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Phenotypic Characterization of Chickpea (*Cicer arietinum* L.) base on Agromorphological Traits at Fedis Eastern Oromia, Ethiopia

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Abstract

As study indicated characterization of crops based on agro morphological traits are important for breeding to select the best quality accession in the field gene bank. 34 chickpea accessions were characterized based on agro morphological traits. All studied accessions were characterized by absences of plant pigmentation and most accessions were characterized by erect plant growth type and pink flowering color. Accessions were characterized by medium pod length and angular ram's seed shape. Majority of accessions were characterized by rough seed textures and brown to reddish brown seed color. Most accessions were characterized by medium seed size and early flowering days. The highest coefficients of variation were observed for Days to 50% flowering (0.57%) and least coefficient of variation (0.04) for Plant height. 32 accessions were flowering lately than the check varieties and 25 accessions were more lately matured than the check varieties. Twenty accessions produced more primary branches than the check varieties. 24 accessions produced higher pods per plant compared to the check varieties. Cluster I consisted of eleven accessions and cluster II consisted of eighteen accessions and also cluster III consisted of five accessions. The intra cluster distance ranged from 474.48 to 953.36. There was significantly strong positive correlation observed between days to 75% maturity with plant height(r=1.00) while weak and negative correlation were observed between days to 50% flowering days with secondary branch but no correlation secondary branch with 100 seed weight.

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Keywords

Descriptor, Agromorpholgy traits, accessions, Genetic diversity, Correlation.

Introduction

Chickpea (*Cicer arietinum* L.) is the third important food legume and production after common beans and Faba beans in Ethiopia and the third most important pulse crop in the world (FAO, 2020). Chickpea is a versatile and the cheapest crop with multiple benefits for integrated crop-livestock farming systems. It is an important source of protein and micro-nutrients; improves soil fertility through nitrogen fixation; has low carbon footprint and aids climate change mitigation; and is easily incorporated into crop rotations (Chaudhary *et al.*, 2021). The leading chickpea growing countries in the world are India, Pakistan, Mexico, Turkey, Ethiopia and Myanmar (Keneni *et al.*, 2011). The crop most probably originated from the area of present day Southeastern Turkey and the adjoining areas of Syria. India and Ethiopia have been proposed as secondary centers for diversity of cultivated chickpea (Harlan, 1992).

Plant genetic resources and the genetic diversity present in them provide an assurance for future genetic progress and an insurance against unforeseen threats to agricultural production (Hari *et al.*, 2008). The studies of genetic diversity of plants are very important for developing high yielding varieties and maintaining the productivity of such varieties in the plant breeding strategies. The screening and selection for crop improvement would be based more likely on availability of promising genotypes; which solemnly depends on the availability for better agronomic traits coupled with disease resistance, earliness and high yield (Keneni *et al.*, 2011). Unfortunately, despite its nutritional values and economic importance, chickpea production is very low per hectare as a result of non-use of improved varieties and technologies generated by the research system in Ethiopia (Bejiga *et al.*, 1996). This is primarily due to poor genetic makeup of the available cultivars. Genetic variability is a prerequisite for any breeding program, which provides opportunity to a plant breeder for selection of high yielding genotypes. One way to estimate genetic diversity is based on morphological traits which are the classical methods to distinguish variations based on the observation of the external morphological differences in different geographical regions (Ghaffari *et al.*, 2014; Hari *et al.*, 2008). Moreover, morphological characters are simple to score and economical to use. In the studies of Ethiopian chickpea morphological characters, the landraces showed considerable variability within and between chickpea populations (Bejiga *et al.*, 1996). Its important information on the associations between yield and various components provide the basis for the selection of improved varieties crops. Therefore characterization is very significant for identifying accessions or varieties with their distinct agro morphology traits playing important function in seed production, seed quality, seed certification and genetic purity. Modern plant breeding and agricultural systems have narrowed the base for the genetic diversity of cultivated chickpea. The objective of this study is to assess morphological diversity of the selected chickpea accession varieties using qualitative and quantitative traits of chickpea.

Materials and Methods

Studying site

The experiment was conducted at Fadis Agdora demonstration site and priority protected area which is located in Eastern Hararghe Zone in Oromia regional state of Ethiopia. Fadis is one of the districts in Eastern Hararghe, 658 km far from Addis Ababa and located 25 km, to the direction of East form Harar city and Agdora kebele is found in Fadis Woreda of Easter Hararghe zone far away 33km from Harar city and 8km from Fadis Woreda. Geographically, the study site is located at geographic position at latitude of 08^{o}02'30"- 09^{o}00'14"N and longitude of 42^{o}06'02"-42^{o}19'00"E. The altitude in the sanctuary ranges from 1200 to 2118 m.a.s.l. Fedis is bordered on the southwest by Gola Odana Meyumuluke, on the west by Girawa, on the northwest by Haramaya, on the north by the Harari Region, on the east by Babile, and on the southeast by the Erer River which separates it from the Somali Region. There were 23 Farmers Associations with 29,713 members and 4 Farmers Service Cooperatives with 346 members (Wikipedia website accessed may 2018). Fedis has only dry-weather roads. The mean annual temperature is about 20.2°C, ranging from a mean minimum of 12.8°C to mean Maximum of 29.4°C. There is only a slight difference in temperature throughout the year, with the hottest months during April to June (maximum 28.6°C) and the coldest during October to December (minimum 10.2°C). The mean annual rainfall is 740.6 mm per year, with high variation from year to year, ranging from 470.6 mm to 1270.4 mm per year. Rainfall is bimodal, occurring from February to April (short rain season) and June to September (long rain season) (Source: National Meteorological Service Agency of Ethiopia Data from 1965 to 2005).

