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Common Bean Germplasm Diversity Study for Cold Tolerance in Ethiopia

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Abstract

Limited tolerance of common beans (*Phaseolus vulgaris* L.) to cold temperatures hinders an additional harvest during the small rainy season crop cycle (February to May) in the Ethiopian highlands that comprise two-thirds of the country. Therefore, identification of cold tolerant common bean genotypes is of paramount importance for the region. Field screening of 99 common bean genotypes originally procured from CIAT (International Center for Tropical Agriculture) was carried out for nine different plant traits associated with crop growth and yield at two locations differing in climates: Dire Dawa-higher daily maximum and minimum temperatures and absence of near zero chilling temperatures from February to May; Haramaya-lower daily maximum and minimum temperatures and occasionally near zero chilling temperatures during this period. The analysis of variance (ANOVA) showed the existence of significant variation among genotypes for the parameters measured. Principal component analysis (PCA) was carried out to assess the variation and correlation among genotypes for the traits and group them based on their performance at the two locations. The combination of first three principal components explained more than 50% of the genotypic variations. Principal component analysis was also able to discriminate the performance of genotypes between the two locations. It was grouped into at least 17 genotypes that were specific to Haramaya highland location. The results also revealed significant variation in performance among the 17 genotypes. These genotypes are specific to Ethiopian highlands and prominent resources for *in-situ* conservation of germplasms.

Keywords

Cold Tolerance, Germpalsm Conservation, Common Bean, Principal Component Analysis

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1. Introduction

Common bean, also known as dry bean, is the most important legume crop in the world and the main source of dietary protein in the developing countries [1] [2]. It is grown on subsistence farms by small holders in Africa with acreage exceeding 4 million hectares and serves more than 70 million livelihoods in sub-Saharan African continent [3]-[5]. Highlands (>1500 m) cover about two-thirds of Ethiopia and therefore are crucial to any effort to expand agriculture in the country. Common bean is cultivated both in highlands and lowlands, but its production is constrained by low temperature prevalence in the Ethiopian highlands with varying amounts of rainfall. Ethiopia receives on an average rainfall of 800 to 2200 mm in the highlands [6]. Rainfall is divided in two seasons—the big rains (kirmet) from mid-June to mid-September and small rains (belg) from February to May. Common bean cultivation is widely practiced during the main growing season (meher) coinciding with the big rains. However, there exists the potential of increased acreage if the crop can also be grown during secondary rainy period when other major crops fail. The suboptimal temperatures (0˚C - 10˚C) in the Ethiopian highlands constitute a critical problem to the production of common bean during the secondary rainy period in the region. Lowlands have very conducive temperature for common bean cultivation during secondary rainy period but also have varying rainfall patterns. Screening for genotypes with superior cold tolerance is, thus, needed in order to achieve the goal of two crops of common bean in a year. A few reports of genotypic variation for cold tolerance in common bean exist suggesting the probable success of such efforts [7]-[9].

This experiment was carried out with the objective to evaluate common bean germplasm accessions (original source-CIAT) for adaptability to the lowland (Dire Dawa), highland (Haramaya) or common to both elevation ranges of Ethiopia which differ by 900 m altitude. These accessions were evaluated for agronomic performance for yield and other morphological traits in the two locations. Since many variables account for the growth and ultimate seed yield of a plant but not all of them contribute equally, and the amount of total variance represented contains a huge redundancy due to correlated traits measuring the same trait. The principal component analysis (PCA) is a multivariate analysis based on the factorization of variance matrix to produce a reduced set of variables [10]-[12] which may be used effectively for germplasm screening. This study was carried out to identify genotypes with cold tolerance potential using principal component analysis to reduce a huge redundancy due to correlated traits measuring the same trait. The results of the study were thus subjected to PCA for the identification of the most suited genotypes for the two elevations.

2. Materials and Methods

2.1. Plant Materials

The field experiment was carried out at the Research Centers of Haramaya University, Ethiopia at Haramaya (altitude 2047 m) and Dire Dawa (altitude 1146 m) locations. The field plot design implemented was randomized complete block design at Dire Dawa and Haramaya with three replications in each location. Field plots were prepared using appropriate tillage practices and planted in the beginning of February. The experiment consisted of three replications and planted with 99 common bean genotypes obtained from CIAT and one local variety, Awash1 were evaluated at both locations. These genotypes were obtained from CIAT centers and the selection of genotypes was based on their adaptability to both highland and lowland environments of Ethiopia. The list of genotypes along with the associated numerical used in the current study is presented (**Table 1**). The genotypes were planted in two rows of 4 m in length with row-to-row distance of 60 cm and plant-to-plant spacing of 10 cm. Weeding was carried out manually. Plots were harvested and threshed manually.

