

Morphological description of chickpea (*Cicer arietanum* L) genotypes using DUS characterization

Abstract

The cultivated chickpea (*Cicer arietinum*) holds great importance as a pulse crop in India.

The identification and classification of diverse genotypes are crucial for implementing effective strategies to improve this crop. This study was conducted to get a comprehensive morphological characterization of desi chickpea genotypes using the DUS (Distinctness, Uniformity, and Stability) descriptors suggested by the Protection of Plant Varieties and Farmer's Rights Authority, Government of India, in 2018. Environmental conditions, such as temperature, light, humidity, and nutrient availability, can influence plant variability. Different environments impose selective pressures on plants resulting in variability within plant populations. The objective of the investigation was to identify and classify diverse chickpea genotypes based on 17 different qualitative traits observed in a field experiment. Among the 17 DUS traits only one trait exhibited a consistent phenotype (monomorphic), six traits displayed two distinct phenotypes (dimorphic), nine traits exhibited three distinct phenotypes (trimorphic), and only one trait showed more than three phenotypic variations (polymorphic) among all the chickpea genotypes studied. This indicates the presence of significant genetic variability within the chickpea germplasm, offering the potential for assigning different morphological profiles for varietal identification and characterization. In particular, for features like seed and foliar colour, pod size, leaflet size, and seed shape, it was found that a high level of diversity within the chickpea germplasm using Shannon's diversity indices. The characterization of these genotypes enabled the development of distinct profiles for each line, facilitating their identification and evaluation as elite chickpea lines.

Keywords: Chickpea, DUS characterization, Shannon's diversity index

Introduction

Chickpea (*Cicer arietanum* L.) is an important cool season legume crop with a genome size of 738 Mb [1]. It is also known as Gram, Bengal gram, Egyptian pea, Chana, or Kabuli chana, Garbanzo bean is one of the first grain legumes to be domesticated by humans in old world [2]. It also exhibits the ability to enhance soil fertility through symbiotic nitrogen fixation, whereby it converts atmospheric nitrogen into a form usable by plants [3]. This

process contributes to the overall improvement of soil health and productivity [4]. It is highly nutritious encompassing of vitamins, minerals, and vital amino acids, including lysine, methionine, threonine, valine, and leucine, as well as β -carotene, calcium, phosphorus magnesium, and potassium” [5-10]. It is currently cultivated in more than 50 countries across the globe. India accounts for more than 65% of the global production of desi type chickpea. Therefore, it influences the global yield trends [11]. Currently, 15.004 million hectares of area are used to cultivate chickpea, with a productivity of 1,057.8 kg per hectare and a production of 15.87 mt per year worldwide [11]. As estimated 73.78 % (10.943mha) of the world’s total chickpea area and 73.45 % (11.91m tonnes) come from India [12].

Modern plant breeding and agricultural systems have narrowed the base for the genetic diversity of cultivated chickpea and to explore new sources of variation that might be used in plant breeding programmes [13-15]. Genetic diversity is a basic requirement to begin any crop improvement programme [16-23]. Breeders need to include diverse germplasm lines in the breeding programmes to break the yield plateau and attain sustainable gains [24-34]. There is an imperative requirement for the systematic characterization and evaluation of Cicer species to utilize target traits [35]. When analysing genotype performance without being predisposed by environmental influences, qualitative features provide an easy technique to measure genetic variation [36-39]. Morphological characterization studies are carried out by employing morphological markers, which are highly heritable traits [36-39]. They are cheap, simple, does not necessitate the use of sophisticated laboratory techniques and quick to score [36-39].

The evaluation of seed quality typically involves assessing varietal purity, which encompasses both physical and genetic characteristics. A variety or cultivar is a group of cultivated plants that can be clearly distinguished by various traits, such as morphological, physiological, cytological, or chemical features. When a variety is reproduced either sexually or asexually, it retains its distinctive characteristics. In the context of crop varieties, plant morphological traits have long been recognized as essential descriptors for conducting Distinctness, Uniformity, and Stability (DUS) testing and classifying varieties [40]. Therefore, any morphological characteristic that is closely associated with and significantly contributes to increased seed yield would be advantageous for yield improvement. Morphological descriptors are not only valuable for DUS testing and varietal classification nonetheless also for assessing diversity and revealing phylogenetic relationships among different lines. By conducting morphological characterization, breeders can identify recurring

parents and gain insights into the genetic diversity of chickpea germplasm lines [8-9]. This information proves valuable for developing improved varieties with a broader genetic base [41]. Consequently, establishing a comprehensive understanding of the relationships between chickpea genotypes is crucial for effectively planning strategies and crop breeding programs [42].

In the present investigation, it is aimed to examine the morphological descriptors of different desi chickpea genotypes and analyse their consistency over multiple years using various qualitative parameters. By employing these tools, we can assess the stability of morphological traits and their usefulness as indicators of varietal purity and genetic relationships among different chickpea genotypes. Present study specifically concentrates on the unique characteristics of chickpea plants, providing valuable insights into their genetic diversity and potential applications in crop improvement.

Materials and Method

The present investigation was conducted during the Rabi season of session 2022 at the Research Farm, Department of Genetics & Plant Breeding, College of Agriculture, RVSVV, Gwalior, Madhya Pradesh, India. The experimental material consisted of 78 diverse chickpea genotypes. The evaluation of different genotypes was performed in three replications using a Randomized Complete Block Design (RCBD). Each entry was grown in four row measuring 3.0 m in length in each replication. The inter-row and intra-row spacing were maintained at 30×10 cm, respectively. The recommended agronomical and plant protection practices were implemented to ensure successful crop cultivation.

Data pertaining to 17 different morphological descriptors *i.e.*, stem anthocyanin pigmentation, stem height at initiation of first flower, plant growth habit, leaflet size (mm), numbers of flower per peduncle, flower colour, flower stripes, peduncle length (mm), plant height, pod length, numbers of seeds per pod, seed colour, seed shape, seed testa texture, seed ribbing and seed type were recorded on 10 randomly selected plants, following the DUS (Distinctness, Uniformity, and Stability) as guideline provided by the Protection of Plant Varieties and Farmers' Rights Authority, Government of India [43] for chickpea.

To estimate the diversity present within the genotypes, the phenotypic frequencies of these traits were employed, and the Shannon-Weaver Diversity Index was calculated. The index (H) was computed according to the methodology presented by Negassa [44] to assess the current level of diversity using following formulae:

$$H = -\sum [p_i \times \log p_i]$$

Where, p_i is the portion of the total numbers of entries belonging to the i^{th} class.

The clustering of genotypes based on their morphology was done using algorithm UPGMA (Unweighted Paired Group Method using Arithmetic Averages) using NTSYS-pc (numerical taxonomy and multivariate analysis system) 2.02i. [45]

Results and Discussion

The limited genetic diversity in chickpea poses a challenge to crop improvement efforts, necessitating the expansion of the genetic base to fully exploit the genetic potential of these lines. Therefore, the assessment of genetic diversity is a fundamental requirement for developing effective crop improvement strategies in chickpea [46]. Analysing genetic diversity based on qualitative traits represents an important approach for identifying and enhancing crop varieties [36-38]. In this investigation, an attempt was made to group and distinguish chickpea genotypes based on variations present in their morphological and seed-related characteristics. These traits were carefully examined to unravel the genetic diversity within the chickpea genotypes under investigation. Using descriptors, each genotype was identified and characterized. The **present** investigation focused on **different** agromorphological traits, and it was observed that although some lines shared common qualitative features, they could still be differentiated from one **other** based on their monomorphic traits. This highlights the presence of distinct genetic variations among the lines, even in cases where only a few characteristics differ. Notably, the genetic base has been narrowed due to selective breeding for yield improvement [47].

Morphological characterization

The 78 genotypes were characterized based on the different morphological traits as described in the DUS guidelines [43] and details are given in Table 1, Fig. 1a and Fig.1b. Anthocyanin colouration of stem being an important trait observed before flowering of plants was recorded in two categories *i.e.*, presence or absence. Out of the 78 genotypes, 61 showed the presence of anthocyanin pigmentation in the stem, while the remaining 17 genotypes exhibited the absence of anthocyanin coloration. The genotypes were further classified based on the height of the stem at the initiation of the first flower. Three categories were identified: low stem height (<8 nodes at initiation of first flower) with 14 genotypes, medium stem height (8-15 nodes at initiation of first flower) with the highest representation of 60 genotypes, and high stem height (>15 nodes at initiation of first flower) with only four genotypes. Plant growth

habit was another distinguishing feature for varietal characterization. Among the 78 genotypes, 25 were classified as erect types, 50 as semi-erect types, and the remaining three as spreading types. Variation in foliage colour intensity was also investigated. Thirteen genotypes exhibiting light green foliage, 36 genotypes medium green foliage, whereas the remaining 29 genotypes having dark green foliage. The size of leaflets also exhibited notable variation. They were categorized into three main groups: small leaflets ($\leq 10.0\text{mm}$) observed in 23 lines, medium-sized leaflets (10.0-15.0mm) in 24 lines, whilst large leaflets ($>15.0\text{mm}$) in the 31 genotypes.

