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Evaluation of varietal responses for growth, yield and yield components of haricot bean (*Phaseolus vulgaris* L.) in two districts at Bench- Maji Zone, Southwest Ethiopia

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Variety trials with haricot bean have long been studied; varietal response for maximum yielding ability, however, depends on agro-ecological conditions of a particular growing environment. Therefore, the current study evaluates the performance of varieties on growth, yield and yield components of Haricot bean at two locations of Bench-Maji Zone. The treatment consists of eight nationally released varieties and one local check. The experiments were conducted during 2015 and 2016 main cropping seasons at South Bench and Menit Shasha districts, respectively. It was laid out in a randomized complete block design with three replications. Data on growth yield and yield related parameters were collected and analyzed using SAS software. The results showed that varieties had a significant effect on plant height, primary branches, number of pods per plant, and number of seeds per pod, stand count at harvest, total biomass, harvesting index, 100 seed weight, and grain yield. Four nationally released varieties, namely Nasir, Roba, Awash-Melka and Red Wolayita were found to be the top performing and best-adapted varieties under the agro-ecological conditions of the studied areas. On the other hand, variety Nasir outperformed over the local checks, at both locations. The yield advantage of this variety over the local checks at Menit Shasha and South Bench districts was 23 and 37%, respectively. Therefore, variety Nasir is recommended for cultivation in the studied areas and other locations with similar agro-ecological conditions. If need arises for additional confirmation; further adaptation trials across more locations and years are of paramount importance.

Key words: Haricot bean, variety, evaluation, growth, yield, yield component.

INTRODUCTION

Haricot bean is the most important grain legume for human consumption; and comprises 50% of the grain legumes consumed worldwide (Broughton et al., 2003; Graham et al., 2003). It is the most economically important pulse crop grown in Ethiopia (Dereje et al., 1995). The crop is usually grown by subsistence farmers as a sole crop and/or intercropped with other crops. Considering the production volume and importance, it is seen as a major pulse crop in many parts of the country (Legesse et al., 2006).

Accordingly, a continuous increase in area and volume of production has been registered. The national production

of haricot bean in 2015 cropping season is estimated at over 540.24 thousand tons, with a production area of 357.29 thousand hectares. The average yield per hectare is 1.48 tons (CSA, 2016). Haricot bean is the most important food legume and source of protein in Ethiopia (Dejene et al., 2016). It is also an important export commodity that generates foreign exchange and a major staple food, supplementing the protein source for the majority of citizens in the country (Ferris and Kaganzi, 2008; Girma, 2009).

In Benchi Maji Zone, farmers grow haricot bean mostly as an intercrop and/or in pure stand as a sole crop. The average yield per hectare of haricot bean in Bench-Maji Zone is (1.796 t ha^{-1}) which was far greater than the national annual average yield (1.48 t ha^{-1}) (CSA, 2016). In fact, the area has possibly the highest potential for haricot bean production than any region in Ethiopia; its productivity has never reached full potential of production that has been attained in research centers (2.6-3.6 t ha^{-1}) (CSA, 2011). Several factors are responsible for this, among which are infertility caused by acidic soils, lack of adapted varieties and biotic factors (disease and pests), consider as the top list (Assefa, 1994; Girma et al., 2017). If the natural potential of the area is supported by technologies, it can be said that the Bench-Maji Zone will be a major bulk-producing area of haricot bean.

In Bench-Maji Zone where experiment was conducted, very little information is available on how growth and yield components of haricot bean are affected by different varieties. Cognizant of the sparse information available in the region, the objectives of the current study were, to investigate the response of haricot bean varieties regarding growth, yield and yield components of haricot bean; with the view to identify the best adapted haricot bean varieties for higher yield in the studied area.

MATERIALS AND METHODS

Description of the study areas

The experiments were conducted in two locations at the Bench-Maji Zone during the 2015 and 2016 main cropping seasons. The first location was South Bench, which is located at 6°49'47''N of latitude and 35°29'12``E of longitude and elevation 1385 masl. The second location was Menit Shasha, which is located at 6°52' N latitude and 35°21' E longitude and elevation 1150 masl.

The two districts had a long period rain fall distribution and receive a mean annual rain fall ranging from 1200 to 1800 mm with mean minimum and maximum temperatures of 20 to 29°C, respectively. The districts are particularly characterized by mid and high land elevations, with a long growing period.

