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GENOTYPE X ENVIRONMENT INTERACTION AND STABILITY ANALYSIS FOR YIELD AND YIELD RELATED TRAITS OF DESI-TYPE CHICKPEA (*CICER ARIETINUM* L.) IN ETHIOPIA

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ABSTRACT

Chickpea is the major pulses grown in Ethiopia, mainly by subsistence farmers usually under rain-fed conditions. However, its production is constrained due to genotype instability, environmental variability and interaction of genotype with environment. This research was carried out to examine the magnitude of environmental effect on yield of chickpea genotypes and to investigate the stability and adaptability of the genotypes under different agro-ecological conditions. 17 genotypes each of were evaluated in RCBD with four replications in five environments. Various stability indices were used to assess stability and genotype by environment performances. The combined ANOVA for yield and yield related traits revealed highly significant (P≤0.01) differences for genotypes, environments and their interaction. The significant interaction showed that the genotypes respond differently across the various environments. At Akaki, Chefe Donsa, Debre Zeit, Dembia and Haramaya the top performing genotype were DZ-2012-CK-0040 (2229 kg/ha), DZ-2012-CK-0027 (3966 kg/ha), DZ-2012-CK-0040 (4060 kg/ha), DZ-2012-CK-0032 (1394 kg/ha) and Natoli (3247 kg/ha) respectively. The first two PCs explained 84.3% of the variance of original variables for the genotypes. There were remarkable inconsistencies with the univariate stability parameters to select stable genotypes. However, multivariate approach, the AMMI model was better for partitioning the G x E into the causes of variation. Based on ASV value, DZ-2012-CK-0035 was most stable genotype. As per AMMI biplot, Minjar and local variety were the most widely adapted genotypes. Dembia and Haramaya are the most discriminative environments. Environments Debre Zeit and Chefe Donsa were the favorable environment. Genotypes, DZ-2012-CK-0040, DZ-2012-CK-0036 and DZ-2012-CK-0040, DZ-2012-CK-0032 and variety Natoli were recommended as specifically adapted to sites Akaki, Chefe Donsa, Debre Zeit, Dembia and Haramaya respectively.

Keywords: AMMI, ASV, Clustering, Desi-type, Phonologic traits, Multivariate, Univariate statistics.

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1. INTRODUCTION

Chickpea is the third leading legume grain in the world and in Ethiopia as well. Its range of cultivation extends from the Mediterranean basin to the Indian sub-continent and south ward of Ethiopia and eastern Africa highlands [1]. About 92% of the area and 89% of production of the grain are concentrated in the semi-arid tropical countries [1]. In Ethiopia, it accounts for about one third of the area and production of pulses following faba bean(V*icia faba* L.) and haricot bean (*Phaseolus vulgaris* L.) [2].

Desi-type chickpeas (*Cicer arietinum* L.) with colored and thick seed coat with small and angular in shape having an average 1-2 seeds per pod. The plants are short with small leaflets and purplish flowers, and contain anthocyanin. Desi-type chickpea seeds germinate at an optimum temperature (28-33°C) and moisture level 10 % in about 5-6 days [3]. The flowers are generally pink and the plants show various degrees of anthocyanin pigmentation. The Desi-types account for 80-85% of chickpea global production area [3]. The crop grows mainly concentrated in two into major administrative regional stats namely Amhara and Oromiya and it accounts 94% the total production in the country with altitude range of 1400-2300 masl, and annual rainfall of 700-2000 mm [4].

Environmental factors such as soil moisture, sowing time, fertility, and temperature and day length have strong influence during various stages of plant growth [5]. The environment is changing day-by-day and this implies that it is necessary to evaluate crop genotypes at different environments to assess their performances. The performance of a genotype is not always the same in different environments as it is influenced by environmental factors. To assess yield stability among varieties, multi-location trials with appropriate stability analysis method is required. In Ethiopia, there is no sufficient information on the genotype by environment interaction effects on yield and yield related traits. Therefore the current research was undertaken To examine the magnitude of environmental effect on yield and yield related traits of Desi-type chickpea genotypes,to study the nature and extent of G x E Interaction on seed yield of Desi -chickpea genotypes and to investigate the stability and adaptability of the varieties under different agro-ecological condition.

2. MATERIALS AND METHODS

The experiment was conducted during the 2012/13 main cropping season at five environments representing various chickpea agro-ecologies of Ethiopia. The sites were Akaki, Chefe Donsa Debre Zeit, Dembia and Haramaya. Fourteen pipelines and three released Desi-type chickpea genotypes were included in the study. The plant materials were obtained from Debre Zeit Agricultural Research Center. Planting of the genotypes was done in early mid August up to first week of September using Randomized Complete Block Design (RCBD) with four replications at each site under rain fed conditions. Each genotype was planted in six rows of 4 m row length and at 1.2 m width. A spacing of 30 cm between rows and 10 cm between plants were used on a plot size of 4.8 m^2. Fertilizer was not applied. Weeding and other management practice were done as required for each site. Data were recorded on days to 50% flowering, 90% physiological maturity, plant height, the number of pods per plant, the number of seeds per plant, the number of seeds per pod, 100-seed weight, biomass yield, grain yield, and harvest index. Data were computed by using SAS 9.1.3 for analysis of variance, Genstat13th for biplot graph and Agrobase20 for stability analysis.