The colour of the flower is a prominent visual trait and is commonly utilized as a marker gene in genetic studies and breeding endeavours in chickpea [48] (Kumawat et al., 2020). In this study, the genotypes were examined for flower: colour, revealing three distinct variations. Among the 78 genotypes, 14 genotypes exhibited white flowers, 55 genotypes displayed pink flowers, whilst the remaining nine genotypes showed blue-coloured flowers. Another characteristic evaluated was the presence of stripes on the standard of the petal. Out of the 78 genotypes, 16 genotypes were found to have no stripes, while the remaining 62 genotypes exhibited stripes on the standard of the petal. Additionally, the genotypes were assessed for the number of flowers per peduncle on the standard. Limited variation was observed among the genotypes in terms of the numbers of flowers per peduncle. Only three genotypes displayed twin flowers per peduncle, while the remaining 75 genotypes exhibited a single flower per peduncle. Various other reports are available on the morphological characterization of the chickpea crop [49-58].

The investigation focused on the study of peduncle length during the pod development stage, which led to the classification of experimental genotypes into three groups based on their peduncle characteristics: short, medium, and long. Among the analysed genotypes, 49 exhibited a peduncle length of less than 5mm (short), 20 genotypes had a length ranging from 5-10mm (medium), whilst nine genotypes displayed a peduncle length exceeding 10mm (long). Furthermore, the genotypes were categorized into three groups based on their plant height. Fourteen genotypes were considered as short, with a height of 45cm. Fifty-seven genotypes fell into the medium category, displaying a height range of 45-65cm. Lastly, only seven genotypes were classified as tall, surpassing a height of 65cm. The genotypes were also analysed based on pod size, resulting in three groups. Fourteen genotypes had small-sized pods, measuring less than 15mm. Forty-one genotypes possessed medium-sized pods, ranging from 15-20mm. however, 23 genotypes displayed large-sized

Pods, exceeding 20mm in size. Another observed parameter was the numbers of seeds per pod. Among the analysed genotypes, 64 genotypes contained one seed per pod, while the remaining 14 genotypes exhibited two seeds per pod. These genotypes with large and extra-large pods may be selected for screening purposes, particularly for exportation and utilization in chickpea hybridization programs. The findings of this study are consistent with previous research conducted by Upadhyaya et al. [59], Kaul et al. [60], Bayahi et al. [55], Shrivastava et al. [61], Solanki et al. [62], and Gyandev et al. [63].

Seed-related traits were assessed approximately 30 days after harvesting to determine their significance in categorizing chickpea genotypes and their relevance in consumer preference and marketing. Among these traits, seed colour and seed size were identified as key traits for grouping chickpea varieties [62] and were also found to be highly valued by consumers [62]. Based on the variation in seed colour, the genotypes were classified into eight distinct groups: brown (22), dark brown (22), beige (6), black (3), creamy beige (4), green (6), orange (5), and yellow (10). Seed shape displayed three major variations: angular type in 39 genotypes, pea-shaped in 17 genotypes, and Owl's head seed shape in 22 genotypes. The seed testa texture exhibited two main groups, with rough texture found in 12 genotypes while smooth texture in 66 genotypes. Seed ribbing analysis resulted in the categorization of genotypes into two groups, with 43 genotypes displaying ribbing whereas 35 genotypes lacking ribbing. No variations were observed in seed type, as all genotypes belonged to the desi type. Genotype identification based on discernible morphological characteristics were conducted and reported by various researchers [64-73,40,62,48,42]. These studies contributed to the comprehensive understanding of chickpea genotypes and their morphological variations.

Shannon's diversity indices

Diverse parents are the prime requirement of any hybridization programme. Frequency distribution of diversity index was estimated using H' index for 17 qualitative traits (Table 2). The Shannon's diversity indices estimated for 17 morphological traits ranged from 0 to 1.825 with a mean value of 0.743. The H' index of the trait seed colour was observed to be higher (1.825) among all the traits while seed type had minimum value (0.00). These findings align with similar observations reported by previous studies [74-76, 41]. These studies also support the notion that seed colour is a highly diverse trait, while seed type exhibits minimal diversity.

Qualitative cluster analysis

A qualitative cluster analysis was conducted on 78 chickpea genotypes using algorithm UPGMA using NTSYS pc 2.02i, considering 17 qualitative traits (Table 3). The resulting dendrogram, as shown in Fig. 2, illustrates the similarities among the genotypes based on the measured qualitative variables. This dendrogram highlights the effectiveness of the methodology employed in this study for classifying chickpea genotypes.

The dendrogram revealed two distinct clusters, *viz.*, Cluster A and Cluster B. Cluster A comprised 16 genotypes, while Cluster B consisted of 62 genotypes. Within Cluster B, further subdivision occurred into two subgroups denoted as 'b₁' and 'b₂'. Subgroup 'b₁' contained three genotypes, whereas Subgroup 'b₂' encompassed 59 genotypes. Subgroup 'b₁' was then divided into two additional subgroups, one comprising three genotypes and the other comprising 56 genotypes. Furthermore, these 56 genotypes were segregated into two clusters, one consisting of 37 genotypes and the other comprising 19 genotypes. Mishra et al. (2022) [37] constructed dendrogram, obtained from 53 soybean genotypes for five qualitative traits. The dendrogram depicted two distinct clusters. The cluster-I consisting nineteen genotypes further divided into two groups, while in cluster-II remaining 34 genotypes further divided into two subgroups with 9 and 25 genotypes respectively. Basak et al. [77] constructed dendrogram using landraces for 17 qualitative traits of 81 tomato landraces. The dendrogram revealed the formation of distinct clusters representing different groups of landraces. Likewise, Kumar et al. [78] studied on 50 barley genotypes using 18 qualitative traits and constructed a dendrogram.

Conclusion

The utilization of DUS guidelines in the morphological characterization of chickpea genotypes, along with the assessment of diversity using Shannon's diversity index (H), facilitated the accurate classification of the genotypes. Systematic characterization of germplasm enables more efficient utilization of the genetic material, offering advantages over traditional selection methods. Studies have revealed a substantial amount of diversity present in chickpea germplasm lines, particularly in traits such as seed colour, foliage colour, pod size, leaflet size, and seed shape. These traits play an important role in determining market and consumer preferences, making them desirable targets for improvement. The presence of diverse morphological characteristics in chickpea germplasm lines offers a wide range of options for plant breeders to select and develop improved varieties. This profile

served as a valuable resource for identification, characterization, and evaluation of elite chickpea genotypes. Plant breeders can utilize this information to make informed decisions while selecting suitable genotypes for field trials and seed production.

References

1. Varshney R K, Song C, Saxena R K, Azam S, Yu S, Sharpe A G. et al. Draft genome sequence of chickpea (*Cicer arietinum*) provides a resource for trait improvement. Nat. Biotechnol. 2013; 31: 240–246.
2. Asati R, Tripathi MK, Tiwari S, Yadav RK, Tripathi N. Molecular breeding and drought tolerance in chickpea. Life. 2022; 12:1846. <https://doi.org/10.3390/life12111846>
3. Yadav RK, Tripathi MK, Tiwari S, Tripathi N, Asati R, Patel V, Sikarwar RS, Payasi DK. Breeding and genomic approaches towards development of Fusarium wilt resistance in chickpea. Life 2023a; 13, 988. <https://doi.org/10.3390/life13040988>
4. Tiwari PN, Tiwari S, Sapre S, Babbar A, Tripathi N, Tiwari S, Tripathi MK. Screening and selection of drought-tolerant high-yielding chickpea genotypes based on physio-biochemical selection indices and yield trials. Life. 2023; 13(6):1405. <https://doi.org/10.3390/life13061405>
5. Sahu VK, Tiwari S, Tripathi MK, Gupta N, Tomar RS, Yasin M. Morpho-physiological and biochemical traits analysis for Fusarium wilt disease using gene-based markers in desi and Kabuli genotypes of chickpea (*Cicer arietinum* L.). Indian J Genet. 2020a;80:16.
6. Sahu VK, Tiwari S, Gupta N, Tripathi MK, Yasin M. Evaluation of physiological and biochemical contents in desi and Kabuli chickpea. Legume Research. 2020b. DOI:10.18805/LR-4265
7. Gupta N, Tiwari S, Tripathi MK, Bhagyawant SS. Antinutritional and protein-based profiling of diverse desi and wild chickpea accessions. Current Journal of Applied Science and Technology, 2021; 40(6):7-18
8. Mihoariya M, Tiwari S, Yadav R K, Asati R, Solanki R S, Tiwari P N, Chauhan S, Tripathi N, Tripathi M.K. Genetic variability and diversity analysis for yield and its associated traits in chickpea (*Cicer arietinum* L.). Current Journal of Applied Science and Technology, 2023; 42(16):17-33.
9. Ningwal R, Tripathi MK, Tiwari S, Yadav RK, Tripathi N, Solanki RS, Asati R, Yasin M. Assessment of genetic variability, correlation and path coefficient analysis for yield and its attributing traits in chickpea (*Cicer arietinum* L.). Pharma Innovation. 2023a;12(3):4851-4859

