“Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (*Cicer arietinum L.*)”

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By

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CERTIFICATE – I

This is to certify that this thesis entitled “**Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (Cicer arietinum L.)**”, submitted in partial fulfillment of the requirements for the degree of Master of Science in Agriculture in the subject of **Genetics and Plant Breeding**, in Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior (M.P.) is a record of the bonafide research work carried out by **Jai Singh Yadav ID No. 21131605** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The subject of the thesis has been approved by Student Advisory Committee and the Director of Instruction. All the assistance and help received during the course of investigation have been fully acknowledged.

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This is to certify that the thesis entitled "**Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (Cicer arietinum L.)**", submitted by **Jai Singh Yadav** to the **Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya, Gwalior** in partial fulfillment of the requirements for the degree of M.Sc. (Ag.) in the **Department of Genetics and Plant Breeding**, **R.A.K. College of Agriculture, Sehore**, has after evaluation, been approved by external examiner and by Student Advisory Committee after an oral examination of same.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	per cent
σ^2p	Phenotypic variance
σ^2g	Genotypic variance
Σ	Summation
&	And
>	Greater than
√	Square root
<	Less than
=	Equal to
×	Cross or multiply
/	Per
°C	Degree Celsius
ANOVA	Analysis of Variance
Cm	Centimetre
Mm	Millimetre
C.D.	Critical Difference
C.V.	Coefficient of Variation
d.f.	Degrees of freedom
et al.	and others
D^2	Genetic divergence
Ha	hectare
m.ha	Million hectares
DUS	Distinctness, Uniformity and Stability
viz.	Namely
G	grams
MSS	Mean sum of squares
RBD	Randomized Block Design
i.e.,	that is
h^2	heritability in broad sense
Etc	and the rest
e.g.,	Example

CHAPTER I

INTRODUCTION

Pulses are balanced sources of human nutrient and animal forage and contributing to economic and environmental sustainability. Pulses are important sections of production systems that are flexible to climate change. Asia and Africa contribute 78% of world use production for pulses. India is a leading country in the production and consumption of pulses as growing pulses is a cost-effective or profitable option for developing countries. Among pulses, the share of chickpea to the total pulse production has increased up to 35.22% in 2017–18 but the yield of chickpea is comparatively low.

The genus Cicer is rewarded with rich germplasm which includes 44 species (43 wild relatives and 1 domesticated). Chickpea (*Cicer arietinum L*.) is an ancient, self pollinated pulse crop supposed to have originated in south-eastern Turkey and the neighbor part of Syria. Chickpea is a *rabi* season annual crop belonging to the family Leguminosae and it has a diploid chromosome number of 2x = 2n = 16. It is an annual herb which does not have more than 1.0 m in height and has an indeterminate growth habit. The plants can be classified into erect, semi-erect, semi-spreading, spreading and prostrate based on the angle formed by the branches with respect to the ground. The leaves are compound imparipinnate with serrated margins and are oval or elliptical in shape. The inflorescence is an axillary raceme with a single flower but the occurrence of two or three flowers also has been reported in rare instances. The inflorescence is papilionaceous type with 5 petals and diadelphous arrangement (9 stamens fused and one free stamen) and a globose stigma (Sajja *et al*., 2017).

Chickpea or chana is an important legume crop from perspective of food basket for a large and growing population in the country. The crop is a very staple food for many people in India, particularly in the rural areas with the country being the largest producer and consumer of the pulses in the world. In 2021, world production of chickpea was 14.8 million tonnes, led by India with 67% of the global total. In India, it covers 9.99 (million ha) area and 11.91 (million tonnes) production with a mean productivity of 1192 kg/ha. In Madhya Pradesh, it covers a 2.10 million ha area with a production of 3.13 (million tonnes) and an average productivity of 1488 kg/ha which is the largest among different pulse crops (iipr.icar.gov.in /e-pulse-data-book).