These accessions were evaluated for agronomic performance including yield and other morphological traits at the two locations. Five random plants were excavated at the pod set stage to collect data on aboveground and belowground vegetative growth. The measurements included plant height (Ht, cm), leaf number/plant (Ln), branch number/plant (Bn), nodule number/plant (Nn), root length (Rl, cm). At harvest time, ten random plants from the middle rows were sampled to evaluate number of pods/plant (Npp), number of seeds/ pod (Nspp), and seed weight/pod (Swpp, gm). Harvested plants were hand threshed to determine the grain yield per line (Yl, Kg/ha^{-1}).

2.2. Statistical Analyses

All the statistical analyses were performed in SAS [13]. Descriptive statistics score summary was arrived using

Table 1. List of genotypes as represented by serial numbers in the study.

Genotype Number	Genotype name	Genotype Number	Genotype name	Genotype Number	Genotype name	Genotype Number	Genotype name
1	Belmidak RR-4 (s)	26	B94022 (M)	51	LR3201723	76	MANTE Quilla DE (s)
2	N 91401 (s)	27	MX9065-T (M)	52	ARS-R93007 (M)	77	P30-42 (s)
3	EMP-101 (s)	28	MX9065-8-T	53	I-79 (s)	78	MX-9065-14 B (s)
4	G-124-1 (s)	29	CIFEP91401	54	ECAB-0626 (s)	79	LM93203237 (s)
5	Belmidak RR-1 (s)	30	ALPINE	55	CREST WOOD	80	LM93203237 (s)
6	BRB 212 (s)	31	LE-93-7 (M)	56	ECAB-06271 (s)	81	SC91211740 (s)
7	HR-20 (s)	32	SWQ-43	57	TURKY-1 (s)	82	LM932004324 (s)
8	Belmidak RR-6 (s)	33	OMAR-V (M)	58	AR-04-GY (s)	83	RH33-1 (s)
9	BRB-150 (s)	34	G-92317 (M)	59	ECAB-0632 (s)	84	LR9320182
10	EMP-308 (s)	35	WMI-93-8	60	ECAB-0621 (s)	85	LM93204395 (s)
11	ICB-37 (s)	36	WU-3-94-9 (M)	61	BRB-236 (s)	86	SC912111750 (s)
12	AuRORA (s)	37	Starr light (M)	62	OD-04-RB (s)	87	VAX-1 (s)
13	EMP-291 (s)	38	C-92317 (M)	63	SARRAG	88	FEB-216 (s)
14	ARBITUS (s)	39	LAVINIA (M)	64	TURKY-2 (s)	89	MX9065-12-B
15	ICB-53 (M)	40	COWU3-94-9 (M)	65	ECAB-0609 (s)	90	BRB-237 (s)
16	P92606 (M)	41	Belneb RR-2 (M)	66	TEBUS (s)	91	DOR-750 (s)
17	VAX-2	42	NSRN03 (M)	67	ECAB-0607 (s)	92	LR-920168 (s)
18	MX9065-11-M (M)	43	ICTAJU-95-3 (M)	68	TAD4II (s)	93	ICTAJU 95-1 (s)
19	MX9065-3-B (M)	44	BRB-180 (M)	69	ECAB-0619 (s)	94	DICTA 118 (s)
20	SC91212087 (M)	45	ARS93006 (M)	70	OR-04-DH (s)	95	DICTA-122 (s)
21	P94056 (M)	46	L 94D217 (M)	71	ECAB-0618 (s)	96	DICTA-103 (s)
22	F-M-38-1 (M)	47	LE-93-5 (M)	72	AR-04-AJ (s)	97	J-65 (CHE) (s)
23	HX9065-4M (M)	48	SEQ-45 (M)	73	ECAB-0603 (s)	98	Awash 1
24	MX9065-7-T (M)	49	I-72 (M)	74	EARDSEID (s)	99	LR-93201688 (s)
25	MX9065-7-T (M)	50	VCR-5 (M)	75	CARIDCAPLTDGO (s)	100	ICTAJU 95-14 (s)

PROC MEANS procedure with desired statistic estimates such as Mean ± SE, Standard Deviation (SD), Range, Coefficient of Variation (CV), and Least Significant Difference (LSD). Pearson's correlation coefficients were determined using PROC CORR procedure of SAS.