10. Rajput S, Jain S, Tiwari S, Sikarwar R S, Tripathi N, Barela A, Tripathi, M K. Evaluation of gene-based markers against Fusarium wilt disease in chickpea (*Cicer arietinum* L.). Current Journal of Applied Science and Technology, 2023a; 42(6): 26-32.
11. FAO. Food and Agriculture Organization of The United Nations, 2020
12. FAOSTAT.<http://faostat.fao.org/site>. 2021; Accessed 30 May, 2023.
13. Ningwal R, Tripathi MK, Tiwari S, Asati R. Yadav RK, Tripathi N, Yasin M. Identification of polymorphic SSR marker and diversity analysis in a set of desi chickpea genotypes, Biological Forum-An International Journal. 2023b; 15(3): 45-51.
14. Rajput S, Jain S, Tiwari S, Gupta N, Sikarwar RS, Tripathi N, Tripathi MK. Biochemical characterization of chickpea (*Cicer arietinum* L.) genotypes. Plant Cell Biotechnology & Molecular Biology, 2023b;24(3-4):1-9.
15. Solanki, R.S., Babbar, A. and Tripathi, N. Genetic diversity analysis in *kabuli* chickpea (*Cicer arietinum* L.) genotypes based on quantitative traits and molecular markers. Bangladesh Journal of Botany, 2022; 51(3): 581-587.
16. Baghel R, Sharma AK, Tiwari S, Tripathi MK, Tripathi N. Genetic diversity analysis of Indian mustard (*Brassica spp.*) germplasm lines using SSR molecular markers. Int J Curr Microbiol App Sci. 2020; 9 (12): 137-143.
17. Bhawar PC, Tiwari S, Tripathi MK, Tomar RS, Sikarwar RS. Screening of groundnut germplasm for foliar fungal diseases and population structure analysis using gene based SSR markers. Current Journal of Applied Science and Technology. 2020;39(2): 75-84.
18. Makwana K, Tiwari S, Tripathi MK, Sharma AK, Pandya RK, Singh AK. Morphological characterization and DNA finger printing of pearl millet [*Pennisetum glaucum* (L.)] germplasms. Range Mgmt. & Agroforestry. 2021;42(2):205-211
19. Mishra N, Tripathi MK, Tiwari S, Tripathi N, Trivedi HK. Morphological and molecular screening of soybean genotypes against yellow mosaic virus disease. Legume Research. 2020. DOI: 10.18805/LR-4240.
20. Mishra N, Tripathi MK, Tiwari S, Tripathi N, Gupta N, Sharma A. Morphological and physiological performance of Indian soybean [*Glycine max* (L.) Merrill] genotypes in respect to drought. Legume Research. 2021. DOI:10.18805/LR-4550
21. Pramanik A, Tiwari S, Tripathi MK, Mandloi S, Tomar R.S. Identification of groundnut germplasm lines for foliar disease resistance and high oleic traits using SNP and gene-based markers and their morphological characterization Legume Res. 2021; 10.18805/LR-4666

22. Rajpoot P, Tripathi MK, Tiwari S, Bimal, S S, Tripathi N, Parihar P, Pandya R K, C. Tara Satyavathi. Characterization of pearl millet [*Pennisetum glaucum* (L.) R br.] genotypes against blast disease employing disease scoring and gene specific SSR markers. SCI, 2023;3(3);16-30.
23. Sharma A, Tripathi MK, Tiwari S, Gupta N, Tripathi N and Mishra N. Evaluation of soybean (*Glycine max* L.) genotypes on the basis of biochemical contents and anti-oxidant enzyme activities. Legume Res. 2021; 44, LR-467.
24. Sharma S., Tripathi M. K., Tiwari S., Solanki R. S., Chauhan S., Tripathi N., Dwivedi N, Kandalkar, V. S. The Exploitation of genetic variability and trait association analysis for diverse quantitative traits in bread wheat (*Triticum aestivum* L.). Current Journal of Applied Science and Technology, 2023a; 42(8) 19-33.
25. Sharma S., Tripathi M. K., Tiwari S., Solanki R. S., Chauhan S., Tripathi N., Dwivedi N. and Tiwari, P.N. Discriminant function analysis for yield improvement in bread wheat (*Triticum aestivum* L.). The Pharma Innovation Journal, 2023b;.12(5): 224-232.
26. Shrivastava A, Tripathi MK, Solanki RS, Tiwari S, Tripathi N, Singh J, Yadav RK. Genetic correlation and path coefficient analysis of yield attributing parameters in Indian mustard. Current Journal of Applied Science and Technology, 2023; 42(7): 42–58. <https://doi.org/10.9734/cjast/2023/v42i74079>
27. Shyam C, Tripathi MK, Tripathi N, Tiwari S, Sikarwar R S. Genetic variations in fatty acids and oil compositions among 188 Indian mustard *Brassica juncea* (Linn.) Czern & Coss genotypes. Curr J Appl Sci Technol. 2022a;40(46):9-28 DOI: [10.9734/CJAST/2021/v40i4631629](https://doi.org/10.9734/CJAST/2021/v40i4631629)
28. Shyam C., Tripathi M. K., Tripathi N, Tiwari S, and Sikarwar R. S. Analysis of genetic differences in fatty acids and oil contents among *Brassica juncea* (Linn.) Czern & Coss genotypes. In book: Research Developments in Science and Technology, 2022b;1:127-149, DOI: [10.9734/bpi/rdst/v1/6010F](https://doi.org/10.9734/bpi/rdst/v1/6010F)
29. Tripathi N, Tripathi MK, Tiwari S, Payasi DK. Molecular breeding to overcome biotic stresses in soybean: update. Plants (Basel). 2022;11(15):1967.
30. Tripathi MK, Tripathi N, Tiwari S, Mishra N, Sharma A, Tiwari S, Singh S. Identification of Indian soybean (*Glycine max* [L.] Merr.) genotypes for drought tolerance and genetic diversity analysis using SSR markers SCI 2023;3(3);2023;31-46.
31. Upadhyay S, Singh AK, Tripathi MK, Tiwari S, Tripathi N. Biotechnological interventions to combat against charcoal rot and *Rhizoctonia* root rot diseases of soybean

- [*Glycine max* (L.) Merrill]. In book: Current Topics in Agricultural Sciences; 2022. 6:1-18 DOI: <https://doi.org/10.9734/bpi/ctas/v6/3250E>
32. Yadav PK, Singh AK, Tripathi MK, Tiwari S, Rathore J. Morpho-physiological characterization of maize (*Zea mays* L.) genotypes against drought. Biological Forum: An International Journal. 2022a;14(2):0975-1130.
 33. Yadav PK, Singh AK, Tripathi MK, Tiwari S, Yadav SK, Tripathi N. Morpho-Physiological and molecular characterization of maize (*Zea mays* L.) genotypes for drought tolerance. European Journal of Applied Sciences, 2022b;10(6):65-87
 34. Yadav S, Tiwari S, Tripathi MK, Tripathi N, Gupta N, Tiwari S. Evaluation of high oleic acid content in a set of 96 genotypes of *Arachis hypogaea* L Scientist, 2023b;2 :132-143
 35. Singh, M., Malhotra, N. and Singh, K. Broadening the Genetic Base of Cultivated Chickpea Following Introgression of Wild Cicer Species-Progress, Constraints and Prospects. Genetic Resources and Crop Evolution, 2021; 68: 2181–2205
 36. Makwana K, Tiwari S, Tripathi MK, Patel V. Morphological diversity analysis of foxtail millet (*Sateria Italica* (L.) Beauv.) using qualitative and quantitative traits. Scientist.2(2);2023; 319-326.DOI: <https://doi.org/10.5281/zenodo.7654168>.
 37. Mishra N, Tripathi MK, Tiwari S, Tripathi N and Sikarwar, RS. Evaluation of qualitative trait based variability among soybean genotypes. The Pharma Innovation,2022 11(9): 1115-1121
 38. Sharma A, Mishra N, Tripathi N, Nehra S, Singh J. Tiwari S, Tripathi M K. Qualitative trait based variability among soybean genotypes. Acta Scientific Agriculture, 2023c; 7(1): 02-13.
 39. Shyam C, Tripathi MK, Tripathi N, Tiwari S, Sikarwar R S. Identification of low and high erucic acid containing genotype(s) in Indian mustard employing molecular markers. In book: Recent Progress in Plant and Soil Research, 2022c; 5: 18-36 DOI: [10.9734/bpi/rppsr/v5/15384D](https://doi.org/10.9734/bpi/rppsr/v5/15384D)
 40. Joshi M A, Aggarwal D, Sanyal A. Cultivar Identification and Diversity Analysis Based on Morphological Descriptors and Image Analysis in Chickpea (*Cicer arietanum* L.). Legume Research-An International Journal, 2018;41(5): 647-655
 41. Thakur S, Mishra G, Pachori S, Babbar A. Characterization of morphological traits and diversity assessment of desi chickpea (*Cicer arietanum* L.) lines. Biological Forum – An International Journal, 2022;14(1): 481-486.

