Performance of Introduced Climbing Bean (*Phaseolus vulgaris* L.) Varieties for Registration in Ethiopia

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Abstract

Testing the adaptability of newly introduced crop varieties under potential growing agro-ecologies is an imperative component of a fast-track breeding approach in Ethiopia. A field experiment was conducted to evaluate the performance of climbing bean varieties for grain yield and other agronomic traits at four locations (Jimma, Haru, Assosa and Pawe) during 2019-2020 main cropping seasons. A total of 25climbing bean varieties including standard check (Dandesu) were used in this study. The trial was laid down using 5x5 triple lattice design. Data was collected on 11 traits: numbers of days to 50% flowering, 95% maturity, pods per plant, seeds per pod, seed per plant, plant height (cm), common bacterial blight, angular leaf spot, floury leaf spot, hundred seed weight (g), and grain yield per plant (tha^{-1}). The data was subjected to statistical analysis using SAS software. The combined ANOVA revealed significant variation (P≤ 0.01) among varieties for most of the traits except for number of days to 95% maturity and hundred seed weight. The mean grain yield performance for the combined data was the highest for variety RWV 1272 (5.37 tha^{-1}) followed by G13607 (4.53 t/ha), and CAB2 (tha^{-1}). The three high yielding varieties had produced 117.4%, 83.4% and 54.7% yield increase over the standard check, Dendesu (2.47 tha^{-1}), respectively. In addition to their high yielding ability the varieties showed good resistance/tolerance reaction against common bacterial blight, angular leaf spot and floury leaf spot disease. The three varieties have medium seed size but have different seed color. The color of their seed is, brun purple for RWV1272; red forG13607; and white for CAB2, which have their own marketed demand and farmers' preference. The other major attributes of the varieties were acceptable cooking time of 81-88 minutes. The three varieties were planted under verification plot and evaluated by variety release committee for official registration. Based on their best performance in grain yield, disease reaction and acceptable quality in terms of seed size, color and cooking time, the two varieties RWV1272 and CAB2 were accepted by national variety release committee to be registered as commercial variety in Ethiopia since June 2022. The registered varieties are recommended for Southwest, West and other similar agro ecologies with high rain fall in Ethiopia. To exploit the high yield advantage of the varieties and partly solve the food self-sufficiency in the country, major emphasis should be given for early generation seed multiplication, well organized demonstration and popularization of the varieties to farmers.

Keywords: climbing bean, growth habit, Adaptation, Yield

Introduction

Common beans (*Phaseolus vulgaris* L., 2n = 2x = 22)are the second most important crop in Eastern, Central, and Southern African agriculture. Ethiopia is one of primary beans growing regions in Africa. Common bean has been introduced by the Portuguese in the 16th century in Ethiopia (Imru, 1985).It has been known as an export crop and has probably been grown as a food crop for a much longer period. In terms of nutrition, common bean is often called the "poor man's meat" rich in protein (about 22%) and good source of Iron and Zinc (Beebe *et al.*, 2000). The crop is a key component in intensifying production because it is easily intercropped and crop rotated with other crops and improve soil fertility through nitrogen fixation. In Ethiopia common bean covers 18.60% (1311, 583.58hectares) of the pulse area coverage and 17.28% (about 552, 564.074tons) of pulse production. National average productivity common bean in Ethiopia is generally low, 1.73 t/ha (CSA, 2021), this is because of lack of alternative improved bean type varieties, biotic and abiotic factors and poor extension services.

Depending on their growth habit common bean has classified in to four groups: Class I has a determinate growth habit (bush type bean); Class II-IV have an indeterminate growth habit, out of which class IIIb and class IV are referred to as climbing beans or pole beans. Climbing beans originated from the medium to high-altitude regions of the Andes and Central America (Voysest, 2000). Climbing is a twinning, annual, herbaceous plant with various growth habits, morphological traits, and seed and pod characteristics. The crop is adapted to an altitude ranging from sea level to nearly 3000 masl (CIAT, 1986a).

