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Adaptation Study of Improved Common Bean (Phaseolus vulgaris L.) Varieties under Irrigated Condition in the middle Awash Rift Valley, Werer, Ethiopia.

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Common bean (Phaseolus vulgaris L.) is one of the most important leguminous cash crops and source of protein for farmers in many lowlands and mid-altitude zones of Ethiopia. The crop is mainly produced in rain fed areas and its production using irrigation water remained stagnant in most regions of the country, like middle awash rift valley region. Consequently, this particular study was conducted to identify, select and recommend adaptable, high yielding, and tolerant varieties for irrigation growing condition, as well as to test the suitability of the area for common bean production. Fifteen improved common bean varieties were evaluated at Werer Agricultural Research Center, during 2015/2016 cropping season. Result from ANOVA revealed that, highly significant (P≤0.01) varietal differences were observed for all of the studied parameters except for harvest index. The varieties BATU, KAT-B1, KAT-B9 and SAB-736 were flowered and matured early among the tested common bean varieties. Grain yield was highly, significantly (p≤0.01) and positively associated with plant height, number of seeds pod^{-1}, number of pods plant^{-1} and biomass yield, indicating the traits were found to be yield contributing factors of common bean. The maximum grain yield coupled with better number of seeds pod^{-1} and pods plant^{-1} was noted for the varieties NASIR, SER-119, AWASH-MELKA and AWASH-1. Generally, common bean varieties tested for their adaptation under this new growing environment respond well and thus the area was suitable for production of beans using irrigation water.

Key words: adaptation, common bean, *Phaseolus vulgaris,* variety, irrigation, grain yield.

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INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is the world's most important food legume for direct human consumption. Average per capita consumption of common bean in the main bean production areas is higher in Africa, estimated at 31.4kg year^{-1} (Schoonhoven and Voysest, 1991). Of the five domesticated species of *Phaseolus*, the common bean (*P. vulgaris*) is the most widely grown, occupying more than 85% of production area sown to all *Phaseolus* species in the world (Singh, 2001).

In Ethiopia, the crop is one of the most important cash crops and source of protein for farmers in many lowlands and mid-altitude zones. The country's export earnings is estimated to be over 85 % of other pulses, exceeding that of pulses such as lentils, horse (faba) bean and chickpea (Negash, 2007). Overall, common bean ranks third as an export commodity in Ethiopia next to coffee and sesame (Mekuria, 2015), contributing about 9.5% of total export value from agriculture (FAOSTAT, 2010). Total national production was estimated at 421,418 ton in 2008 with average productivity of 1.6t ha^{-1}(CSA, 2016), with a market value of US$ 132,900,609 (FAOSTAT, 2010).

Common bean is also highly preferred by Ethiopian farmers because of its fast maturing characteristics that enables households to get cash income required to purchase food and other household needs when other crops have not yet matured (Legesse *et al*., 2006). Two types of common bean are grown: the canning type primarily grown for export market dominates the Oromiya region (North-East rift valley), and the cooking type primarily grown for food in the Southern National Nationality Peoples' region, south of lake Ziway (Alemu and Bekele, 2005). Significant amounts of the cooking type are exported to the neighboring countries particularly Kenya (Ferris and Kaganzi, 2008).

In Ethiopia, production of major field crops is concentrated in rain fed areas and irrigation production systems remained stagnant in almost all potential growing regions of the country. Limited irrigation facilities, limited use of available irrigation water for field crops production (rather attentions given for commercial crops like fruits, vegetables etc.) and limited accessibility of improved agricultural technologies (especially crops) to pastoral and agro-pastoral areas of the country where at least surface irrigation facilities are available but neglected to produce valuable crops, are among the constraints related with irrigation based production and productivity of beans.