42. Admas S, Tesfaye K, Haileselassie T, Shiferaw E, Flynn, K C. (). Genetic Variability and Population Structure of Ethiopian Chickpea (*Cicer arietanum* L.) Germplasm. PLOS ONE, 2021; 1371: 0260651.
43. PPV & FRA. Guidelines for the Conduct of Test for Distinctness, Uniformity and Stability on Chickpea (*Cicer arietanum* L.). 2018; http://www.plantauthority.gov.in/pdf/G_Chick_pea.pdf
44. Negassa M. Patterns of Phenotypic diversity in an Ethiopian barley collection and the Arussi-Bale Highland as a center of origin of barley. Hereditas, 1985;102: 139–150.
45. Rohlf F.J., NTSYS-pc (numerical taxonomy and multivariate analysis system), version 2.02i, Exeter, Setauket, New York, USA. 2002
46. Kumar D, Raje RS, Singh AK, Singh AM, Pandey A, Singh NK. Assessment of genetic diversity based on agro-morphological traits and genic microsatellite markers in inter-specific derivatives and cultivars of pigeon pea. Indian J Genet. 2015;75(2):215-224.
47. Tiwari S, Koutu G K, Pathak N. Diversity Analysis of Grain Attributes in Restorer Lines of Rice (*Oryza sativa*). Biological Forum – An International Journal, 13(2): 2021; 386-392.
48. Kumawat S, Babbar A, Solanki R S, Biswal M, Banjarey P. Morphological characterization of elite kabuli chickpea lines. International Journal of Current Microbiology and Applied Sciences, 2020; 9(09): 1241-1250.
49. Upadhyaya HD, Ortiz R, Bramel PJ, Singh S. Phenotypic diversity for morphological and agronomic characteristics in chickpea core collection. Euphytica. 2002; 123(3):333-42.
50. Lalitha A. Varietal characterization of chickpea (*Cicer arietinum*) varieties. Doctoral dissertation, Acharya N. G. Ranga Agricultural University, Rajendranagar, Hyderabad, 2007
51. Sarao, NK, Joshi MA, Sharma RC, Sandhu JS, Kumar J. Characterization of chickpea based on morphological markers. Journal of Food Legumes, 200922(4): 251-253.
52. Heidaryvand L, Reza MA, Mohammad RN, Yadollah F, Behzad S, Khoshnood A. 2011. Physiological and morphological characteristics of chickpea accessions under low temperature stress. 58(1):126-32.
53. Zaccardelli M, Sonnante G, Lupo F, Piergiovanni AR, Laghetti G, Sparvoli F, Lioi L. Characterization of Italian chickpea (*Cicer arietanum* L.) germplasm by multidisciplinary approach. Genetic resources and crop evolution. 2013; 60(3):865-877.

54. Bodake KK, Wagh RS, Deshmukh DV. Morpho-physiological characterization of chickpea (*Cicer arietanum* L.) genotypes. International Journal of Agricultural Sciences, 2014; 10(2):512-8.
55. Bayahi K, Rezgui S. Agro-Morphological and Genetic Study of New Improved Lines and Cultivars of Chickpea. Journal of Plant Breeding and Genetics, 2015; 3(3): 1-3.
56. Sangram S, Sasidharan N. Assessment of genetic diversity in chickpea (*Cicer arietanum* L.) through morphological characterization. Plant Archives.; 2018;18(1):167-72.
57. Nandedkar K, Saxena R R, Dixit GP, Rawte S, Saxena RR. DUS based Agro-morphological characterization and classification of desi chickpea (*Cicer arietanum* L.). The Pharma Innovation Journal 2021; 10(11): 716-722.
58. Rana L, Kumari S, Nandedkar K, Rawte S, Saxena RR. Agro-morphological characterization of desi chickpea (*Cicer arietanum* L.) genotypes based on DUS descriptor. The Pharma Innovation Journal 2022; 11(11): 383-387.
59. Upadhyaya HD, Gowda C, Sastry DV. Plant genetic resources management: collection, characterization, conservation and 9(9): 1241-1250 1250 utilization. Journal of SAT Agricultural Research,2008; 6(1):16-17.
60. Kaul J, Kumar S, Gurha SN. Evaluation of exotic germplasm of kabuli chickpea. Indian Journal of Plant Genetic Resources, 2007; 20(2):1-3
61. Shrivastava A, Babbar A, Shrivastava S P, Shukla S S. (). Variability studies in some genotypes of chickpea (*Cicer arietanum* L.) under rice fallow. Journal of Food Legumes, 2012; 25(1): 70-77.
62. Solanki RS, Biswal M, Kumawat S, Babbar A. Characterization of indigenous and exotic chickpea lines for qualitative traits. International Journal of Chemical Studies, 2019;7(4): 1018-1023.
63. Gnyandev B, Kurdikeri MB, Salimath P M. Study on characterization of chickpea varieties. Journal of Pharmacognosy and Phytochemistry, 2019; 8(2): 531-533.
64. Saha S. Morphological Characterization and Genetic Analysis in Elite Lines of Chickpea (*Cicer arietanum* L.). Doctoral dissertation, Jawaharlal Nehru Krishi Vishwa Vidyalaya Jabalpur, 2017.
65. Joshi MA, Aggarwal, D. Image analysis as an emerging tool for varietal identification in chickpea (*Cicer arietanum* L.) varieties. International Journal of Advanced Technology in Engineering and Science 2016;4(11):2348-7550.
66. Archak S, Tyagi R K, Harer P N, Mahase L B, Singh N, Dahiya OP, Nizar M A, Singh M, Tilekar V, Kumar V, Dutta M. Characterization of chickpea germplasm conserved in

- the Indian National gene bank and development of a core set using qualitative and quantitative trait data. *The Crop Journal*, 2016;4(5): 417-424.
67. Singh S, Sasidharan N. and Kalyanrao. Assessment of genetic diversity in chickpea (*Cicer arietanum* L.) through morphological characterization. *Plant Archives*, 2018;18(1): 167-172.
 68. Adem A, Tesso B. Phenotypic characterization and assessment of genetic diversity for agro- morphological traits of Ethiopian chickpea (*Cicer arietanum* L.) landraces. *Black Sea Journal of Agriculture*, 2019; 2(3):146-55.
 69. Awol M, and Bulti T. Characterization and assessment of genetic diversity for agro-morphological traits of Ethiopian chickpea (*Cicer arietanum* L.) landraces. *Uganda Journal of Agricultural Sciences*, 2018; 8(1): 1- 13.
 70. Gediya L N, Patel D A, Kumar D, Nayak KV. Characterization of chickpea genotypes based on morphological traits. *Journal of Pharmacognosy and Phytochemistry*, 2018; 7(4): 3008-3015.
 71. Janghel DK, Kumar K, Sunil R, Chhabra, AK Genetic diversity analysis, characterization and evaluation of elite chickpea (*Cicer arietanum* L.) genotypes. *International Journal Current Microbiology Applied Science*, 2020; 9(1): 199-209.
 72. Aktar-Uz-Zaman M, Kamal M M, Alam M A, Islam M R, Zaman SM, and Hossaini M. Characterization of chickpea germplasm. *Agriculturae Conspectus Scientificus*, 2020;85(1): 19-35.
 73. Chaudhary L, Rajat S, Kumar M, Kumar S. Morphological characterization and assessment of genetic diversity in pigeonpea [*Cajanus cajan* (L.) Millsp.] germplasm. *Electronic Journal of Plant Breeding*, 2021; 12(3): 707-711.
 74. Rawte S, Saxena RR. Phenotypic diversity and correlation analysis for agro-Morphological traits in 100 landraces of rice (*Oryza sativa* L.) from Chhattisgarh. *International Journal Pure and Applied Bioscience*, 2018;6(6): 345-353.
 75. Bouri A, Mediouni MR, Kaouadji Z, Meghili I, Gaouar SBS. Assessing agro-morphological diversity of chickpea accessions in Western Algeria. *Genetics and Biodiversity Journal*, 2021; 5(2): 49–58.
 76. Ashinie SK, Tesfaye, B, Wakeyo G K, Fenta BA. Genetic diversity for immature pod traits in Ethiopian cowpea [*Vigna unguiculata* (L.) Walp.] landrace collections. *African Journal of Biotechnology*, 2020;19(4): 171-182.

77. Basak J, Singh AK, Singh R, and Rai M. Morphological characterization and assessment of genetic diversity in tomato (*Solanum lycopersicum* L.) landraces using qualitative traits. *Indian Journal of Agricultural Sciences*, 2018; 88(9), 1470-1476.
78. Kumar N, Singh AK, Yadav VK, Sharma SK. Evaluation of genetic diversity and population structure in barley (*Hordeum vulgare* L.) genotypes using qualitative traits. *Indian Journal of Agricultural Sciences*, 2021; 91(2), 219-223.

