Trends in Agricultural Sciences

OPEN ACCESS

Field Performance Evaluation of Climbing Beans (*Phaseolus vulgaris* L.) Varieties for Agronomic Traits Under Pawe District, North-West, Ethiopia

Zeru Yimer Kebede

Department of Field Crops Improvement Program (Lowland Pulse Breeding and Genetics), Ethiopian Institute of Agricultural Research, Pawe Agricultural Research Center, P.O. Box 25, Pawe, Ethiopia

ABSTRACT

Background and Objective: Adaptation and promotion of improved crop varieties was one of the best means to solve the shortage of widely adapted crop technologies. Therefore, the objective, of the study was to evaluate the adaptability and field performance of climbing bean varieties' yield and yield-related traits with a full practice. **Materials and Methods:** Twenty-five climbing bean varieties with standard check, Dandesu, were involved in the study during the 2020 and 2021 cropping seasons with full packages of agronomic practices. Triple lattice design with three sets of replications applied. The agronomic traits evaluated were 50% days to flowering, 95% days to pod maturity, plant height, angular leaf spot, number of pods per plant, number of seeds per pod, hundred seed weight, adjusted grain yield per hectare and other yield-related agronomic characters. **Results:** There was a significant difference between treatments at ($p<0.05$ level). The highest grain yield was obtained from RWV1272 (1904.30 kg/ha) followed by CAB2 (1765.60 kg/ha) and SELIAN06 (1692.50) while the lowest grain yield was scored by CMKN1810 (805.10 kg/ha). The RWV1272 (17.29) scored the highest pods per plant whereas CMKN1551 scored the lowest (7.48); this implied the variety RWV1272 was a high grain yielder among the tested climbing beans for this study. Besides; the yield advantage of better-performing climbing bean varieties (RWV1272, CAB2 and SELIAN06) over the standard check (Dandesu) was 58.06, 46.55 and 40.48%, respectively. **Conclusion:** Based on the data collected, at field conditions, variation occurred among climbing bean varieties; therefore, the performance evaluation of climbing bean varieties was an indicator for future improvement of dry beans and recommended for further evaluation, demonstration and large-scale demonstration (LSD) purposes for the study area (Pawe District) and similar areas.

KEYWORDS

Agronomic characters, climbing beans, crop technologies improvement, large scale demonstration, variation, yield advantage

INTRODUCTION

Pulses are widely known and frequently consumed commodities in various parts of the world. Among them, common bean plays a crucial role across the world mainly in the warm and lowland areas of the country including Ethiopia[1]. Legumes are a critical component of many agricultural systems and a major contributor to global food systems[2]. Within recent years, probably within a few decades, achieving food

ISSN: 2957-9449 (Online)
ISSN: 2957-9430 (Print)
https://doi.org/10.17311/tas.2024.255.273

Received: 03 Apr. 2023
Accepted: 23 Jul. 2024
Published: 30 Sep. 2024

security will be a major challenge in Ethiopia as most of the population practices mixed agricultural activity[3].

However, Gaspard *et al*.[4] studied and reported that in the agriculture sector so far has played an important role in the economic growth and development prospects of the majority of developing countries. In addition, Stagnari *et al*.[5] reported that legume crops could play an important role in food security, climate change mitigation and increasing the demands of energy by delivering multiple services in line with sustainability principles.

Besides, climbing beans offer the potential for sustainable intensification in the East African highlands, but their introduction requires a major change in the cropping system compared with the commonly grown bush bean[5].

Currently, to enhance yield and other by-products, the area for production of pulses increased slightly. Furthermore, Baraki *et al*.[6] studied and reported, that in terms of area coverage and production, legume crops placed second rank next to cereals. Even though crops cultivated in Africa play a vital role in their contribution to food security, they produce below potential yields compared to the rest of the world[7]. Low productivity in Africa is also related to poor soil fertility and shortage of moisture, as well as a variety of insect pests, diseases and weeds[7].

Similarly, Kebede[8] reported currently the interest of small-scale farmers to use improved crop varieties is getting sound. Furthermore, Bassa *et al*.[9] studied and reported that improved agricultural technologies have a direct role in improving productivity, income generation and food security as far as the focus is on increasing yield and market-oriented tasks. However, under the study area, the use and application of improved climbing bean varieties were limited due to a shortage of well-adapted and performed cultivars. To support the above sentence; a survey result reported by Gichangi *et al*.[10] revealed among the numerous factors, for low bean yield, one of the challenges was non-use of high-yielding varieties, particularly, the result showed that about 70% of the households had difficulties in accessing clean seeds of improved climbing bean varieties. This has had a negative impact on food security and income in rural households.

Thus, field performance evaluation of climbing beans (*Phaseolus vulgaris* L.) varieties for agronomic traits under Pawe District, North-West, Ethiopia was aimed to evaluate and recommend better performing climbing beans for grain yield and other traits for the study area and to generate relevant data/information for future improvements of climbing beans under the study area and similar ecologies.

MATERIALS AND METHODS

The field experiment was implemented from 08 August, 2020 up to 10 December 2021. Following this, the first sowing date was conducted on 08 August, 2020 and the second sowing date was executed on 06 August, 2021, respectively.

Description of the study area: The study site is located in Metekel Zone, Pawe District, North-West, Ethiopia. The specific location lies between 11°19'0"N Latitude and 36°24'0"E Longitude. The mean annual minimum and maximum temperature is 16.3 and 32.6°C, respectively. The area has an unimodal rainfall pattern extended from early June up to mid-October. The dominant soil type is vertisol however the experiment was conducted on nitisol.

Study materials: The twenty-five genetic materials incorporated for this particular study were brought from the national lowland pulse program base at Melkassa Agricultural Research Center (MARC) and the collaborating Jimma Agricultural Research Center (JARC). The source of the materials is from the crossing program and released cultivars or from commercial scheme. Additional information on the materials is presented in (Table 1).

Table 1: Climbing bean varieties tested under field conditions during 2020-2021 cropping seasons

Number	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	Burundi
19	NABE 26C	CIAT	Burundi
20	NABE 29C	CIAT	Burundi
21	MAC 44	CIAT	Burundi, Uganda, Tanzania
22	NYIRAMUHONDO	CIAT	Burundi
23	G 2333	CIAT	Burundi, Rwanda
24	CAB 2	CIAT	Burundi, Tanzania
25	Check (Dandesu)	Ethiopia	Ethiopia

Source of materials: Melkassa and Jimma Agricultural Research Centers (MARC and JARC), Ethiopian Institute of Agricultural Research (EIAR)

Appropriate agricultural design: The number of materials or varieties involved in this particular study was twenty-five. Hence, the entries tested to study their difference were large in number, thus the appropriate agricultural design was a triple lattice with three sets of replications.

Field layout: The plot size was 3 by 1.6 m with size of 4.8 m^2 (four-point- eight-meter square) similarly the net plot size was 3 by 0.8 m which is equal with 2.4 m^2 (two-point-four-meter square). Spacing between plots was half meter and the spacing between blocks was one meter, in the same way, the spacing between replications was one and half meter (1.5 m). Therefore, the experimental total area was about 17.0 by 28.0 m which was 476.0 m^2. The field layout is presented in (Appendix 1).