Genotype-by-location interaction was analyzed with linear mixed model procedure of SAS. Genotypes, locations and their interactions were considered as random effects, where locations represent the chilling and non-chilling growing environment conditions in Ethiopia. Significance of covariance parameter estimates was tested using the Wald test.

The dimensionality of dataset was reduced using PCA analysis to assess the multiple traits and screen genotypes that exhibit tolerance to low temperature. The correlation matrix was utilized in determining the eigenvector values. The eigenvalues were scored to determine the significant genotypes influencing the observed variation. The number of components was extracted using scree plot of eigenvalues. Biplots was developed from first two principal components (PRN1 and PRIN2). The eigenvalues and the eigenvector values were extracted to construct the biplots from first two principal components. The number of variables that can best fit to describe the performance of genotypes for observed variation was identified from eigenvector values of PCA analysis. Venn diagram was drawn to delineate the best performing genotype for each location.

3. Results and Discussion

A large germplasm collection of common bean is available [14]. However, only few usually outperform at a given location due to inherent genetic potential to adapt to prevailing environmental conditions. Therefore, assessment of genetic variation present in a set of germplasm core collection is important for evaluating their agronomic performance in a given set of environment [15]. This further helps in making decisions related to the selection of sites and germplasms for in-situ conservation [16].

A narrow genetic base exists for common bean cultivars within the market class in Ethiopia which can be improved by introgression of favorable alleles for resistance to abiotic stresses [17] [18]. The information on cold tolerant common bean genotypes in Ethiopia is inadequate due to lack of research effort in this area and the existing varieties are susceptible to temperatures below 15˚C [19]-[23]. Therefore, screening of common bean germplasm for genetic variation for cold tolerance is needed.

Summary of the descriptive statistics are presented (**Table 2**). Descriptive statistics showed higher mean values for most traits measured at Dire Dawa (chill-free location) compared to Haramaya (Chill-prone location). Of these traits, plant height and nodule number showed significant difference between the two locations which is useful information for dry bean researchers in this region due to increased emphasis on water-use efficiency and nitrogen-use efficiency in common bean breeding programs. The observed variation is attributed to genotypic response of 100 common bean genotypes to low temperature prevailing in Haramaya location during secondary rainy period. Correlation matrix revealed the significant correlations between the traits affecting yield (**Table 3**). The correlation coefficient values indicated a significant correlation between seed yield and yield related traits at Haramaya and Dire Dawa locations. This study revealed ample genetic variation among yield and other morphological traits due to effect of differential response of genotypes to both the chill prone and chill free conditions. Common bean yields were higher on average for Dire Dawa location compared to Haramaya location indicating that lower temperature imposed a limit on common bean productivity in Haramaya location. Variance estimates for genotype x location interactions are significantly different for nine traits (**Table 4**). The results revealed that yield values were significantly different between two locations arising from genotype X location effect. Genetic variation was significantly different for yield, number of pods/plant, number of seed/pod, seed weight/pod. This indicates the genotype performance for Haramaya and Dire Dawa is different for all the traits.

PCA analysis was done to assess the multiple traits to screen genotypes that exhibit frost and low temperature tolerance. The evaluation of germplasm through principal component analysis is a robust tool to reduce the large number of correlated variables and germplasms into smaller components (factors) of uncorrelated variables.

Table 2. Descriptive statistics for traits measured at Dire Dawa (D) and Haramaya (H) locations.