UNDER PEER REVIEW

Table 1 List of morphological traits with DUS descriptors as per PPVFRA, 2018

S. No.	Descriptors	States	Stage of observation
1	Stem Anthocyanin pigmentation	Absent, Present	Before flowering
2	Stem height at initiation of first flower	Low (<8 nodes), medium (8-15 nodes) and high (>15 nodes)	50 % flowering
3	Plant: Growth habit	Semi erect (20-40° from vertical), semi spreading (40-60° from vertical) and spreading (60-80° from vertical)	50 % flowering
4	Plant: Colour of foliage	Light green, medium green and dark green	50 % flowering
5	Leaflet size (mm)	Small (<10mm), medium (10-15mm) and large (>15mm)	50 % flowering
6	Flower: Number per peduncle	Single and twin	50 % flowering
7	Flower: colour	White, pink and blue	50 % flowering
8	Flower: stripes	Absent and present	50 % flowering
9	Peduncle length (mm)	Short (<5mm), medium (5-10mm) and long (>10mm)	Pod development
10	Plant: height	Short (<45 cm), medium (45-65 cm) and tall (>65 cm)	Fully developed green pods
11	Pod: Length	Small (< 15 mm), medium (15-20 mm) and large (>20 mm)	Harvest maturity
12	Number of seeds per pod	One and more than one	Harvest maturity
13	Seed colour	Beige, Creamy beige, Green, Yellow, Orange, Brown, Dark brown, Grey, Black	30 days after harvest
14	Seed shape	Pea shaped, owl's head and angular	30 days after harvest
15	Seed testa texture	Smooth, rough and tuberculated	30 days after harvest
16	Seed ribbing	Absent and present	30 days after harvest
17	Seed type	Desi and kabuli	30 days after harvest

Table 2 Frequency distribution and Shannon-weaver diversity index for various morphological traits of chickpea genotypes

S. No.	Descriptors	Score	Genotype frequency	Percentage contribution (%)	Shannon's diversity index
1	Stem Anthocyanin pigmentation				0.52
	Absent	1	17	21.79	
	Present	9	61	78.20	
2	Stem Height at initiation of first flower				0.662
	Low (<8 nodes)	3	14	17.94	
	Medium (8-15 nodes)	5	60	76.92	
	High (>15 nodes)	7	4	5.12	
3	Plant: Growth habit				0.775
	Erect (20-40° vertical)	3	25	32.05	
	Semi spreading (40-60° vertical)	5	50	64.10	
	Spreading (60-80° vertical)	7	3	3.84	
4	Plant: Colour of foliage				1.023
	Light green	1	13	16.66	
	Medium green	2	36	46.15	
	Dark green	3	29	37.17	
	Greenish purple	4	0	0	
5	Leaflet size (mm)				1.089
	Small (<10mm)	3	23	29.48	
	Medium (10-15mm)	5	24	30.76	
	Large (>15mm)	7	31	39.74	
6	Flower: Number per peduncle				0.163
	Single	1	75	96.15	
	Twin	3	3	3.84	
7	Flower: colour				0.803
	White	1	14	17.94	
	Pink	2	55	70.51	
	Blue	3	9	11.53	
8	Flower: stripes				0.507
	Absent	1	16	20.51	
	Present	9	62	79.48	
9	Peduncle length (mm)				0.890
	Short (<5mm)	3	49	62.82	
	Medium (5-10mm)	5	20	25.64	
	Long (>10mm)	7	9	11.53	
10	Plant: Height				0.753
	Short (<45 cm)	3	14	17.94	
	Medium (45-65 cm)	5	57	73.07	
	Tall (>65 cm)	7	7	8.97	
11	Pod: size (Length)				1.006
	Small (<15mm)	3	14	17.94	
	Medium (15-20mm)	5	41	52.56	
	Large (>20mm)	7	23	29.48	
12	Number of seeds per pod				0.470

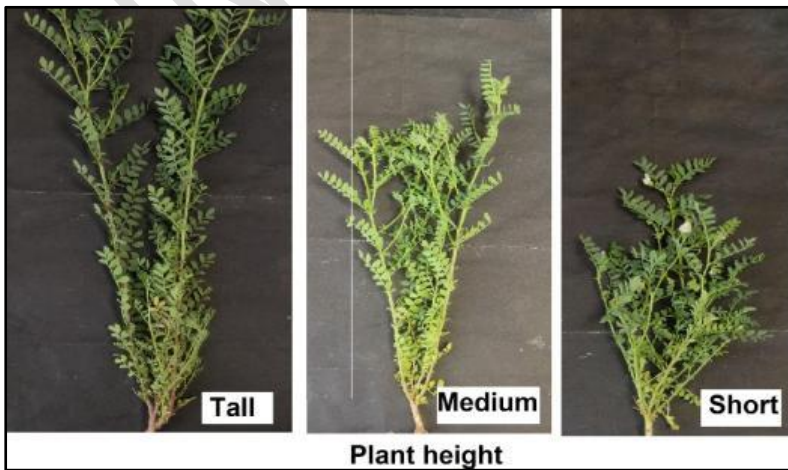
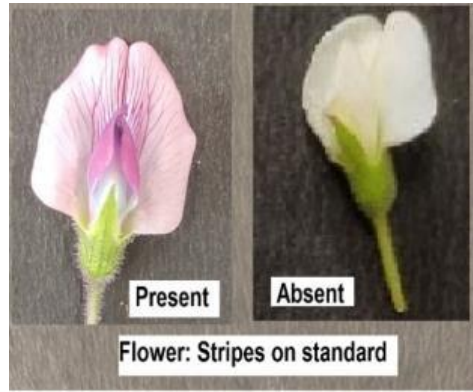
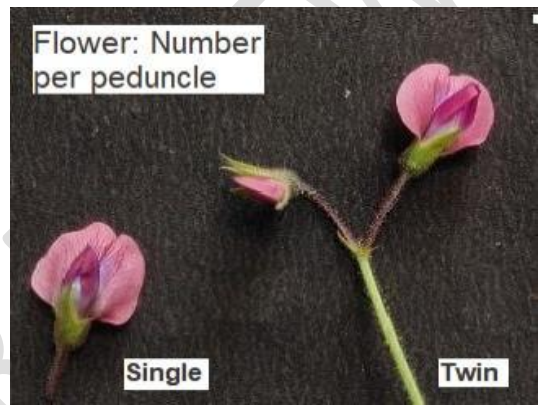
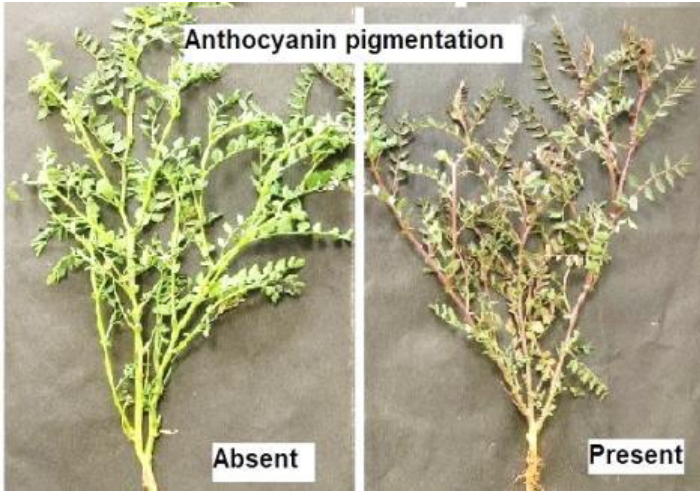
	One	1	64	82.05	
	More than one	3	14	17.94	
13	Seed colour				1.825
	Beige	1	6	7.69	
	Creamy beige	2	4	5.12	
	Green	3	6	7.69	
	Yellow	4	10	12.82	
	Orange	5	5	6.41	
	Brown	6	22	28.20	
	Dark brown	7	22	28.20	
	Grey	8	0	0	
	Black	9	3	3.84	
14	Seed: shape				1.035
	Pea shaped	1	17	21.79	
	Owl's head	2	22	28.20	
	Angular	3	39	50	
15	Seed: Testa texture				0.429
	Rough	1	12	15.38	
	Smooth	2	66	84.61	
	Tuberculated	3	0	0	
16	Seed: Ribbing				0.687
	Absent	1	43	55.12	
	Present	9	35	44.87	
17	Seed: Type				0.000
	Desi	1	78	100	
	Kabuli	3	0	0	

Table 3 Agro-morphological characterization of desi chickpea based on DUS descriptors