Randomization: To avoid biasness and simultaneously to keep uniformity among the tested materials and thereby to reduce type II error, randomization task was carried out. To effective more, the author applied and used a software package (program) that is, randomization procedures in R software (R version 4.2.2 (2022-10-31 ucrt)):

```
#Lattice Design str(design.lattice)
function (trt, r = 3, serie = 2, seed = 0,
          kinds = "Super-Duper")
trt<-letters [1:5]
trt
outdesign <-design.lattice(trt, r = 3, serie = 2,
          seed = 33, kinds = "Super-Duper")
book01<- outdesign$book
outdesign$parameters
outdesign$sketch
head(book01)
book <- zigzag(outdesign)
```

1.6 m	22		17		3		8		19	
0.5 m										
1.6 m	9		6		13		10		1	
0.5 m										
1.6 m	14		23		5		15		4	Rep-III
0.5 m										
1.6 m	20		18		2		11		7	
0.5 m										
1.6 m	25		24		16		12		21	
		1.0 m								
1.6 m	7		16		6		18		5	
0.5 m										
1.6 m	3		12		4		8		14	
0.5 m										
1.6 m	17		24		2		13		23	Rep-II
0.5 m										
1.6 m	10		9		25		21		11	
0.5 m										
1.6 m	22		19		15		20		1	
		1.0 m								
1.6 m	7		17		3		10		22	
0.5 m										
1.6 m	25		9		6		2		16	
0.5 m										
1.6 m	12		8		20		24		18	Rep-I
0.5 m										
1.6 m	23		4		11		21		1	
0.5 m										
1.6 m	13	0.5 m	5	0.5 m	19	0.5 m	14	0.5 m	15	
	3.0 m		3.0 m		3.0 m		3.0 m		3.0 m	
					17.0 m					

Appendix 1: Field layout of the tested climbing bean varieties (2020-2021)

Therefore, the randomly assigning (randomization) of the tested climbing bean materials is presented in Table 2.

Recommended spacing's: The spacing used to apply the experiment was 10 cm between seeds and 40 cm between rows or ridges[11].

The study area is known for the production of field crops mainly cereals and pulses. This is because North-Western part of Ethiopia has great potential for agricultural practices. A recent study conducted by Ketema and Geleta[12] reported that western part of Ethiopia is conducive to bean production because of genetically diversified cultivars presence.

Currently, a greater number of bean varieties have been released and registered. However, still, the productivity of beans in the study area has not improved and low grain yield recorded. A field experiment implemented by Ersulo and Dana[13] indicated although a number of bean varieties have been released the productivity of the study area (Segen peoples, SNNPRS, Ethiopia) for growing beans is low despite its potential.

Table 2: Randomly assigning (randomization) of the tested climbing bean materials

		Replication(s)		
Entry number	Entries	01	02	03
1	NAMBE12C	2	46	54
2	NU76	7	38	62
3	CMKN517	15	29	65
4	CMKN1353	19	39	53
5	CMKN605	20	50	63
6	MAC44	14	40	67
7	CAB2	25	30	52
8	CMKN604	18	42	56
9	CMKN819	17	34	74
10	CMKN491	6	27	57
11	CMKN1810	12	47	59
12	RWV3006	23	32	60
13	G13605	21	43	64
14	DONTIMOTEO	10	49	73
15	CMKN370	1	36	58
16	CMKN829	4	31	61
17	CMKN898	16	28	66
18	CMKN2141	3	41	69
19	RWV1272	11	35	55
20	CMKN1551	13	45	72
21	CHEUPE	9	44	51
22	SELIAN15	5	26	75
23	SELIAN14	22	48	68
24	SELIAN06	8	33	70
25	Dandesu	24	37	71

Source of materials: Melkassa and Jimma Agricultural Research Centers, Ethiopian Institute of Agricultural Research (EIAR)

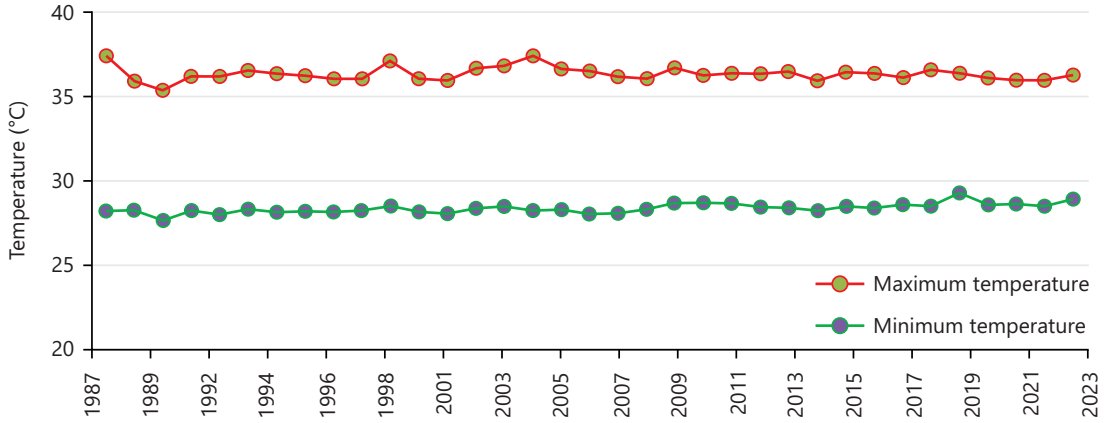
Data collection and statistical analysis: Data for each phenology and agronomic trait were collected based on a plot basis. Numbers of days to emergence, number of days to 50% flowering, number of days to 95% pod maturity, stand count at maturity, plant height (cm), number of pods per plant, number of seeds per pod, disease score (1-9 scale) mainly for (angular leaf Spot, Common Bacterial Blight, Anthracnose and Halo blight), seed moisture content (%), hundred seed weight (g), unadjusted plot yield (g) and adjusted yield (kg/ha), respectively.

Data analysis was conducted by SAS 9.4 version program. The F-test was used to test the significance differences between the genotypes. Least Significance Difference (LSD) for comparing the varieties means at ($p \leq 0.05$) level of probability.

RESULTS

The study was conducted under Pawe District, North-West during 2020-2021 cropping seasons. The area had minimum and maximum temperatures with mean values of 16.30 and 32.6°C, respectively. The area has unimodal rainfall pattern extended from early June up to mid-October with mean values of 1587 mm. The meteorological data (annual average temperature, annual average relative humidity and annual average rainfall) collected and highlighted by different graphs was presented by (Appendix 2-4), respectively.

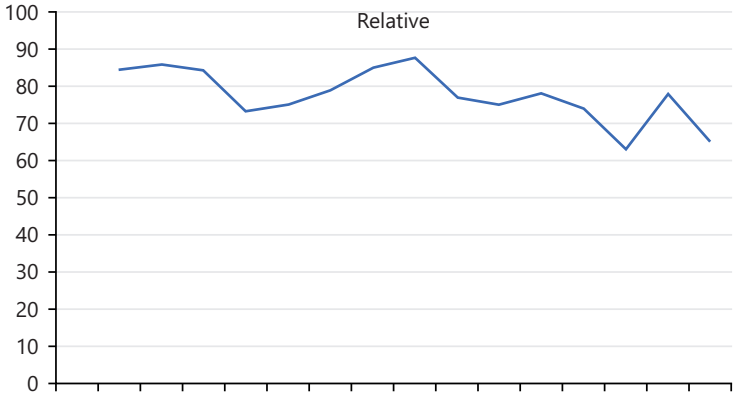
The analysis result revealed there was a significant difference among the tested climbing bean varieties except for plant height (Table 3). In line with this, numbers of days to 50% flowering ranged from 39.0 to 53.67 days, numbers of days to 95% pod maturity ranged from 89.0 to 93 days, angular leaf spot on leaves ranged from 1.00 to 4.22 scale, plant height (cm) ranged from 181.33 to 232.67, numbers of pods per plant ranged from 6.30 to 17.02, numbers of seeds per pod ranged from 2.67 to 5.95, hundred seed weight (g) ranged from 19.00 to 32.67 and adjusted yield ranged from 762.30 to 1925.30 kg/ha, respectively (Table 3).



