Journal of Equity in Science and Sustainable Development

Vol. 3(1):76-83
Article Number: JESSD23.5.2018
ISSN 2523-1901(Online)

URL: http://197.156.115.18/index.php/jessd
Email: jessd@mwu.edu.et

Full Length Research Paper

Adaptability Evaluation of White Haricot Bean (*Phaseolus vulgaris* L) Genotypes at the Eastern Amhara Regional State, Ethiopia

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Received 23 June, 2018; Accepted 11 November, 2018; Published January, 2019

Abstract
An experiment conducted to identify and recommend widely adaptable and high yielder variety. Thirty genotypes with the standard check were evaluated in randomized complete block design with three replications at Sirinka, Chefa, Jari and Shewa robit for two years. Analysis of variance revealed highly significant differences (P<0.01) among the genotypes for all of the studied traits except number of seeds per pod. The mean grain yield performance ranged from 1630 to 3127kg ha^{-1}. According to the result, genotype Bifort small seeded-15 scored the highest grain yield performance, 3127.9kg ha^{-1}, followed by Navy line-40 and ZABR16574-37F-32 with average grain yield of 2929.7 kg ha^{-1} and 2857.3 kg ha^{-1}, respectively. The combined analysis of variance showed significant difference for both main and interaction effects of genotypes and locations which led to exploit the significant effect of genotype by environment interaction. AMMI analysis was employed totally on six environments' grain yield to assess the genotype and environment interaction to identify widely adaptable genotype. Based on variance and AMMI analysis on multi environment data, genotype Bifort small seeded-15 has the highest grain yield performance (3127.9 kg ha^{-1}) and the most adaptable genotype. This genotype has 94.5% yield advantage overall countries' haricot bean productivity. Therefore; Bifort small seeded-15 has been recommended for the tested and other similar haricot bean growing areas to increase production and productivity of this crop in the region.
Keywords: Phaseolus vulgaris, genotype, environment, interaction, seed yield

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Introduction

Haricot bean (*Phaseolus vulgaris* L.) is an annual leguminous crop originated in South America and Central America and is one of the most important leguminous crops worldwide (HarvestPlus, 2009; Nicolai *et al*., 2015). Among pulse crops which cultivated in Ethiopia, haricot bean is regarded as the main cash crop and the least expensive source of protein for the farmers in many lowlands and mid altitude of the country (Asfaw and Blair, 2014). An overview of four years' data from 2011 to 2014 indicates that more than 337,000 ha were dedicated to production of 455,000 tons of haricot bean annually (FAOSTAT, 2016).

Haricot bean contributes to the national economy as both a food and an export commodity, in both cases serving as a source of income and employment to a large supply chain (Tumsa *et al*., 2014). The crop provides vital nutrients as a food including proteins, vitamins and minerals and the stems are also used as fodder for livestock, especially in the dry spell following the main cropping season (Kwabena *et al*., 2016). According to Shaun and Elly (2008), it has high starch, protein and dietary fiber and is an excellent source of minerals and vitamins including iron, potassium, selenium, molybdenum, thiamine, vitamin B6, and folic acid. As a legume, common bean plants also contribute to soil fertility enhancement through atmospheric nitrogen fixation (Kwabena *et al*., 2016).