Experimental materials

Thirty two selected chickpea genotypic accessions with two check verity were sown on 25 August 2021 at Fedise Agdora demonstration site and protected area. All the agronomic practices were carried out throughout the crop growing season. When the experiment conducted on twelve Agro morphological qualitative traits characterization such as plant pigmentation, Plant height, Seed shape, plant growth habit, Shattering absence/presence, flower colour, Pod length, Lodging absence/presence, Seed colour, Seed size, seed shape and seed testa texture. And nine Agromorphological quantitative traits were Characterized such as days to 50% flowering, days to maturity, Primary branch, Plant height, Secondary branch, pods per plant, 100 Seed weight (TGW) in gm, Yield per plot in gm and Yield per hectare (kg ha-1). Characterization was done according to Descriptor traits of Chickpea (IBPGR *et al.*, 1993).

Experimental design and layout

Randomized block design (RBD) was used with three replications. Each accession was sown in five rows with

3 m^2 (1 m x 3 m) plots area and 1 m and 0.6 m spacing between blocks and plots respectively. In each plot one hundred seeds were planted by using 0.1m spacing between plants. Five individual plants were tagged randomly from each accession per plot and used for morphological traits data recording. The morphological data recorded on qualitative and quantitative agronomic traits were collected during the cropping season according to descriptors of chickpea (IBPGR *et al.,* 1993). The data of plant height, number of primary branches, number of secondary branches, pod length, number of pods per plant, days to 50% flowering, days to 75% maturity, 100 Seed weight (TGW) in gm, Yield per plot, Yield per hectare (kg ha^{-1}), Plant pigmentation, Growth habit, Seed size, Seed colour, Flowering colour, Seed shape, Shattering, Pod length, Seed testa texture and lodging were determined. The data recording on qualitative and quantitative characters were listed with its measuring scale and period of time on (Table 1&2) respectively. For data on plant bases, the mean of five plants which were randomly selected from the two central rows for the plot bases and the two interior rows were used for data collection.

Statistical data analysis

Analysis of Variance (ANOVA) was performed to calculate agro morphological traits variation using SAS computer software (SAS, 2004). ANOVA was computed for all quantitative traits to detect the variability present among the thirty two selected chickpea varieties with check varieties. The variation of each morphological trait such as quantitative traits was estimated using simple statistical measures: mean, range, genotypic and phenotypic variances and coefficient of variations. The phenotypic and genotypic variation and coefficient of variations were calculated following the formula suggested (Singh and Chaudhary, 1977).

Results and Discussion

Qualitative traits

Qualitative characterizations of 32 accessions qualitative agromorphological traits were characterized based on the characteristics described in the DUS guidelines and characterization through morphological traits have been used as a major component for identification of genotypes or cultivar. Identification of any cultivar is not possible based on a single trait where a detailed morphological description of plants and seeds should be prepared (PPV and FRA, 2018). Twelve agromorphological qualitative traits of 32 chickpea accessions were characterized and presented in Tables 3. Plant pigmentation on stem is one of most important morphological markers in chickpea accessions and categorize into two groups based on the presence or absence of plant pigmentation but all accessions were characterized as absences of plant pigmentation and no variations have occurred in plant pigmentation among 32 chickpea accessions similarly to (Sarla Kumawat *et al.,* 2020). Based on plant growth habit the accessions were categorized into four: erect, semi erect, semi spreading, and spreading type growth. Among 32 accessions 17(53.22%) accessions were characterized as erect plant growth type, 12(37.5%) accessions were characterized as semi-erect type and 3(8.37%) accessions were as semi spreading type but no spreading type was observed in the study. The most studied accessions were characterized by erect plant growth type followed with semi erect. Similar findings were reported by (Lalji N Gediya *et al.,* 2018). Flower colour is one of the most important diagnostic visual easily observable traits. It is widely used as a marker gene in genetic studies and breeding work (Sarla Kumawat *et al.,* 2020). Based on flower color the accessions were categorized into three (pink, light pink and dark pink). Among 32 chickpea accession flower colors were characterized as 23(71.88%) accessions pink flower colour, 6(18.75%) accessions light pink flower colour and 3(9.37%) accessions dark pink flower colour. Study accessions were dominantly characterized as pink flowering color followed by light pink flowering color. Variations of pod length of study accessions were categorized into three (short, medium and long pod size). As the result 32 accession were characterized as 23(71.88%) accessions medium pod length, 7(21.87%) accessions short pod length and only 2(6.25%) accessions (HBC-30311 and HBC-30315) had long pod length. As the result showed that most study accessions were characterized medium pod length followed by short pod length. Chickpea pod size was found to variable due to polygenic control and, genotypic and environmental interactions similarly to (Janghel *et al.,* 2020).