Variable	Mean ± SE (D)	Mean ± SE (H)	SD (D)	SD (H)	Range (D)	Range (H)	CV (D)	CV (H)	LSD (5%) (D)	LSD (5%) (H)
Plant height (cm)	81.2 ± 1.75	65.4 ± 1.61	19.1	17.3	39.67 - 113.67	39.67 - 101.00	23.5	26.4	15.1	12.2
Leaf number/plant	35.4 ± 0.65	39.3 ± 1.09	8.0	11.1	23.00 - 60.67	16.33 - 64.33	22.6	28.2	8.9	4.0
Branch number/plant	4.1 ± 0.06	4.1 ± 0.06	0.77	0.73	3.00 - 5.67	3.00 - 5.67	18.6	17.7	0.99	0.82
Nodule number/plant	84.8 ± 3.49	38.2 ± 1.54	40.7	19.0	13.00 - 192.67	6.00 - 86.00	48.0	49.8	38.2	21.5
Root length (cm)	21.9 ± 0.19	21.0 ± 0.21	2.5	2.6	15.00 - 26.67	16.67 - 32.67	11.5	12.5	3.0	3.1
No of pods/plant	31.0 ± .58	19.2 ± 0.37	8.1	4.5	18.00 - 45.00	12.67 - 31.00	26.2	23.6	10.8	4.9
No of seeds/pod	5.7 ± .06	5.2 ± 0.08	0.75	0.92	4.00 - 7.00	3.67 - 6.67	13.1	17.7	0.94	0.87
Seed weight/pod (gm)	0.87 ± 0.04	0.92 ± 0.05	0.50	0.56	0.13 - 1.93	0.13 - 2.53	57.8	61.1	0.58	0.57
Seed yield (Kg/ha)	279.0 ± 5.98	259.9 ± 11	78.5	161.7	140.00 - 586.67	60.00 - 993.33	28.1	62.2	100.8	228.2

Ht-plant height, Ln-leaf number/plant, Bn-branch number/plant, Nn-Nodule number/plant, Rl-Root length, Npp-Number of pods/plant, Nspp-Number of seeds/pod, Swpp-Seed weight/pod, Yl-Seed yield/plant.

Table 3. Correlation matrix for 9 traits of the 100 genotypes evaluated is represented with correlation coefficients between yield and different morphological traits. The upper and lower diagonal correlations represent Dire Dawa and Haramaya locations, respectively.

Traits	Plant height	Leaf no/plant	Branch no/plant	Nodule no/plant	Root length	No of pods/plant	No of seeds/pod	Seed weight/ pod	Seed yield
Plant height (cm)	-	0.32***	0.04	0.19**	0.16**	0.04	0.13*	0.06	0.018
Leaf no/plant	0.50***	-	0.39***	0.13*	0.39***	0.05	0.06	−0.14	0.20***
Branch no/plant	0.10	0.07	-	0.08	0.35***	0.02	0.10	−0.19	0.08
Nodule no/plant	0.15**	0.06	0.12*	-	0.20***	−0.04	0.19***	−0.21***	0.02
Root Length (cm)	−0.02	0.003	0.12*	0.11	-	−0.02	0.05	−0.15***	−0.01
No of pods/plant	−0.12*	−0.05	0.21**	−0.01	0.19***	-	0.12*	−0.21***	0.14*
No of seeds/pod	−0.01	0.13*	0.03	0.02	0.05	0.27***	-	0.09	0.13*
Seed weight/pod (gm)	0.27***	0.14*	−0.08	0.03	−0.05	−0.24***	−0.15**	-	0.09
Seed yield (Kg/ha)	0.17**	0.21***	0.12*	−0.007	0.17**	0.34***	0.16**	0.03	-

***, **, and * are significant at probability of 0.001, 0.01, and 0.05, respectively. Ht-plant height, Ln-leaf number/plant, Bn-branch number/plant, Nn-Nodule number/plant, Rl-Root length, Npp-Number of pods/plant, Nspp-Number of seeds/pod, Swpp-Seed weight/pod, Yl-Seed yield/plant.

Table 4. Variance component estimates for location (L), blocks within location (B), genotype (G) and genotype x environment interaction for nine traits measure at Dire Dawa and Haramaya.

	Plant height	Leaf number	Branch number	Nodule number	Root length	Number of pods/plant	Number of seeds per pod	Seed weight per pod	Yield
L	123.0	6.6	0.0	1063.7	0.25	69.3	0.14	0.0	243.9
L (B)	0.39	1.1	0.015	54.2	0.19	2.4	0.003	0.007	157.4
G	122.5***	5.3	0.037	108.1	0.34	7.5**	0.20***	0.065**	1125.6*
G × L	138.2***	69.7***	0.19***	497.0***	2.5***	7.0**	0.19***	0.088***	2426.6***
Error	72.93	18.3	0.32	370.6	3.7	27.3	0.32	0.13	5003.6

*, ** and *** indicate $P < 0.05$, 0.01, and 0.001, respectively.