In Ethiopia, the crop is widely grown in areas between 1400-2000 m.a.s.l. The main production areas include the East Hararghe, West Wellega, East shewa, West Arsi, Sidama, Wolayita, Wollo and East Gojam (Ephrem, 2016). The crop is grown either as a sole crop and/or intercropped with either cereal or perennial crops. There are a wide range of haricot bean types grown in Ethiopia, including the mottled, red, white and black varieties. The pure red and pure white colored beans are the most common commercial varieties. Whereas red beans are mainly produced for domestic consumption, white beans are almost exclusively grown to supply a longstanding export market from the country (Ferris and Kaganzi, 2008). According to CSA (2017), white haricot bean is grown on an estimated 290,102.43 hectares by 3.9 million smallholder farmers. Its production also reaches 4,839,226.5 quintals in the country. Eastern Amhara region is the major white haricot bean growing areas in the region but its production is very low, 19,867.15 quintals (2017). Lack of improved white haricot bean variety, even in the country as a whole, is one of the factors limiting the farmers from exploiting the potential of this crop. The productivity of this crop in the country and eastern Amhara region under farmers' condition is very low, 15.97 and 16.08 quintals per hectare; respectively, but its yield potential reaches 30 to 40q/ha on research fields (Beebe *et al*., 2013). The major reason for this gap comes due to unaddressed of widely adaptable and high yielding varieties. Therefore; the objective of this experiment was to identify and recommend widely adaptable and high yielder of white haricot bean variety especially in growing areas of eastern Amhara region.

Materials and Method

Description of Experimental Site

The experiment was executed under rain fed condition at Sirinka, Chefa, Jari and Shewa robit which are far 513km, 367km, 440km and 220km; respectively, from Addis Abeba. The experiment was done on agricultural research stations during 2016 and 2017. These locations represent the major haricot bean producing areas of Eastern Amhara Regional State with various agro-ecological conditions. Agro-ecological description of the locations is given in Table 1.

Table1. Environmental description of experimental sites

Location	Altitude (m.a.s.l.)	Temp./min and max	Rain fall average (mm)	Soil type	Latitude	Longitude
Sirinka	1850	13.6-26.7^{0}c	1006.3	Vertisol	11^0 45'	39^0 36'
Chefa	1465	11.6-30.4 ^{0}C	850	Vertisol	10^0 57'	39^0 47'
Jari	1680	14.2^{0}c-28.7^{0}c	987.3	Vertisol	11^0 21'	39^0 47'
Shewa robit	1300	13.1- 32.5^{0}C	928	Vertisol	10^0 06'	39^0 53'

Source: Sirinka and Debre Birhan Agricultural Research Centers

Experimental Materials and Design

The experiment was started on 150 white haricot bean genotypes which was collected from Melkasa Agricultural Research Center and evaluated as observation nursery in 2015 at Sirinka then thirteen genotypes selected for further evaluation. These thirteen promising genotypes with Awash two as standard check evaluated on a plot size of 1.6 m x 4m for each genotypes with three replications. The design was Randomized Completed Block Design (RCBD). Data were collected for 50% days to flowering, 75% days to maturity, plant height (cm), number of pods per plant, number of seeds per pod, hundred seed weight (gm) and grain yield (gm/plot). All the data were subjected to analysis using SAS 9.0 and Gen stat 18 software versions. AMMI analysis was done to assess the genotype and environment interaction to identify widely adaptable genotype.

Results and Discussion

The combined analysis of variance for seed yield showed significant different ($P<0.01$) among the environments, genotype and genotype x environment interaction (Table 2). This indicates that the environments have different impact on the yield potential of the genotypes while the varieties have different performance in the tested environments.

Table 2. Combined analyses of small haricot bean genotypes for seed yield and yield related traits