Chickpea cultivars were classified into different groups based on seed colour, seed size and seed testa texture. On the basis of seed colour all 32 accessions were categorized into three types of seed shape presented in table 1. The three categories of seed shape were characterized as 25(78.12%) accessions angular rams head shape, 6(18.75%) accessions as irregular rounded owl's head shape, and only one (3.13%) accession (HBC-26925) were characterized as Owl's head seed shape. As the result most of seed shapes were characterized angular ram's head shape followed by irregular rounded owl's head shape this is similar with the result conducted(11). Based on Seed testa texture the study accessions were categorized into three such as rough, tuberculated and smooth seed texture. 21(65.62%) accessions were characterized as rough seed texture and 6(18.75%) accessions had tuberculated texture whereas 5(15.63%) accessions had smooth seed texture. majority of accessions were characterized rough seed texture similarly with (11). Based on Seed colour variations observed among 32 accessions were categorized into five. All 32 chickpea accessions were characterized as 22 accessions (68.75%) were yellow to orange yellow seed colour, 4 accession(12.5%) brown to reddish brown seed colour, 2 accessions (6.25%) were light orange to light seed colour, 2 accessions (6.25%) had black brown mosaic seed color and 2 accessions (6.25%) had green to light green seeds. As the study showed majority of accessions seed were characterized brown to reddish brown seed color. Characterization of various seed traits such as seed size, seed testa texture, seed shape and seed colour facilitate the identification for selection of desirable traits and genes.

These results supported by the research of (23, 15). Based on plant height all accessions were categorized into three (short <45cm, medium 45-65cm and tall >65cm) but all the study accessions height were characterized as short heighted (< 45 cm) and no variations were observed among accessions for Plant height. Therefore all study accessions were characterized as short heighted plant. In case of seed size the study accessions were categorized into four (very small 20g sized, small 21-25g sized, medium 26-36g sized and large >36g sized) based on 100 seed weight presented in table 1. The study accessions seed size were characterized as 22(68.75%) accessions medium seed size and 10(31.25%) accession small seed size but no very small and large seed size were observed in the accessions. As the result showed most seed sizes were characterized medium seed size followed by small seed size. Based on seed shattering accessions were categorized into two by the presence or absence of seed shattering, however all the study accessions were characterized as absences of seed shattering/ no seed shattering were observed. As studied the accessions on the presence or absence of lodging all the 32 accessions were characterized absence of lodging. Based on days to 50% flowering of accessions were categorized into three such as 40-60 days early flowering date, 62-80 days medium flowering date and more than 80 days late flowering date. As the result showed 24(75%) accessions were characterized early flowering date, 8(25%) accessions have medium flowering date but no late flowering dates were observed on the studied accessions. Agromorphological characterizations of accession have been a major component of varietal identification and efficient utilization in the breeding program (Gediya *et al.,* 2018). It is not possible to identify advanced varieties using any single parameter. A detailed morphological description of plants and seeds should therefore be assigned distinctive morphological profiles. Similar morphological characterization was reported by (Janghel *et al.,* 2020; Chaudhary *et al.,* 2021).

Differential traits in respect of growth type, plant height, days to 50% flowering, seed size, seed color, flowering color, seed shape, primary branch, secondary branch, pods per plant,100 seed weight in gram, yield per plot and yield in kilogram per hectare showed significant variation in yield which leads to distinguish from each other. Similar results noticed by (Bodake *et al.,* 2014). Utilization of agro-morphological features in sequential fashion is useful and convenient to distinguish different genotypes. Similarly, genotypes identification based on distinguishable morphological characters were reported in chickpea by (Sarao *et al.,* 2009; Chowdhury *et al.*, 2002). Results of investigation concluded that distinct morphological profile would be most practically valuable to a plant breeder while selecting genotypes in field and seed level. Morphological character those associated with higher seed yield or which makes a significant contribution to yield would be useful in the improvement of seed yield.

Quantitative character

Nine quantitative traits of 34 chickpea accessions along with two check varieties are presented in the Tables 4&5. From the nine quantitative traits, the highest coefficients of variation (CV) were observed for Days to 50% flowering (0.57%), Secondary branch(0.49%), 100 Seed weight (0.47%) and Yield per hectare (0.34%) indicating the maximum variability among these traits.

While Primary branch (0.06%), Days to 75% maturity (0.06%) and Plant height (0.04) were observed least coefficient of variation. The days to 50% flowering were recorded from 51 to 66th days after sowing and days to 75% maturity were recorded from 79th to 92th days. All 32 accessions were flowering later than the check varieties, whereas 7 accessions matured earlier and 25 accessions were later matured than the check varieties.

Twenty accessions were produced more primary branches than the check varieties and all 32 accessions were produced more secondary branches than check varieties. 24 accessions produced higher pods per plant compared to the check varieties and the highest 141.4 pods per plant was recorded for HBC-30345 with better yield per plot (524.1) and yield per hectare (1747) compared to all check varieties. The individual data of each accession is shown in Table 4.