Table-1. Some characteristic features of the test sites

Trial site	Soil type	Altitude (masl)	Rainfall average (mm)	Temperature (^oC)		Geographical position	
				Min	Max	Latitude(N)	Longitude(E)
Akaki	Vertisol	2120	1055	10.36	22.3	$08^{0}52'$	$38^{0}48'$
Chefe Donsa	Vertisol	2450	950	10.5	23.2	$08^{0}\ 52'$	$39^{0}08'$
Dembia	Vertisol	2021	1000	14.0	29.2	$12^{0}1'$	$37^{0}19'$
Debre zeit	Vertisol	1950	851	10.8	26.9	$08^{0}\ 44'$	$38^{0}58'$
Haramaya	Vertisol	1980	780	15.8	24.3	$9^{0}26'$	$42^{0}30'$

Source: Debre Zeit Agricultural Research Center (2012)

Table-2. List of Desi-type chickpea genotypes included in the experiment

Entry no	Entry name	Entry no	Entry name	Entry no	Entry name
1	DZ-2012-CK-0027	8	DZ-2012-CK-0027	15	Natoli
2	DZ-2012-CK-0027	9	DZ-2012-CK-0027	16	Minjar
3	DZ-2012-CK-0027	10	DZ-2012-CK-0027	17	Local check
4	DZ-2012-CK-0027	11	DZ-2012-CK-0027		
5	DZ-2012-CK-0027	12	DZ-2012-CK-0027		
6	DZ-2012-CK-0027	13	DZ-2012-CK-0027		
7	DZ-2012-CK-0027	14	DZ-2012-CK-0027		

3. RESULTS AND DISCUSSION

The combined analysis of variance revealed significant ($P \leq 0.01$) differences for environments, genotypes and genotype by environment interaction in desi-type chickpea genotype. Except seed per pod, the variations were significant for all the characters studied viz. days to flowering, days to maturity, grain yield, number pod per plant, plant height, 100 seed weight , above ground dry biomass yield and harvest index when tested against pooled error variance.

Yield and its components are poly genic traits and are strongly influenced by environment in chickpea. Highly significant variation was observed for grain yield in desi-type chickpea genotypes (Table 3). The mean squares due to G X E interactions were also highly significant exhibiting the differential response of genotype in various environments. Similar results were obtained by Khan, et al. [6], Khan, et al. [7] and Bains, et al. [8] in chickpea.

Bartlett's test showed that homogenous error variance for the grain yields these allowing proceeding further for pooled analysis of variance across environments. Indicating differences in environments and the presence of genetic variability among genotypes. The highly significant difference among the genotypes showed that they may carry genes with different additive effects. Variations for genotypes performances across environments were also reported by Malik, et al. [9], Bozoglu and Gulumser [10].

Table-3. Mean sum of squares of yield and other traits from combined ANOVA of 17 desi type chickpea genotypes grown across five environments

Source	df	DF	DM	PPP	SPP	PHT	HSW	BM	HI	YLD
E	4	1218**	12427**	6254**	0.04ns	1310**	72.7**	7515613**	1528**	2859358**
G	16	175**	105**	847**	0.7ns	55.4**	385.5**	22518.8**	102.9**	41648**
GxE	64	37**	55**	218**	0.15ns	19.8**	12.9**	235591**	59.3**	25708**
Error	240	3.5	4.7	38.3	0.02	7.2	4.7	25955	27.2	5104

Table 4. Mean grain yield (kg/ha) 17 Desi-type chickpea genotypes grown at five environments

Genotype	Akaki	Chefe Donsa	Debre Zeit	Dembia	Haramaya	Mean yield
DZ-2012-CK-0027	2073	3966	2908	939	2273	2053
DZ-2012-CK-0028	1304	2374	2958	823	1710	1620
DZ-2012-CK-0029	1540	3575	2741	836	1523	1636
DZ-2012-CK-0030	1444	3488	3031	970	2028	1783
DZ-2012-CK-0031	1596	3501	3569	667	1502	1792
DZ-2012-CK-0032	1483	3446	2810	1394	1147	1663
DZ-2012-CK-0033	1785	2943	3398	745	1208	1784
DZ-2012-CK-0034	1556	3641	3208	833	1870	1805
DZ-2012-CK-0035	1556	2928	2997	667	1655	1686
DZ-2012-CK-0036	1821	3237	3717	1183	1991	2106
DZ-2012-CK-0037	1367	3150	3408	1117	1424	1737
DZ-2012-CK-0038	1693	3245	3367	766	1352	1774
DZ-2012-CK0039	1793	3347	3415	771	1538	1861
DZ-2012-CK-0040	2229	3622	4060	956	1641	2223
Natoli (SC)	1703	3655	3485	743	3247	2176
Minjar (SC)	1367	2945	3876	1010	1756	1875
Local check	1796	2837	2366	1329	1033	1664
Means	1653	3288	3250.	928.	1670	1838
CV(%)	16	11	12	20	20	16
LSD (5%)	91	123	133	64	115	45