SN	Genotypes	DF	DM	DS	pH	NPP	NSP	HSW	AYKGHA
1	Bifort small seeded-15	47.22ab	84.3cd	0.24bcd	57.5cd	16.8abc	5.5a	19.0cd	3127.9a
2	RAZ-11 *	43.16g	79.6f	0.46a	48.3g	15.3c	4.6de	19.2cd	1920.9j
3	NAVY LINE-40	47.7a	84.0cde	0.16cde	57.2cde	18.1ab	5.4a	19.4c	2929.7b
4	ZABR16574-37 F-22	47.0ab	86.9a	0.10e	65.6ab	16.1bc	5.6a	19.4b	2736.8cd
5	Bifort-19 *	45.4cd	86.4ab	0.18cde	65.6de	15.7c	5.6a	19.1cd	2877.4bc
6	SEC-27	43.4fg	82.5e	0.33b	56.6de	18.3a	5.0bcd	15.9fg	2133.5i
7	SEC-28	44.7d	86.9a	0.23bcde	70.7a	17.2abc	5.4ab	16.4	2669.2de
8	Bifort-19(20) *AMBACHWE	44.6def	85.2ab	0.24bcd	63.3b	16.5abc	5.5a	18.7d	2172.5hi
9	SEC-12	44.6d	82.4e	0.32b	55.6def	17.5abc	5.4ab	17.4e	2492.4f
10	SMC-23	42.8g	87.2a	0.21bcde	63.4b	12.6d	4.5e	25.4a	2112.1i
11	NAVEY LINE-49	44.7de	83.0de	0.32b	52.2efg	16.7abc	5.0bc	15.6g	1630.2k
12	ZABR 16577-39 F-22	46.4bc	84.5cd	0.24bcd	62.2bc	15.5c	5.3ab	19.7c	2387.9fg
13	SEC-29	46.6ab	85.2ab	0.13de	51.1fg	16.2abc	5.5a	17.4e	2531.1ef
14	Awash 2	43.5efg	83.4cde	0.28bc	62.1bc	17.2abc	4.7cde	20.9b	2290.4gh
	GM	45.15	84.4	0.24	58.8	16.4	5.2	18.9	2429.42
	CV%	4.01	5.2	11.3	13.1	20.0	12.1	5.4	22.0

DF: Days to flowering, DM: Days maturity, DS: Disease score, PH: Plant height in cm NPP: Number of pods per plant, NSP: Number of seeds per pod, HSW: Hundred seed weight, AYKGHA: Adjusted yield in kg per ha.

The same results were reported by Perreira *et al*., (2009) and Perreira *et al*. (2010) which indicated that haricot bean genotypes can have different response and interact highly to environmental change. Combined analysis of variance revealed highly significant differences (P<0.01) among the genotypes for all of the studied traits except number of seeds per pod (Table 2). This suggested that the presence of sufficient variability for these traits that can be exploited in breeding progress. The mean grain yield performance ranged from 1630 – 3127.9 kg ha^{-1} (Table 2), this indicates the degree of variation between the tested genotypes for grain yield. Highly significant variation for grain yield in haricot bean genotypes was also reported by Zelalem (2014). According to the result, genotype Bifort small seeded-15 scored the highest grain yield performance (3127.9 kg ha^{-1}) followed by genotype NAVY LINE-40 (2929.7 kg/ha), Bifort-19* (2877.4 kg/ha) and ZABR16574-37 F-22 (2736.8 kg ha^{-1}) whereas, the lowest grain yield performance was recorded for genotype NAVEY LINE-49 (1630 kg ha^{-1}) (Table 2). The standard check, Awash 2, scored 2290 kg ha^{-1}. Genotype RAZ-11* the most early type (80days) followed by SEC-12 (82 days), SEC-27 (82 days), Awash 2 (83 days) and Bifort small seeded-15 (84 days) (Table 2).

Table 3. Combined ANOVA of seed yield for fourteen small white bean genotypes

Source of variation	Df	SS	MS
Genotype	13	40999440	3153803**
Environments	5	45863410	45863410**
Reps within environments.	10	1158550	1158550
Genotype x environment	65	13390492	206008**
Residual	140	6979055	44738
Total	251	108708856	

*** = highly significant difference (p< 0.01); Reps = Replications; SS= Sum of square; MS= Mean square*

The mean seed yield performance of genotypes at individual and over location is presented in Table 4. The mean grain yield value of genotypes averaged over environments indicated that Bifort small seeded-15 followed by NAVY LINE-40, Bifort-19* and ZABR16574-37 F-22 had the highest and lowest for NAVEY LINE-49. The mean of standard checks, Awsha 2, scored below over all mean of locations (2351 kg ha^{-1}). However genotypes showed inconsistent performances across environments, Bifort small seeded-15, NAVY LINE-40, Bifort-19 * and ZABR16574-37 F-22 were high yielder genotypes in most of locations. The standard check scored higher over all location mean only at SHR-16 and JR-17.