Appendix 2: Annual average temperature (°C) of Pawe District from 1987-2023

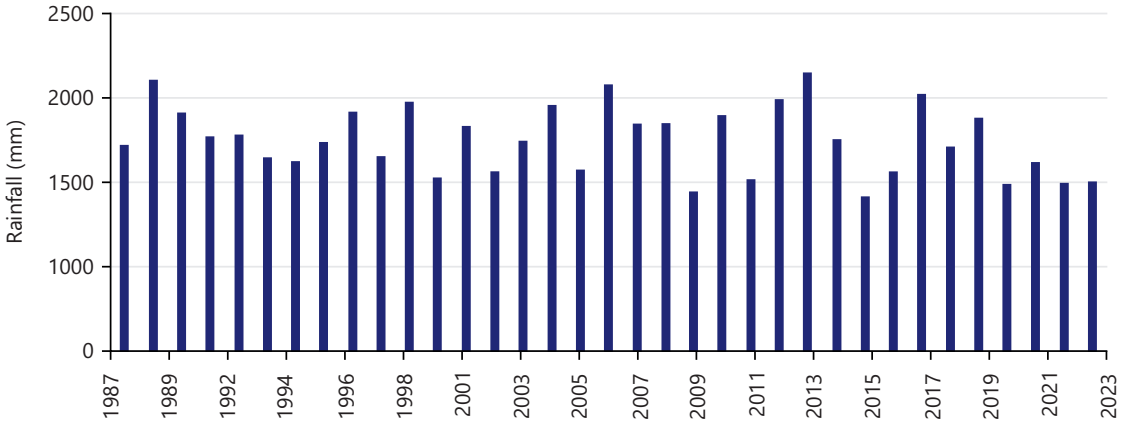
Source: Pawe Agricultural Research Center (PARC) Meteorological data, 2023 (Unpublished data)

Year	R.H
2009	84
2010	86
2011	84
2012	73
2013	75
2014	79
2015	85
2016	88
2017	77
2018	75
2019	78
2020	74
2021	63
2022	78
2023	65



Appendix 3: Annual average relative humidity (%) of Pawe District from 2009-2023

Source: Pawe Agricultural Research Center (PARC) Meteorological data, 2023 (Unpublished data)



Appendix 4: Annual average rainfall (mm) of Pawe District from 1987-2023

Source: Pawe Agricultural Research Center (PARC) Meteorological data, 2023 (Unpublished data)

The analysis result revealed there was significant difference among the tested climbing beans varieties except plant height (Table 4). In line with this, numbers of days to 50% flowering ranged from 45.0 to 53.67 days, numbers of days to 95% pods maturity ranged from 91.0 to 95.67 days, angular leaf spot on leaves ranged from 1.00 to 3.33 scale, plant height ranged from 181.0 to 229.0 cm, numbers of pods per

Table 3: Mean values of grain yield and other traits of climbing bean varieties under Pawe District (2020)

Entry	Treatment numbers	Sch	Sch groups	Df	Df groups	Dm	Dm groups	Als	Als groups	Pht	Pht groups	Ppp	Ppp groups	Spp	Spp groups	Hsw	Hsw groups	Yield	Yield groups
NAMBE12C	1	51.67	ab	48.67	bcdef	89	f	2.67	cde	225.33	abcd	11.08	bcdefgh	4.42	abcde	31.5	a	1447.84	abcdef
NU76	2	39.33	defghi	50.33	abcde	89.33	f	2.67	cde	232.67	ab	16.15	ab	5.92	a	20.17	gh	1719.97	abc
CMKN517	3	46	abcde	50.67	abcde	91.33	bcd	3.11	bcd	215.33	abcdef	8.5	efgh	2.12	fg	25	abcdefgh	947.19	fghi
CMKN1353	4	44	abcdef	51.67	abc	89.33	f	2.56	cdef	220.67	abcde	10.1	defgh	4.17	abcdef	31.17	ab	1352.14	bcdefg
CMKN605	5	42	cdefg	52	ab	92	ab	3	bcd	189.33	defg	8.35	efgh	3.08	cdefg	27.33	abcdefg	1003.63	efghi
MAC44	6	48.33	abcd	48	cdef	89.67	ef	1.55	f	186	efg	12.82	abcdefg	3.75	bcdef	29.67	abcd	1174.6	defgh
CAB2	7	46.67	abcde	48.33	bcdef	93	a	3.33	abc	229.33	abc	15.72	abc	5.92	a	20.83	efgh	1815.73	ab
CMKN604	8	44	abcdef	45.33	f	89.33	f	3.22	abc	228	abc	11.02	bcdefgh	4.17	abcdef	32.67	a	1149.65	efgh
CMKN819	9	49.33	abc	50.67	abcde	89.67	ef	3	bcd	223.33	abcde	9.25	defgh	3.67	bcdef	29	abcde	1060.01	efgh
CMKN491	10	41	cdefgh	48.67	bcdef	90	def	3.78	ab	196.08	bcdefg	8	fgh	3.45	cdefg	28.83	abcdef	1076.82	efgh
CMKN1810	11	32.33	hi	47.33	def	90.33	cdef	4.22	a	161.53	g	7.65	gh	1.35	g	19.33	gh	505.69	i
RWV3006	12	36.67	fghi	45.33	f	89.33	f	3	bcd	227.33	abcd	9.97	defgh	3.33	cdefg	25	abcdefgh	1045.16	efgh
G13605	13	30.33	i	41	g	89	f	3.11	bcd	198	abcdefg	10.02	defgh	2.67	efg	20.83	efgh	762.28	hi
DONTIMOTEO	14	38.67	efghi	52.67	a	89.67	ef	3.11	bcd	221	abcde	6.87	h	3.42	cdefg	28.83	abcdef	851.26	ghi
CMKN370	15	43	bcdef	48	cdef	91	bcde	2.55	cdef	213.33	abcdef	10.17	cdefgh	3.1	cdefg	29	abcde	1066.39	efgh
CMKN829	16	39.33	defghi	47.67	def	91	bcde	3.22	abc	209.33	abcdef	11	bcdefgh	4.08	abcdef	23.17	bcdefgh	1127.73	efgh
CMKN898	17	40	defgh	46	f	92.33	ab	2.89	bcd	196	bcdefg	9.35	defgh	3	cdefg	22	defgh	884.05	ghi
CMKN2141	18	43.67	bcdef	51	abcd	89.33	f	2.67	cde	213	abcdef	14.38	abcd	4.83	abcd	22.83	cdefgh	1358.43	bcdefg
RWV1272	19	53	a	39	g	89	f	2.45	cdef	192.67	cdefg	17.02	a	5.95	a	30.67	abc	1925.32	a
CMKN1551	20	33.67	ghi	50.33	abcde	91.67	abc	3.11	bcd	181.33	fg	6.3	h	2.75	defg	20.67	fgh	814.86	hi
CHEUPE	21	52	ab	53.67	a	91	bcde	3.11	bcd	221.33	abcde	14.53	abcd	3.2	cdefg	19	h	1184.3	defgh
SELIAN15	22	48	abcd	45.33	f	89	f	2.89	bcd	235.33	a	7.82	fgh	3.45	cdefg	30	abcd	1023.02	efghi
SELIAN14	23	47.33	abcde	47	ef	89.67	ef	2.89	bcd	234	ab	13.22	abcdef	4.92	abc	33.17	a	1497	abcde
SELIAN06	24	43.67	bcdef	46	f	89.33	f	2.11	def	226.67	abcd	13.8	abcde	5.67	ab	33	a	1686.25	abcd
Dandesu	25	43.67	bcdef	50	abcde	89	f	1.78	ef	194.33	cdefg	11	bcdefgh	4.17	abcdef	20.33	gh	1208.75	cdefgh

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5 % moisture content and Means with the same letter under the same column are not significantly different (like means with efg alphabets are not significantly different means with efg alphabets)

http://doi.org/10.17311/tas.2024.255.273 | Page 261

Table 4: Mean values of grain yield and other traits of climbing bean varieties under Pawe District (2021)