Climbing beans in Ethiopia are mainly adapted in mid to highland areas and produced around homestead gardens and along the fences and sometimes intercropped with maize/pigeon peas. It can also be planted in the production fields by using supporting sticks (Berhanu *et al.*, 2019). Cropping land is getting shorter in Ethiopia, so, climbing bean which has high yield potential up to 4 to 5 $tha^{-1}$is becoming useful to maximize income per unit area. Even though, climbing beans are relatively high grain yield, there is a limitation of climbing bean improved variety in the country. Hence, alternative improved variety development of different common beans types across agro-ecology is important to increase production and productivity in the country.

Variety adaptation is one of the fast tracks variety development approach in common bean breeding program in Ethiopia. This approach requires introduction of commercial varieties from abroad and testing their performance for official registration of the best varieties for commercial production. A few numbers of varieties were released in this way so far. However, yield maximization and

development of disease resistant and tolerant varieties that meet the increased demand of the growing industries and market still remain as gaps in common bean technology development. Bearing in mind the above facts, the tested materials were introduced from International Centre for Tropical Agriculture (CIAT). Therefore, this study was conducted to evaluate, select and recommend adaptable commercial climbing bean varieties for potential climbing bean growing agro-ecologies in Ethiopia.

Materials and Methods

The experiment was conducted at Jimma, Haru, Assosa and Pawe during 2019-2020 cropping season. The description of experimental locations is stated in Table1.

Experimental Materials, Design and management

The field experiment was conducted using 25 introduced climbing bean varieties including the standard check variety (Dandesu). The tested climbing bean varieties were released commercial varieties in Burundi, Uganda, Rwanda and Tanzania (Table 2). The experiment was laid out in triple lattice design. Planting was done in a plot of 4 rows with 4m length and 10cm spacing between plants and 50cm between rows. Fertilizer NPS (19%N, 38% P, 7% Sulfur, and the rest filler) at the rate of 121kgha^{-1} was applied at planting. Supporting stick was used and the rest agronomic management was done as per the recommendation.

The candidate climbing bean varieties; RWV1272, G1360 and CAB2 along with the check Dendesu were tested under verification plot. The verification plot was planted at Jimma, Haru and Pawe research stations and on two farmer's field surrounding each research center. The trial was planted in a 10m X 10m single plot. All cultural practices for climbing were carried out as stated above. The verification plots were evaluated by variety release technical committee.

Data Collection and analysis

Data were collected both at plot and plant basis. Date of emergence, date of 50% flowering, date of 95% maturity, stand count at emergence, stand count at harvest, disease severity visual score (1-9 scale), plant height(cm), number of pods/plant, number of seed/plants, hundred seeds weight(g), and yield (tha^{-1}) were collected. The data analysis was done using SAS software. General linear mode of SAS was used to do the ANOVA and computation of the means.

Table 1. Descriptions of the experimental locations

Location	Altitude (m.a.s.l.)	Latitude	Longitude	Temperature		RF(mm)
				min	max	
Jimma	1,754	7°46'0" N	36°00'0"E	11.6°C	26.3°C	1,572
Assosa	1580	10° 03' 0" N	34° 59' E	14°C	39°C	1,275
Haru	1252	8°59' 0" N	35°47' 0"E	16°c	27°c	1227
Pawe	1120	11°19' 0"N	36°24' 0"E	16.3 °c	32.6°c	1587

Table 2. Climbing bean varieties tested in four locations during 2019-2020

No.	Varieties	Source	Origin
1	NAKAJA	CIAT	Burundi
2	RWV 1129	CIAT	Burundi, Tanzania
3	VCB 81013	CIAT	Burundi
4	GASILIDA	CIAT	Burundi, Rwanda
5	MAC 70	CIAT	Burundi
6	Kinure	CIAT	Burundi
7	MUHORO	CIAT	Burundi
8	GSZ 611	CIAT	Burundi
9	AND 10	CIAT	Burundi
10	Vuninkingi	CIAT	Burundi, Rwanda
11	G13607	CIAT	Burundi
12	IZO201543	CIAT	Burundi
13	Bihogo(MLV-206/96B)	CIAT	Burundi
14	RWV 1272	CIAT	Burundi, Rwanda
15	Nokia	CIAT	Burundi
16	Jaune volubile	CIAT	Burundi
17	NUV 30	CIAT	Burundi
18	NABE 12C	CIAT	Uganda
19	NABE 26C	CIAT	Uganda
20	NABE 29C	CIAT	Uganda
21	MAC 44	CIAT	Burundi,Uganda,Tanzania
22	NYIRAMUHONDO	CIAT	Uganda
23	G 2333	CIAT	Uganda, Rwanda
24	CAB 2	CIAT	Rwanda, Tanzania
25	Check (Dandesu)	Ethiopia,	Ethiopia