The environment's mean yield varied from 928 to 3288 kg/ha (Table 4). Maximum mean grain yield was obtained from Chefe Donsa and Debre Zeit; while, the minimum was from Dembia. Genotypes means across the environments indicated that the maximum mean grain yield was obtained from DZ-2012-CK-0039 (2223 kg/ha) while Natoli (2176 kg/ha) was ranked second and DZ-2012-CK-0036 (2106 kg/ha) third and the minimum from genotype DZ-2012-CK-0028 (1620 kg/ha). Genotypes DZ-2012-CK-0040 (2229 kg/ha), DZ-2012-CK-0027 (2073 kg/ha) and DZ-2012-CK-0036 (1821kg/ha) were ranked first, second and third at environment Akaki based on mean grain yield. At Chefe Donsa genotype DZ-2012-CK-0027 (3966 kg/ha), Natoli (3655 kg/ha) and DZ-2012-CK-0034 (3641kg/ha) ranked first, second and third respectively. At Debre Zeit genotype DZ-2012-CK-0040 (4060 kg/ha), Minjar (3876 kg/ha) DZ-2012-CK-0036 (3717 kg/ha) performed first, second and third respectively. At Dembia genotype DZ-2012-CK-0032(1394 kg/ha), local variety (1329 kg/ha) and DZ-2012-CK-0036 (1183 kg/ha) ranked first, second and third respectively. At Dembia, the performances of the genotypes were generally poor as compared to Akaki, Chefe Donsa, Debre Zeit, and Haramaya, because at Dembia there was moisture stress during planting and vegetative stage. At Haramaya genotypes Natoli (3247 kg/ha) DZ-2012-CK-0040 (2273) and DZ-2012-CK-0030 (2028 kg/ha) were found first, second and third respectively. The majority of the genotypes were best performing at Debre Zeit. G X E interaction causes differences in yield rank of genotype in different environments hence it is important for chickpea breeders to enhance selection efficiency and development of specifically adapted genotypes for different environments.

3.1. Performance of Desi-Type Chickpea Genotypes for Yield Related Traits

The mean square values due to genotypes, environments and genotype by environment interactions from the combined ANOVA were highly significantly for the traits: days to flowering, days to maturity, plant height, pods per plant, hundred seed weight, above ground dry biomass and harvest index. However, all of these were not significant for number of seeds per pod.

Days to flowering and maturity (days): Days to flowering and to maturity were significantly affected not only by genotypes but also G X E interaction, reflecting genetic variability in experimental material as well as differential response across environments (Table 3).

Averaged over all genotype, early flowering and maturity were observed at Debre Zeit (42 and 102 respectively) and late flowering and maturity occurred at Akaki (52 and 130 days respectively) (Table 5). The probable reason is due to high temperature and early cessation of rain at Debre Zeit and, relatively long rain season and low temperature at Akaki. In all research sites, mean value of days to flowering and days to maturity ranged from 42 days (Debre Zeit) to 52 days (Dembia) and 102 days (Debre Zeit) to 130 days (Haramaya), respectively (Table 6).

Number of pods per plant: Number of pods per plant is an important selection criterion for the development of high yielding genotypes and it is strongly influenced by environment in chickpea [9]. Marked variation for number of pods per plant was observed in the performance of genotypes over the five environments (Table 3) and this indicated sensitiveness of number of pods for environmental variations. The highest mean number of pods per plant was recorded by genotypes local variety (57) followed by DZ-2012-CK-0036 (52) and DZ-2012-CK-0035 (42) (Table 5). Number of pods per plant was highest at Haramaya (50) and lowest at Akaki (31) (Table 6).The highest pod per plant was as result of extended vegetative and reproductive growth stages. These results are consistent with the findings of Malik, et al. [9] in Kabuli type chickpeas.

Plant height: Significant effects were observed not only for genotypes but also for genotype environment interaction, reflecting genetic variability in experimental material as well as differences in genotype performances over location the (Table 3). The relative performance of genotypes for plant height was markedly inconsistent over the environments which is in line with finding of Malik, et al. [9] and Iliadis [11] in chickpea who found high magnitude of G X E interaction. Plant height was highest at Debre Zeit (40 cm) and lowest at Akaki (30 cm) (Table 5).the shortest was DZ-2012-ck-0036 (32 cm) and the longest was DZ-2012-ck-0031 (39 cm) (Table 6).