Entry	Sch	Sch groups	Df	Df groups	Dm	Dm groups	Als	Als groups	Pht	Pht groups	Ppp	Ppp groups	Spp	Spp groups	Hsw	Hsw groups	Yield	Yield groups
NAMBE12C	51.67	ab	50.67	abcde	92.67	de	2.67	cde	221.33	ab	13.45	abcdef	5.17	bcdef	31.5	a	1438.67	abcde
NU76	39.33	defghi	52.33	abc	94	bcd	2.67	cde	228	a	17.1	ab	6.33	ab	20.17	gh	1743.33	ab
CMKN517	46	abcde	52	abcd	94.33	bcd	3.11	bcd	209.33	abcde	9.6	fg	4.08	efgh	25	abcdefgh	1032.93	ef
CMKN1353	44	abcdef	52.33	abc	94	bcd	2.56	cdef	219	abc	14.1	abcde	5.17	bcdef	31.17	ab	1387.33	abcdef
CMKN605	42	cdefg	52.67	ab	96	ab	3	bcd	196	bcde	11.15	defg	4.5	defgh	27.33	abcdefg	1137.37	ef
MAC44	48.33	abcd	49.33	cdef	93.67	bcd	1.55	f	188.33	de	12.62	cdefg	4.75	defgh	29.67	abcd	1224.68	cdef
CAB2	46.67	abcde	49.33	cdef	97	a	3.33	abc	228.67	a	15.67	abc	6	abc	20.83	efgh	1715.5	abc
CMKN604	44	abcdef	47.33	fgh	94	bcd	3.22	abc	220	ab	11.82	cdefg	4.67	defgh	32.67	a	1238.93	bcdef
CMKN819	49.33	abc	52.67	ab	93.33	cde	3	bcd	222.67	ab	12.08	cdefg	4.33	efgh	29	abcde	1171.53	ef
CMKN491	41	cdefgh	50.67	abcde	94	bcd	3.78	ab	207.67	abcde	12.92	bcdefg	4.67	defgh	28.83	abcdef	1254.05	bcdef
CMKN1810	32.33	hi	50	bcdef	94.33	bcd	4.22	a	195	bcde	10.67	efg	4.33	efgh	19.33	gh	1104.51	ef
RWV3006	36.67	fghi	47.33	fgh	94.67	abcd	3	bcd	217	abcd	10.18	efg	4.25	efgh	25	abcdefgh	1111	ef
G13605	30.33	i	45	h	93.67	bcd	3.11	bcd	209	abcde	10.02	efg	4.17	efgh	20.83	efgh	1094.71	ef
DONTIMOTEO	38.67	efghi	53	ab	93.67	bcd	3.11	bcd	220.67	ab	10.95	defg	4.17	efgh	28.83	abcdef	1181.54	def
CMKN370	43	bcdef	51	abcde	95	abcd	2.55	cdef	214.67	abcd	10.28	efg	4.33	efgh	29	abcde	1066.24	ef
CMKN829	39.33	defghi	50.33	bcdef	94.33	bcd	3.22	abc	206	abcde	11.1	defg	4.33	efgh	23.17	bcdefgh	1159.28	ef
CMKN898	40	defgh	48	efgh	95.33	abc	2.89	bcd	196	bcde	9.35	fg	3.83	gh	22	defgh	981.46	ef
CMKN2141	43.67	bcdef	52.33	abc	94.33	bcd	2.67	cde	216	abcd	13.23	abcdef	4.67	defgh	22.83	cdefgh	1319.08	bcdef
RWV1272	53	a	46	gh	91	e	2.45	cdef	189.33	cde	17.57	a	6.58	a	30.67	abc	1883.24	a
CMKN1551	33.67	ghi	51.33	abcd	95.67	abc	3.11	bcd	181	e	8.65	g	3.67	h	20.67	fgh	892.01	f
CHEUPE	52	ab	53.67	a	95.67	abc	3.11	bcd	217	abcd	11.9	cdefg	4.92	cdefg	19	h	1257.26	bcdef
SELIAN15	48	abcd	47.33	fgh	94	bcd	2.89	bcd	229	a	10.93	defg	4	fgh	30	abcd	1085.56	ef
SELIAN14	47.33	abcde	49	defg	93.67	bcd	2.89	bcd	228	a	13.72	abcdef	5.25	bcde	33.17	a	1429.13	abcde
SELIAN06	43.67	bcdef	48	efgh	94.67	abcd	2.11	def	214.33	abcd	15.25	abcd	5.67	abcd	33	a	1698.72	abcd
Dandesu	43.67	bcdef	52.33	abc	95	abcd	1.78	ef	210.33	abcde	12.6	cdefg	4.92	cdefg	20.33	gh	1200.77	cdef

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5 % moisture content and Means with the same letter under the same column are not significantly different (like means with abcd alphabets are not significantly different means with abcd alphabets)

Table 5: Mean values of grain yield and other traits of climbing bean varieties under Pawe District (2020-2021) over year

Entry	Sch	Sch groups	Df	Df groups	Dm	Dm groups	Als	Als groups	Pht	Pht groups	Ppp	Ppp groups	Spp	Spp groups	Hsw	Hsw groups	Yield	Yield groups
NAMBE12C	51.67	abc	49.67	cdef	90.83	cd	2.67	defg	223.33	abc	12.27	defghi	4.79	bcde	31.5	ab	1443.25	cde
NU76	39.33	ijk	51.33	abcd	91.67	bcd	2.67	defg	230.33	a	16.62	ab	6.12	a	20.17	f	1731.65	abc
CMKN517	46	defgh	51.33	abcd	92.83	abcd	3.11	cde	212.33	abcdef	9.05	jk	3.1	hi	25	cde	990.06	ghi
CMKN1353	44	efghi	52	abc	91.67	bcd	2.56	efg	219.83	abcd	12.1	defghij	4.67	cdef	31.17	ab	1369.74	def
CMKN605	42	ghij	52.33	ab	94	ab	3	cdef	192.67	fghi	9.75	hijk	3.79	efghi	27.33	bcd	1070.5	fghi
MAC44	48.33	abcde	48.67	efgh	91.67	bcd	1.55	h	187.17	ghi	12.72	cdefgh	4.25	defgh	29.67	ab	1199.64	defg
CAB2	46.67	cdefg	48.83	defgh	95	a	3.33	bc	229	a	15.69	abc	5.96	ab	20.83	ef	1765.62	ab
CMKN604	44	efghi	46.33	h	91.67	bcd	3.22	bcd	224	ab	11.42	defghij	4.42	cdefg	32.67	a	1194.29	defg
CMKN819	49.33	abcd	51.67	abc	91.5	bcd	3	cdef	223	abc	10.67	efghijk	4	defghi	29	abc	1115.77	fghi
CMKN491	41	hijk	49.67	cdef	92	abcd	3.78	ab	201.88	defgh	10.46	fghijk	4.06	defghi	28.83	abc	1165.44	defgh
CMKN1810	32.33	mn	48.67	efgh	92.33	abcd	4.22	a	178.27	i	9.16	ijk	2.84	i	19.33	f	805.1	i
RWV3006	36.67	klm	46.33	h	92	abcd	3	cdef	222.17	abcd	10.07	ghijk	3.79	efghi	25	cde	1078.08	fghi
G13605	30.33	n	43	i	91.33	bcd	3.11	cde	203.5	bcdefg	10.02	ghijk	3.42	fghi	20.83	ef	928.49	ghi
DONTIMOTEO	38.67	jkl	52.83	ab	91.67	bcd	3.11	cde	220.83	abcd	8.91	jk	3.79	efghi	28.83	abc	1016.4	ghi
CMKN370	43	fghij	49.5	cdefg	93	abcd	2.55	efg	214	abcde	10.22	ghijk	3.72	efghi	29	abc	1066.32	fghi
CMKN829	39.33	ijk	49	defg	92.67	abcd	3.22	bcd	207.67	bcdefg	11.05	efghij	4.21	defgh	23.17	def	1143.5	efgh
CMKN898	40	ijk	47	gh	93.83	abc	2.89	cdef	196	efghi	9.35	ijk	3.42	fghi	22	ef	932.75	ghi
CMKN2141	43.67	efghij	51.67	abc	91.83	bcd	2.67	defg	214.5	abcde	13.81	bcde	4.75	bcde	22.83	def	1338.76	def
RWV1272	53	a	42.5	i	90	d	2.45	fg	191	ghi	17.29	a	6.27	a	30.67	ab	1904.28	a
CMKN1551	33.67	lmn	50.83	bcde	93.67	abc	3.11	cde	181.17	hi	7.47	k	3.21	ghi	20.67	ef	853.44	hi
CHEUPE	52	ab	53.67	a	93.33	abc	3.11	cde	219.17	abcd	13.22	cdefg	4.06	defghi	19	f	1220.78	defg
SELIAN15	48	abcdef	46.33	h	91.5	bcd	2.89	cdef	232.17	a	9.38	ijk	3.72	efghi	30	ab	1054.29	fghi
SELIAN14	47.33	bcdef	48	fgh	91.67	bcd	2.89	cdef	231	a	13.47	bcdef	5.08	abcd	33.17	a	1463.07	bcd
SELIAN06	43.67	efghij	47	gh	92	abcd	2.11	gh	220.5	abcd	14.52	abcd	5.67	abc	33	a	1692.49	abc
Dandesu	43.67	efghij	51.17	abcde	92	abcd	1.78	h	202.33	cdefg	11.8	defghij	4.54	cdef	20.33	f	1204.76	defg

