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Research Article

Performance of Snap Bean (*Phaseolus vulgaris* L.) Genotypes for Green Pod Yield and Quality in the Central Rift Valley of Ethiopia

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ABSTRACT

Multi-location variety trials were conducted to evaluate snap bean genotypes for yield and quality in 2013 and 2014 at Melkassa and Debrezeit agricultural research centers and Wonji. The experiment was laid out in RCBD with three replications. Data on yield and yield contributing traits were collected and subjected to environment wise analysis of variance followed by pooled analysis. The pooled analysis of variance for marketable yield showed significant difference ($p< 0.01$); and ranged from 7.5 t ha^{-1} to 9.14 t ha^{-1}. Total green pod yield was also significant ($p < 0.05$); and ranged from 9.72 t ha^{-1} to 11.73 t ha^{-1} for genotypes BC4.4 and Plati respectively. There was also significant difference ($p< 0.01$) among genotypes in days to 50% flowering, pod diameter and length. Genotype Plati had the largest pod diameter (7.02 mm) and length(119.3 mm). The rest pod characters such as pod shape, color, fiber content and curvature were also diverse among genotypes. On the basis of total yield (11.73 t ha^{-1}) and pod characters such as pod diameter(7.02 mm) and length(119.3 mm), low fiber content, green pod color, smooth pod surface, straight pod curvature and round pod shape, genotype Plati was identified as potential variety and thus released for production in the Central Rift Valley and similar agro-ecologies of Ethiopia.

1. INTRODUCTION

Common bean (*Phaseolus vulgaris*) is widely cultivated in the world due to its high market value and good nutritional composition; high protein content in dry seed, and good source of fiber in snap bean. It is consumed either as dry bean (grain) or snap bean (fresh vegetable) (Santalla *et al*., 1999). Its immature edible pod and ripe seeds contain protein, carbohydrate, fat, fiber, thiamine, riboflavin, calcium and iron. Snap bean and other beans, such as kidney bean, navy bean and black bean are referred as common bean probably they all derived from a common ancestors (CIAT, 2006).

Snap bean is strain of common bean which is developed for succulent pods having little fiber through breeding and selection (CIAT,2006).The immature pods and seeds are produced for fresh consumption and processing in the form of canned or frozen products (Getachew,2006). Different market classes of snap bean exist based on pod characteristics and plant type. Pod characteristics such as sieve size, percent seed weight of total pod weight, pod fiber content, smoothness and straightness, color and flavor are among others determine the degree to which snap beans are accepted by consumers and processors. Among the three types of snap bean varieties bush, pole and half runners (USDA, 1995), the former two are the most important types available for different markets (Getachew, 2006; USDA, 1995).

Production of snap bean in Ethiopia was started in the early 1970s with the purpose of exporting to different market destinations. Different private commercial companies mainly business partners of European companies have been involved in the production of snap bean in Ethiopia during the winter season when their domestic production is limited (Hussein, 2015). Different snap bean types mainly bobby and fine beans have been exported to European and Middle East countries with the highest share among all vegetables (Lemma, 2003; Lemma *et al*., 2006). Non-exportable grades have also been used for local markets and the demand of domestic consumption has been increasing (Lemma *et al*., 2006).

The area and production of snap bean in Ethiopia during the last ten years (2003-2013) increased by 76. 5% and 77.1%, respectively, (FAOSTAT, 2013). Despite its production and export potential, limited efforts have been made on varietal development to identify suitable varieties for local use and export market. Ethiopian farmers in most cases have been limited to grow introduced, private company owned snap bean cultivars with high seed cost. The introduced cultivars in general require high rates of nitrogen as they have been developed under intensive production systems (Hussein, 2015).

Currently, there is only one open pollinated snap bean variety nationally released by Melkassa Agricultural Research Center (MARC) and additional four varieties registered by local companies for large scale production in the country (MoARD, 2014). With the growing demand for local and export markets, there is a need to develop varieties with high pod yield and required pod characters . Thus the present study was conducted to evaluate and identify snap bean vareties with high green pod yield and quality for wider production and consumption in the country.