100-grain weight: Statistically, highly significant variance was observed for genotypes, genotype and environment (Table 3). In addition, the relative performance of the genotypes was quite inconsistent across the environments. Significant pooled deviation for 100-grain weight suggested that these genotypes differ considerably with respect to their suitability for this trait. The results obtained are in conformity with the findings of Singh and Singh [12] in chickpea and Sanghi and Kandalkar [13] in fodder cow pea. Hundred seed weight was highest at Akaki (25 g) and lowest at Chefe Donsa (22 g) (Table 5). Hundred seed weight varied from 13 g for farmers or local variety to 31 g for DZ-2012-CK-0031 (Table 6).

Above ground dry biomass. Statistically, highly significant variance was observed for genotypes, environments and G X E interaction (Table 3). Averaged over all genotypes above ground dry biomass was highest at Debre Zeit (1469 g) and lowest at Akaki (765 g) (Table 5).On the other hand, where averaged over all environments above ground dry biomass ranged from 920 g for local check and 1320 g for Natoli (Table 6).

Harvest index. Statistically, highly significant variance was observed for genotype and genotypes, environments and G X E interaction (Table 3). Over all genotypes harvest index was highest at Chefe Donsa (57%) and least at Dembia (28%) (Table 5). Pooled over all environments, harvest index ranged from 41.1% for DZ-2012-ck-0028 to 49.5% for DZ-2012-CK-0036 (Table 6). High harvest index is very important for increasing yield potential in crops because it is sensitive to environmental variations. However, a high vegetative growth is not always a symptom for high chickpea yield.

3.2. Stability Analysis

3.2.1. Wricke's Ecovalence Analysis

Wricke [14]; Wricke [15] defined the concept of ecovalence as the contribution of each genotype to the GEI sum of squares.

Genotypes with the lowest eco valence contributed the least to the G X E interaction and are therefore, more stable. Accordingly, DZ-2012-CK-0035, DZ-2012-CK-0034, DZ-2012-CK-0036, DZ-2012-CK-0028, DZ-2012-CK-0039, DZ-2012-CK-0029 and DZ-2012-CK-0038 were the most stable genotypes. In that order these ranked 13th, 7th, 3th, 17th, 6th, 16th, and 11th for grain yield. Whereas most unstable genotypes were Natoli, DZ-2012-CK-0032, DZ-2012-CK-0040, DZ-2012-CK-0027, DZ-2012-CK-0037, DZ-2012-CK-0030, DZ-2012-CK-0033, DZ-2012-CK-0031, Minjar and the local variety. These ranked 2nd 15th, 1st, 4th, 12th, 10th, 9th, 8th, 5th and 14th for grain yield, respectively.

The results indicated that high yielders have higher ecovalence and *vice versa*, and because of this genotypes recommendation for general adaptability would be difficult (Table 7). According to Asrat, et al. [16] genotypes with high ecovalence mean and large estimated value are suitable for high input environments.

Table-5. Mean values yield related traits of desi-type chickpea genotype tested at five environments in Ethiopia

Environment	DF	DM	PPP	SPP	PHT	HSW	BM	HI	YLD
Akaki	52	130	31	1.05	30.2	25.3	765.4	52.9	1653.3
Chefe Donsa	48	129	38	1.04	35.9	22.1	1408	57	3287.9
Debre Zeit	42	102	49	1.01	40.1	24.6	1469.1	53.3	3250
Dembia	52	109	38	1.01	37.2	22.7	1329.4	28	928.3
Haramaya	43	130	50	1.01	35.8	24	886.7	47.1	1699.5
Means	50	121	40	1.08	34.7	24.4	1043.2	44.9	1837.7
CV (%)	3.8	1.8	15.5	1.02	7.8	8.8	15.4	11.6	16.1
SE±	0.30	0.69	0.74	0.01	0.28	0.27	22.2	0.79	11.60
LSD (5%)	1.16	1.26	3.85	0.06	1.67	1.34	100.4	3.24	44.5

Where: YLD= grain yield, DF= days to flower, DM=days to mature, PPP= pod per plant, SPP=seed per pod, PHT=plant height, BM= biomass yield, HI= harvest index, HSW= hundred seed weight

Table-6. Means for yield related traits of 17 Desi-type chickpea genotypes grown at five environments

Genotype	DF	DM	PPP	SPP	PHT	HSW	BM	HI
DZ-2012-CK-0027	48	122	38	1	36	29	1145	44
DZ-2012-CK-0028	58	119	38	1	36	21	975	41
DZ-2012-CK-0029	50	113	40	1	37	27	950	45
DZ-2012-CK-0030	46	122	29	1	35	29	970	47
DZ-2012-CK-0031	50	120	35	1	39	31	1030	45
DZ-2012-CK-0032	47	115	35	1	33	24	960	48
DZ-2012-CK-0033	50	122	40	1	35	23	1010	42
DZ-2012-CK-0034	46	120	33	1	32	28	1170	43
DZ-2012-CK-0035	49	120	41	1	33	22	945	43
DZ-2012-CK-0036	48	124	52	1	32	23	1015	50
DZ-2012-CK-0037	51	122	42	1	35	22	1095	46
DZ-2012-CK-0038	46	121	41	1	34	24	1060	45
DZ-2012-CK0039	48	118	40	1	35	24	1030	45
DZ-2012-CK-0040	49	124	41	1	34	27	1170	46
Natoli (SC)	54	123	36	1	35	28	1320	42
Minjar (SC)	48	119	38	1	35	20	970	47
Local check	47	118	57	2	34	13	920	46
Means	50	121	40	1	35	24	1043	45
CV (%)	4	2	16	10	8	9	15	12
SE±	0.3	0.7	0.7	0.01	0.3	0.3	22	1
LSD	1	1	4	0.1	2	1	100	3