In Ethiopia about 57 improved common bean varieties has been released yielding up to 2.5-3.5 t ha^{-1} at research fields (MoANR, 2016), and there is still a gap with national average yield (1.6 t ha^{-1}) and remain below the potential productivity. Therefore, this has to be supported with other agricultural production systems like using irrigation water, and hence this experiment was initiated for identifying, selecting and recommending, adaptable, high yielding and tolerant common bean varieties, under full irrigation agriculture system in pastoralist and agro-pastoralist community in middle awash rift valley area, and assessing suitability of the site for production of *Phaseolus vulgaris.*

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Werer Agricultural Research Center, found in Zone three of Afar Regional State, cover a long broad alluvial plain along the right bank of the Awash river. The elevation is at about 740 *masl* and located at 9°20'31" N latitude and 40°10'11" E longitude in the Middle Awash Rift Valley, close to the main high way linking Addis Ababa to Djibouti, and 280 km far from the capital of Ethiopia, Addis Ababa.

The climate is semi-arid with a bimodal rainfall of 533 mm annually. The mean minimum temperature is 15.2^{O}C and the mean maximum temperature is 38^{O}C. Mean relative humidity is lowest in June at 36% and highest in August at 58%. The area receives the average daily sunshine of 8.5 hours with an average solar radiation of 536 calories square $centimeter^{-1}$ day^{-1} (Girma and Awulachew, 2007).

The soils are brown in color and turn to dark brown when moist. The pH of the soil is slightly alkaline and ranges from 7.5 to 8.5.The major crops grown in the area are, cotton and sugar cane with minor crops including maize, sesame, rice, wheat, pulses, date palm, banana and vegetables in some areas around Werer Agricultural Research Center and other areas in the region.

Experimental Procedures and Plant Materials

Field evaluation of fifteen released common bean varieties introduced from Melkasa Agricultural Research Center was conducted during the main cropping season of 2015/2016 at Werer Agricultural Research Center. The treatments were laid in RCB design with three replications having plot size of 9.6m^2 (4m x 2.4m), accommodating 8 rows of 4m length. The spacing between rows and plants was 30cm and 10cm, respectively. Harvesting was done from six central rows and each plot has net harvestable area of 7.2m^2. The plots were surface irrigated by Awash River and the interval varied depending on climatic conditions. (Table 1)

Measurements of Plant Growth and Yield Parameters

The study consisted of crop phenology parameters (days to 50% flowering (DTF), days to physiological maturity (DTM) and grain filling period (GFP)); growth parameters (plant height (PTH)) and yield parameters (number of pods $plant^{-1}$ (NPPL), number of seeds pod^{-1} (NSPD), biomass yield (BMY), hundred seeds weight (HSW), harvest index (HI) and grain yield $hectare^{-1}$ (GYHA)). DTF and DTM were recorded for each variety on the plot by regular observation, when 50% or more of the plants flowered, as days to 50% flowering and when 90% of the pods in a plot dried, as days to physiological maturity of each plot.

At physiological maturity, five plants from central rows were randomly selected and PTH in centimeters was determined. At harvest, five plants were randomly collected and yield components like NPPL, NSPD and HSW were recorded. HI (%) was calculated as ratio of

Table 1. List of common bean cultivars used in the experiments.

GLP-2	Nasir	SER-125	Deme	Awash-2
SAB-736	SER-119	Awash-1	KAT-B1	Batu
Eac-0056	SAB-632	Melka-Dima	Awash-Melka	KAT-B9

GYHA to total BMY x100. Grain yield was collected from six central rows of each plot (7.2m^2) and the harvested aerial plant parts were air dried at field condition for 48hrs to determine BMY. GFP, which was defined as the number of days from 50% flowering to number of days to physiological maturity was also computed and analyzed.

All measured parameters (crop phenology, growth parameters, grain yield and yield components) were subjected to analysis of variance (ANOVA) using PROC GLM of SAS software version 9.1 (Anonymous, 2002) and the significance of mean differences were tested by least significant difference test *p≤0.05* (LSD) as stated in Gomez and Gomez (1984).