Genetic Diversity analysis

Cluster Analysis

34 accessions of chickpea were grouped into three clusters (Table 6) which revealed the accession varied significantly for all the characters studied indicating a considerable variable in the accession. Cluster I consisted of eleven accessions that were characterized as dwarf type; least Secondary branch, pod per plant, yield per plant and yield per hectare, whereas medium days to 50% flowering days, days to maturity and primary branch (Table 8). Cluster II consisted of eighteen accessions characterized by maximum days to 50% flowering days, days to maturity, plant height, secondary branch and 100 Seed weight while yield per plot and yield per hectare were characterized as medium and also minimum primary branch. Cluster III consisted of five accessions that were characterized maximum primary branch, pods per plant, yields per plant, yields per hectare; while medium plant height, secondary branch and 100 Seed weight (TGW) but minimum days to 50% flowering days and days to maturity plant were characterized (table 6&7).

Generally Cluster II consists of 18 accessions followed by Cluster I with 11 accessions. Cluster II consisted of maximum accessions indicating that the accession had narrowed genetic divergence among them. The similarity in the parental population, which had evolved, might be the cause of genetic uniformity. However, the unidirectional selection potential for one particular trait or a group of linked traits in several places may produce similar phenotypes which can be aggregated into one cluster irrespective of their geographic origin (Joshi *et al.*, 2006; Parashi *et al.*, 2013). For improving the grain yield the genotypes in Cluster I and Cluster II would be crossed with genotypes in Cluster III. The comparison of Cluster I with Cluster II the Cluster I accessions were characterized minimum secondary branch, plant height and 100 seed weight but Cluster II were characterized by maximum plant height, secondary branch and 100 seed weight and Cluster I with Cluster III were characterized by minimum pods per plant, yield per plant and yield per hectare but Cluster III were characterized as maximum pods per plot, yield per hectare and yield per plot. The comparisons of Cluster II with Cluster III the Cluster II accessions were characterized maximum days to 50% flowering and days to 75% maturity but Cluster III were characterized by minimum days to 50% flowering and days to 75% maturity. Similar results were reported (Malik *et al.*, 2014).

The intra cluster distance ranged from 474.48 to 953.36 (Table 8). The maximum intra cluster distance was found in Cluster III (953.36) followed by Cluster I(474.48) and Cluster II (474.48) indicating that the five(5) accessions in the Cluster III were most divergent. clusters are quite divergent from each other and the accessions belonging to them can be used for hybridization by crossing between accessions belonging to the clusters with maximum inter cluster distance, may give high heterotic response resulting in better recombinants. The genotypes of higher intra- and inter-cluster distances have more genetic divergence than the genotypes of minimum intra- and inter-cluster distance similar reports conducted (Janghel *et al.*, 2020).

Correlation study of quantitative traits of the accessions

The correlations among the 9 quantitative traits were characterized and presented in (Table 9). The result indicated that there was significantly strong positive correlation observed between days to 75% maturity with plant height (r=1.00) followed by 100 seed weight with yield per hectare (r=0.64); secondary branch with pods per plant (r=0.59); secondary branch with yield per plot(0.43); pods per plant with yield per plant (r=0.30) while weak and negative correlation were observed between days to 50% flowering day with secondary branch; 100 seed weight with yield per plot; pods per plot with days to 50% flowering days; primary branch with pods per plot but no correlation secondary branch with 100 seed weight.

Chickpea (*Cicer arietinum* L.) is the third important food legume both in area and production after common beans and Faba beans in Ethiopia. Chickpea is a versatile and the cheapest crop with multiple benefits for integrated crop-livestock smallholder farming systems. Twelve agro morphological qualitative traits accessions were characterized (Table 3). All accessions were characterized as absences of plant pigmentation.

Table.1 Assessment and List of chickpea qualitative traits using descriptor scale during 2021-22.

Characteristics	Data recording period/ observation	Using scale
Plant pigmentation	During Vegetative stage	1 -No-anthocyanin, stems and leaves pale green, 3-No-anthocyanin, stems and leaves green, 5-Low anthocyanin, stems and leaves partly light purple
Plant Growth habit	During Pod filling stage (50% flowering stage)	1-Erect, 3-Semi erect, 5-Semi-spreading, 7-Spreading .
Flower colour	During Flowering stage	1-Dark pink, 3-Pink, 5-Light pink, 7- **White pink striped**
Pod length	During Podding stage	1-Short, 5-Medium, 7-Long
Lodging	Before harvesting	0= no lodging, 1=very few lodging, 3=almost 50% lodging , 5=completely lodging
Seed shape	30 days After harvesting	1-Angular, rams head, 3-Irregular rounded owl's head , 5- Owl's head, 7-Pea shaped
Seed colour	After harvesting	1-Black(BL) ,3-Brown to Reddish brown (B) 5-Green to light green (GR), 7-Yellow to orange yellow(Y),9-Black brown mosaic (BM) , 11-Light Orange to light(LO)
Seed testa texture	After harvesting	1. Rough, 2. Smooth, 3. Tuberculated
Seed size	30 days after harvest	1-Very small, 2-Small, 3-Medium, 4-Large, 5-Very large
Seed Ribbing	30 days after harvest	1-Absent 3-Present
Days to 50% flowering	During Flowering stage	1. Early, 2. Extra early, 3. Medium, 4. Late
Plant height	During maturity stage	1. Short, 2. Medium, 3. Tall