Results and Discussion

The results of the combined analysis of variance (Table 5) revealed that, the mean square due to location was significant ($P \leq 0.01$), indicating the distinct nature of the four test locations. The mean square due variety was significant for most of the traits ($P \leq 0.01$) except for days to maturity and hundred seed weight, indicating varieties were responded differently for each trait. Mean squares due to location x variety were significant for most of traits except days to flowering and maturity, seed per pod, seed per plant and angular leaf spot, meaning

that varieties exhibited different relative performance in each location. Generally, the result for yield and related traits indicated that phenotypic variability for these traits is dependent on genetic factors, environmental variables and the interaction between varieties and environment.

The yield performances of 25varieties for separate analysis are presented in Table4.The maximum mean environmental grain yield across varieties was recorded at Haru in 2020 from the variety RWV 1272 (8.58 tha^{-1}), while the minimum yield was recorded at Pawe in 2020 from the variety Jaune volubile(0.29 t/ha). The mean yield performance of the varieties at Jimma (4.60 tha^{-1} of the two years) and Haru (3.98 tha^{-1}) was relatively high, while mean yield of varieties at Pawe (2.12 tha^{-1}) followed by Assosa (1.33 tha^{-1}) was relatively low. So, Jima and Haru which are characterized by mid altitude with high in rainfall are found more suitable environment for climbing bean production compared to Assosa and Pawe. In most of the environments varieties RWV1272, G13607 and CAB2 produced consistent and high grain yield over the check Dandesu. The mean yield performance across the five environments indicated that, maximum yield was recorded from varieties RWV 1272 (5.37 tha^{-1}) followed by G13607 (4.53 tha^{-1}), and CAB2(3.82tha^{-1}), which exhibited a yield advantage of 117.4%, 83.4% and 54.7% over the standard check, Dandesu (2.5 tha^{-1}), respectively.

The mean performance of the tested varieties across environment was also ranged widely for other agro-morphological traits (Table5). The earliest days to flowering (48) and maturing (98) was recorded from variety RWV 1129, and IZO201543, while the latest flowering (54) and latest maturing (150) was recorded from varietyMLV-206/96B and Jaune volubile, respectively. The high yielding varieties RWV 1272, G13607 and CAB2 were relatively found medium maturing, which takes 106,104 and 103 days to physiologically maturity, respectively. The tallest plant height (243.8cm) was recorded for the standard check Dandesu, while shortest height (144.8cm) was recorded for the variety Jaune volubile.Highest range was also obtained for number of pod per plant (10 to 20), number of seed per pod (4 to 6), number of seed per plant (42 to 85), hundred seed weight(24 to 38gm) and yield per plant(14 to 39$gmplant^{-1}$), which played important role in the total variability of the tested climbing bean varieties.

The tested varieties also showed significantly different reaction against common bacterial blight, angular leaf spot and floury leaf spot. The varieties; RWV 1272, G13607 and CAB 2 also showed resistance/tolerance level of reaction against common bacterial blight, angular leaf spot and floury leaf spot. These three varieties were grouped under medium seed size and characterized by brun purple, red and white seed color, respectively. They have also fast cooking with 81, 88, and

82minutes of cooking time, respectively (Table 6). Therefore, these three varieties which have statistically considerable yield difference and other yield component traits were promoted to variety verification trial for registration. After evaluation the two candidate varieties by the national variety release committee, RWV 1272 and CAB2 were registered for production since 2022 for their high grain yield, good agronomic performance, acceptable quality, fast cooking time and high market demand. The registered varieties are recommended for Southwest, West and other similar agro ecologies with high rain fall in Ethiopia.