PCA helps to extract the independent variables that matter the most and gives direct measurement of total variance explained by few of the important components.

Principal components and their respective proportion of the variation explained by eigenvalues and eigenvectors are presented (**Table 5** and **Table 6**). The first three components in Dire Dawa location explained 55.14% of the variation, whereas cold and chill affected Haramaya location, explained 56.38% of the variation. The high amount of variation explained by PCA for Haramaya location reflects on the impact of adverse climate on the performance of genotypes at this location. Biplots of PCA analysis with first two principal components for two locations are presented (**Figure 1**). The graph clearly demarcated the distinct genotypes that dispersed along two principal components axis which emphasized on the extent of phenotypic variation explained by these clusters. Genotypes that positively correlated and performed best in respective locations are on the upper right side of the quadrant. The number of genotypes that performed well in frost affected site, Haramaya is less than those in frost free location, Dire Dawa. Genotypes that exhibited overall good performance in chill free location and chill affected site are grouped and represented through Venn diagram (**Figure 2**). Among 100 genotypes, 23 were in Dire Dawa and 17 were at Haramaya clustered with positive loading of eigenvalues for first three principle components and 14 genotypes were overlapping in both the locations. Our experimental results show that PCA analysis was able to identify 54 out of 100 genotypes suitable for both locations. Of which, 17 genotypes were tolerant to low temperature and also exhibited significant variations for agronomic traits (**Table 7**).

Common bean productivity in the highlands of Ethiopia is drastically hindered by lack of cold tolerant varieties that can be intercropped with other seasonal crops during small rain period. Common bean germplasm pos-

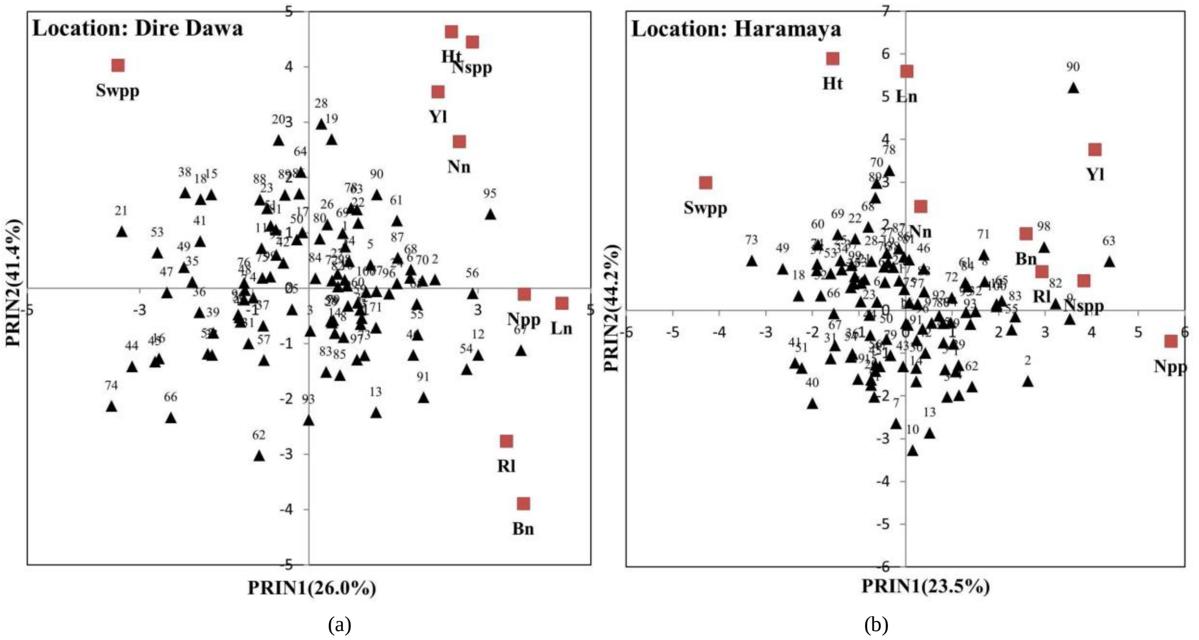

Figure 1. Biplot scores of two principal components (PRIN1 & PRIN2) for (a) Dire Dawa location and (b) Haramaya location. Ht-plant height, Ln-leaf number/plant, Bn-branch number/plant, Nn-Nodule number/plant, Rl-Root length, Npp-Number of pods/plant, Nspp-Number of seeds/pod, Swpp-Seed weight/pod, Yl-Seed yield/plant.