2. MATERIAL AND METHODS

Six genotypes which were originally obtained from CIAT and FAO with the standard check variety were evaluated in 2013 and 2014 at Melkassa and Debrezeit Agricultural Research Centers and Wonji. The field trials in 2013 were conducted in the rainy season with supplementary irrigation while in 2014 conducted in the dry season using full irrigation.

The experiment was laid out in RCBD with three replications in a plot size of 11.2m^2 having eight rows with the spacing of 40cm x 10cm between rows and plants in that order. Fertilizers, DAP and Urea were applied at a rate of 200 and 100 kg/ha respectively. Other necessary cultural practices were applied to all plots uniformly as needed. Data were collected from the central six rows.

Table 1: Altitude, rainfall, soil type and temperature of experiment locations

Location	Altitude (m.a.s.l.)	Annual rain fall (mm)	Soil type	Temperature (°C)	
				Min	Max
Melkassa	1550	818	Andosol	14	29
Wonji	1540	831	Fluvisol	15	28
Debrezeit	1900	851	Alfisols/Mollisols	8.9	28.3

2.1. Data collection and analysis

Data on days to 50% flowering, growth habit, green marketable, unmarketable and total yield, pod characters (length, diameter, curvature, color, shape and fiber content) were collected. Quantitative data was subjected to environment wise analysis of variance followed by pooled analysis of variance. GENES software package was used to compute the pooled ANOVA while Statstix8 was used for mean separation.

3. RESULTS AND DISCUSSIONS

3.1. Marketable yield

The overall pooled analysis of variance for marketable green pod yield was highly significant *($p<0.01$)* (Table 2), and ranged from 7.5 t ha^{-1} to 9.14 t ha^{-1}. Similarly,

significant difference was observed in marketable green pod yield among locations in both 2013 and 2014 cropping season. In 2013, the highest marketable green pod yield was obtained at Wonji (9.53 t ha^{-1}) followed by Debrezeit (8.73 t ha^{-1}) and Melkassa (7.23 t ha^{-1}); whereas in 2014, the highest marketable green pod yield was obtained at Melkassa (9.95 t ha^{-1}) followed by Debrezeit (8.37 t ha^{-1}) and Wonji (6.94 t ha^{-1}). This variation might be due to considerable variation among the genotypes, locations and seasons.

The analysis of years across locations indicated highly significant difference among genotypes in marketable yield ($p < 0.05$) in 2013 cropping season (Table 2). The marketable green pod yield ranged from 7.54 t ha^{-1} to 9.01 t ha^{-1} for genotypes L12 and Nelson in that order. There was highly significant difference among genotypes in marketable yield at Melkassa and Debrezeit ($P<0.01$). Genotypes HAB-410, HAB-419 and Plati were the highest yielder at Melkassa (8.41 t ha^{-1}), wonji (10.33 t ha^{-1}) and Debrezeit (9.89 t ha^{-1}). In this season, the highest yield was recorded from genotype Nelson (9.01 t ha^{-1}) followed by Plati (8.84 t ha^{-1}) and HAB-410 (8.8t ha^{-1}).

In 2014, the combined marketable yield over the three locations was significant ($p < 0.05$) (Table 2) and ranged from 6.86 t ha^{-1} to 9.45 t ha^{-1} for the genotypes BC4.4 and Plati respectively. The individual location analysis indicated highly significant difference among genotypes ($p < 0.01$) at Wonji and Debrezeit. Genotype Plati was the highest yielder at Melkassa (11.12 t ha^{-1}) and wonji (9.66 t ha^{-1}). However, at Debrezeit, genotype HAB-410 (10.23 t ha^{-1}) was the highest yielder followed by L12 (10.1 t ha^{-1}) and BC4.4 (7.82 t ha^{-1}). In this year, the highest yielding cultivar was Plati (9.45 t ha^{-1}).

Table 2: Marketable green pod yield (t ha^{-1}) of snap bean genotypes tested at Melkassa and Debrezeit Agricultural Research Centers and Wonji in 2013 and 2014.