Table 4. Mean seed yield (kg/ha) of fourteen small white haricot bean genotypes at individual environment

EN	Genotypes	Testing Environments						Over all mean
		SR-16	CH-16	SHR-16	SR-17	CH-17	JR-17	
1	Bifort small seeded-15	2768	2262.4	4042	2768	3161.9	3597.9	3127.9
2	RAZ-11 *	1977.9	1562.2	2844.7	1977.9	1239.7	1923.2	1920.9
3	NAVY LINE-40	2631	2275.8	3538.7	2631	3079.6	3422	2929.7
4	ZABR16574-37 F-22	2857.3	2134.7	2952.0	2857.3	2629.6	3388.8	2803.3
5	Bifort-19 *	2739.1	2129.4	3567	2739.1	2815.1	3274.5	2877.4
6	SEC-27	2024	1521.1	3056	2024	1777	2398.8	2133.5
7	SEC-28	2780.5	1898.9	2828	2780.5	2655.8	3071.5	2669.2
8	Bifort-19(20) *AMBACHWE	1740.1	1695.2	3007.7	1740.1	2018.7	2833.3	2172.5
9	SEC-12	2449.3	2044.5	3275.3	2449.3	1956.7	2779.5	2492.4
10	SMC-23	1649	1588.9	3316.7	1649	1917.6	2551.7	2112.2
11	NAVEY LINE-49	1453.9	1248.5	2056.7	1453.9	1275.7	2292.3	1630.2
12	ZABR 16577-39 F-22	2407.8	1685.1	2697	2407.8	2140	2989.9	2387.9
13	SEC-29	2617.9	1895.1	2757.7	2617.9	2278.8	3031.5	2533.2
14	Awash 2	2045.1	1914.3	3544.7	2045.1	1365.6	3192.1	2351.2
	EM	2295.8	1844.5	3106	2295.8	2165.1	2910.4	2438.7
	MSE	205.2	164.6	234.5	205.2	267.6	156.9	
	LSD 5%	344.5**	276.3**	393.6**	344.5**	449.2**	263.3**	
	CV (%)	13.9	19..9	17.6	11.9	12.3	15.6	

GM = Grand means, EM = Environmental means, MSE = Mean square of error, LSD 5%=Least significant difference at 5%, CV=Coefficient of variance, SR-16=Sirinka 2016, CH-16=Chefa 2016, SHR-16=Shewa robit 2016, SR-17=Sirinka 2017, CH-17=Chefa 2017, JR-17=Jari 2017.

The mean grain yield ranged from 1248.5 kg ha^{-1} for SR-16 to 4042 kg ha^{-1} for SHR-16 (Table 4). The highest mean grain yield at SHR-16 was attributed to uniform distribution and adequate rainfall during the growing season. On the other hand, irregular and early cessation of rainfall contributed to the low grain yield at SR-16. The mean grain yield averaged over environments and genotypes was 2438.7 kg ha^{-1} (Table 4).

The significant GEIs (genotypes and environment) suggest that grain yield of genotypes varied across six environmental conditions. Significant differences for genotypes, environments, and interaction indicated the effect of environments in GEI, genetic variability among entries, and the possibility of selecting stable genotypes (Table 5). Lotan *et al*. (2013) reported that GEI with location is more important than GEI with year. Since GEI was significant, we therefore move further to estimate phenotypic stability.