Treatments and experimental design

The treatment consisted of evaluating eight nationally recognized varieties including Awash Melka, Awash-1, Roba, Chercher, Red–wolayita, Nasir, Mexican–142 and Gofta. One local variety was also included in the trial. The experiment was laid out in a randomized complete block design with three replications. A 2.1 m X 4.8 m (10.08 m^2) gross plot size was used as one experimental unit.

Each of these experimental units included 12 rows, with a spacing of 0.4 m between rows and 0.1 m between plants. A 1.5 m wide-open space was used to separate the block, whereas plots within each block were separated by 1 m.

Experimental procedure

Haricot bean varieties evaluated in this trial were obtained from Melkasa Agricultural Research Center, while the local variety was obtained from farmers in the district. These varieties were selected based on market value, average yield performance and agro ecological adaptation.

Planting was done in accordance with the onset of the rainy season in the area. The national recommended rate of fertilizer, 46 kg P_2O_5 ha^{-1}, was used in form of diammonium phosphate (DAP). The whole dose was applied during planting. All crop management practices were carried out as per the time schedule and existing conditions of the study area. Ten middle rows were used for data collection.

Data collection

Responses of haricot bean varieties in two districts at Bench-Maji Zone were evaluated by, recording growth yield and yield related parameters. Data on growth parameters were taken in each plot from ten randomly selected plants.

Accordingly, ten plants from each plot were randomly taken at harvest for recording yield components such as: numbers of pods per plant, hundred seed weight, and seed number per pod. For biological and grain yield the whole plant from the net plot area was harvested and the yield per hectare was determined by converting the yield per plot (kg per plot) into tons per hectare.

Data analysis

The statistical significance of differences among means for the above parameters was evaluated using analysis of variance (SAS version 9.1.3 software). Mean comparisons were evaluated using a least significant difference test at 5% probability level.

RESULTS AND DISCUSSION

Plant height

Plant height was significantly influenced by varieties at both locations (Table 1). At Menit Shasha and South Bench districts, the lowest mean plant heights, 65.13 and 69.20 cm, respectively, were recorded for variety Nasir; while the recorded maximum heights (83 and 84 cm) were for Gofta; which, however, were statistically at par with the mean plant heights recorded for Red Wolayita

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Table 1. Mean squares of haricot bean as affected by varietal trial in Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variable		Mean square value at Menit Shasha district								
Source of variation	DF	PH	NPB	BYH	SCH	NPP	NSP	HI	HSW	GY
Replication	2	443.43**	0.10^{ns}	0.225**	85.18^{ns}	5.018^{ns}	1.27^{ns}	0.02**	6.04^{ns}	0.19^{ns}
Varieties	8	117.77*	1.35**	0.55**	3206.94**	68.39**	1.86**	0.008**	47.04**	0.41**
Error	16	43.72	0.123	00 0.15	45.49	2.64	0.33	0.002	8.66	0.058
		Mean square value at South Bench district								
Replication	2	450.13^{ns}	0.096^{ns}	0.245^{ns}	64.84^{ns}	3.27^{ns}	1.18*	0.018*	6.82^{ns}	0.16*
Varieties	8	117.82*	1.37**	0.56*	3208.21**	66.99**	1.94**	0.008**	45.51*	0.42**
Error	16	45.67	0.12	0.14	42.27	2.57	0.316	0.002	9.13	0.036

DF: Degrees of freedom, PH: plant height, NPB: number of primary branches, BYH: biomass yield at harvest, SCH: stand count at harvest, NPP: numbers of pod per plant, NSP: number of seed per pod, HI: harvest index, HSW: hundred seed weight, GY: grain yield, *: significant at 5% probability level; **: significant at 1% probability level; ***: significant at 0.1% probability level.