Correlation Coefficient (r)

A correlation coefficient is a coefficient that illustrates a quantitative measure of some type of correlation and dependence, meaning statistical relationships between two or more random variables or observed data values. Several correlation coefficient types have been widely used. Pearson's correlation (also called Pearson's *R*) is a correlation coefficient that was commonly used in linear regression. Therefore, for this particular experiment, Pearson's correlation (*r*) was used to illustrate statistical relationships among the studied traits and calculated using the formula below.

$$r_{XY} = \frac{\sum_{i=1}^{n}(X_i - \overline{X})(}{\sqrt{\sum^{n} (X_{\cdot} - \overline{X})^2}\sqrt{}}$$

RESULT AND DISCUSSIONS

Analysis of Variance

Analysis of variance obtained from ten studied traits of common bean was indicated in table 2. According to the result, there was presence of highly significant varietal differences *(P≤ 0.01)* for DTF, DTM, PTH, NPPL, NSPD, BMY, HSW, and GYHA. However, no significant varietal differences observed in HI percentage. The replication effect was not significantly different for all characters (Table 2). Similarly, Biru and Dereje (2014), reported presence of significant varietal differences for GYHA, DTF, DTM, NSPD, NPPL, HSW, and PTH, and no significant replication effect in common bean varieties.

Variations in Mean Performances of the Varieties

Mean performances of common bean varieties grown under irrigation condition at Werer indicated the presence of variability among the cultivars for crop phenology traits, growth traits, yield and yield determining traits were shown in table 3 and 4.

Variations in Crop Phenology

Among the cultivars included in the experiment, BATU, KAT-B1 and KAT-B9 were early flowered with mean values of 37.00, 37.33 and 37.67 days after sowing, respectively. Whereas, AWASH-MELKA, AWASH-1 and SER-125 cultivars were flowered late with mean values of 52.00, 48.67 and 44.00 days after sowing, respectively. SAB-736, KAT-B1 and KAT-B9 cultivars were relatively matured earlier with mean values of 77.67, 78.67 and 80.67 days after sowing, respectively. In addition, minimum days to fill grains were noted in cultivars SER-125, AWASH-MELKA, and SAB-736 with mean values of 36.00, 38.00 and 39.00 days, respectively (Table 3).

Variation in Growth Trait

Plant height was highly and significantly *(p≤0.01)* varied among the cultivars. Hence, the cultivars with shortest plant stature were KAT-B9, SAB-736 and BATU with above ground heights of 21.47cm, 25.00cm and 26.60cm, respectively. In contrast, GLP-2, DEME and NASIR exhibited longest plant stature of all the cultivars with mean values of 95.07cm, 93.45cm and 92.87cm, respectively (Table 3).

Variations in Yield and Yield Related Traits

The maximum grain yield was obtained from the varieties NASIR (1658.6kg ha^{-1}), followed by SER-119 (1648.3kg ha^{-1}), AWASH-MELKA (1468.7kg ha^{-1}) and AWASH-1 (1336.6kg ha^{-1}). On the contrary, the lowest grain yield was obtained from SAB-736 (550.4kg ha^{-1}), DEME (593.3 kg ha^{-1}) and SAB-632 (693.4kg ha^{-1}). The varieties AWASH-MELKA, AWASH-1, AWASH-2 and NASIR were top in bearing higher number of seeds pod^{-1} and pods plant^{-1}, and were lower on EAC-0056, KAT-B9, SAB-736 and DEME varieties (Table 4).

Better hundred seeds weight was noted in SAB-632

Table 2. Mean squares for different sources of variation, the corresponding CV (%) and R^2 of the 10 common bean characters studied at Werer, during 2015/16.

S/No	Characters	Mean Squares: Source of Variation: Treatment (14)¥	Mean Squares: Source of Variation: Replication (2)	Mean Squares: Source of Variation: Error (28)	Grand Mean	CV	R^2
1	DTF	50.72**	27.8	4.25	42.07	4.9	0.87
2	DTM	58.33**	69.07	10.69	85.33	3.83	0.76
3	GFP	47.01**	92.47	14.63	43.27	8.84	0.67
4	PTH	2009.69**	547.46	40.78	52.84	12.09	0.96
5	NSPD	2.80**	2.00	0.58	4.22	18.06	0.73
6	NPPL	47.94**	37.98	12.29	14.65	23.93	0.68
7	BMY	29258414.0**	144123424.3	3454280.8	9234.67	20.13	0.88
8	GYHA	388550.9**	1892387.6	158448.1	1050.82	37.88	0.68
9	HSW	158.23**	109.98	4.59	28.83	7.43	0.95
10	HI (%)	48.69^{ns}	8.96	31.18	12.60	44.30	0.44