Where: YLD= grain yield, DF= days to flower, DM= days to mature, PPP= pod per plant, SPP= seed per pod, PHT=plant height, BM= biomass yield, HI= harvest index, HSW=hundred seed weight; SC=standard Check.

3.3.2. Eberhart-Russell's Joint Regression Stability Analysis

Eberhart and Russell [17] joint regression model for stability of some agronomical and physiological data provide the estimate of the desired stability parameters.

The GE (linear) interaction was not significant, indicating that the stability parameter 'bi' estimated by linear response to change in environment was the same for all genotypes or genotypes have the same slope (Table 8). This confirms that GE was not a linear function of environments indices. The variations among the genotypes and for G X E interactions were significant. It means that genotypes exhibited different performance in different environments, which is due to their different genetic makeup or the variation due to the environments or both.

Mean sum of squares due to pooled deviation from regression was significant (P≤0.01) for grain yield indicating the importance of the non- linear GE.

Table-7. Wrickes ecovalence value for 17 desi-type chickpea genotypes at five environments

Genotypes	W*i*	Rank	Mean seed yield (Kg/ha)	Rank
DZ-2012-CK-0027	32724	5	2053	4
DZ-2012-CK-0028	6038	14	1620	17
DZ-2012-CK-0029	7232	12	1636	16
DZ-2012-CK-0030	13365	9	1783	10
DZ-2012-CK-0031	10795	10	1792	8
DZ-2012-CK-0032	36057	3	1663	15
DZ-2012-CK-0033	18199	7	1784	9
DZ-2012-CK-0034	3063	16	1805	7
DZ-2012-CK-0035	2338	17	1686	13
DZ-2012-CK-0036	3385	15	2106	3
DZ-2012-CK-0037	14406	8	1737	12
DZ-2012-CK-0038	8231	11	1774	11
DZ-2012-CK0039	6479	13	1861	6
DZ-2012-CK-0040	33034	4	2223	1
Natoli (SC)	110185	1	2176	2
Minjar (SC)	31917	6	1875	5
Local check	73873	2	1664	14

W*i* =wrickes ecovalence, SC= standared check

Table-8. Analysis of variance for linear regressions of desi-type chickpea genotypes means on environmental index according to Eberhart and Russell's joint regression model

Source of variation	Df	SS	MS
Total	339	3437279	
Genotype	16	166591	10412*
Env + in Gen + Env	68	3270687	48098
Env. in linear	1	2859358	2859358**
Gen x Env.(linear)	16	140037	8752
Pooled deviation	34	271293	5319**
Residual	240	445758	1748

*, ** -significant at P ≤0.05 and 0.01; Grand mean = 441.04; R-squared = 0.91%; C.V. = 18.96%

The stability parameters according to the model of Eberhart and Russell are given on Table 9. The most stable genotypes with the lowest S^2di values were DZ-2012-CK-0028, DZ-2012-CK-0038, DZ-2012-CK-0039, DZ-2012-CK-0034 in decreasing order.

The most unstable genotypes with the highest S^2di values were Natoli, local and DZ-2012-CK-0028. So, these genotypes would best fit for specific adaptation in favorable environments. If themean yield (x), regression coefficient value (*bi*) and the deviation from theregression (S^2di) are considered together, then the most stable genotype would be DZ-2012-CK-0034 with a mean yield x = 1805 kg /ha ranked first, *bi* = 1.01 close to 1 and the S^2di = 735 ranked fourth. On the other hand, genotypes DZ-2012-CK-0027, DZ-2012-CK-0028, DZ-2012-CK-0029, DZ-2012-CK-0030, DZ-2012-CK-0032, DZ-2012-CK-0035 and local had regression coefficient values (bi) less than one (i.e. above average stability and significant deviation from regression). So these genotypes were specifically adapted to poor environments. Genotype DZ-2012-CK-0031, DZ-

2012-CK-0033, DZ-2012-CK-0034, DZ-2012-CK-0036, DZ-2012-CK-0037, DZ-2012-CK-0038, DZ-2012-CK-0039, DZ-2012-CK-0040, Natoli, and Minjar had regression coefficients (bi) greater than one (i.e. below average stability and significant deviation from regression). Hence, these genotypes were specifically adapted to favorable environments. Similar results were obtained in common bean genotype tested [18] in different parts of Ethiopia and Ferreira, et al. [19] in Brazil.