Table 2. Growth parameters of haricot bean as affected by varietal trial at Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variety	Menit Shasha				South Bench			
	PH	NPB	BYH (t/ha)	SCH	PH	NPB	BYH (t/ha)	SCH
Local	71.00^{bc}	5.00^{ab}	4.18^{ab}	165.01^{d}	71.00^{bc}	4.83^{a}	4.06^{bc}	164.33^{e}
Awash melka	68.28^{c}	5.29^{a}	4.07^{ab}	183.67^{bc}	68.27^{c}	5.06^{a}	5.39^{a}	204.33^{a}
Chercher	67.00^{c}	4.07^{cd}	3.57^{bcd}	125.53^{e}	67.00^{c}	4.53^{ab}	3.62^{c}	184.17^{bcd}
Awash 1	70.40^{bc}	5.00^{a}	3.34^{cd}	182.48c	67.80^{c}	4.60^{ab}	4.84^{ab}	199.83^{ab}
Roba	69.20^{bc}	5.27^{a}	4.00^{abc}	194.35^{ab}	70.40^{bc}	4.87^{a}	4.74^{abc}	191.83a^{bc}
Red wolayita	80.13^{ab}	4.30^{bc}	3.61^{abcd}	166.16^{d}	81.11^{ab}	4.33^{ab}	4.19^{abc}	193.67^{abc}
Nasir	65.13^{c}	5.17^{a}	4.29^{a}	203.36^{a}	69.20^{bc}	4.47^{ab}	5.27^{a}	196.50^{abc}
Gofta	83.00^{a}	3.53^{d}	3.15^{d}	116.61^{e}	84.00^{a}	3.73^{b}	3.60^{c}	170.33^{cde}
Mexican 142	76.53^{abc}	3.80^{cd}	3.11^{d}	123.44^{e}	67.50^{c}	4.47^{ab}	4.00^{bc}	181.50^{cde}
LSD	11.4	3.13	0.65	11.67	11.5	0.93	1.2	5.11
CV%	9.12	2.31	10.18	7.16	9.8	17.78	15.71	17.99

Means followed by the same letter in the same column are not significantly different at p $\leq$ 0.05 probability level. PH = plant height, NPB = number of primary branches, BYH = biomass yield at harvest, SCH = stand count at harvest.

(Table 2). However, at Menit Shasha district the heights of Mexican 142 performed similarly with varieties Gofta and Red Wolayita.

The data presented in the preceding paragraph showed that, plant height of haricot bean is influenced by varietal differences in both locations. This finding was in conformity with previous results reported by Mekonen et al. (2012), who also reported significant differences in plant heights among haricot bean varieties. The same result also was reported by Daniel et al. (2014) who found a highly significant variation in plant height among haricot bean varieties in West Belessa, Northwest Ethiopia.

Number of primary branches

The mean number of primary branches in haricot bean was significantly different among the varieties (Table 1). At both Menit Shasha and South Bench, the lowest mean numbers of primary branches 3.53 and 3.73, respectively, were obtained with variety Gofta; while the highest 5.29 and 5.06 were recorded from Awash melka, at par with the majority of the varieties tested in both locations (Table 2).

Variations in the number of primary branches, found among varieties could be due to differences in genotypic characters, responsible for branching. The current results were in agreement with previous reports using the same crop (Amanullah et al., 2006), where the number of primary branches varied significantly among bean varieties.

Biomass yield at harvest

In both locations, a significant (P< 0.01) variation was

Table 3. Yield and yield components of haricot bean as affected by varietal difference at Menit Shasha and South Bench districts of Bench-Maji Zone (2015-2016).

Variety	Menit Shasha					South Bench				
	NPP	NSP	HI	HSW (g)	GY (t/ha)	NPP	NSP	HI	HSW (g)	GY (t/ha)
Local	19.35^{d}	5.38^{a}	0.51^{a}	20.85^{c}	1.92^{bcd}	23.21^{bc}	5.68^{ab}	0.48^{abc}	18.98^{c}	1.96^{bcd}
Awash melka	22.92^{b}	5.45a	0.51^{a}	22.55^{c}	2.05^{abc}	26.23^{abc}	5.64^{b}	0.44^{c}	21.89^{bc}	2.36^{ab}
Chercher	14.92^{e}	4.63^{a}	0.47^{ab}	21.54^{c}	1.68^{cd}	23.92^{bc}	5.55^{b}	0.45^{bc}	22.14^{bc}	1.64^{bcd}
Awash 1	22.44b^{c}	5.26^{a}	0.53^{a}	23.65^{bc}	1.77^{c}	27.06^{ab}	5.99^{ab}	.47^{ab}	21.47^{c}	2.27^{abc}
Roba	26.62^{a}	5.17^{a}	0.55^{a}	23.33^{bc}	2.18^{ab}	23.30^{bc}	6.24^{a}	0.51^{a}	21.38^{c}	2.40^{ab}
Red wolayita	19.96^{cd}	5.15^{a}	0.49^{ab}	24.38^{bc}	2.03^{abc}	22.77^{c}	5.56^{b}	0.50^{ab}	22.67^{bc}	2.08^{abc}
Nasir	26.27^{a}	5.10^{a}	0.54^{a}	27.12^{b}	2.36^{a}	28.94^{a}	5.61^{b}	0.51^{a}	25.82^{b}	2.69^{a}
Gofta	12.57^{e}	3.53^{b}	0.42^{c}	32.71^{a}	1.34^{de}	16.89^{d}	4.78^{c}	0.37^{d}	33.47^{a}	1.24^{d}
Mexican 142	18.72^{d}	3.26^{b}	0.40^{c}	19.50^{c}	1.23^{e}	19.46^{cd}	5.53^{b}	0.38^{d}	18.87^{c}	1.55^{cd}
LSD	2.81	0.99	0.07	5.07	0.035	4.12	0.57	0.051	4.37	0.47
CV%	8.00	12.20	9.02	12.29	11.13	9.67	5.88	6.39	11.01	13.47