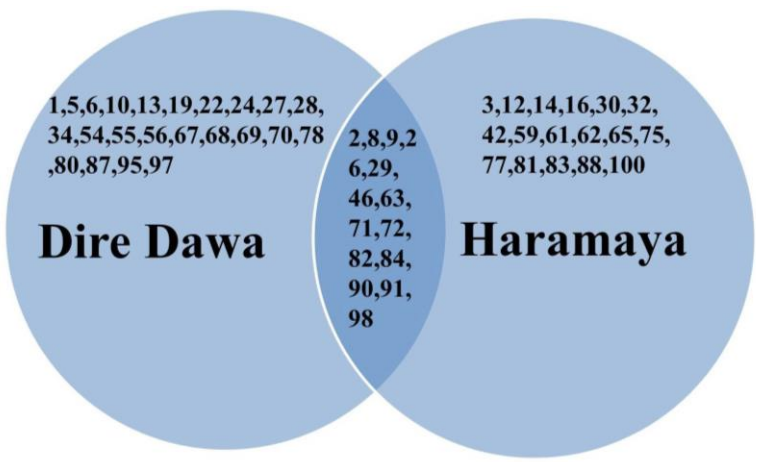

Figure 2. Genotypes clustered are represented based on the performance in two locations through Venn diagram. Footnote: Numbers associated with each genotype can be referred to **Table 1**.

sess diversity for cold tolerance which can be exploited to develop superior cold tolerant genotypes for this region of Ethiopia. Cold tolerant lines are competitively advantageous over susceptible lines due to their strong morphological physiological performance. There are several studies which highlighted the importance of screening for cold tolerance in common bean. The frost tolerance of several species of beans original to the southwestern United States and Mexico were reported which showed ample amount of variation for cold tolerance along with several other biotic and abiotic stresses [7]. Freezing injury directly influenced the appearance of exotherm and seedling death in beans where susceptible varieties responded earlier than tolerant varieties at lower temperatures [9]. Suboptimal temperatures in the seed bed during early spring constrained the proper emergence of seedling in common bean [22]. In addition to morphological and physiological traits, function of pollen and ovule play an important role in determining yield. A significant genetic variation for flower mor-

Table 5. Eigen values and cumulative variation for principal components at Dire Dawa (D) and Haramaya (H) locations.

PC	Eigenvalue (D)	Eigenvalue (H)	Difference (D)	Difference (H)	Proportion (D)	Proportion (H)	Cumulative (D)	Cumulative (H)
1	2.34	2.12	0.96	0.25	0.26	0.24	0.26	0.24
2	1.39	1.87	0.16	0.78	0.15	0.2	0.41	0.44
3	1.23	1.09	0.06	0.09	0.14	0.12	0.55	0.56
4	1.17	0.99	0.36	0.04	0.13	0.11	0.68	0.67
5	0.81	0.95	0.1	0.34	0.09	0.11	0.77	0.78
6	0.7	0.62	0.08	0.08	0.08	0.07	0.85	0.85
7	0.62	0.54	0.23	0.06	0.07	0.06	0.92	0.91
8	0.39	0.47	0.07	0.11	0.04	0.05	0.96	0.96
9	0.33	0.36			0.04	0.04	1	1

PC-Principal components.

Table 6. Eigenvector values for Dire Dawa (D) and Haramaya (H) locations.