Table-9. Mean seed yield, regression coefficients (bi), coefficients of determination (r^2i) and deviation from regression (S^2di)

Genotypes	*bi*	*r^2i*	*S^2di*	Seed Yield (kg/ha)	Rank
DZ-2012-CK-0027	0.74	1.01	5629	2053	4
DZ-2012-CK-0028	0.93	1.00	13	1620	17
DZ-2012-CK-0029	0.80	0.99	1535	1636	16
DZ-2012-CK-0030	0.89	1.00	2028	1783	10
DZ-2012-CK-0031	1.24	0.99	1405	1792	8
DZ-2012-CK-0032	0.68	1.01	4775	1663	15
DZ-2012-CK-0033	1.13	1.01	3318	1784	9
DZ-2012-CK-0034	1.01	0.99	735	1805	7
DZ-2012-CK-0035	0.97	0.99	1015	1686	13
DZ-2012-CK-0036	1.11	0.99	1302	2106	3
DZ-2012-CK-0037	1.06	1.00	2803	1737	12
DZ-2012-CK-0038	1.11	1.00	232	1774	11
DZ-2012-CK0039	1.11	0.99	357	1861	6
DZ-2012-CK-0040	1.31	1.01	3811	2223	1
Natoli (st.ck)	1.09	1.12	34519	2176	2
Minjar (st.ck)	1.30	1.01	3516	1875	5
local check	0.45	1.02	6418	1664	14

bi- regression coefficients, r^2i-coefficients of determination, S^2di-Deviation from regression.

Table-10. AMMI analysis of variance for grain yield (kg/ha) of the 17 desi -type genotypes tested across five environments

Source	Df	Sum of squares	Mean of squares	% Explained
Total	339	22006783	64917	
Environment (E)	4	17449755	4362439**	79.3%
Genotype (G)	16	804949	50309**	3.7%
G × E	64	1844379	28818**	8.4%
IPCA1	19	779080	41004**	42.2%
IPCA2	17	603319	35489**	32.7%
IPCA3	15	318905	21260**	17.3%
IPCA Residuals	13	143075	11006	7.8%

**=significant at the $P \leq 0.01$ probability level

3.3.3. AMMI Analysis and Biplot Representation of 17 Desi-Type Chickpea Genotypes

The main effects of E and G accounted for 79.3 % and only 3.7% respectively, and G X E interaction accounted for 8.4% of the total variation in GE data for grain yield (Table 10). The high percentage of the environment is an indication that environment is the major factor that influence yield performance of chickpea in Ethiopia. The variation due to GE is more than double than the variation due to genotypes as main effect. Tarakanovas and Ruzgus [20], reported significant G X E interaction for grain yield and stressed the usefulness of AMMI analysis for selection of promising genotypes for specific environments or environmental conditions. The first two principal components (PC1 and PC2) which were used to create a two-dimensional biplot, explained 42.24% and 32.72% of AMMI sum of squares, respectively (Table 10). The first two IPCA captures more than 74.96% of the total interaction main effect. The large sum of squares for environments showed that the environments were diverse, with large differences among environmental means causing most of the variation in grain yield, which is in synchronization with the findings of Yan and Tinker [21] in chickpea. This result also indicated the great influence the test environments have had on the yield performance of Desi-type genotypes in Ethiopia.

The AMMI I biplot for grain yield of 17 Desi-type genotypes at five environmental conditions is presented on Fig. 1. The main effects (genotypes and environments) accounted for 82.99 %, and IPCA 1 accounted for 42.24% and IPCA2 accounted for 32.71% of the total variation in genotype by environment interaction. The three IPCAs together accounted for 92.24% of the total interaction, the remaining 7.76% being the residual or noise, which is not interpretable and thus discarded. Environments showed high variation in both main effects and interactions (IPCA1) (Fig. 1).Chefe Donsa and Debre Zeit were most favorable environments; Haramaya and Dembia were least favorable environments as these two environments are far from the origin, while Akaki is the average environment. Environments are also classified into four main groups based on their IPCA1 scores, those of Haramaya and Chefe Donsa in quadrant I have large positive IPCA1 scores, which interact positively with genotypes that have positive IPCA1 scores and negatively those genotypes with negative IPCA1 scores. Debre Zeit in quadrant III has large negative IPCA1 scores, which interact positively with genotypes having negative IPCA1 scores and negatively with genotypes that have positive IPCA1 scores. Akaki and Dembia in quadrant IV have large negative IPCA1 scores, which interact positively with genotypes having negative IPCA1 scores and negatively with genotypes that have positive IPCA1 scores. The environments can be sub-grouped according to their average yield over the genotypes.