Table 3. Mean squares of the combined analysis of variance for yield and related characters of 25 introduced climbing bean varieties at five environments

Source	DF	DTF	DTM	PH	NPP	SPd	NSP	CBB	ALS	FLS	HSW	Yld(gm/pl)	Yld(t/ha)
Year	1	0.14ns	2145.5ns	13180.0**	313.5**	1.6ns	4114.0*	1.2ns	13.7**	8.7*	8381.1**	37.4ns	80.6**
Loc	3	2327.1**	9167.0**	142486.30**	1959.7**	13.8**	41125.4**	50.3**	67.3**	53.2**	4105.4**	2720.7**	160.7**
Rep	2	120.0**	43.7ns	15951.7**	158.6*	0.4ns	2056.8ns	3.6ns	7.6**	9.8**	9.6ns	310.3ns	59.8**
Block(Rep)	12	16.0**	738.3ns	5172.7**	15.8ns	1.5ns	834.6ns	3.8ns	1.8ns	1.5ns	21.4ns	149.5ns	2.7ns
Geno	24	20.0**	376.9ns	4972.9**	58.8*	2.7**	1712.7*	3.8*	2.8*	4.7**	31.6ns	218.2*	5.8**
L*G	72	23.40ns	387.30ns	3319.7**	53.2*	1.6ns	1279.3ns	3.6**	2.1ns	4.2**	55.3**	189.3*	3.7**
Y*G	24	21.6ns	509.2ns	1665.8ns	77.2**	2.5*	2255.6ns	2.3ns	1.8nss	4.4**	93.4**	246.3**	2.6ns

Where, * = significant at (P≤0.05) and **= significant at (P≤ .01), yr=year, loc=location, Geno=variety, DF =degree of freedom, DTF = days to 50% flowering, DTM = days to 95% pod maturity, PH = plant height, NPP =pod per plant, NSD= seed per pod, NSP= seed per plant, CBB=common bacterial blight, ALS= angular leaf spot,FLS=flory leaf spot, HSW=hundred seed weight, YLDpl= yield per plant, YLDha= yield per ha-1

Table 4. Mean grain yield performance (tha^{-1}) of 25 climbing bean varieties evaluated at 4 locations during 2019-2020

		2019	2020	2020			
No.	Variety	Jimma	Jimma	Assossa	Haru	Pawe	Overall yld(t/ha^{-1})
1	NAKAJA	4.98	4.47	2.79	4.99	1.33	3.69
2	RWV 1129	0.95	2.75	2.23	3.43	1.22	2.09
3	VCB 81013	3.79	6.19	2.26	3.92	1.36	3.53
4	GASILIDA	3.46	4.32	2.08	4.00	1.54	2.92
5	MAC 70	1.54	1.63	1.47	1.97	1.33	1.44
6	Kinure	4.62	3.61	2.82	2.00	1.48	2.76
7	MUHORO	2.87	3.05	1.04	2.25	1.32	2.32
8	GSZ 611	5.33	6.60	2.64	3.50	1.37	3.93
9	AND 10	2.78	5.29	1.73	2.11	1.37	2.78
10	Vuninkingi	4.79	7.31	2.80	5.57	1.30	3.94
11	**G13607**	**3.05**	**7.23**	**2.62**	**7.81**	**1.42**	4.53
12	IZO201543	3.55	3.97	2.34	5.71	1.15	3.52
13	MLV-206/96B	3.36	5.91	3.13	3.88	1.15	3.60
14	**RWV 1272**	**4.79**	**7.81**	**2.87**	**8.58**	**1.47**	5.37
15	Nokia	5.29	8.39	2.02	3.94	1.43	4.20
16	Jaune volubile	0.45	0.64	1.55	2.37	0.29	0.88
17	NUV 30	5.60	3.84	2.23	4.83	1.32	3.55
18	NABE 12C	2.39	4.49	1.87	1.82	1.48	2.50
19	NABE 26C	1.90	3.10	1.30	4.04	1.38	2.54
20	NABE 29C	2.70	2.84	2.40	4.38	1.28	2.99
21	MAC 44	1.23	3.74	1.69	2.54	1.49	2.41
22	NYIRAMUHONDO	4.61	5.77	2.43	5.52	1.46	4.02
23	G 2333	2.81	2.86	0.57	1.28	1.56	2.08
24	**CAB 2**	**3.75**	**5.45**	**2.73**	**4.16**	**1.46**	3.82
25	Check (Dandesu)	2.20	3.00	1.36	4.84	1.37	2.47
	Mean	3.31	4.57	2.12	3.98	1.33	3.12
	CV	19.5	25.9	17.0	43.0	8.3	**28.5**
	LSD	1.37	1.9567	0.76	2.8307	0.1831	1.12