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5 % moisture content and Means with the same letter under the same column are not Significantly different (like means with bcde alphabets are not significantly different means with bcde alphabets

http://doi.org/10.17311/tas.2024.255.273 | Page 263

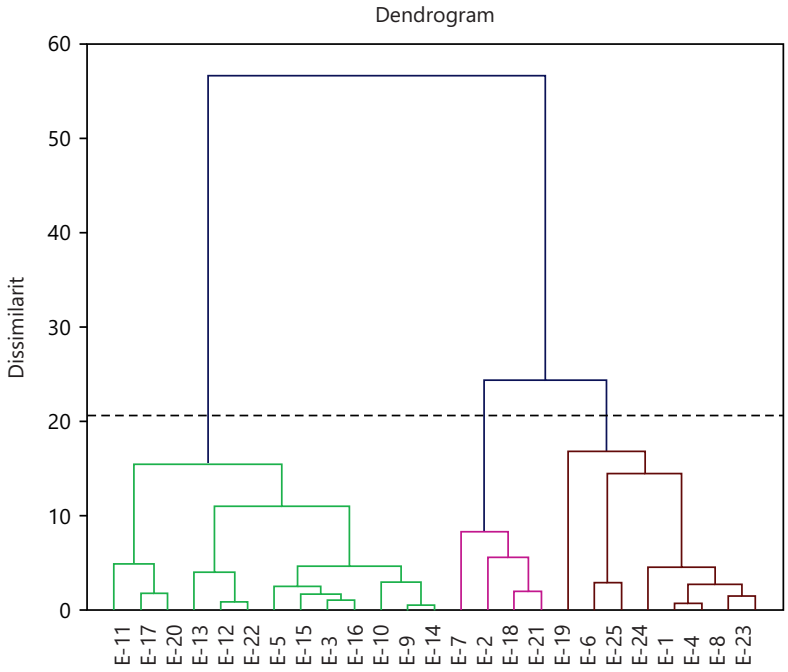


Fig. 1: Hierarchical clustering of climbing bean varieties by Agglomerative Hierarchical Clustering (AHC) method with XLSTAT 2014.0 excel function

Table 6: Better performing climbing bean varieties yield an advantage over the standard check (Dandesu)

Variety	Grain yield (kg/ha)	Yield advantage (%)	Rank	Remark
RWV1272	1904.3	58.06	1	
CAB2	1765.6	46.55	2	
SELIAN06	1692.5	40.48	3	
Dandesu	1204.8	*	4	*Not meaningful

plant ranged from 9.35 to 17.57, numbers of seeds per pod ranged from 3.83 to 6.58, hundred seed weight (g) ranged from 19.00 to 33.17 and adjusted yield ranged from 892.0 to 1883.20 kg/ha, respectively (Table 4).

The analysis result revealed there was a significant difference among the tested climbing bean varieties with their clear mean values (Table 5). In line with this, number of days to 50% flowering ranged from 47.0 to 53.67 days, the number of days to 95% pod maturity ranged from 90.83 to 94.00 days, angular leaf spot on leaves ranged from 1.55 to 4.22 scale, plant height ranged from 178.27 to 232.17 cm, numbers of pods per plant ranged from 7.48 to 17.29, numbers of seeds per pod ranged from 3.21 to 6.27, hundred seed weight (g) ranged from 19.00 to 33.17, adjusted yield ranged from 805.10 to 1904.30 kg/ha, respectively (Table 5). The candidate varieties RWV1272, CAB2 and SELIAN06 had a better yield advantage over the standard check (Dandesu) with values of 58.06, 46.55 and 40.48%, respectively (Table 6).

The tested climbing bean varieties formed different clusters as shown in (Fig. 1); which in turn revealed the genetic distance among the varieties to be closely related or far apart each other.

Correlations: There was a high correlation among the tested climbing bean varieties for yield and yield contributing traits (Fig. 2). However, Kläsener *et al.*[14] reported several plant architecture traits were correlated, but none was highly correlated with grain yield.

Grain yield was positively correlated with most of the studied characters except with days to flowering, days to maturity and angular leaf spot, respectively (Table 7). Based on the analysis result grain yield was positively correlated with plant height with values of 0.401 (40.1%), with numbers of pods of 0.949 (94.9%), with number of seeds per pod of 0.981 (98.1%) and with hundred seeds weight 0.276 (27.65), respectively

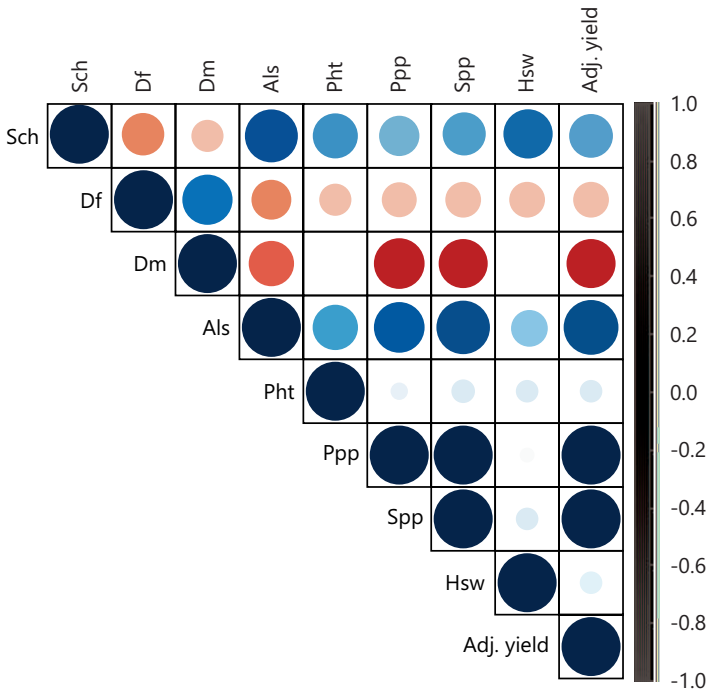


Fig. 2: Correlations of climbing bean varieties quantitative traits with corrplot R-function