Table 5. ANOVA table for AMMI model

Source	d.f.	SS	MS	F pr
Total	251	111470276	444105	
Treatments	83	102887342	1239607	<0.001
Genotypes	13	40754106	3134931	<0.001
Environments	5	47735628	9547126	<0.001
Block	12	1754602	146217	<0.001
Interactions	65	14397608	221502	<0.001
IPCA 1	17	7739975	455293	<0.001
IPCA 2	15	4132532	275502	<0.001
Residuals	33	2525101	71103	0.2633
Error	156	6828331	43771	

Blocks source of variation refers to blocks within environments

The AMMI analysis of variance of 14 small white genotypes tested over six environments revealed that 42.2% of the total sum of squares (SS) was attributable to environments (E), 36.6% to the genotypes (G) and 12.9% to GEI effects (Table 5). A large SS for E indicated that the genotypes were diverse with large differences among the means. The magnitude of G x E SS was almost three times smaller than that for the SS for G, thus indicating that the differences in the response of the genotypes across environments were not that substantial. The first interaction principal component axis (IPCA-1) accounted for 53.8% of the interaction SS in 25.89% of the interaction degrees of freedom (Table 5). Similarly, IPCA-2 explained further 28.7% of the interaction SS (Table 5). The mean square (MS) for both IPCA-1 and IPCA-2 were significant at $P<0.001$ level and cumulatively contributed to 84.5% of the total interaction. Therefore, the interaction of the 14 genotypes across six environments was best predictable by the first two principal components. Genotypes with IPCA-1 scores close to zero have small interactions and hence show wider adaptation to the tested environments. Based on this, Genotype (G) 3 is the most stable followed by G5 and G1.

The length of vectors of an environment from the bi-plot origin, which is proportional to the genotypic mean standard deviation within the respective environment, is used to measure the discriminating power of the test environments (Yan, 2011). These environmental variables and the genotype sensitivities are estimated from the table itself (Table 7). For simple interpretation of AMMI 2, the genotypes far from the origin contribute relatively more to the interaction than those close to the origin (Mukherjee *et al*., 2013). Based on this, G6, G11, G5 are relatively stable but their yield performance was very low comparing to others genotypes. Genotypes which are found around ideal environment, SHR-16 and JR-17 highly discriminate the genotypes; G1, G8, G10 and G3 are the groups which is best to select best genotype.

Table 6. The first four AMMI selections per environment

Environment	Environment	Mean	Score	1	2	3	4
5	CH-17	2165	14	G1	G3	G5	G4
4	SR-17	2296	13.03	G4	G7	G1	G5
1	SR-16	2296	13.03	G4	G7	G1	G5
6	JR-17	2910	-0.89	G1	G3	G5	G4
2	CH-16	1845	-7.27	G1	G5	G3	G4
3	SHR-16	3106	-31.9	G1	G14	G3	G5

According to the first four AMMI selections per environment, G1 (Bifort small seeded-15) selected four times under first class and twice under third class this indicates G1 was the best performed overall the genotypes (Table 6). The yield performance of genotype Bifort small seeded-15 (3127.9 kg ha^{-1}) has 94.5% yield advantage overall countries haricot bean productivity, 16.08 kg ha^{-1} (CSA, 2017). This positive yield gap is very important to increase production and productivity of this crop simultaneously increases income of producer and foreign currency to the country. In addition to this, depending on its adaptability and yield performance, this genotype has also released by Melkasa Agricultural Rsearch Center (2017) for other haricot bean growing areas of the country as a variety, with name of Awash Mitin.

Conclusion

The combined analysis of variance revealed significant difference both on main and interaction effects for most of the traits. Based on variance and AMMI analysis on multi environment data, genotype Bifort small seeded-15 has the highest grain yield performance (3127.9 kg ha^{-1}) and the most adaptable genotype. This genotype has 94.5% yield advantage overall countries' haricot bean productivity. Therefore; Bifort small seeded-15 has been recommended for the tested and other similar haricot bean growing areas to increase production and productivity of this crop in the region.

Acknowledgements

The authors deepest gratitude and acknowledge goes to Amhaera Agricultural Research Institute and/or Sirinka Agricultural Research Center for providing research budget and facilitate the process. We would like also to express sincere thanks to Sirinka and Debrebirhan Agricultural Research Center pulse case team members for contributing their great effort this successful accomplishment of the experiment.

Conflict of Interests

Authors have not declared any conflict of interests.

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