Table 5. Mean grain yield and other traits of climbing bean varieties evaluated at 4 locations in 2019-2020

No.	Genotype	DTF	DTM	PH	NPP	SPd	SPP	CBB	ALS	FLS	HSW	Yld (gm/plant)	Yld (tha^{-1})
1	NAKAJA	49.3	98.7	200.5	11.9	5.0	52.4	4.5	4.5	2.3	27.6	23.7	3.69
2	RWV 1129	47.6	102.7	179.9	10.7	5.1	54.2	3.7	3.2	3.2	34.1	21.8	2.09
3	VCB 81013	49.9	104.5	218.1	16.3	4.9	73.0	4.2	3.6	2.3	26.3	23.9	3.53
4	GASILIDA	50.4	104.8	237.5	13.7	5.2	63.5	3.9	2.8	3.7	28.9	38.7	2.92
5	MAC 70	51.5	99.7	178.5	11.3	4.9	50.0	3.7	2.3	2.6	31.3	21.6	1.44
6	Kinure	50.0	103.5	186.8	14.0	5.1	62.1	4.2	3.7	2.3	30.0	22.7	2.76
7	MUHORO	50.5	103.7	187.2	12.3	4.5	45.9	4.2	3.5	2.6	30.3	22.6	2.32
8	GSZ 611	53.9	103.5	227.4	15.1	5.5	74.2	4.2	2.7	1.2	29.1	24.4	3.93
9	AND 10	52.5	105.0	204.8	12.2	6	69.2	3.3	3.2	2.8	28.7	18.2	2.78
10	Vuninkingi	51.1	106.0	226.7	12.8	5.7	66.1	3.2	2.3	1.9	26.7	22.4	3.94
11	G13607	52.1	103.7	216.7	18.9	4.7	78.8	3.9	2.9	1.8	30.2	18.9	4.53
12	IZO201543	49.8	97.8	183.3	15.0	4.4	53.8	3.9	2.7	1.7	28.4	17.5	3.52
13	MLV-206/96B	54.1	106.1	208.9	10.0	5.1	49.6	3.3	2.6	1.9	30.4	22.8	3.60
14	RWV 1272	50.8	105.8	219.1	14.7	5.1	73.1	3.2	2.6	1.7	26.1	19.3	5.37
15	Nokia	50.1	101.3	198.9	14.6	5.4	70.6	3.4	2.5	1.9	24.3	23.9	4.20
16	Jaune volubile	48.9	150.5	144.9	12.6	4.4	53.8	4.0	3.0	3.8	28.3	14.5	0.88
17	NUV 30	49.9	100.7	202.3	15.1	4.9	73.2	3.7	2.9	1.2	25.9	18.1	3.55
18	NABE 12C	51.3	99.9	218.5	9.6	5.2	49.6	2.9	2.7	3.0	33.9	18.9	2.50
19	NABE 26C	50.0	102.0	190.7	12.2	4.5	50.3	3.9	3.2	2.9	31.7	17.6	2.54
20	NABE 29C	48.9	101.7	187.9	10.3	4.1	41.8	2.9	2.5	2.0	30.5	18.7	2.99
21	MAC 44	48.7	99.4	172.4	13.5	4.5	62.4	3.3	2.6	3.0	34.7	20.7	2.41
22	NYIRAMUHONO	51.5	104.3	241.0	19.2	4.9	85.1	2.5	2.5	1.5	25.9	20.4	4.02
23	G 2333	49.9	102.8	190.6	12.7	4.6	56.0	5.1	3.9	3.0	24.2	20.9	2.08
24	CAB 2	50.2	102.7	226.5	14.8	5.1	68.9	3.2	3.2	3.5	25.8	24.4	3.82
25	C1(Dandesu)	52.3	102.9	243.9	10.0	4.6	46.1	4.4	3.5	2.0	27.2	19.3	2.47
	Mean	**50.6**	**104.5**	**203.7**	**13.3**	**4.9**	**60.9**	**3.7**	**3.0**	**2.4**	**28.8**	**21.4**	**3.12**
	CV	**8.8**	**24.7**	**22.4**	**44.8**	**24.2**	**50.7**	**39.2**	**41.4**	**54.0**	**18.0**	**52.6**	**28.49**
	LSD	**NS**	**NS**	**34.7**	**4.6**	**0.9**	**24.0**	**1.1**	**1.0**	**1.0**	**4.0**	**8.7**	**1.12**