Chickpea is a highly nutritive legume crop and ranked third in the list of food legumes that are cultivated mostly worldwide. It has nearly 25% protein and 60% carbohydrates. The nutritive benefits of chickpea, specifically present them as a good source of carbohydrates and protein content, with protein quality in especially better than other legumes. Chickpea contain key amounts of all the essential amino acids apart from the sulfur-containing amino acid, which can be balanced by adding cereals to the daily diet beacuse cereals are good in sulfur-containing amino acids. Chickpea is an economical source of protein, carbohydrates, minerals and vitamins, dietary fiber, folate, b-carotene, and health-promoting fatty acids. (Jukanti *et al.,* 2012).

Conventionally chickpea harvesting methods involve labor-intensive manual labor, which is time-consuming and costly. Traditionally the plants are harvested by pulling them out of the ground by hand or through sickle and then threshed mechanically. But this practice has its own limitation such as the unavailability of labour during the harvesting time due to high demand and the nitrogen-fixing nodules being lost with roots while pulling them out and plants leading to loss of nitrogen-fixing bacteria in the soil (*Golpira et al.,* 2013).

A relative economic analysis between machine-harvested and threshed chickpea farms over manually harvested and mechanically threshed farms in Maharashtra and Madhya Pradesh showed a net return of Rs 989 and Rs 1168, respectively (*Shilpa et al.,* 2017).

In contrast to totally mechanized cereal crop cultivation, lack of mechanization is a major constraint to the expansion of chickpea areas in many countries (Oram and Belaid, 1990; Osrnan *et al.*, 1990). Strengthen mechanization of farm operations to improve efficiency and reduce the cost of cultivation is being broadly adopted in India. This is possible either by developing varieties suited to mechanical harvesting or by modifying the harvesting machine so that it is suitable for chickpea and other related pulse crops. Machine harvestable varieties should be taller and more erect than, the present semi erect varieties as the present varieties incur heavy harvest losses during machine harvesting.

One of the main challenges in developing mechanical cultivars for chickpea harvesting is the delicate nature of the pods. Chickpea pods are easily damaged, which can be resulting in lower quality yields. Therefore, mechanical cultivars must be designed to pick the pods gently and carefully to avoid damage. Another challenge is the diversity of chickpea varieties. Chickpea varieties differ in size, shape, and color, which can make it difficult to design a single mechanical cultivar that can handle all varieties. To overcome this challenge, researchers have been developing cultivars that can be adjusted to handle different varieties. Despite these challenges, several promising mechanical cultivars have been developed and tested in India. These cultivars have shown promising results, reducing labor costs, increasing productivity, and improving yield quality.

Therefore chickpea genotypes/cultivars with tall plant height, lodging resistance, upright and erect growth habit, fruiting zone starting above 20 to 25 cm from the ground, acceptable branch angle, more internodes and short internodal length are considered suitable for combined harvesting and need to be developed through intensive breeding programmes. Also, these cultivars must be characterized for high productivity, early maturity, disease resistance and good seed quality as well as satisfy the high requirements of mechanical harvesting, which is a new challenge in chickpea breeding.

There have been some success stories of farmers who have adopted mechanical cultivars in India. These farmers have noted an increased productivity, higher-quality yields, and reduced labor costs. One such success story is that of Jitendra Singh, a farmer in Uttar Pradesh. Singh adopted a mechanical cultivar for chickpea harvesting and reported a 40% increase in productivity and a 30% reduction in labor costs. He also reported an improvement in the quality of yields, with fewer damaged pods and more uniform seeds. Another success story is that of Ramesh Kumar, a farmer in Haryana. Kumar adopted a mechanical cultivar for chickpea harvesting and reported a 50% increase in productivity and a 40% reduction in labor costs. He also reported an improvement in the quality of yields, with more uniform seeds and fewer damaged pods. As a result, there has been an increasing demand for mechanical cultivars that can revolutionize the chickpea harvesting process. The farmers are demanding chickpea cultivars that can be directly harvested by combine harvesters. With continuously increasing labour costs, manual harvesting has become an expensive field operation for any crop in India and farmers are increasingly opting for mechanization wherever it is feasible. Also, untimely availability of labour causes delays in harvesting which can result in yield losses through pod drop and shattering, wherein seed quality also deteriorates. Chickpea is harvested by hand in India as the existing chickpea cultivars are not suitable for mechanical harvesting because of inadequate plant height, semi-spreading growth habit and lower height of the first pod. This necessitates the development of cultivars suited to mechanical harvesting.