Means followed by the same letter in the same column are not significantly different at $p \leq 0.05$ probability level. NPP = numbers of pod per plant, NSP = number of seed per pod, HI = harvest index, HSW = hundred seed weight, GY = grain yield.

observed among varieties with respect to biomass yield of the haricot bean plants (Table 1). The highest value (4.29 ton ha^{-1}) was recorded for variety Nasir followed by local check (4.18 ton ha^{-1}), Awash Melka (4.07 ton ha^{-1}) at Menit Shasha District.

Similarly, (5.39 ton ha^{-1}) was recorded for variety Awash Melka followed by Nasir (5.27 ton ha^{1}) and Awash 1 (4.84 ton ha^{-1}) at South Bench district. Although, the lowest biomass (3.11 and 3.15 ton ha^{-1}) and (3.60 and 3.62 ton ha^{-1}) were recorded for varieties Mexican 142 and Gofta at Menit Shasha, and for varieties Gofta and Chercher at South Bench, respectively (Table 2).

Hence, this variation could be attributed to the heritable characteristics of the varieties when responding and adapting to growth conditions at Menit Shasha and South bench, as well as other ecological conditions. This finding conforms to previous reports by Wondimu and Tana (2017) who found significant differences among haricot bean varieties with respect to biological yield at harvest.

Stand count at harvest

Variety had a highly significant (P< 0.01) effect on stand count of haricot bean plants, at harvest in both locations (Table 1). The highest number of plants per plot at harvest (203.36 and 204.34) was recorded for variety Nasir and Awash Melka at Menit Shasha and South bench districts, respectively. Whereas, the lowest number of plants per plot (116.51 and 123.44) were recorded for variety Gofta and Mexican 142, at Menit Shasha, respectively; and (164.33 and 170.30) for the local check and variety Gofta at South Bench, respectively (Table 2).

Variety Gofta and Mexican 142 performed poorly for most parameters, including yield and yield components. This variation could be due to the resistance and adaptability of the varieties and/or suitability of the study conditions to permit expression of the plants' genetic potentials.

Number of pods per plant

Mean number of pods per plant was highly significantly ($p < 0.01$) influenced by varieties tested in both locations (Table 1). At both Menit Shasha and South Bench districts, the lowest numbers of pod per plant 12.57 and 16.89, respectively, were recorded for variety Gofta; while the maxima of 26.27 and 28.94 at the two districts, respectively, were reached by Nasir (Table 3). Statistically, there were no significant differences between Roba and Nasir on number of pods per plant at Menit Shasha, and among the varieties Nasir, Roba and Awash Melka at the South Bench district.

The difference among genotypes in numbers of pod per plant is attributed to the variation in their growth habit. For instance, Worku (2008) reported that the indeterminate types such as Roba produced higher numbers of pods per plant compared with determinate types. This result was also in line with a previous study by Shubhashree (2007), who reported significant differences in number of pods per plant among haricot bean varieties.

Number of seeds per pod

Varieties had a highly significant (P< 0.01) influence on number of seeds per pod at both districts (Table 1). At Menit Shasha district, the highest (5.45) and the lowest (3.26) numbers of seeds per pod, respectively, were

recorded for varieties Awash-Melka and Mexican-142. Except variety Gofta and Mexican-142, all other varieties varied non-significantly with Awash-Melka at the Menit Shasha district (Table 3).

On the other hand, the highest and lowest (6.24 and 4.78) number of seeds per pod, respectively, were recorded for variety Roba and Gofta at the South Bench location (Table 3). The difference in number of seeds per pod among the genotypes is attributed to the same contrast, which showed a variation for number of pods per plant. For example, number of seeds in indeterminate and bush genotypes, such as Roba, was superior to semi-climbing types. This can be explained by the fact that their upright growth habit allows better light distribution throughout their canopy.