The biplot analysis revealed that genotypes DZ-2012-CK-0029, DZ-2012-CK-0031, DZ-2012-CK-0036, and Minjar exhibited IPCA scores close to zero and high mean yield; thus they are found to be stable. Variety Natoli and local are far from the origin, were sensitive to environmental interactive force, and are considered unstable. Genotypes DZ-2012-CK-0029, Minjar and DZ-2012-CK-0031 are close to the origin, were non-sensitive to environmental intercations and are stable. The biplot also revealed association between environment and genotypes. The local variety, DZ-2012-CK-0032, DZ-2012-CK-0033 is related to environment Akaki and Natoli are not associated to any particular environment. DZ-2012-CK-0027 and DZ-2012-CK-0036 are related to Chefe Donsa and DZ-2012-CK-0040 is related to Debre Zeit. Genotypes DZ-2012-CK-0031was high yielder since its mean was greater than the grand mean; it had positive IPCA scores, thus adapted to Debre Zeit. Genotypes with negative IPCA score were not adapted to any of the environments. Among environments, Chefe Donsa and Haramaya are favorable environments as they exhibited the highest positive IPCA1 score, while Debr zeit, Akaki and Dembia are marginal environments showing the highest negative IPCA scores.

Genotypes DZ-2012-CK-0040, Natoli, DZ-2012-CK-0036 and DZ-2012-CK-0027 have higher average yields and adapted to favorable environments, while genotypes Minjar, DZ-2012-CK-0039 and DZ-2012-CK-0034 were adapted to poor environments. DZ-2012-CK-0027, DZ-2012-CK-0030, DZ-2012-CK-0034, DZ-2012-CK-0036, Minjar were adapted to Chefe Donsa while DZ-2012-CK-0032, DZ-2012-CK-0039, and DZ-2012-CK-0040 were adapted to Debrezeit. Genotypes DZ-2012-CK-0037, DZ-2012-CK-0038, DZ-2012-CK-0032, DZ-2012-CK-0033 and local variety were adapted to Akaki. Genotypes DZ-2012-CK-0040, Natoli, DZ-2012-CK-0036, and DZ-2012-CK-0027 had higher average mean grain yield and had highest positive and negative IPCA1 scores which makes them unstable genotypes. Genotype DZ-2012-CK-0032and DZ-2012-CK-0033 had low yield and large IPCA1 scores which indicates that they unstable.

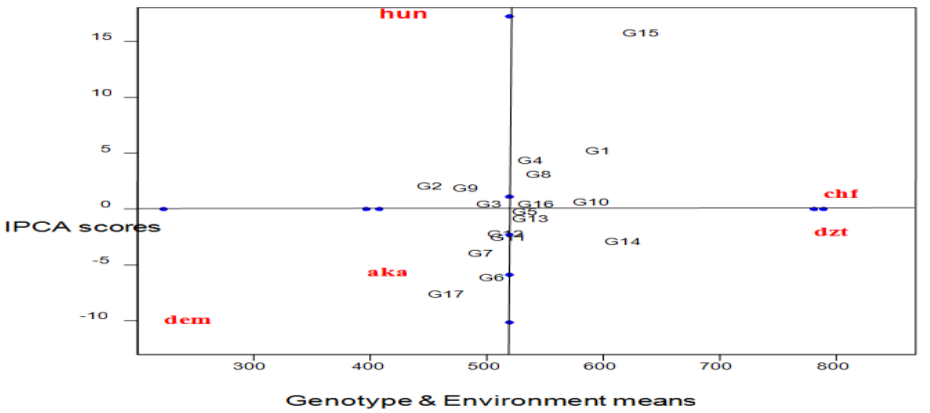

Fig-1. AMMI biplot of IPCA1 *vs.* Main effects using yield data for Desi-type chickpea genotypes.
Akk=akaki, dzt= Debre Zeit, hun= haramaya, dem= dembia and chf= Chefe Donsa; G1-G17 graph ID for the genotypes

Table-11. Yield (kg/ha) and parametric stability statistics for grain yield on 17 genotypes grown in five environments

Genotype	IPCA1	IPCA2	ASV	Rank	Yield
DZ-2012-CK-0027	4.81	-8.06	9.74	14	2053
DZ-2012-CK-0028	1.61	2.30	2.93	3	1620
DZ-2012-CK-0029	0.02	-6.21	6.21	10	1636
DZ-2012-CK-0030	3.91	-3.39	5.59	9	1783
DZ-2012-CK-0031	0.66	3.23	3.32	4	1792
DZ-2012-CK-0032	6.55	-6.32	9.76	15	1663
DZ-2012-CK-0033	-4.40	3.99	6.39	10	1784
DZ-2012-CK-0034	2.69	-1.89	3.59	5	1805
DZ-2012-CK-0035	1.44	0.13	1.64	1	1686
DZ-2012-CK-0036	0.17	3.80	3.81	7	2106
DZ-2012-CK-0037	-2.99	2.34	4.12	8	1737
DZ-2012-CK-0038	-2.65	2.12	3.68	6	1774
DZ-2012-CK0039	-1.26	1.82	2.31	2	1861
DZ-2012-CK-0040	-3.35	5.88	7.00	12	2223
Natoli (SC)	15.29	0.01	17.37	17	2176
Minjar(SC)	0.00	8.34	8.34	13	1875
Local check	-8.07	-8.10	12.23	16	1664