Table 6. Seed Characteristics and cooking time of climbing bean Candidate and check varieties

No.	Variety	Seed color	Seed size	Cooking time (minute)	Decision of the committee (NVRC)	Year of release
1	RWV1272 (candidate1)	brun purple	medium	81	released	2022
2	G13607(candidate2)	red	medium	88	rejected	-
3	CAB2	white	medium	82	released	2022
5	Dandesu(check1)	red	medium	87	check	2012

Conclusion and Recommendation

Evaluating the performance of climbing bean varieties and recommending the adaptable once for suitable agro-ecologies can boost production and productivity of bean in Ethiopia. The combined analysis of variance (ANOVA) revealed significant variation ($P \leq 0.01$) among varieties for most of the traits considered. The mean yield performance across the five environments recorded maximum grain yield from variety RWV 1272 followed by G13607, and CAB2. The outstanding varieties were also showed resistance/tolerance to foliar disease and fast cooking time. Therefore, these three varieties which exhibited high grain yield and good agronomic performance were promoted to variety verification trial for registration. After evaluation, the two varieties RWV 1272 and CAB2 were registered for production since 2022 for their high grain yield, good agronomic performance, acceptable qualityin terms of seed size, color, cooking time and high market demand.These varieties are suitable for Southwest, West and other similar agro ecologies with high rain fall in Ethiopia. It is highly recommended to make available the initial seed, demonstration and popularization of these varieties in suitable agro-ecologies. In the future, major effort will have to be put into mind to multiplying early generation seeds, demonstration and promotion of these varieties.

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Reference

Beebe, S., Skroch, P.W., Tohme, J., Duque, M.C., Pedraza, F. and Nienhuis, J., 2000. Structure of genetic diversity among

common bean landraces of Middle American origin based on correspondence analysis of RAPD. *Crop science*, *40*(1), pp.264-273.

Berhanu Amsalu, Kassaye Negash, Tigist Shiferaw, Kidane Tumssa, DagmawitTsegaye, Rubyogo Jean Claude, and Clare Mugisha Mukankusi, 2018. Progress of common bean breeding and genetics research in Ethiopia. *Ethiopian Journal of Crop Science*.

Central Statistical Authority (CSA), 2021. Agricultural sample survey, Area and production of temporary crops, private holdings for the 2021.

Imru, A., 1985. Bean production in Ethiopia, pp.15- 38. In Proceedings of Regional Workshop on Potential for Field Beans (Phaseolus vulgaris L.) in West Asia and North Africa. 21-23 May, 1983. Aleppo, Syria

Ohlander, 1980. Research on haricot bean (Phaseolus vulgaris L.) production in Ethiopia 1972-1976. Rapport, Institutionen for Vaxtodling No.82 pp.288pp. ref.131

Voysest, 2000. Mejoramientogenetico del frijol (Phaseolus vulgaris L.): legado de variedadas de America Latina 1930-1999.