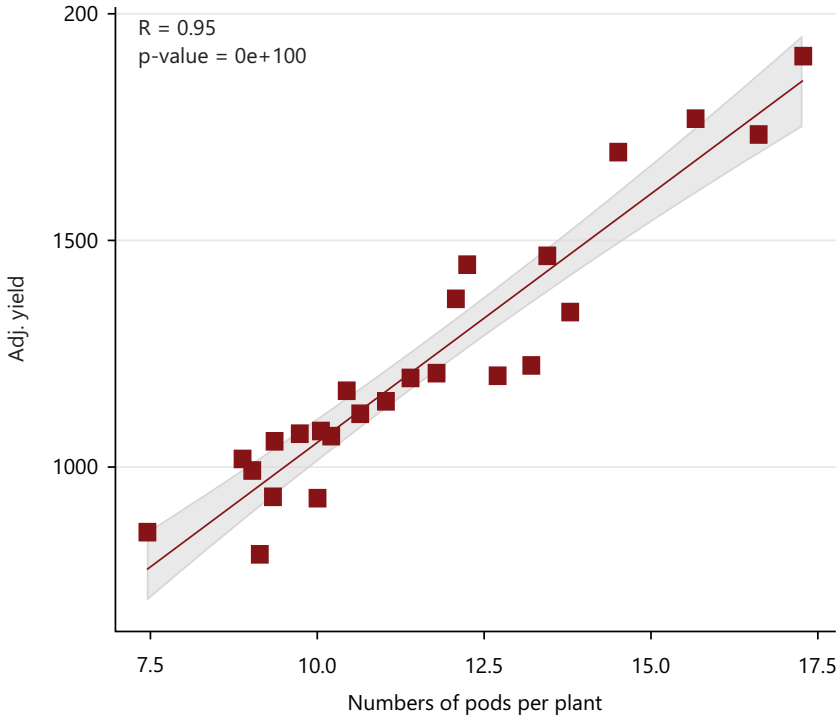


Fig. 3: Correlations of number of pods per plant with adjusted yield

(Table 7). On the other hand, it was negatively correlated with a date of 50% flowering, a date of 95% maturity and angular leaf spot (Table 7).

Similarly, the correlation of numbers of pods per plant against adjusted grain yield was high and positively correlated, as it has been shown in Fig. 3.

Whereas, adjusted yield was negatively correlated with days to 50% flowering, as it has been shown in Fig. 4.

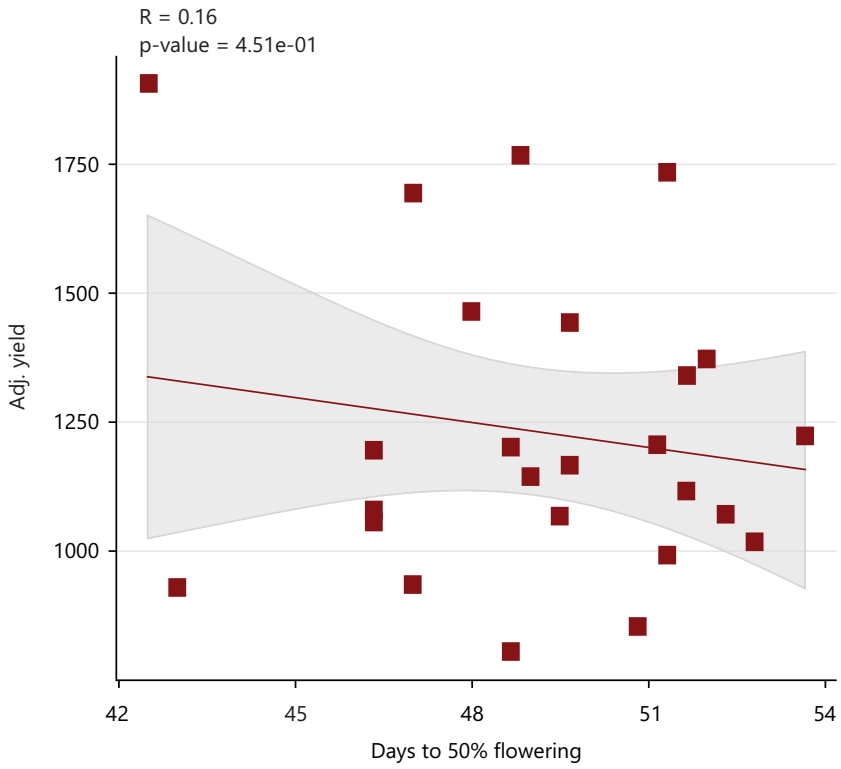


Fig. 4: Correlations of days to 50% flowering with adjusted yield

Table 7: Correlation coefficients of climbing bean varieties quantitative traits

Traits	Sch	Df	Dm	Als	Pht	Ppp	Spp	Hsw	Adj. yield
Sch	1.000	-0.015	-0.055	-0.2828	0.361	0.358	0.344	0.415	0.421
Df	-0.015	1.000	0.343	-0.043	0.045	-0.050	-0.000	-0.116	-0.089
Dm	-0.055	0.343	1.000	0.009	-0.081	0.072	0.164	-0.133	0.017
Als	-0.282	-0.043	0.009	1.000	-0.115	-0.277	-0.326	-0.292	-0.324
Pht	0.361	0.045	-0.081	-0.115	1.000	0.351	0.386	0.306	0.422
Ppp	0.358	-0.050	0.072	-0.277	0.351	1.000	0.811	0.278	0.869
Spp	0.344	0.000	0.164	-0.326	0.386	0.811	1.000	0.353	0.857
Hsw	0.415	-0.116	-0.133	-0.292	0.306	0.278	0.353	1.000	0.377
Adj. yield	0.421	-0.089	0.017	-0.324	0.422	0.869	0.857	0.377	1.000

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g) and Adj.Yield: Adjusted yield at 12.5 % moisture content

Table 8: Least Significant Difference (LSD) values of grain yield and other traits of climbing bean varieties under Pawe District (2020)

Traits	MSerror	Df	Mean	CV	t-value	LSD
Sch	31.52444	36	43.10667	13.02505	2.028094	9.2975
Df	5.506296	36	48.18667	4.869708	2.028094	3.885727
Dm	0.986667	36	90.13333	1.102046	2.028094	1.644855
Als	0.441883	36	2.879867	23.08242	2.028094	1.100769
Pht	531.6245	36	210.8513	10.93519	2.028094	38.18079
Ppp	11.26209	36	10.96267	30.61212	2.028094	5.557149
Spp	1.712602	36	3.8616	33.88917	2.028094	2.167059
Hsw	24.61352	36	26.16	18.96484	2.028094	8.215411
yield	100055.7	36	1187.523	26.63662	2.028094	523.7975

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5% moisture content, Test-statistics, MSerror: Error mean square, Df: Degree of freedom, Mean: Population/sample average, CV: Coefficient of variation, t-value: t-statistics and LSD: Least Significant Difference

The Least Significant Difference (LSD) values of grain yield and yield-related traits during 2020 season are presented in Table 8.