Table.2 Assessment and List of 8 quantitative traits of chickpea using measuring scale during 2021-22

Quantitative characters	Data recording period	Using scale/Measurement procedure
Days to 50% flowering	Flowering stage	Days from sowing to 50% flowering
Days to 75% maturity	Ripening stage	Days from sowing date to maturity stage or just before harvesting of the pods
Plant height	Maturity stage	Average number of five selected plant height from ground level to the top of the plants
Primary branch	Ripening stage	The total branches of each plant, from average of five plants
Secondary branch	Ripening stage	The total branches of each plant, from average of five plants
pods per plant	Harvesting stage	Average of five selected plants pods
100 Seed weight (TGW) in gm	After threshing	Weight of 100 seeds from randomly selected five plants at 8 - 10% (air dry) seed moisture content
Yield per plot in gm	After Harvesting stage	Total weight of the plot harvested, measured in gm
grain yield (kg ha^{-1})	After threshing	Percentage yield ratio of economical yield and biological yield

Table.3 Frequency distribution of qualitative traits assessed in 34 chickpea accessions at Fadis demonstration site during 2021-2022/23.

Traits/ Descriptor	Traits expressions	genotypes(Accessions) belonging to each traits	Percentage contribution %	Accession of genotype
Plant pigmentation	No-anthocyanin	32	32%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26925, HBC-26926, HBC-30343, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062, HBC-29063,
	Low – anthocyanin	0	0%	-
	High-anthocyanin	0	0%	-
Days to 50% flowering	Early (40-60 days)	24	75%	HBC-26916, HBC-26917, HBC-26919, HBC-26920, HBC-26921, HBC-26924, HBC-26925, HBC-30343, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30348, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062, HBC-29063
	Medium(61-80days)	8	25%	HBC-26915, HBC-26918, HBC-26923, HBC-26926, HBC-30344, HBC-30349, HBC-30308, HBC-30320
	Late (>80days	0	0%	-
Plant height	<45 cm short	32	100%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26925, HBC-26926, HBC-30343, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062, HBC-29063
	45-65cm medium	0	0%	-
	>65cm tall	0	0%	-
Growth habit	Erect	17	53.22%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26925, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30311, HBC-30312, HBC-29063,
	Semi erect	12	37.5%	HBC-26926, HBC-30343, HBC-30344, HBC-

				30349, HBC-30348, HBC-30308, HBC-30315, HBC-30316, HBC-30317, HBC-30320, HBC-30329, HBC-29062
	Semi spreading	3	9.37	HBC-29062, HBC-30318, HBC- 30346,
	Spreading	0	0%	-----
Seed size	Very small	0	0%	------
	Small	10	31.25%	HBC-26923, HBC-26924, HBC-26925, HBC-30343, HBC-30349, HBC-30315, HBC-30316, HBC-30317, HBC-29062, HBC-29063,
	Medium	22	68.75%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26926, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30318, HBC-30319, HBC-30320, HBC-30329,
	Large	0	0%	------
Seed colour	Black(BL),	0	0%	------
	Brown to Reddish brown(B)	4	12.5%	HBC-26915, HBC-26920, HBC-26926, HBC-30349
	Green to light green (GR)	2	6.25%	HBC-29062, HBC-29063,
	Yellow to orange yellow(Y)	22	68.75%	HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26921, HBC-26923, HBC-30343, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329,
	Black brown mosaic (BM) ,	2	6.25%	HBC-26924, HBC-30350,
	Light Orange to light(LO)	2	6.25%	HBC-26925, HBC-30315,
Flowering colour	Dark pink,	3	9.37%	HBC-26917, HBC-26925, HBC-30349,
	Pink,	23	71.88%	HBC-26915, HBC-26916, HBC-26918, HBC-26919, HBC-26921, HBC-26923, HBC-26926, HBC-30343, HBC-30344, HBC- 30346, HBC-30347, HBC-30350, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30319, HBC-30329, HBC-29062, HBC-29063,
	Light pink,	6	18.75%	HBC-26920, HBC-26924, HBC-30342, HBC-30345, HBC-30318, HBC-30320,
	White pink striped	0	0%	------
Seed shape	Angular, rams head	25	78.12%	HBC-26916, HBC-26917, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26926, HBC-30343, HBC-30344, HBC-