S.No.	Genotypes	Anthocyanin Pigment	Stem Height	Growth habit	colour of foliage	Leaflet size	number per peduncle	Flower colour	Flower: stripes	peduncle length	Plant: height	Pod size	Number of seeds per pod	Seed colour	Seed shape	Seed testa texture	Seed ribbing	Seed type
1	ICCV-201111	9	7	3	2	5	1	2	9	5	7	7	1	7	2	2	9	1
2	JG-36	9	5	5	1	5	1	2	9	3	5	3	1	4	2	2	9	1
3	GCP-101	9	5	5	3	3	1	2	1	3	5	3	3	4	2	2	9	1
4	ICCV-201105	9	5	5	3	7	1	2	9	3	5	5	1	7	2	2	9	1
5	ICCV-201209	9	3	3	2	3	1	3	9	5	3	3	1	6	2	2	9	1
6	ICCV-201113	9	3	5	2	7	1	2	9	3	5	5	1	4	2	2	9	1
7	ICCV-201118	9	5	3	2	7	1	2	9	5	5	5	1	4	2	2	9	1
8	ICCV-201212	1	5	7	1	7	1	2	9	3	7	5	3	6	2	2	9	1
9	ICCV-201217	9	7	3	1	5	1	3	1	5	7	5	1	4	3	1	9	1
10	ICCV-201102	1	7	5	3	7	1	2	9	7	7	5	1	7	3	2	9	1
11	ICCV-201218	9	5	3	3	3	1	1	9	3	5	3	1	6	2	2	9	1
12	ICCV-201108	9	5	3	1	5	1	3	9	5	5	5	1	6	3	1	9	1
13	CHAFFA	1	3	3	1	3	1	2	1	7	5	3	1	6	3	2	9	1
14	JG-24	9	5	3	3	7	1	2	9	3	5	3	1	6	3	1	9	1
15	ICCV-201114	9	5	3	3	5	1	3	9	5	5	3	1	7	3	2	9	1
16	ICCV-201107	9	5	5	3	3	1	3	9	7	5	3	1	6	3	2	1	1
17	SAGL 22-101	9	5	5	3	5	1	2	9	5	5	5	1	6	1	2	1	1
18	SAGL 22-102	9	5	5	3	7	1	2	9	7	5	5	1	7	3	2	9	1
19	SAGL 22-103	9	5	5	2	7	1	2	9	3	3	5	1	5	1	2	1	1
20	SAGL 22-104	9	5	5	2	5	1	2	9	7	5	5	1	7	1	1	1	1
21	SAGL 22-105	1	3	5	2	5	1	1	1	5	3	5	3	5	1	2	1	1
22	SAGL 22-106	9	5	3	2	7	1	2	9	5	5	3	1	7	3	2	1	1
23	SAGL 22-107	9	5	5	3	7	1	2	9	3	5	3	1	4	3	2	1	1
24	SAGL 22-108	9	5	5	3	5	3	2	9	7	5	7	1	7	1	2	1	1

S.No.	Genotypes	Anthocyanin Pigment	Stem Height	Growth habit	colour of foliage	Leaflet size	number per peduncle	Flower colour	Flower: stripes	peduncle length	Plant: height	Pod size	Number of seeds per pod	Seed colour	Seed shape	Seed testa texture	Seed ribbing	Seed type
25	SAGL 22-109	9	5	3	1	7	3	2	9	5	5	5	1	6	3	2	9	1
26	SAGL 22-111	9	5	3	2	3	1	2	9	3	5	5	1	7	3	2	9	1
27	SAGL 22-112	9	5	5	2	7	1	3	9	3	5	5	1	4	3	2	9	1
28	SAGL 22-113	9	5	3	2	7	1	2	9	3	5	7	1	6	1	2	1	1
29	SAGL 22-114	9	5	5	2	7	3	2	9	7	5	7	1	6	3	2	9	1
30	SAGL 22 -115	9	3	3	2	5	1	2	9	3	3	7	1	4	3	2	9	1
31	SAGL-152403	9	3	5	2	5	1	2	9	3	3	5	1	7	3	2	9	1
32	SAGL-152254	9	5	3	3	7	1	2	1	3	5	5	3	1	2	2	1	1
33	SAGL-162370	9	5	5	2	7	1	1	9	7	5	5	1	1	2	2	1	1
34	SAGL-152210	9	5	5	1	3	1	2	9	3	5	3	1	7	3	2	9	1
35	SAGL-152273	9	5	5	2	7	1	3	9	5	5	7	1	6	2	2	1	1
36	SAGL-152216	9	5	5	2	3	1	2	9	3	5	3	3	6	3	2	9	1
37	RVSSG-64	9	5	5	2	3	1	2	9	3	5	5	3	3	3	2	9	1
38	SAGL-162265	1	5	3	1	3	1	2	9	5	5	7	1	1	2	2	1	1
39	SAGL-152347	1	5	7	2	7	1	2	9	3	5	7	1	7	2	2	1	1
40	SAGL-162376	1	5	5	3	7	1	1	1	3	5	7	1	6	2	2	1	1
41	SAGL-152314	9	5	5	3	7	1	2	9	5	5	7	1	7	2	2	1	1
42	SAGL-162375	9	5	5	2	5	1	2	1	3	5	5	1	6	1	2	1	1
43	SAGL-152278	9	5	5	2	7	1	2	9	3	5	5	1	7	2	2	9	1
44	SAGL-152242	1	5	5	1	5	1	1	1	3	5	7	1	1	1	2	1	1
45	SAGL-152238	9	5	5	1	7	1	2	9	5	5	7	1	7	1	2	1	1
46	SAGL-162390	9	5	5	3	5	1	2	9	5	5	5	1	7	2	1	9	1
47	RVSSG-69	9	7	3	3	5	1	2	9	3	7	5	3	7	3	2	9	1
48	SAGL-152256	9	5	5	2	5	1	2	9	5	5	5	1	5	3	1	9	1
49	SAGL-152208	9	5	3	3	3	1	2	9	5	5	5	1	3	1	2	1	1
50	SAGL-152303	1	5	5	1	3	1	1	1	3	5	7	1	1	1	2	1	1

S.No.	Genotypes	Anthocyan in Pigment	Stem Height	Growth habit	colour of foliage	Leaflet size	number per peduncle	Flower colour	Flower: stripes	peduncle length	Plant: height	Pod size	Number of seeds per pod	Seed colour	Seed shape	Seed testa texture	Seed ribbing	Seed type
51	SAGL-152404	9	3	5	3	3	1	2	9	3	3	7	3	7	3	1	9	1
52	SAGL-152236	1	3	5	1	5	1	1	1	3	3	5	1	2	1	2	1	1
53	SAGL-152252	1	3	5	1	3	1	1	1	3	3	5	1	1	2	2	1	1
54	SAGL-152349	9	5	5	3	5	1	2	9	3	5	5	1	6	3	1	9	1
55	SAGL-152347	9	3	5	2	7	1	3	9	3	3	7	1	7	2	2	9	1
56	SAGL-162371	1	5	5	2	5	1	1	1	3	5	7	1	2	1	2	1	1
57	SAGL-152342	1	5	5	2	7	1	1	1	3	5	7	1	2	1	2	1	1
58	SAGL-152334	9	5	5	3	7	1	1	1	3	5	7	1	5	1	2	1	1
59	RVSSG-75	9	3	5	2	5	1	2	9	3	3	7	1	6	3	1	9	1
60	JG-14	9	5	5	2	5	1	2	9	3	5	5	1	7	3	2	9	1
61	JG-11	9	5	5	3	3	1	2	9	3	5	5	1	4	3	2	9	1
62	NG-47	9	5	3	3	5	1	2	9	3	5	5	1	6	3	2	9	1
63	JGG-1	1	3	7	2	3	1	1	9	5	3	5	1	5	3	1	1	1
64	RVG-205	1	3	3	3	7	1	2	9	3	3	5	1	3	3	2	9	1
65	RVG-201	9	5	3	3	5	1	2	9	3	5	5	3	7	2	2	1	1
66	VISHAL	9	3	5	3	7	1	3	9	3	3	5	1	7	3	2	9	1
67	JG-63	9	3	5	3	3	1	2	9	3	3	5	3	6	3	2	1	1
68	RVSSG-85	9	5	5	3	3	1	2	9	3	5	5	1	6	3	2	9	1
69	RVG-210	1	5	3	2	5	1	1	1	3	5	7	1	2	1	2	1	1
70	SAGL-161032	1	5	5	2	7	1	1	1	5	5	7	1	3	1	2	1	1
71	SAGL-163603	9	5	5	2	7	1	2	9	7	5	7	1	9	3	2	1	1
72	SAGL-161008	9	5	3	2	7	1	2	9	5	5	7	1	9	2	2	1	1
73	SAGL-162008	9	5	3	2	3	1	2	9	3	5	5	3	9	3	2	9	1
74	SAGL-161001	9	5	5	3	7	1	2	9	3	5	5	1	3	3	2	1	1
75	RVSSG-68	9	5	5	2	3	1	2	9	3	5	3	3	3	3	2	9	1
76	JG-315	9	5	5	2	3	1	2	9	3	5	5	1	6	3	1	9	1
77	JG-74	9	5	5	2	3	1	2	9	3	5	3	3	4	3	1	9	1
78	ICC-4958	9	5	5	3	3	1	2	9	3	5	5	3	6	3	2	1	1