In recent years, researchers and agricultural experts have been working tirelessly to develop and test new technologies and cultivars by which farmers can automate the harvesting process, reduce costs, and increase productivity. The first machine-harvestable chickpea variety NBeG 47 was developed by ANGRAU, Andhra Pradesh with the collaboration of ICRISAT, Hyderabad in 2016 (Source: ICRISAT). This search for mechanical cultivars has the potential to transform the chickpea farming industry in India, making it more efficient, profitable, and sustainable.

It is important that future research focuses on understanding the nature and strength of the relationship between yield and its components, which will improve the efficiency of genetic selection in plant breeding programs. Associating and studying how the traits related to mechanical harvesting such as plant height or first pod height affect the grain yield, gives us insights into how they can be used further for developing cultivars.

Mahalanobis's D^2 Statistic is a very sensitive tool for measuring genetic divergence based on quantitative traits and is widely used by many geneticists and breeders for selecting divergent parents for hybridization aiming at yield improvement in chickpea.

The decision-making process includes identifying the desired characters that need to be improved and understanding the inheritance and gene action of the traits under consideration. The inheritance of characters ranges from being controlled by one major gene whose expression is not influenced by the environment (qualitative characters) to being controlled by many genes whose expression is more influenced by the environment (quantitative characters). Since the information on these aspects is lacking, the present investigation is designed to understand the genetics of traits suitable for mechanical harvesting and to develop a potential breeding population for traits related to mechanical harvesting. The present investigation will be carried out bearing into account the aforementioned viewpoints, with the following objectives:

Objectives of Investigation:

1. To evaluate the genetic variability for different traits in available chickpea genotypes.
2. To estimate associations among yield-related traits using correlation and path coefficient analysis.
3. To perform D^2 analysis to assess the difference among the genotypes suitable for machine harvesting.

CHAPTER II

REVIEW OF LITERATURE

Literature authored by various scientists and researchers that is available for the research titled "Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (*Cicer arietinum* L.)." has been discussed below under the following headers:

Literature Review

2.1 Overview of Chickpea Production and Harvesting Methods

2.2 Genetic Variability in Chickpea and Yield Traits

2.3 Correlation and Path Coefficient Analysis in Chickpea

2.4 D^2 Analysis for Genotype Clustering

2.1 Overview of Chickpea Production and Harvesting Methods

Harvesting chickpeas is often done by hand. The plants are gathered at one location after being dug up from the ground and then threshed. Because the plants are small and semi prostrate, combine harvesters are rarely used to harvest chickpeas. The development of tall and upright plants may make it possible to harvest chickpeas with combined harvesters.

Saxena *et al.,* (1987) found that yield losses due to mechanical harvesting using a plot combine for end winter- (early spring-) sown chickpea were 29 per cent in ILC 482, a cultivar of conventional plant height, compared with no seed yield loss in ILC 3279, a tall cultivar.

Mundinamani and Laxmi (2014) in their study reported that the chickpea variety Annigeri-1 was found to be not suitable for machine harvesting by some farmers. Also, there was scattering of pods due to high temperature and damage/split of grains. The major constraints in adoption of mechanical harvesting of chickpea were non-availability of suitable chickpea varieties (85–86 %) and machines (81–90 %). Efforts should be made to popularize the erect type of chickpea varieties among farmers of the state.