				30346, HBC-30342, HBC-30345, HBC-30347, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329,
	Irregular rounded owl's head	6	18.75%	HBC-26915,HBC-26918, HBC-30350, HBC-30316, HBC-29062 HBC-29063,
	Owl's head	1	3.13%	HBC-26925,
Shattering	Present	0	0%	------
	Absent	32	100%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26925, HBC-26926, HBC-30343, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062, HBC-29063,
Pod length	Short,	7	21.87%	HBC-26915, HBC-26924, HBC-26925, HBC-30344, HBC-30345, HBC-30347, HBC-29063,
	Medium,	23	71.88%	HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26926, HBC-30343, HBC- 30346, HBC-30342, HBC-30350, HBC-30349, HBC-30348, HBC-30308, HBC-30312, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062,
	Long	2	6.25%	HBC-30311, HBC-30315,
Seed testa texture	Rough,	21	65.62%	HBC-26915, HBC-26917, HBC-26919, HBC-26920, HBC-26921, HBC-26924, HBC-26925, HBC-26926, HBC-30343, HBC-30342, HBC-30345, HBC-30347, HBC-30349, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30317, HBC-30320, HBC-30329, HBC-29063,
	Smooth,	5	15.63%	HBC-26918, HBC-30344, HBC-30350, HBC-30316, HBC-29062,
	Tuberculated	6	18.75%	HBC-26916, HBC-26923, HBC- 30346, HBC-30348, HBC-30318, HBC-30319,
Lodging	Present	0	0%	------------
	Absent	32	100%	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26924, HBC-26925, HBC-26926, HBC-30343, HBC-30344, HBC- 30346, HBC-30342, HBC-30345, HBC-30347, HBC-30350, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30315, HBC-30316, HBC-30317, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062, HBC-29063,

Table.4 Frequency distribution of quantitative traits of 34 accessions at Fadis demonstration site during 2021-2022/23

Genotypes	PH	DF	DM	PB	SB	PPP	TGW	YPP	YPH
HBC-26915	40	63	89	5	9.3	47.4	41.5	324.2	1080.67
HBC-26916	40	53	79	6.3	10.6	110.4	41.4	342.5	1141.67
HBC-26917	40	56	82	8.3	12	46	54.9	331.9	1106.33
HBC-26918	40	65	91	3.7	9.3	93.8	28.3	350.6	1168.67
HBC-26919	34	57	83	7.9	11.9	33.8	27.5	176.5	588.33
HBC-26920	38	57	83	4.7	9	28.4	43	167.5	558.33
HBC-26921	38	57	83	3.3	6	23.8	28.2	98.5	328.33
HBC-26923	40	62	88	3.3	6.7	41.4	27.1	151.5	505
HBC-26924	42	58	84	3.4	6	47.9	29.8	294.2	980.67
HBC-26925	38	59	85	4.2	11	39.8	52.5	233.3	777.67
HBC-26926	42	54	80	3	8.6	37	31.2	351.1	1170.33
HBC-30343	36	56	82	3.8	8.8	62.8	28.7	287.3	957.67
HBC-30344	40	62	88	4.4	11.2	54	28.8	359.6	1198.67
HBC- 30346	40	55	81	4.4	9.2	74.4	26.4	449.5	1498.33
HBC-30342	40	60	86	2.5	6.5	108	28.5	420.4	1401.33
HBC-30345	40	55	81	3.4	11	141.4	29.4	524.1	1747
HBC-30347	36	57	83	3	9	66.2	24.9	238.6	795.33
HBC-30350	40	57	83	2	7	72.4	26.4	468	1560
HBC-30349	40	63	89	2.2	6.8	50.2	27.6	361.1	1203.67
HBC-30348	42	56	82	2	9.2	29.4	25.2	317.4	1058
HBC-30308	37	65	91	1.6	6.6	62.8	26.7	248	826.67
HBC-30311	37	60	86	3.2	8.6	84	27.3	277.3	924.33
HBC-30312	36	54	80	4	13	98.2	29.2	373	1243.33
HBC-30315	40	57	83	1.75	7	72	29.1	400.2	1334
HBC-30316	33	58	84	3	13	101.6	29.6	297.8	992.67
HBC-30317	42	58	84	2.25	11.5	106.8	30.3	310.7	1035.67
HBC-30318	40	58	84	2.8	9.2	53.8	29.1	170.3	567.67
HBC-30319	40	56	82	1.2	5.4	40	26.6	169	563.33
HBC-30320	35	66	92	1.5	8	38.8	30.5	201.8	672.67
HBC-30329	41	56	82	2.4	9	69	28	219.3	731
HBC-29062	40	59	85	1	6.25	39.8	46.9	141.4	471.33
HBC-29063	42	58	84	4	13	42	51.9	270.6	902
Cheeck1	40.5	51	87	2.9	4.9	37.2	38.4	280.1	933.3
Check 2	36	51	87	1.7	5.9	39.2	29.6	294.3	980.8

Key: (PH)-Plant height; (DF)-Days to 50% flowering; (DM)-Days to 75% maturity; (YPH)-Yield per hectare; (YPP)-Yield per plot in gm; (TGW)-100 Seed weight; (PPP)-Pods per plant; (SB)-Secondary branch; (PB)-Primary branch.

Table.5 Standard deviation, Mean performance of yield, and CV (%) and yield contributing characters of 34 accession varieties at Fadis demonstration site during 2021-2022/23.