Table 9: Least Significant Difference (LSD) values of grain yield and other traits of climbing bean varieties under Pawe District (2021)

Traits	MSerror	Df	Mean	CV	t-value	LSD
Sch	31.52444	36	43.10667	13.02505	2.028094	9.2975
Df	3.550741	36	50.16	3.756661	2.028094	3.12034
Dm	2.531852	36	94.32	1.687001	2.028094	2.634885
Als	0.441883	36	2.879867	23.08242	2.028094	1.100769
Pht	327.8615	36	211.3733	8.566334	2.028094	29.98387
Ppp	6.998519	36	12.276	21.54995	2.028094	4.38072
Spp	0.558495	36	4.75	15.73317	2.028094	1.23752
Hsw	24.61352	36	26.16	18.96484	2.028094	8.215411
yield	97854.47	36	1272.353	24.5857	2.028094	518.0036

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5% moisture content, Test-statistics, MSerror: Error mean square, Df: Degree of freedom, Mean: Population/sample average, CV: Coefficient of variation, t-value: t-statistics and LSD: Least Significant Difference

Table 10: Least Significant Difference (LSD) values of grain yield and other traits of climbing bean varieties under Pawe District (2020-2021) over the year

Traits	MSerror	Df	Mean	CV	t-value	LSD
Sch	20.44829	111	43.10667	10.49021	1.981567	5.173406
Df	4.95982	111	49.17333	4.52901	1.981567	2.547892
Dm	7.54012	111	92.22667	2.977369	1.981567	3.141501
Als	0.286627	111	2.879867	18.59029	1.981567	0.612501
Pht	337.313	111	211.1123	8.699673	1.981567	21.01187
Ppp	7.829838	111	11.61933	24.08215	1.981567	3.201286
Spp	1.230238	111	4.3058	25.75969	1.981567	1.268945
Hsw	15.96553	111	26.16	15.27404	1.981567	4.5713
yield	76206.86	111	1229.938	22.4447	1.981567	315.824

Sch: Stand count at harvest, Df 50%: Numbers of days to 50% flowering, Dm 95%: Numbers of days to 95% pods maturity, Alsf: Angular leaf spot on leaves, Pht: Plant height (cm), Ppp: Numbers of pods per plant, Spp: Numbers of seeds per pod, Hsw: Hundred seed weight (g), Adj.Yield: Adjusted yield at 12.5 % moisture content, Test-statistics, MSerror: Error mean square, Df: Degree of freedom, Mean: Population/sample average, CV: Coefficient of variation, t-value: t-statistics and LSD: Least Significant Difference

The Least Significant Difference (LSD) values of grain yield and yield-related traits during 2021 season are presented in Table 9.

The Least Significant Difference (LSD) values of grain yield and yield-related traits during 2020-2021 season are presented in Table 10.

DISCUSSION

Data collected and subjected for analysis purposes were numbers of days to 50% flowering, number of days to 95% pod maturity, angular leaf spot on leaves, plant height (cm), number of pods per plant, number of seeds per pod, hundred seed weight (g) and adjusted yield at 12.8 % moisture content. The over-year analysis result indicated there was a significant difference ($p \leq 0.05$) among the tested climbing varieties. The variety SELIAN06 was earlier to flower 50% with mean value of 47 days where as CHEUPE variety took 53.67 days to flower at 50%. Variety RWV1272 took 90 days to mature 95% whereas CAB2 took 95 days to mature 95% (Table 5). However; fieldwork conducted by Yirga *et al.*[15] reported there was no significant difference among the tested climbing varieties under the study area. With this, the highest grain yield scorer climbing bean varieties were RWV1272, CAB2 and SELIAN06 with mean values of 1904.30, 1765.60 and 1692.50 kg/ha, respectively (Table 5). Similarly, fieldwork conducted by Yirga *et al.*[15] reported the two climbing bean varieties RWV1272 and CAB2 scored higher grain yield among the tested entries. The yield advantage of RWV1272, CAB2 and SELIAN06 over the standard check (Dandesu) was 58.06, 46.55 and 40.48%, respectively (Table 6). Another field experiment conducted by Yirga *et al.*[16]

reported promising climbing varieties showed yield advantage over the standard check (Dandesu). Furthermore, Teshome *et al.*[17] reported the newly improved common bean varieties performed and were preferred more over the standard check in terms of regarding yield, early maturity, tolerance to disease and insect infestation, drought tolerance and food test.

In terms of disease reaction, Degu *et al.*[18] reported angular leaf spot (*Pseudocercospora griseola*), Anthracnose (*Colletotrichum lindemuthianum*), floury leaf spot (*Mycovellosiella phaseoli*) and cercospora leaf spot (*Cercospora cruenta*) were major diseases of common bean under the study area. Similar findings reported by Etana[19] indicated, the common bean (*Phaseolus vulgaris* L.) production in Ethiopia is injured by several insect pests and diseases. However, for this particular study, promising climbing bean cultivars were obtained for resistance/tolerance to angular leaf spots; these varieties were MAC44, SELIAN06 and RWV1272 (Table 5).

Variety SELIAN15 scored the highest plant height (cm) whereas the lowest plant height (cm) was scored by CMKN1810 with mean values of 232.17 and 178.27 cm, respectively (Table 5). There was also a significant difference in the traits of pods per plant and seeds per pod. and A research work implemented by Gebeyehu *et al.*[20] reported that among the studied traits of climbing beans, the number of seeds per pod, 100-seed weight, harvest index and seed yield were significant. Another field experiment conducted by Yirga *et al.*[16] revealed significant variation ($p \leq 0.01$) among varieties of climbing beans for most of the traits except for number of days to 95% maturity and hundred seed weight. Similarly, Ersulo and Dana[13] field experiment reported the tested common bean varieties were significantly different for all traits except for days to 50% flowering and number of seed per pod.

The top seven climbing bean varieties scorers for hundred seed weight (g) over the standard check (Dandesu) were SELIAN15, RWV1272, CMKN1353, NAMBE12C, CMKN604, SELIAN06 and SELIAN14 with mean scores of 30, 30.67, 31.17, 31.5, 32.67, 33 and 33.17 g, respectively (Table 5). This output showed the direct correlation of hundred seed weight (g) with seed yield (kg/ha). Furthermore, similar research result was reported by Yirga *et al.*[16]. The top nine climbing bean varieties scorers for adjusted grain yield over the standard check (Dandesu) were CHEUPE, CMKN2141, CMKN1353, NAMBE12C, SELIAN14, SELIAN06, NU76, CAB2 and RWV1272 with mean values of 1220.8, 1338.8, 1369.7, 1443.3, 1463.1, 1692.5, 1731.7, 1765.6 and 1904.3 kg/ha, respectively (Table 5). Another field experiment implemented by Yirga *et al.*[16] indicated the top three climbing bean varieties with the highest grain yield (kg/ha) were RWV1272, G13607 and CAB2 with mean values of 5.37, 4.53 and 3.82 ton/ha, respectively. Similarly, Gaspard *et al.*[4] reported climbing beans produce up to three times more than the bush beans varieties.

The study identified main challenges of climbing bean production under the study area properly. The information generated from the study can directly benefit those who actively engage in beans production and processing agents. The study has given clues for the production of climbing beans under the study area and similar ecologies because, currently, most of the production area is covered by other lowland pulses with different commodities such as bush-type dry beans and mung beans. Finally, the tested and well-performed climbing bean varieties were an indicator of cropping system, food security and alternative source of income for the growers under small scale conditions and had comparative advantages over bush-type beans. To support the above sentence more, Portilla *et al.*[21] reported that, due to higher yields and resilience, climbing beans are better when compared with bush type. However, the other challenge to cultivate climbing bean varieties on large scale was the management part mainly the availability and handling of stacking materials. This statement was in line with the findings reported by Gaspard *et al.*[4]. Currently, the trends of global crop production are affected by variability of climate phenomena or climate changes; due to this, production is reducing from season to season and thereby quality is under question. With this, scenario, because of the nature of the growth habit of common bean indicated, some cultivars

can mature within short period of time. This helped the crop even to escape the harsh conditions and weather variability and can give reasonable yields. According to Smith *et al*.[22] report, common bean can maintain the nutritional content of individual pods under varying nutrient availabilities demonstrating the resilience of processes determining the viability of reproductive tissues.