Gupta *et al.,* (2015) indicated that most of the genotypes were suitable for mechanical harvesting as they possess tall plant height, erect growth habit, acceptable branch angle (70-80 0) and first pod height (>30cm). However, based on seed yield potential five genotypes namely GL12021 (2313 kg/ha), GL13016 (2204 kg/ha), ICCV13604 (2146 kg/ha), ICEL3 (1713 kg/ha) and ICCV11605 (1638 kg/ha) were identified as promising genotypes.

Joshi (2017) identified Lines possessing first pod above 20cm from soil surface with erect and semi erect plant and yield from 2000 to 2500kg/ha. Only 159 genotypes with erect and semi erect plant type growth habit were identified from 5300 lines and they were further evaluated for yield traits and suitability to mechanical harvesting as per standard procedure in 2015-16. Best 159 tall lines were evaluated for yield and yield contributing traits with standard check varieties. The most suitable lines for mechanical harvesting were identified were SAGBL 8102, SAGBL 1439, SAGBL1440, SAGBL1447, SAGBL1448 and SAGBL1449 from Sehore breeding lines. These lines will be taken for further study in investigation.

Mannur *et al.,* (2017), revealed significant difference between genotypes for all traits *viz.,* plant height, plant height from bottom to first pod bearing length, primary branches, 43 number of pods, grain yield per plant, 100-seeded weight and net plot yield in all the three locations indicating presence of genetic variability among the genotypes. Among the genotypes RCBM-3 ranked top for most of the traits and showed maximum height, thus the genotypes with high heritability for plant height is suitable for mechanical harvesting.

Vishnu *et al.,* (2018) found promising genotypes with suitable traits for mechanical harvesting besides having yield advantage are 'NBeG 780', 'NBeG 857', 'NBeG 47', 'NBeG 863' and 'BG 3061' of cluster I under rainfed and cluster II under irrigated, 'GBM 2' of cluster II in rainfed and cluster I in irrigated, 'ICCL 85213' and 'NBeG 865' of cluster III under rainfed, 'DBGV 3104' of cluster I under rainfed and 'GL 12021' of cluster V under both rainfed and irrigated are suggested for utilization in the crossing programs to breed varieties of chickpea for high yield with amenability to combine harvesting.

Basha *et al.,* (2020) indicated Chickpea varieties GBM2, Dheera and BRC1 were best suitable for mechanical harvesting and higher seed yield due to their excellent morphology.

Madhuri *et al.,* (2020) conducted a study to determine high yielding mechanical harvestable genotypes in rainfed and irrigated conditions and found

NBeG 776, NBeG 779 and NBeG 868 are suitable under both rainfed and irrigated conditions with significantly higher yields over their respective means. ICCV 181606, MH 13 and MH 14 are suitable exclusively for rainfed condition with significantly superior yields over the mean. ICCV 181607 that produced high yield along with machine harvestable traits should be deployed in breeding programmes planned to improve yield as well as machine harvest ability.

Singh *et al.,* (2020) concluded that high density planting of cv. HC 5 could increase the productivity as well as improve plant architecture for machine harvesting but not for semi spreading cultivar JAKI 9218. High density planting of cv. HC 5 resulted in erect plants and increased ground clearance (>30 cm), as essential prerequisite for mechanical harvesting. Hence, chickpea cv. HC 5 requires a dense planting for higher yield and appropriate plant structure for mechanical harvesting. To this end, it is highly recommended to work out the yield potential of the cultivars bred for mechanical harvesting with optimum planting geometry.

Patil *et al.,* (2021) analyzed variations among five genotypes (ICCV-11601, ICCV11602, ICCV-11603, ICCV-11604 and JG-11) for dry matter production, partitioning, and yields in response to planting densities (33.3 to 46.6 plants m^{-2}). the tall genotype ICCV11604 × 46.6 plants m^{-2} interaction recorded higher seed yield (2840 kg ha^{-1}) than JG-11 × normal density of 33.3 plants m^{-2} (2666 kg ha^{-2}).

The increase in planting density could compensate for the yield reduction in tall chickpea genotypes and facilitate mechanical harvesting to reduce the drudgery on scarce labour and save time and cost.