Eigenvectors	**Dire Dawa**			**Haramaya**		
	Prin1	**Prin2**	**Prin3**	**Prin1**	**Prin2**	**Prin3**
Ht	0.25	0.46	0.43	−0.16	0.59	−0.06
Ln	0.45	−0.02	0.41	0.002	0.56	−0.21
Bn	0.38	−0.39	0.18	0.26	0.18	0.34
Nn	0.27	0.26	−0.15	0.03	0.24	−0.27
Rl	0.35	−0.28	0.31	0.29	0.09	0.45
Npp	0.38	−0.01	−0.5	0.57	−0.07	0.12
Nspp	0.29	0.44	−0.19	0.38	0.07	−0.63
Swpp	−0.34	0.4	0.41	−0.43	0.3	0.32
Yl	0.23	0.35	−0.19	0.40	0.38	0.2

Ht-plant height, Ln-leaf number/plant, Bn-branch number/plant, Nn-Nodule number/plant, Rl-Root length, Npp-Number of pods/plant, Nspp-Number of seeds/pod, Swpp-Seed weight/pod, Yl-Seed yield.

phology and gamete development was observed during cold spells in chickpea [24]. Reduced ovule fertilization due to deterioration of pollen function and viability was observed in cold sensitive cultivars compared to cold tolerance lines in chick pea [25].

This work emphasized on the superior genotypes that can increase common bean productivity in the highland and enhance breeding programs for abiotic stress tolerance. The research contributes new results on the use of novel genotypes that are best adapted to this region of Ethiopia.

4. Conclusion

This study has provided the information on the best suited genotypes for production during the small rainy season in the highlands of Ethiopia, when low and chilling temperatures are encountered, using a core set of germplasm from CIAT which tend to show large genetic diversity. In summary, this study has found two different contrasting sets of genotypes suitable for two different environments and locations. Although the current study was limited by one season data, the results will be useful for future studies involving multi-location and multi-season evaluations. Moreover, the knowledge gained will be utilized to study their molecular diversity using molecular markers which can further help in conserving the adapted genotypes to this region of Ethiopia.

Table 7. Mean values of 17 genotypes from PCA shown to be performing best at Haramaya location.

Genotype Number	Name of genotype	Ht	Ln	Bn	Nn	Rl	Npp	Nspp	Swpp	Yl
3	EMP-101 (s)	53.7	19.7	4.7	19.7	19.7	20.3	5.7	0.40	230.0
12	AuRORA (s)	82.7	32.3	4.0	49.0	21.7	26.3	6.3	0.50	266.7
14	ARBITUS (s)	57.3	24.7	3.3	17.0	20.3	21.0	5.0	0.67	316.7
16	P92606 (M)	68.7	28.7	4.7	33.7	21.0	22.3	4.0	1.13	280.0
30	ALPINE	43.0	25.0	4.7	45.0	22.7	17.3	5.0	0.87	223.3
32	SWQ-43	55.7	30.0	4.0	56.0	23.0	22.3	6.0	1.07	370.0
42	NSRN03 (M)	60.0	34.7	4.7	16.0	20.0	23.7	4.7	0.87	210.0
59	ECAB-0632 (s)	51.7	37.3	4.0	27.7	23.0	21.3	5.7	0.80	263.3
61	BRB-236 (s)	77.0	46.7	4.0	29.7	21.7	22.7	5.3	0.47	356.7
62	OD-04-RB (s)	47.7	37.3	4.7	27.0	21.7	25.0	4.7	0.13	143.3
65	ECAB-0609 (s)	54.0	40.3	4.7	42.7	22.0	22.0	6.3	0.73	373.3
75	CARIDCAPLTDGO (s)	56.7	44.7	4.0	47.7	23.0	16.3	6.7	1.13	173.3
77	P30-42 (s)	59.0	46.0	4.3	40.3	20.0	17.3	5.7	0.67	280.0
81	SC91211740 (s)	81.0	54.7	4.7	34.0	19.0	19.7	5.7	0.80	220.0
83	RH33-1 (s)	50.0	44.7	4.7	39.7	21.7	25.7	5.7	0.53	336.7
88	FEB-216 (s)	65.7	51.7	3.7	38.0	21.0	18.3	6.0	0.60	273.3
100	ICTAJU 95-14 (s)	52.7	51.7	4.7	35.7	23.0	22.7	5.7	0.40	280.0

Ht-plant height, Ln-leaf number/plant, Bn-branch number/plant, Nn-Nodule number/plant, Rl-Root length, Npp-Number of pods/plant, Nspp-Number of seeds/pod, Swpp-Seed weight/pod, Yl-Seed yield.

The identified genotypes are important resources for local plant breeders to further strengthen the breeding program for resistance to abiotic stress.

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