Genotypes	2013				2014				Over all
	Melkassa	Wonji	Debrezeit	**Combined**	Melkassa	Wonji	Debrezeit	**Combined**	
Plati	8.08^{ab}	8.53	9.89^{a}	**8.84^{a}**	11.12	9.66^{a}	7.58^{b}	**9.45^{a}**	**9.14^{a}**
Nelson	8.08^{ab}	11.15	7.80^{c}	**9.01^{a}**	10.41	7.1^{bc}	7.3^{b}	**8.27^{ab}**	**8.64^{ab}**
L 12	5.02^{c}	8.06	9.53^{ab}	**7.54^{b}**	8.43	6.27^{bc}	10.1^{a}	**8.26^{ab}**	**7.9^{bc}**
HAB - 419	6.68^{b}	10.33	8.54^{bc}	**8.53^{a}**	11.12	6.96^{bc}	8.34^{b}	**8.8^{a}**	**8.67^{ab}**
HAB - 407	7.75^{ab}	9.9	8.25^{c}	**8.63^{a}**	11.03	8.2^{ab}	7.23^{b}	**8.82^{a}**	**8.72^{ab}**
HAB - 410	8.41^{a}	9.46	8.53^{bc}	**8.8^{a}**	9.42	5.75^{bc}	10.23^{a}	**8.46^{a}**	**8.63^{ab}**
BC 4.4	6.63^{b}	9.21	8.6^{bc}	**8.14^{ab}**	8.15	4.6^{c}	7.82^{b}	**6.86^{b}**	**7.5^{c}**
Mean	7.23^{c}	9.53^{a}	8.731^{b}	**8.5^{a}**	9.95^{a}	6.94^{c}	8.37^{b}	**8.42^{a}**	**8.46**
CV	11.65	13.06	7.18	**11.02**	22.04	20.56	10.08	**18.29**	**15.11**
F-test	**	NS	**	*	NS	**	**	*	**
LSD	14.99	-	16.05	**8.92**	-	25.37		**14.66**	**8.47**

Means followed by the same letter are not significantly different at p<0.05

3.1. Unmarketable yield

The combined analysis over locations and years indicated that no significant difference among the test genotypes at $p<0.05$ (Table 3). The green pod yield ranged from 2.28 t ha^{-1} for genotype BC4.4 to 2.64 t ha^{-1} for Plati.

However, there was significant difference among genotypes in unmarketable green pod yield in both years 2013 and 2014. The highest unmarketable green pod yield was recorded at Melkassa (3.89 t ha^{-1}) followed by Debrezeit (2.41 t ha^{-1}) and Wonji (1.85 t ha^{-1}) in 2013. Similarly in 2014, the highest unmarketable green pod yield was recorded at Melkassa (2.41 t ha^{-1}) followed by Debrezeit (2.29 t ha^{-1}) and Wonji (1.44 t ha^{-1}). However, there was no significant difference among genotypes in unmarketable yield ($p < 0.05$) in 2013 cropping season (Table 3). The unmarketable green pod yield ranged from 2.4 t ha^{-1} to 3.36 t ha^{-1} for genotypes L12 and HAB-407 in that order. However, genotype HAB-407 had the highest unmarketable yield at Melkassa (4.48 t ha^{-1}) and Debrezeit (3.42 t ha^{-1}) and BC4.4 (2.28 t ha^{-1}) at Wonji.

However, in 2014 cropping season, the unmarketable yield combined over the three locations was highly significant at ($p<0.01$) (Table 3) and ranged from 1.53 t ha^{-1} to 2.75 t ha^{-1} for the genotypes BC4.4 and Plati respectively.

Table 3: Unmarketable green pod yield (t ha^{-1}) of snap bean genotypes tested at Melkassa and Debrezeit Agricultural Research Centers and Wonji in 2013 and 2014

Genotypes	2013				2014				
	Melkassa	Wonji	Debrezeit	**Combined**	Melkassa	Wonji	Debrezeit	**Combined**	Over all
Plati	3.5	1.99	2.1	**2.53**	3.72^{a}	1.54	2.99	**2.75^{a}**	2.64
Nelson	3.56	1.56	2.41	**2.51**	3.13^{a}	1.32	2.56	**2.34^{ab}**	2.42
L 12	3.71	1.01	2.41	**2.40**	2.4^{b}	1.56	2.7	**2.22^{b}**	2.31
HAB - 419	3.93	2.12	3.3	**3.11**	2.29^{bc}	1.47	2.23	**1.99^{bc}**	2.55
HAB - 407	4.48	2.16	3.42	**3.36**	1.59^{cd}	1.48	1.65	**1.57^{c}**	2.46
HAB - 410	3.93	1.76	2.43	**2.71**	2.34^{b}	1.56	1.81	**1.90^{bc}**	2.31
BC 4.4	4.11	2.28	2.41	**3.03**	1.37^{d}	1.15	2.08	**1.53^{c}**	2.28
Mean	3.89^{a}	1.85^{c}	2.69^{b}	**2.81**	2.41^{a}	1.44^{b}	2.29^{a}	**2.05**	2.43
CV	21.65	34.2	33.6	**30.04**	16.78	30.63	23.57	**18.29**	29.83
F-test	NS	NS	NS	NS	**	NS	NS	**	NS
LSD	-	-	-	-	7.18	-	-	**5.26**	-