The trend of farming system of the study area even the country (Ethiopia) indicated that the culture of growing beans in the form of rotation, intercropping, relay cropping, mixed farming and mono-cropping well established to producing quality seed beans and thereby contributes its role regardless of multiple challenges. Other findings reported by Venance *et al*.[23] highlighted the contribution of beans to food security and income generation. The finding indicated that there was a possibility of bean yield enhancement because the study area was known for the production of varieties of beans and other lowland pulses. However, the limitation of the experiment was, that it was conducted in a single location for two years, as more location is expected to exploit the potential of the tested materials.

The finding indicated that there was a possibility of bean yield enhancement because the study area was known for the production of varieties of beans and other lowland pulses. However, the limitation of the experiment was, that it was conducted in single location for two years, as more location is expected to exploit the potential of the tested materials.

CONCLUSION

The study was conducted to narrow the gap that existed between crop technology generated and the ever- increasing demand for improved bean varieties by stakeholders. The climbing bean varieties named RWV1272 (1904.30 kg/ha), CAB2 (1765.60 kg/ha) and SELIAN06 (1692.50 kg/ha) performed well under the study area and were recommended for commercialization. However, further research and development work mainly promotion and multiplication of bean varieties by legal governmental bodies have to be due consideration to cope with the weather variability that is currently happening at national and regional levels.

SIGNIFICANCE STATEMENT

Most area of the study location is covered with bush-type beans but with considerable defects, such as low-yielding, susceptible to biotic agents. However, the study generated and highlighted a new type of bean genotype, climbing beans, with unique features of high grain yield and biomass, better tolerance to bean diseases and pests. Therefore, the findings recommended well-adapted and performed climbing bean cultivars for commercialization purposes as agriculture is still the mainstay for vast population of Ethiopia by contributing as a source of cash, job creation, as raw material, source of feed and food, etc. In this manner, the study paved the way for improvement of beans thereby enhancing the productivity of the area sustainably and maintaining the overall functioning of the ecosystem under the wave of weather variability.

REFERENCES

1. Begna, T. and Z. Asrat, 2021. Evaluation of improved common bean (*Phaseolus vulgaris* L.) varieties for yield and yield components at West Hararghe, Eastern Ethiopia. Int. J. Res. Stud. Agric. Sci., 7: 5-12.
2. Abera, B., M. Berhane, A. Nebiyu, M.L. Ruelle and A. McAlvay *et al*., 2020. Diversity, use and production of farmers' varieties of common bean (*Phaseolus vulgaris* L., Fabaceae) in Southwestern and Northeastern Ethiopia. Genet. Resour. Crop Evol., 67: 339-356.
3. Wendimu, G.Y., 2021. The challenges and prospects of Ethiopian agriculture. Cogent Food Agric., Vol. 7. 10.1080/23311932.2021.1923619.
4. Gaspard, N., T.J. Claude, M. Roger, D.M. Mburu, S.J.M. Vianney and H. Ogwal, 2021. An economic analysis of the factors influencing adoption of climbing beans varieties and challenges of smallholder farmers in Rwanda: A case study of Burera District. Eur. Bus. Manage., 7: 191-198.

5. Stagnari, F., A. Maggio, A. Galieni and M. Pisante, 2017. Multiple benefits of legumes for agriculture sustainability: An overview. Chem. Biol. Technol. Agric., Vol. 4. 10.1186/s40538-016-0085-1.
6. Baraki, F., Z. Gebregergis, Y. Belay, M. Berhe and H. Zibelo, 2020. Genotype x environment interaction and yield stability analysis of mung bean (*Vigna radiata* (L.) Wilczek) genotypes in Northern Ethiopia. Cogent Food Agric., Vol. 6. 10.1080/23311932.2020.1729581.
7. Tadele, Z., 2017. Raising crop productivity in Africa through intensification. Agronomy, Vol. 7. 10.3390/agronomy7010022.
8. Kebede, Z.Y., 2022. Research report on proven sweet lupin varieties demonstration under North-West Ethiopia. Int. J. Adv. Res. Biol. Sci., 9: 207-211.
9. Bassa, Z., M. Alemu and B. Zeleke, 2018. Success story of common bean technology pre-scaling up in Southern Ethiopia. Curr. Invest. Agric. Curr. Res., 4: 566-570.
10. Gichangi, A., S.N. Maobe, D. Karanja, A. Getabu and C.N. Macharia *et al*., 2012. Assessment of production and marketing of climbing beans by smallholder farmers in Nyanza Region, Kenya. World J. Agric. Sci., 8: 293-302.
11. Merga, J.T., 2020. Evaluation of common bean varieties (*Phaseolus vulgaris* L.) to different row-spacing in Jimma, South Western Ethiopia. Heliyon, Vol. 6. 10.1016/j.heliyon.2020.e04822.
12. Ketema, W. and N. Geleta, 2022. Studies on genetic variability of common bean (*Phaseolus vulgaris* L.) varieties for yield and yield related traits in Western Ethiopia. Int. J. Appl. Agric. Sci., 8: 41-49.
13. Ersulo, D. and A. Dana, 2018. Evaluation of common bean varieties for yield and yield component in Segen area peoples zone SNNPRS, Ethiopia. Food Sci. Qual. Manage., 72: 11-14.
14. Kläsener, G.R., N.D. Ribeiro and G.G.D. Santos, 2022. Genetic divergence and selection of common bean cultivars based on plant architecture and grain yield. Rev. Caatinga, 35: 818-828.
15. Yirga, M., Y. Sileshi, B. Atero, B. Amsalu and A. Moges *et al*., 2022. Performance of introduced climbing bean (*Phaseolus vulgaris* L.) varieties for registration in Ethiopia. Ethiopian J. Crop Sci., 10: 41-51.
16. Yirga, M., Y. Sileshi, B. Amsalu, A. Tesfay and B. Atero *et al*., 2022. Evaluation and stability analysis of climbing bean (*Phaseolus vulgaris* L.) genotypes in high potential areas of Ethiopia. Ethiopian J. Crop Sci., 10: 53-66.
17. Teshome, A., B. Amsalu and E. Gabrekiristos, 2022. On-farm improved common bean variety demonstration and evaluation in Central Rift Valley of Ethiopia: Case of Bora and Adami Tullu Jido Kombolcha Districts. Ethiopian J. Crop Sci., 9: 221-232.
18. Degu, T., W. Yaregal and T. Gudisa, 2020. Status of common bean (*Phaseolus vulgaris* L.) diseases in Metekel Zone, North West Ethiopia. J. Plant Pathol. Microbiol., Vol. 11. 10.35248/2157-7471.20.11.494.
19. Etana, D., 2022. Major insect pests and diseases in common bean (*Phaseolus vulgaris* L.) production in Ethiopia. Frontiers, 2: 79-87.
20. Gebeyehu, S., B. Simane and R. Kirkby, 2006. Genotype×cropping system interaction in climbing beans (*Phaseolus vulgaris* L.) grown as sole crop and in association with maize (*Zea mays* L.). Eur. J. Agron., 24: 396-403.
21. Portilla, A.E., V.M. Mayor Duran, H.F. Buendia, M.W. Blair, K. Cichy and B. Raatz, 2022. Climbing bean breeding for disease resistance and grain quality traits. Legume Sci., Vol. 4. 10.1002/leg3.122.
22. Smith, M.R., B.E.R. Hodecker, D. Fuentes and A. Merchant, 2022. Investigating nutrient supply effects on plant growth and seed nutrient content in common bean. Plants, Vol. 11. 10.3390/plants11060737.
23. Venance, S.K., P. Mshenga and E.A. Birachi, 2016. Factors influencing on-farm common bean profitability: The case of smallholder bean farmers in Babati District, Tanzania. J. Econ. Sustainable Dev., 7: 196-201.