Note:*, **, *ns indicate significance at ≤0.05 and ≤0.01 probability levels, and non-significant, respectively, ¥=figures in parenthesis refers to degrees of freedom.*

DTF= days to 50% flowering, DTM= days to physiological maturity, GFP= grain filling period, PTH= plant height (cm), NSPD= number of seeds pod^{-1}, NPPL= number of pods plant^{-1}, BMY= biomass yield (kh ha^{-1}), GYHA= grain yield (kg ha^{-1}), HSW= hundred seeds weight (gm), HI= harvest index.

Table 3. Mean performance values of phenological and growth traits in common bean varieties grown under irrigation condition at Werer, during 2015/2016.

S/No.	VARIETIES	TRAITS: DTF€	DTM	GFP	PTH
1	GLP-2	40.33^{cdef}	89.00^{ab}	48.67^{a}	95.07^{a}
2	SAB-736	38.67^{def}	77.67^{e}	39.00^{def}	25.00^{gh}
3	EAC-0056	41.67^{bcd}	86.67^{ab}	45.00^{abcd}	39.53^{ef}
4	NASIR	43.33^{bc}	86.33^{ab}	43.00^{abcde}	92.87^{a}
5	SER-119	43.33^{bc}	83.67^{bcd}	40.33^{cdef}	69.33^{b}
6	SAB-632	41.33^{bcd}	86.67^{ab}	45.33^{abcd}	32.67^{fg}
7	SER-125	44.00^{b}	80.00^{cde}	36.00^{f}	48.93^{de}
8	AWASH-1	48.67^{a}	90.67^{a}	42.00^{bcdef}	50.93^{d}
9	MELKA-DIMA	41.00^{bcde}	84.33^{bc}	43.33^{abcde}	58.67^{bcd}
10	DEME	41.00^{bcde}	90.00^{a}	49.00^{a}	93.45^{a}
11	KAT-B1	37.33^{f}	78.67^{de}	41.33^{cdef}	23.07^{gh}
12	AWASH-MELKA	52.00^{a}	90.00^{a}	38.00^{ef}	62.80^{bc}
13	AWASH-2	43.67^{bc}	90.33^{a}	46.67^{abc}	52.27^{cd}
14	BATU	37.00^{f}	85.33^{abc}	48.33^{ab}	26.60^{gh}
15	KAT-B9	37.67^{ef}	80.67^{cde}	43.00^{abcde}	21.47^{h}
	LSD	3.45	5.47	6.40	10.68

Note: *Means followed by different letters in the same column differ from each other by the F-test (P≤0.05). €= refer table 2 for the descriptions of abbreviations of the traits.*

(41.40gm) variety, followed by EAC-0056 (37.13gm) and GLP-2 (35.33gm), however AWASH-1, AWASH-2 and AWASH-MELKA were with lowest mean values of 16.57gm, 19.83gm and 20.40gm, respectively (Table 4).

Overall yield performances noted better on the varieties SER-119, NASIR, AWASH-MELKA and AWASH-1 (Figure 1). Generally, the mean values of yield and yield components obtained from data indicated that, released common bean varieties grown under this new and non-previously used environment were respond better and production using irrigation water might be essential, since the crops are highly valuable and exportable commodities.

Table 4. Mean performance values of yield and yield related traits in common bean varieties grown under irrigation condition at Werer, during 2015/2016.

