16^{c}	2.18^{d}	0.22^{b}	0.329^{b}	0.28^{b}	110.0^{e}	123.5^{d}	117^{b}
Awash melka	1.75^{a}	1.91^{a}	1.83^{a}	4.0^{a}	4.19^{a}	4.10^{b}	0.433^{a}	0.480^{a}	0.46^{a}	154.7^{b}	160.9^{b}	158^{b}
Awash-1	0.99^{bc}	1.1^{bc}	1.02^{b}	3.4^{bc}	3.14^{b}	3.27^{c}	0.29^{ab}	0.355^{b}	0.32^{b}	132.7^{c}	138.0^{c}	135^{b}
LSD (5%)	0.525	0.25	0.50	1.05	0.5	0.67	0.16	0.1	0.11	3.90	7.39	114
CV (%)	15.71	11.45	24.4	16.6	17.73	11.7	17.24	7.8	17.3	1.26	2.15	23.13

Means with the same letter are not significantly different at P≤ 0.05. SY=seed yield, BY= biomass yield, HI=harvest index, 1000SW= thousand seed weight, LSD=least significance difference, CV (%) = coefficient of variation in percent.

Table 5. Mean squares of agronomic traits from analysis of variance of Haricot bean varieties tested at Abergelle on station.

Traits	Mean square			Mean	CV (%)
	Replication (DF=2)	Treatments (DF=4)	Error (DF=8)		
Days to emergence	0.133	0.352**	0.03	6.467	5.7
Days to flowering	1.71	3.99*	0.76	49.67	1.8
Seed filling period	0.92	8.34**	0.95	24.12	4
Days to maturity	0.133	3.78**	0.18	73.73	5.1
Plant height	67.36	101.05**	5.87	38.9	4.1
Pod length	0.13	0.126*	0.419	8.57	7.6
Number of seeds per pod	1.218	0.174*	0.03	4.885	3.5
Number of pods per plant	248.48	9.475*	9.91	20.32	5.5
Thousand seed weight	73.05	730.95**	3.61	179.55	23.1
Seed yield	0.181	1.22**	0.08	1.142	24.4
Biomass yield	0.604	0.25*	0.153	3.34	11.7
Harvest index	0.01	0.033*	0.004	0.353	17.3

*, ** = significant at P≤ 0.05 and P≤ 0.01, respectively, DF= degree of freedom, CV (%) = coefficient of variation in percent.

et al. (2014), Yohannes and Berecha (2015), Mulu *et al.* (2016) and Gereziher *et al.* (2017) in common bean; Yoseph (2014) and Belay *et al*. (2017) in cowpea.

Conclusion and Recommendation

The current study entails the presence of significant genetic variation among yield and yield related traits of released common bean varieties. The combined analysis of variance revealed significant varietal differences for days to 50% emergence, flowering, seed filling period and 90% physiological maturity, pod length, plant height, number of pods per plant, number of seeds per pod, seed yield, biomass yield, harvest index and thousand seed weight.

Awash melka had significantly the highest yield (1.9 t ha^{-1}) (performed well and gave better yield) than the other Haricot bean varieties and this variety required less number of days (17) to fill its seeds, whereas, the variety Argene generally performed poorly.

Overall, Awash melka had better performance than the other varieties for yield and yield-related traits. Therefore, it is recommended as a promising variety to increase the source of cash crops for farmers in the study area, Abergelle and foreign currency as export crops of the country, Ethiopia.

CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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