Means followed by the same letter are not significantly different at p<0.05 and p<0.01.

3.2. Total Yield

The performance of seven snap bean genotypes in total green pod yield is presented in Table 4. The pooled analysis of variance for total green pod yield was significant at *p < 0.05*. The overall total green pod yield ranged from 9.8 to 11.784 t ha^{-1} for genotypes BC4.4 and Plati respectively. Most genotypes gave total green pod yield above the grand mean (10.88 t ha^{-1}). Abdel-Mawgoud *et al.*,(2005) reported significant difference among genotypes tested in two successive seasons, 2003 and 2004. The total yield ranged from 14.3 t ha^{-1} to 17 t ha^{-1} and 17.2 t ha^{-1} to 20.4 t ha^{-1} for seasons 2003 and 2004 respectively.

The combined total green pod yield over the three locations in 2013 cropping season showed significant differences for the genotypes at *P < 0.05* and ranged from 11.98 t ha^{-1} for HAB- 407 to 9.93 t ha^{-1} for cultivar L12. However, there was no significant difference among genotypes at Wonji and Debrezeit locations. The highest total green pod yield was obtained at Debrezeit (11.42 t ha^{-1}) followed by Wonji (11.3 t ha^{-1}) and Melkassa (11.12 t ha^{-1}) and from genotypes the highest total yield was obtained from HAB - 407 (11.98 t ha^{-1}).

In 2014, there was highly significant difference at p< 0.01 was observed among genotypes in total pod yield combined over locations which ranged from 8.39 t ha^{-1} for cultivar HAB-410 to 12.2 t ha^{-1} for Plati. Similarly, there was highly significant difference at *p < 0.01* among locations in total green pod yield and the highest total green pod yield was obtained at Melkassa (12.36 t ha^{-1}) followed by Debrezeit (10.66 t ha^{-1}) and Wonji (8.38 t ha^{-1}). Most of the genotypes (57.1%) gave high total yield above the grand mean (10.46 t ha^{-1}). From genotypes the highest yield was obtained from Plati (12.2 t ha^{-1}) followed by HAB-419 (10.8 t ha^{-1}) and Nelson (10.61 t ha^{-1}).

Table 4: Total green pod yield (t ha^{-1}) of snap bean genotypes tested at Melkassa and Debrezeit Agricultural Research Centers and Wonji in 2013 and 2014.

Varieties	2013				2014				Overall
	Melkassa	Wonji	Debrezeit	**Combined**	Melkassa	Wonji	Debrezeit	**Combined**	
Plati	11.58^{ab}	10.53	11.99	**11.37^{a}**	14.83	11.98^{a}	10.57^{bc}	**12.2^{a}**	**11.78^{a}**
Nelson	11.64^{ab}	12.71	10.22	**11.52^{a}**	13.54	8.42^{bc}	9.86^{bc}	**10.61^{b}**	**11.06^{ab}**
L 12	8.73^{c}	9.13	11.94	**9.93^{b}**	10.84	7.84^{bc}	12.78^{a}	**10.48^{b}**	**10.21^{bc}**
HAB - 419	10.6^{b}	12.49	11.83	**11.64^{a}**	13.4	8.44^{bc}	10.56^{bc}	**10.8^{ab}**	**11.22^{a}**
HAB - 407	12.23^{a}	12.06	11.66	**11.98^{a}**	12.62	9.68^{ab}	8.88^{c}	**10.39^{b}**	**11.19^{a}**
HAB - 410	12.33^{a}	11.23	10.97	**11.51^{a}**	11.76	7.31^{cd}	12.03^{ab}	**10.37^{b}**	**10.93^{ab}**
BC 4.4	10.73^{b}	11.49	11.31	**11.17^{a}**	9.52	5.75^{d}	9.9^{bc}	**8.39^{c}**	**9.78^{c}**
Mean	11.12^{a}	11.374^{a}	11.42a	**11.^{3a}**	12.36^{a}	8.38^{c}	10.66b	**10.46^{b}**	**10.88**
CV	7.33	6.9	6.9	**8.83**	17.52	15.83	11.53	**15.72**	**12,85**
F-test	**	NS	NS	*	NS	**	*	**	*
LSD	14.496	-	-	**9.51**	-	23.59		**15.07**	**9.27**