Characteristics	Maximum	Minimum	Range	Mean	SD	CV%
PH	42	33	9	83.91	3.70	0.04
DF	66	51	15	17.50	9.95	0.57
DM	92	77	15	57.91	3.70	0.06
PB	8.3	1	7.3	38.98	2.40	0.06
SB	13	4.9	8.1	3.35	1.67	0.49
PPP	141.4	23.8	117.6	8.83	2.35	0.27
TGW	54.9	24.9	30.0	61.57	28.89	0.47
YPP	524.1	98.5	425.6	32.48	8.40	0.26
YPH	1747	328.3	1418.7	291.22	99.69	0.34

Key: (PH)-Plant height; (DF)-Days to 50% flowering; (DM)-Days to 75% maturity; (YPH)-Yield per hectare; (YPP)-Yield per plot in gm; (TGW)-100 Seed weight; (PPP)-Pods per plant; (SB)-Secondary branch; (PB)-Primary branch

Table.6 Grouping of 34 accessions into three clusters

Cluster	Number of accessions	Entry number accessions	Entry accession.
cluster I	11	5,6,7,8,10,17,27, 28,29,30,31,	HBC-26919, HBC-26920, HBC-26921, HBC-26923, HBC-26925, HBC-30347, HBC-30318, HBC-30319, HBC-30320, HBC-30329, HBC-29062,
Cluster II	18	1,2,3,4,9,11,12, 13,19,20,21,22, 23,25,26,32,33,34,	HBC-26915, HBC-26916, HBC-26917, HBC-26918, HBC-26924, HBC-26926, HBC-30343, HBC-30344, HBC-30349, HBC-30348, HBC-30308, HBC-30311, HBC-30312, HBC-30316, HBC-30317, HBC-29063, Cheeck1, Check2
Cluster III	5	14,15,16,18,24,	HBC- 30346, HBC-30342, HBC-30345, HBC-30350, HBC-30315

Table.7 Cluster mean performances for quantitative traits of 34 accessions.

Cluster	DF	DM	PH	PB	SB	PPP	TGW	YPP	YPH
I	57.0	83.0	38.0	3.3	6.0	23.8	28.2	98.5	328.3
II	58.0	84.0	42.0	2.3	11.5	106.8	30.3	310.7	1035.7
III	55.0	81.0	40.0	3.4	11.0	141.4	29.4	524.1	1747.0
Mean	56.67	82.67	40.00	3.00	9.50	90.67	29.3	311.10	1037

Key: (PH)-Plant height; (DF)-Days to 50% flowering; (DM)-Days to 75% maturity; (YPH)-Yield per hectare(kg ha^{-1}); (YPP)-Yield per plot in gm; (TGW)-100 Seed weight; (PPP)-Pods per plant; (SB)-Secondary branch; (PB)-Primary branch.

Table.8 Intra and Inter-cluster distances value of three clusters from 34 chickpea accession.

	Cluster I	Cluster II	Cluster III
Cluster I		225131.27 (474.48)	908895.28 (953.36)
Cluster II			229383.52 (478.94)
Cluster III			908895.28 (953.36)

Table.9 Estimation of correlation co-efficient among ten quantitative traits with grain yield

	DF	DM	PH	PB	SB	PPP	TGW	YPP	YPH
DF	1	-0.17	-0.17	-0.03	-0.69	-0.191	-0.01	-0.13	-0.10
DM		1	1.00	-0.08	-0.15	-0.05	-0.04	-0.09	-0.15
PH			1	-0.08	-0.15	-0.05	-0.04	-0.09	-0.15
PB				1	-0.12	-0.18	-0.03	0.18	0.25
SB					1	0.59	-0.00	0.43	0.08
PPP						1	0.35	0.30	0.21
TGW							1	-0.24	0.64
YPP								1	-0.12
YPH									1

Key: (PH)-Plant height; (DF)-Days to 50% flowering; (DM)-Days to 75% maturity; (YPH)-Yield per hectare; (YPP)-Yield per plot in gm; (TGW)-100 Seed weight; (PPP)-Pods per plant; (SB)-Secondary branch; (PB)-Primary branch.

Fig.1

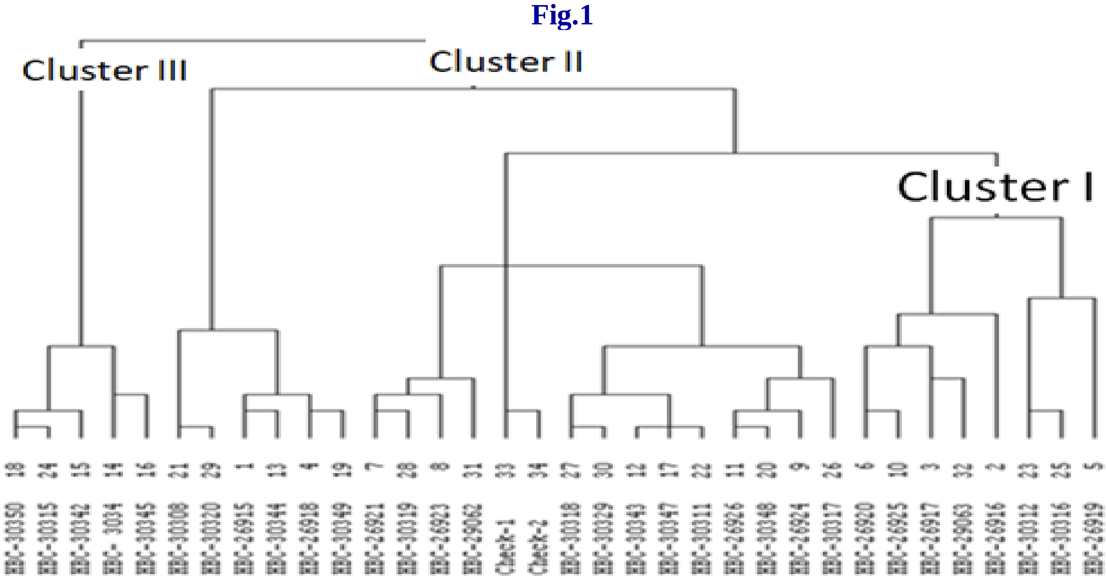

Figure 1.Dendrogram illustrating the distribution of 34 chickpea accessions into three clusters