S/No.	VARIETIES	TRAITS					
		NSPD€	NPPL	BMY	GYHA	HSW	HI
1	GLP-2	3.87^{def}	13.53^{cde}	12963^{ab}	1103.8^{abcd}	35.33^{bc}	8.57^{cd}
2	SAB-736	3.47^{ef}	12.20^{cde}	5648^{ef}	550.4^{d}	28.77^{def}	18.63^{ab}
3	EAC-0056	2.73^{f}	9.40^{e}	7685de	795.8^{cd}	37.13^{b}	11.00^{abcd}
4	NASIR	4.93^{abcd}	20.07^{ab}	11111^{bc}	1658.8^{a}	21.77^{g}	14.37^{abcd}
5	SER-119	4.40^{bcde}	17.33^{bc}	12454^{abd}	1648.3^{a}	25.77^{f}	13.63^{abcd}
6	SAB-632	4.27^{cde}	11.73^{cde}	7917de	693.4^{cd}	41.70^{a}	8.67^{cd}
7	SER-125	4.20^{cde}	14.73^{bcde}	10509^{bcd}	1046.1^{abcd}	25.57^{f}	9.90^{bcd}
8	AWASH-1	5.40^{abc}	24.60^{a}	14491^{a}	1336.6^{abc}	16.57^{h}	9.53^{bcd}
9	MELKA-DIMA	4.27^{cde}	14.53^{bcde}	10231^{bcd}	1162.2^{abcd}	27.70^{ef}	11.00^{abcd}
10	DEME	3.73^{def}	11.20^{de}	11111^{bc}	593.3^{d}	36.67^{b}	5.33^{d}
11	KAT-B1	3.67^{def}	11.93^{cde}	3843^{f}	765.3^{cd}	31.77^{cd}	20.23^{a}
12	AWASH-MELKA	6.20^{a}	17.27^{bc}	9861^{bcd}	1468.7^{ab}	20.40^{g}	14.07^{abcd}
13	AWASH-2	5.60^{ab}	17.00^{bcd}	9722^{cd}	1174.9^{abcd}	19.83^{gh}	12.90^{abcd}
14	BATU	3.40^{ef}	12.40^{cde}	5787^{ef}	949.9^{bcd}	31.20^{de}	16.50^{abc}
15	KAT-B9	3.13^{ef}	11.80^{cde}	5185^{ef}	814.9^{bcd}	32.33^{cd}	14.73^{abc}
LSD		1.27	5.86	3108.5	665.75	3.58	9.34

Note: *Means followed by different letters in the same column differ from each other by the f-test (P≤0.05)*
€= refer table 2 for the descriptions of abbreviations of the traits.

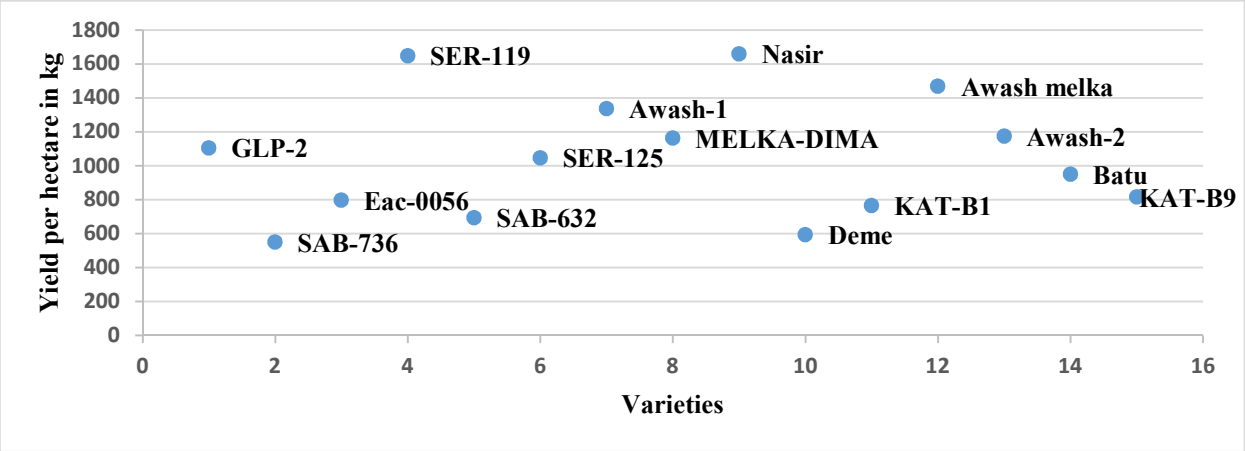

Figure 1. Graphical illustration of yield responses of common bean varieties tested at Werer Agricultural Research Centre, during 2015/16.

Correlation Coefficients Analysis (*r*)

Simple linear correlation (*r*): a measure of the degree to which two variables vary together, or measure of the intensity of the association between the studied traits of common bean varieties grown under irrigation condition at Werer were indicated in table 5.