In view of this, Worku (2008) reported a significant improvement in light interception due to the presence of upright canopy distribution. The result of this experiment was in line with previous work of Tsubo et al. (2004), who also reported that haricot bean varieties exhibited variations in number of seeds per pod. They found that variety Beshbesh produced more seeds per pod (6.83) compared to the other varieties.

Harvest Index

Variety trial in both locations revealed the presence of significant ($P<0.05$) differences, with respect to harvest index of haricot bean plants (Table 1). At both Menit Shasha and South Bench districts, the highest harvest index, 0.55 and 0.51, respectively, were obtained for variety Roba and Nasir; whereas, the lowest, 0.40 and 0.37, respectively, were recorded for variety Mexican 142 and Gofta (Table 3).

Harvest index, the ratio of grain yield to total biomass yield, is a measure of the degree to which a crop can partition photo assimilates into grain during the dry matter portioning periods. This variation in harvest index could be due to the genotypic differences among the haricot bean varieties in mobilizing organic matter from the sources to the sinks at the reproductive growth stages of the plant, for purpose of gain filling and seed development. The result of this experiment was supported by previous findings reported by Daniel et al. (2014), who recorded a highly significant variation among varieties of haricot bean plants that were evaluated for harvest index.

Hundred seed weight

Hundred seed weight was highly significantly ($P< 0.01$) influenced by varieties in both locations (Table 1). The highest hundred seed weights, 32.71 and 33.47g, respectively were recorded in Menit Shasha and South Bench locations for variety Gofta. While the lowest hundred seed weights, 19.50 and 18.87g, respectively, were recorded in Menit Shasha and South Bench districts for variety Mexican 142 (Table 3).

The variation in hundred seed weight among the varieties might be due to the differences in seed size that exist among the varieties. For instance, the determinate types such as Gofta produced smaller number of pods per plant, and seeds per pod, but remarkably heavier seeds compared with indeterminate types. The present finding agreed with Wogayehu (2005) and Emishaw (2007), who reported significant differences among varieties on hundred seed weight for the same crop. A recent report by Daniel et al. (2014) also revealed a very highly significant variation among haricot bean varieties for thousand seed weight. The same source reported differences of 539.52 and 151.95g thousand seed weight for variety Gobe Rasha and Awash-1, respectively.

Grain yield

Highly significant variation ($P<0.01$) was observed among haricot bean varieties in response to grain yield in both locations (Table 1). At both Menit Shasha and South Bench districts; the lowest grain yields 1.34 and 1.23 t ha^{-1}, respectively, were recorded for variety Gofta, but reaching 2.36 and 2.69 t ha^{-1} for variety Nasir; which, however, were statistically at par with that obtained for varieties Roba, Awash-Melka and Red-Wolayita (Table 3). In fact, the latter three varieties were equally superior with variety Nasir; but are not significantly different from the check at both locations. On the other hand, variety Nasir was outperformed over the local check at both Menit Shasha and South Bench districts, with a yield advantage of 23 and 37%, respectively.

Differences in growth habit and morphology among the genotypes may have attributed to the report differences in yield performance. Furthermore, varieties had a significant effect on yield components such as pod number per plant, number of seed per pod and harvest index. The influence of varieties on yield may thus be due to their effects on these parameters. This finding was in agreement with the previous reports of Daniel et al. (2014), who stated seed yield was highly influenced by varieties. Seed yield of haricot bean can be attributed to the results of many plant growth processes, which ultimately influence the yield components such as pods per plant, seeds per pod, and unit weight of seed.

Conclusion

Better understanding of varietal response to a particular growing condition is absolutely essential to improve product and productivity of haricot bean. Therefore, performance of eight nationally released varieties and one local check was evaluated at Menit Shasha and

South Bench districts of Bench-Maji Zone during the 2015 and 2016 cropping season. The result revealed that haricot bean varieties differed significantly in their performances with respect to growth, yield and yield components.

Varieties Nasir, Roba and Awash Melka outperformed over the local check for the majority of yield components tested in the trial. Accordingly, four nationally released varieties namely Nasir, Roba, Awash Melka and Red-Wolayita were found to be relatively high yielding varieties with mean grain yields of 2.36; 2.69, 2.18; 2.40, 2.05; 2.36, and 2.03; 2.08 t ha^{-1}, at Menit Shasha and South Bench districts, respectively. Except variety Nasir; all the other top performing varieties were not significantly different from the local check at both locations. Therefore, variety Nasir is recommended for cultivation in the studied areas and other locations with similar ecological conditions. Further research aimed at investigating the genetic basis of differences in performance among genotypes of out-yielded groups across more locations and years would be worthwhile.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interest.

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