Means followed by the same letter are not significantly different at $p < 0.05$

3.3. Maturity and pod characters

There was no significant difference in days to 50% flowering at $p<0.05$. However, significant difference was observed among the genotypes in pod length and diameter. Genotype Plati had the largest pod diameter (7.02 mm) and length (119.3 mm). In line with the present finding, Kshouni (2017) reported significant difference among genotypes in pod length and diameter pooled across two cropping season, 2015/16 and 2016/17; and pod diameter and length ranged from 128 mm to 143 mm and 6.4 mm to 7.5 mm respectively. Pandey *et al.*, (2011) also reported pod length that ranged from 107 mm to 157 mm among different varieties. There were also great diversity among genotypes in pod shape, color, fiber content, smoothness and curvature. Genotype Plati had low fiber content, green pod color, smooth pod surface, straight pod curvature and round pod shape which determine the degree to which snap bean varieties are accepted by consumers.

Table 5: Days to 50% flowering and pod characters of snap bean genotypes tested at Melkassa and Debrezeit Agricultural Research Centers and Wonji in, 2013 and 2014

Cultivars	DF	PL (mm)	PD (mm)	PC	Fibreless	PSH	PCR	GH
Plati	42.11	119.3^{a}	7.02^{a}	Green	Nill	Round	straight	Bush
Nelson	42.3	116.1^{a}	7.23^{a}	dark green	Medium	Round	straight	Bush
L 12	42.78	118^{a}	6.04^{d}	Green	Nill	Round	straight	Bush
HAB - 419	42.61	101^{c}	6.43^{bc}	light green	Medium	Round	straight	Bush
HAB - 407	42.23	99.7^{c}	6.62^{bc}	light green	Nill	semi-flat	straight	Bush
HAB - 410	41.94	101.3^{c}	6.66^{ab}	Green	Nill	Round	straight	Bush
BC 4.4	43.18	110.7^{b}	6.39^{ab}	light green	Nill	semi-flat	straight	Bush
Mean	42.46	109.4	6.63	-	-	-	-	-
CV	1.64	6.73	5.67	-	-	-	-	-
F-test	NS	**	**	-	-	-	-	-
LSD	0.46	0.49	0.25	-	-	-	-	-

Note: SC =stand count at harvest, DF= Days to 50% flowering, PL= pod length, PD= pod diameter, PC= pod color, PSH= pod shape, PH= plant height, PCR= pod curvature, GH=growth habit.

4. CONCLUSION AND RECOMMENDATION

The snap bean genotypes were diverse in vegetative, pod characteristics and yield responses. The pooled analysis of variance for marketable green pod yield was significant at ($p < 0.01$). The overall combined mean marketable green pod yield ranged from 7.5 t ha^{-1} to 9.14 t ha^{-1}. Total green pod yield was also significant at $p < 0.05$. The overall total green pod yield ranged from11.7 t ha^{-1} to 9.7 t ha^{-1} for genotypes Plati and BC4.4 respectively. The vegetative and pod quality performance of snap bean genotypes across locations and years were highly significant at $p < 0.01$. Genotype Plati gave larger pod diameter and length than the standard check. Thus, based on high green pod yield (11.7 t ha^{-1}) and pod characters (pod diameter (7.02 mm) and length (119.3 mm), low fiber content, green pod color, smooth surface, straight curvature and round pod shape, genotype Plati was identified as potential variety and released for production in the Central Rift Valley and similar agro-ecologies of Ethiopia.

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