From the result obtained, most of measured traits were significantly correlated among each other. For example, from crop phenological traits, days to 50% flowering positively and significantly *(p≤0.01)* associated with days to physiological maturity (*r*=0.42) indicating interdependence of the traits to each other. However, grain filling period was associated negatively with days to 50% flowering (*r*=-0.42), whereas, positively and significantly *(p≤0.05)* with days to physiological maturity (*r*=0.65), indicating time taken to flowering inversely affected grain filling period in common beans.

Both days to 50% flowering and physiological maturity were associated positively and significantly *(p≤0.05)* to grain yield (*r*=0.35 and *r*=0.30) and significantly *(p≤0.01)* correlated with other yield traits like number of seeds pod^{-}

Table 5. Correlation coefficients (*r*) among 10 studied traits of common bean varieties grown under irrigation condition at Werer, 2015/16.

TRAITS	DTF€	DTM	GFP	PTH	NSPD	NPPL	BMY	GYHA	HSW	HI
DTF	**1.00**									
DTM	0.42**	**1.00**								
GFP	-0.42	0.65**	**1.00**							
PTH	0.36*	0.48**	0.17	**1.00**						
NSPD	0.62***	0.35*	-0.18	0.30*	**1.00**					
NPPL	0.52**	0.31*	-0.13	0.33*	0.59**	**1.00**				
BMY	0.42**	0.63**	0.27	0.65**	0.29*	0.52**	**1.00**			
GYHA	0.35*	0.30*	-0.01	0.43**	0.44**	0.63**	0.63**	**1.00**		
HSW	-0.54**	-0.01	0.44*	-0.10	-0.56**	-0.55**	-0.08	-0.29	**1.00**	
HI	-0.20	-0.46**	-0.30	-0.35*	-0.01	0.01	-0.46**	0.28	-0.21	**1.00**

Note: ** and ** indicate significance at ≤0.05 and ≤0.01 probability levels, respectively.*
€= refer table 2 for the descriptions of abbreviations of the traits.

^{1} (*r*=0.62 and *r*=0.35), number of pods plant^{-1} (*r*=0.52 and *r*=0.31), biomass yield (*r*=0.42 and *r*=0.63), and negatively correlated with hundred seeds weight (Table 5).

In general, grain yield was significantly *(p≤0.01)* and positively associated with plant height (*r*=0.43), number of seeds pod^{-1} (*r*=0.44), number of pods plant^{-1} (*r*=0.63) and biomass yield (*r*=0.63), indicating the traits contributed positively for grain yield and recognized as yield contributing factors of common bean in this experiment. However, it was negatively associated with hundred seed weight (*r*= -0.29), indicating the size of the seeds resulted in exhibition of negative impact on yield of common bean in this particular study (Table 5).

CONCLUSION AND RECOMMENDATIONS

The adaptation study of fifteen released common bean varieties introduced from Melkassa Research Center for irrigation production condition was conducted at Werer Agricultural Research Center during the main cropping season of the year 2015/2016, aimed to identify, select and recommend adaptable, high yielding and tolerant varieties for irrigation growing condition in pastoral and agro-pastoral community area of the middle awash rift valley, as well as testing the suitability of the site for common bean production.

Data obtained from the present study entails the presence of significant differences among common bean varieties grown under irrigation condition. Accordingly, SER-119, NASIR, AWASH-MELKA and AWASH-1 were respond better and found top best performed varieties with reasonable grain yield and other studied yield related traits, as well as crop phenology and plant growth parameters.

Grain yield was positively associated with crop phenological traits (days to 50% flowering and days to physiological maturity) and other yield determining traits (seed number pod^{-1}, pod number plant^{-1}, plant height, biomass yield and harvest index) studied in this particular experiment, confirming that, grain yield was dependent on those positively correlated traits in common beans.

In addition, the positive response of varieties to the study area indicated that, the environment was found suitable for common bean production, however additional investigations has to be conducted on other agronomic parameters and crop management packages necessary for augmentation of yield in common bean grown under irrigation condition of the study area and other areas having similar agro-ecology.

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