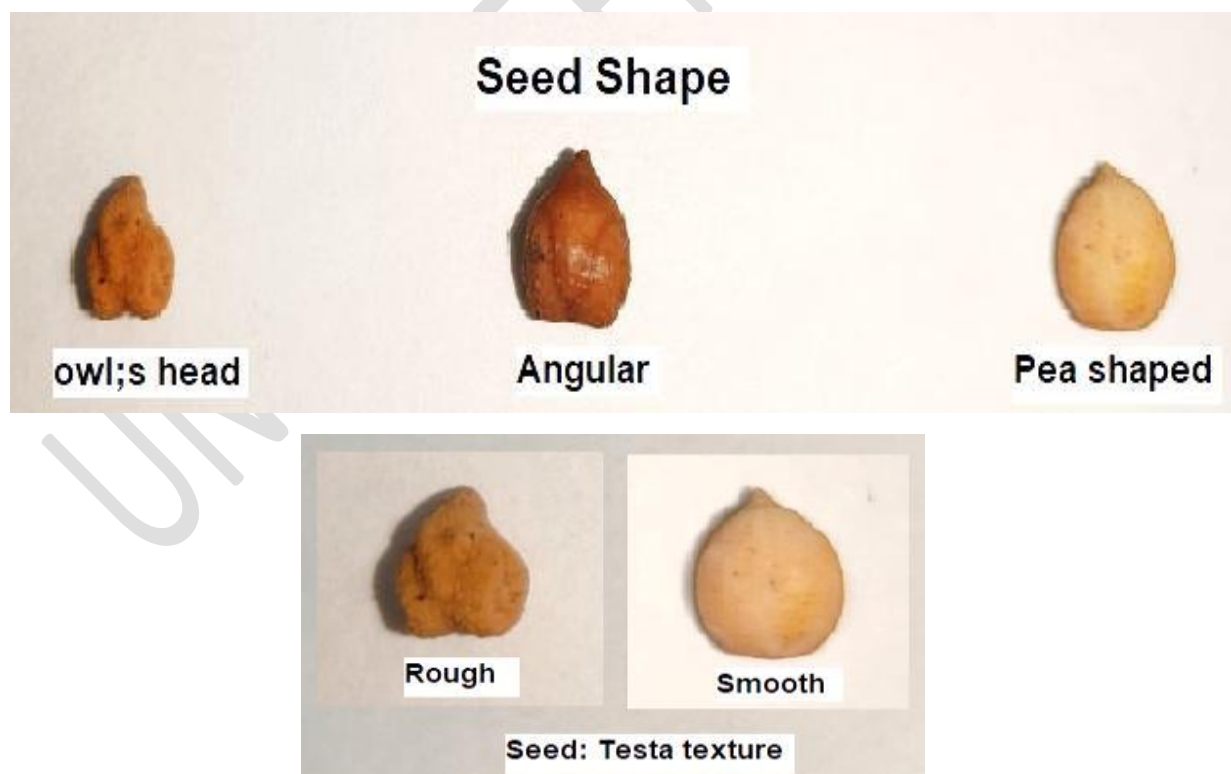
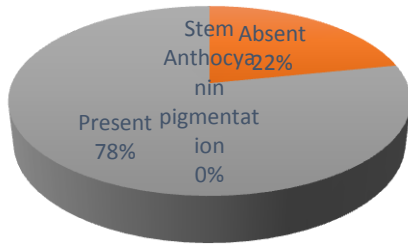


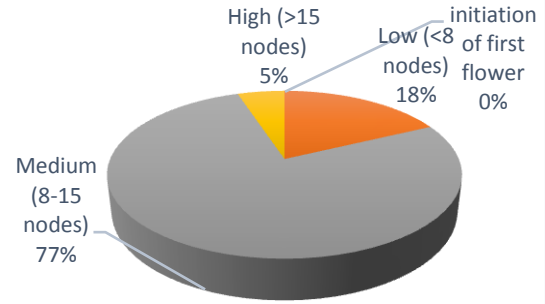
Fig. 1a Pictorial representation of agro-morphological traits in chickpea

Stem Anthocyanin pigmentation



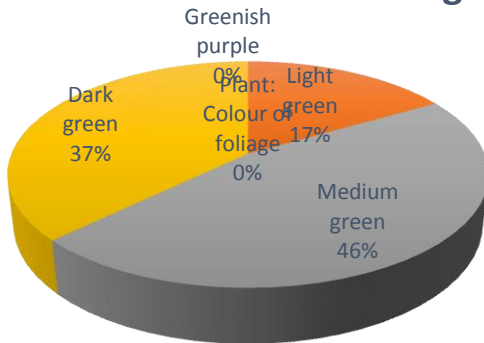
- Stem Anthocyanin pigmentation
- Absent
- Present

Stem Height at initiation of first flower



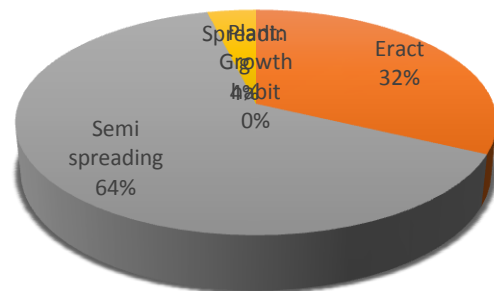
- Stem Height at initiation of first flower
- Low (<8 nodes)
- Medium (8-15 nodes)
- High (>15 nodes)

Plant: Colour of foliage



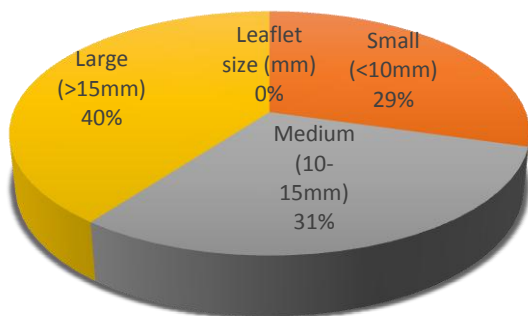
- Plant: Colour of foliage
- Light green
- Medium green
- Dark green
- Greenish purple

Plant: Growth habit



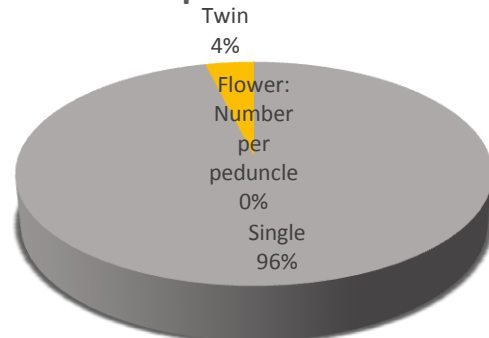
- Plant: Growth habit
- Eract
- Semi spreading
- Spreading

Leaflet size (mm)



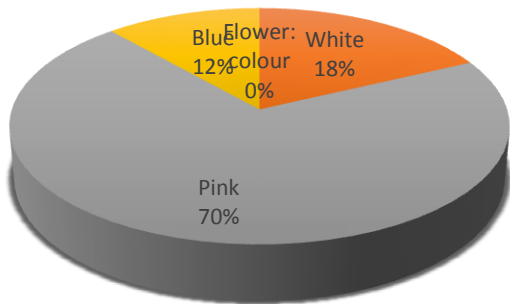
- Leaflet size (mm)
- Small (<10mm)
- Medium (10-15mm)
- Large (>15mm)

Flower: Number per peduncle



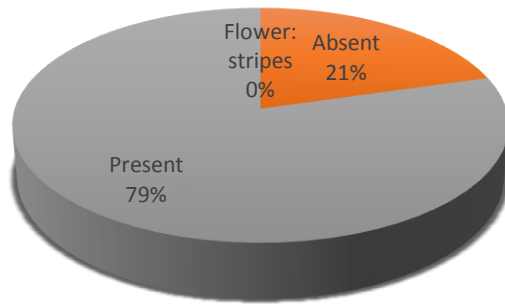
- Flower: Number per peduncle
- Single
- Twin

Flower: colour



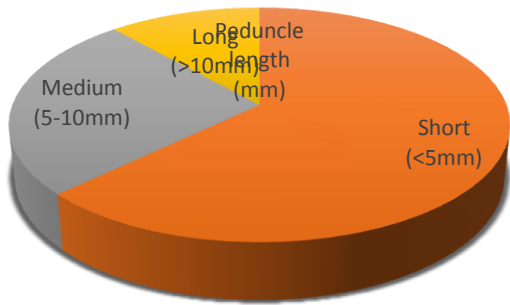
Flower: colour White Pink Blue

Flower: stripes



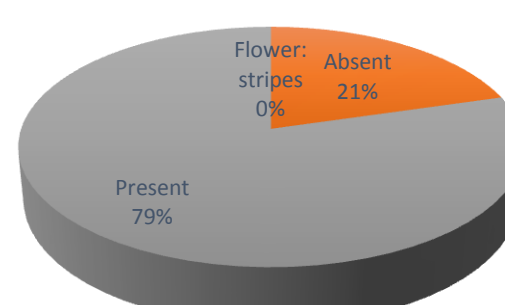
Flower: stripes Absent Present

Peduncle length (mm)