SC=Standard Check

3.3.4. AMMI Stability Value (ASV)

According to the ASV ranking, the most stable genotypes were DZ-2012-CK-0035, DZ-2012-CK-0039 and DZ-2012-CK-0028. DZ-2012-CK-0040 and Minjar were the first and second highest yielders based on the mean yield values (Table 11). However, DZ-2012-CK-0040 which was the highest for mean yield, ranked 12th for the ASV. The most unstable genotypes were Natoli, local, DZ-2012-CK-0032 and DZ-2012-CK-0027. These results are similar with most of the stability indices estimation. ASV was used similarly to identify the stability of common bean varieties in eastern Ethiopia by Nigussie [22].

3.4. Cluster Analysis of Genotypes

Cluster analysis was performed to study the patterns of groupings of genotypes. Dendrograms (Fig. 2) were generated from SAS clustering method of hierarchical algorism method based on Euclidean distances using AMMI adjusted mean yields of genotypes. Clustering of genotypes at a cut-off value of zero produced five clusters. Cluster one consisted of seven genotypes (DZ-2012-CK-0030, DZ-2012-CK-0031, DZ-2012-CK-0033, DZ-2012-CK-0037, DZ-2012-CK-0038, DZ-2012-CK-0039 and Minjar). Cluster two consisted of five genotypes (DZ-2012-CK-0028, DZ-2012-CK-0029, DZ-2012-CK-0032, DZ-2012-CK-0035 and local). Cluster three consists of two genotype (DZ-2012-CK-0027 and DZ-2012-CK-0036) and in this group both genotypes were characterized as high yielder and clearly shown in the AMMI biplot. Cluster four consisted of two genotypes (DZ-2012-CK-0040 and Natoli) which were characterized as high yielders. The last clustering group consists of only one genotype which is DZ-2012-CK-0034.

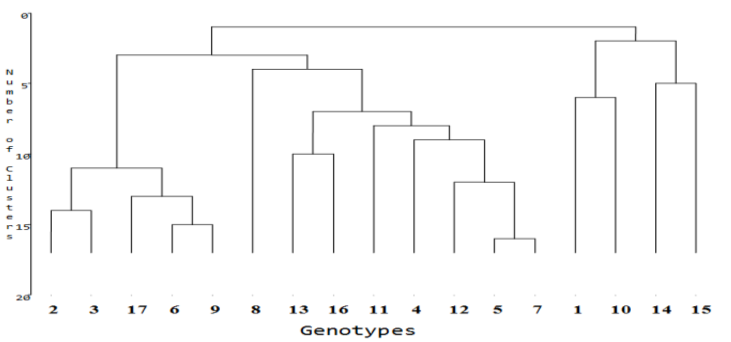

Fig-2. Dendrogram depicting the clustering of 17 Desi-type chickpea genotypes

Note; DZ-2012-CK-0027=1, DZ-2012-CK-0028=2, DZ-2012-CK-0029=3, DZ-2012-CK-0030=4, DZ-2012-CK-0031=5, DZ-2012-CK-0032=6 DZ-2012-CK-0033=7, DZ-2012-CK-0034=8, DZ-2012-CK-0035=9, DZ-2012-CK-0036=10, DZ-2012-CK-0037=11,DZ-2012-CK-0038=12 DZ-2012-CK-0039=13, DZ-2012-CK-0040=14,natoli=15,Minjar=16 and local variety=17.

4. CONCLUSIONS

The combined analysis of variance revealed significant ($P \leq 0.01$) differences for environments, genotypes and genotype by environment interaction in Desi-type chickpea genotype. Except seed per pod, the variations were significant for all the characters studied

In this study, univariate and multivariate stability parameters were used to select the most stable chickpea (Desi-type) genotypes for Ethiopia. The univariate stability parameters showed inconsistence to recommend the most stable genotypes. However, multivariate method, AMMI model could be used to identify superior genotypes for specific adaptation and the AMMI model is one of most important package to investigate patterns, relationships and for predicting performance of genotype and environments. In this experiment Dembia and Haramaya are the most discriminative environments for Desi type chickpea genotypes and Debre Zeit and Chefe Donsa was the favorable environment and Akaki was moderately favorable environment for Desi-type chickpea genotype. Genotypes, DZ-2012-CK-0040, DZ-2012-CK-0036 and DZ-2012-CK-0040, DZ-2012-CK-0032 and variety Natoli were recommended as specifically adapted to sites Akaki, Chefe Donsa, Debre Zeit, Dembia and Haramaya respectively for Desi-type chickpea. As the experiment was tested on five environments, it is imperative to use the recommended genotype for the given environment.

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