The most accessions were characterized by erect plant growth type followed by semi erect and dominantly characterized as pink flowering color followed. As the result showed that most accessions were characterized by medium pod length followed by short pod length and angular ram's seed shape. Majority of accessions were characterized by rough seed texture and brown to reddish brown seed color. All accessions were characterized as absences of seed shattering and early flowering date but no late flowering dates were observed. From the nine quantitative traits, the highest coefficients of variation (CV) were observed for Days to 50% flowering, Secondary branch, 100 Seed weight and Yield per hectare While Primary branch, Days to 75% maturity and Plant height were observed least coefficient of variation.

The days to 50% flowering were recorded from 51 to 66th days after sowing and days to 75% maturity were recorded from 79th to 92th days. 32 accessions were flowering later than the check varieties whereas 7 accessions matured earlier and 25 accessions were later matured than the check varieties. 32 accessions produced more secondary branches than check varieties. 24 accessions produced higher pods per plant compared to the check varieties and the highest 141.4 pods per plant was recorded for HBC-30345 with better yield per plot (524.1) and yield per hectare (1747) compared to all check varieties. 34 accessions were grouped in to three clusters (Table 6).

Cluster I consisted of eleven accessions that were characterized as dwarf type; least Secondary branch, pod per plant, yield per plant and yield per hectare, whereas medium days to 50% flowering days, days to maturity and primary branch (Table 8). Cluster II consisted of eighteen accessions characterized by maximum days to 50% flowering days, days to maturity, plant height, secondary branch and 100 Seed weight while yield per plot and yield per hectare were characterized as medium and also minimum primary branch. Cluster III consisted of five accessions that were characterized by maximum primary branch, pods per plant, yields per plant, yields per hectare; while medium plant height, secondary branch and 100 Seed weight (TGW) but minimum days to 50% flowering days and days to maturity plant were characterized. Cluster II consisted of maximum accessions indicating that the accession had narrowed genetic divergence among them. For improving the grain yield the accessions in Cluster I and Cluster II would be crossed with accessions in Cluster III. The comparison of Cluster I with Cluster II the Cluster I accessions were characterized minimum secondary branch, plant height and 100 seed weight but Cluster II were characterized maximum plant height, secondary branch and 100 seed weight and Cluster I with Cluster III were characterized minimum pods per plant, yield per plant and yield per hectare but Cluster III were characterized as maximum pods per plot, yield per hectare and yield per plot.

The comparisons of Cluster II with Cluster III the Cluster II accessions were characterized by maximum days to 50% flowering and days to 75% maturity but Cluster III were characterized by minimum days to 50% flowering and days to 75% maturity. The intra cluster distance ranged from 474.48 to 953.36 (Table 8). The maximum intra cluster distance was found in Cluster III (953.36) followed by Cluster I(474.48) and Cluster II (474.48) indicating that the five(5) accessions in the Cluster III were most divergent. The result indicated that there was significantly strong positive correlation observed between days to 75% maturity with plant height(r=1.00) followed by 100 seed weight with yield per hectare(r=0.64); secondary branch with pods per plant(r=0.59); secondary branch with yield per plot(0.43); pods per plant with yield per plant (r=0.30) while weak and negative correlation were observed between days to 50% flowering day with secondary branch; 100 seed weight with yield per plot; pods per plot with days to 50% flowering days; primary branch with pods per plot but no correlation secondary branch with 100 seed weight. Characterizations of 32 chickpea accessions were found talented traits with better yield, Environmental adaptability and resistant compared to the check varieties. These study could be used in the future breeding program for improvement of chickpea varieties and hybridizing desired genetic traits to solve disagreement of environment, yield and productivities and this used to address the challenge for the development of climate smart crop.

Recommendation

Estimation of genetic parameters for the traits can be performed to deduce the environmental influence on the traits and their further utilization in the crop improvement programmes and hybridizing.

Morphological characterization can be fruitful in creating core collection at gene banks to improve the availability of accessions to the breeders.

Marker-based identification and characterization of chickpea genotypes might be helped to maintain the purity of varieties to benefit breeders, farmers and consumers in the future.

Authors' Contributions

All authors were involved equally in reading, data collection, analysis and drafting of manuscript as well as approved and submitted the finalized manuscript for publishing.

Competing Interests

All authors declare that there are no competing interests.

Availability of Data and Material

The recorded raw data used for analysis and supplementary information files is available at the author's hand and within the article.

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