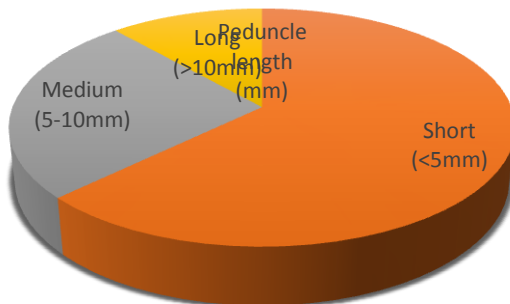
Peduncle length (mm) Short (<5mm) Medium (5-10mm) Long (>10mm)

Flower: stripes



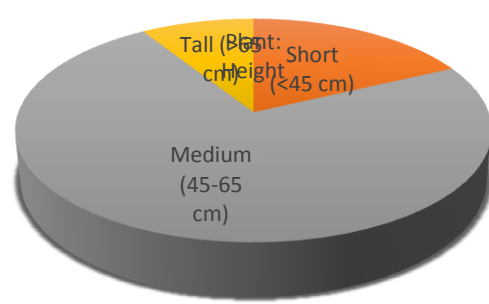
Flower: stripes Absent Present

Peduncle length (mm)



Peduncle length (mm) Short (<5mm) Medium (5-10mm) Long (>10mm)

Plant: Height



Plant: Height Short (<45 cm) Medium (45-65 cm) Tall (>65 cm)

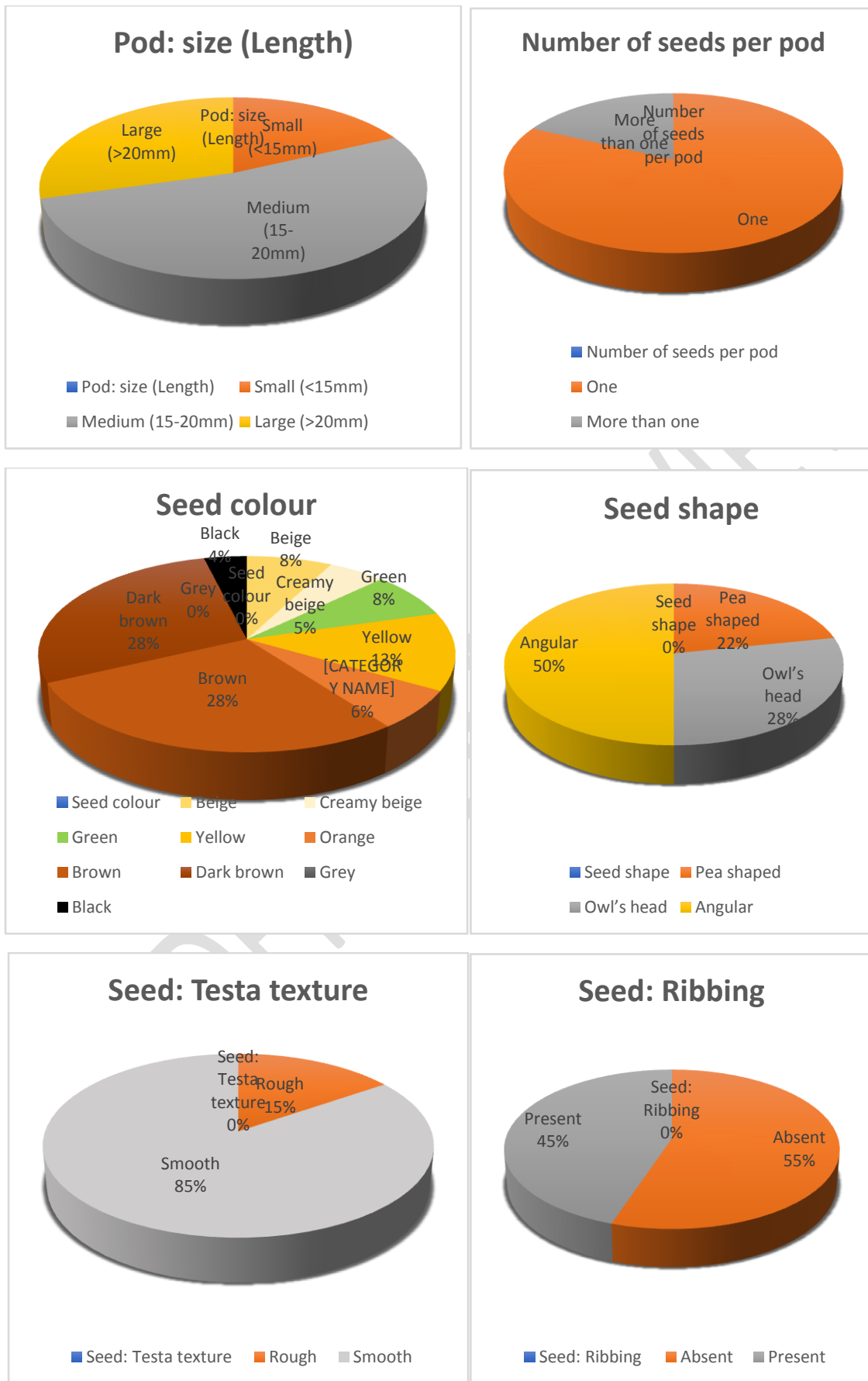


Fig. 1b Diagrammatic representation of different agro-morphological traits in chickpea

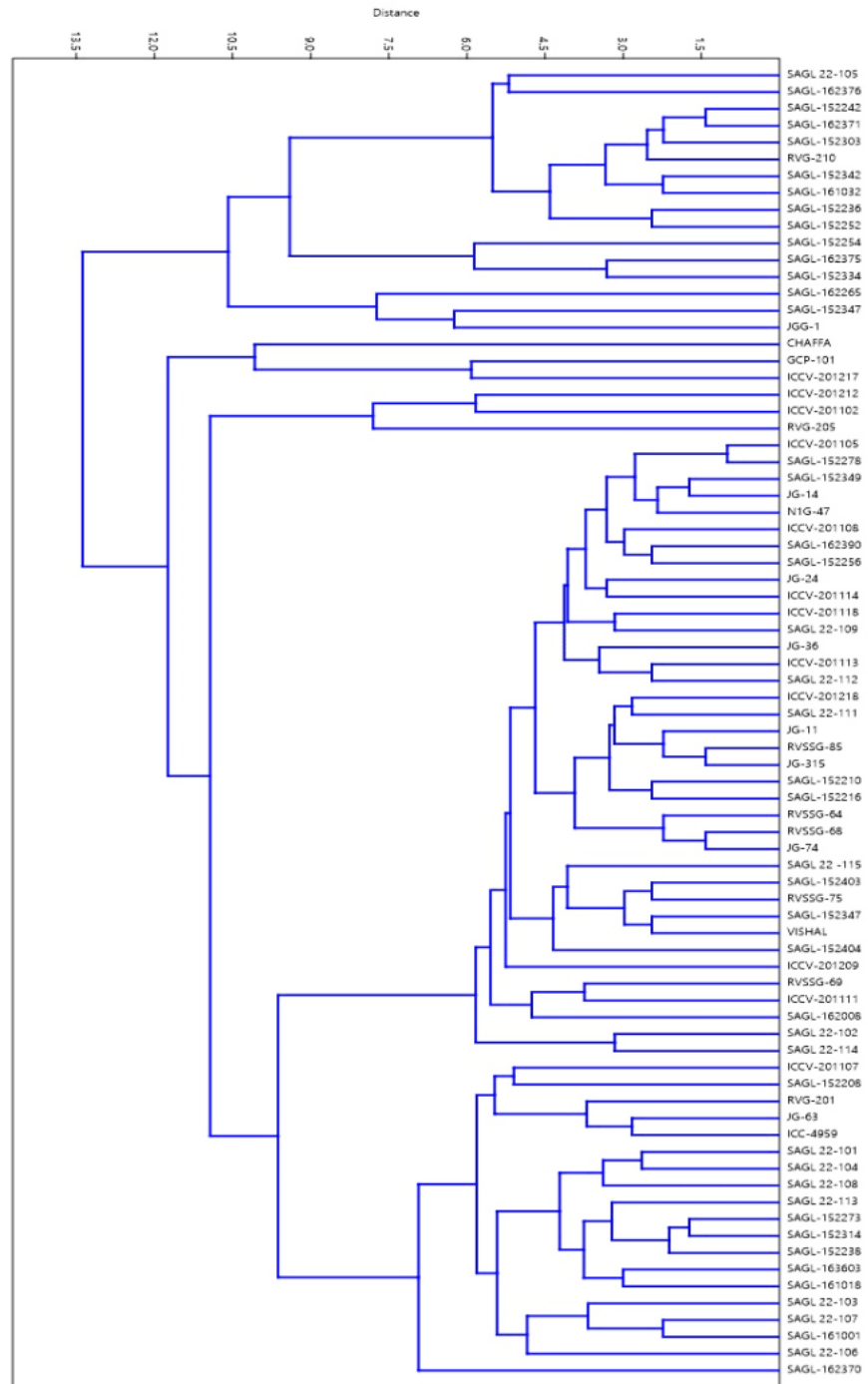


Fig. 2 UPGMA dendrogram based on morphological variability in qualitative traits of 78 Chickpea genotypes