2.2 Genetic Variability in Chickpea and Yield Traits

2.2.1 Phenotypic and Genotypic coefficients of variation

2.2.2 Heritability

2.2.3 Genetic advance

2.2.1 Phenotypic and Genotypic coefficients of variation

Joshi *et al.,* (2018) experimented on 252 lines of RIL population. Seed yield per plant, biological yield, 100 seed weight and harvest index noted a high GCV and PCV estimates.

Vishnu *et al.,* (2018) analysis on chickpea cultivars under rain fed and irrigated conditions showed low PCV and GCV estimates for angle of primary 9 branch and moderate PCV and GCV for 1st pod height whereas plant height showed moderate PCV and low GCV in both the conditions.

Kumar *et al.,* (2019) High PCV and GCV were observed for effective pods per plant (36.41% and 34.38%) followed by total number of pods per plant (34.85% and 32.70%) and seed index (29.98% and 29.78%) indicated large extent of genetic variability for these traits in the material.

Jain *et al.,* (2020) revealed significant wide genetic variation for almost all the quantitative traits. Number of pods per plant exhibited highest PCV and GCV.

Jayalakshmi *et al.,* (2020) divulged that 1st pod height exhibited moderate PCV and GCV while the same parameters are low for angle of primary branch.

Yadav *et al.,* (2020) High genotypic and phenotypic coefficients of variability were observed for plant height, leaf length, leaflet length, width of leaflet, number of primary branches per plant, number of secondary branches per plant, number of pods per plant, pod length, pod width, 100-seed weight and seed yield per plant. The differences between genotypic and phenotypic coefficient of variability was very small in all these traits indicating negligible role of environment. The characters, which showed poor estimates for PCV and GCV were days to maturity, days to 50% flowering, number of leaflets per leaf and seeds per pod.

Gautam *et al.,* (2021) assessed thirteen different yield and its contributing characters and the obtained results indicated that in general the phenotypic coefficient of variance was found to be higher as compared to genotypic coefficient of variance for all studied traits.

Bukke *et al.,* (2022) revealed Plant height, number of main and secondary branches, days to 50% flowering, days to maturity, number of pods per plant, and 100 seed weight provided the highest GCV and PCV values in the experiment.

Nimita Kandwal *et al.,* (2022) evaluated the phenotypic and genotypic coefficients of variation for yield-related traits in a set of diverse chickpea genotypes. The study reported, the number of secondary branches per plant, the number of pods and seeds per plant, the number of seeds per plant and the number of seeds produced per plant all showed higher PCV than GCV. A higher PCV than GCV was seen in the number of seeds per pod, seed yield, biological yield, and number of pods per plant.

2.2.2 Heritability

Biru *et al.,* (2017) reported value of more than 80% for broad sense heritability for 100 seed weight.

Ton *et al.,* (2017) in their assay reckoned that no. of primary branches and secondary branches per plant, 100-seed weight and harvest index showed high heritability.

Banik *et al.,* (2018) showed high values of broad sense heritability complemented by high genetic advance as per cent of mean for number of pods per plant, days to 50 per cent flowering, 100 seed weight, plant height demonstrating that these traits could be prominently reigned by additive gene action.

Joshi *et al.,* (2018) high estimates of heritability in broad sense were observed for days to 50% flowering, days to maturity, plant height, biological yield per plant, seed yield per plant and harvest index per plant and 100-seed weight studied. Findings also showed high heritability with high variation for pods per plant, seed yield per plant, 100-seed weight, days to 50% flowering, days to pod initiation and plant height.

Aswathi *et al*., (2019) analysis and results on variability studies showed high heritability coupled with GA as percent of mean for single plant yield, 100 seed weight, number of secondary branches, number of pods per plant and height of first pod.

Tamvar *et al.,* (2019) heritability was high for protein content (89.1 %), followed by 100-seed weight (81.88 %), seed yield per plant (79.82 %), number of secondary branches per plant (78.96 %), height at first pod (75.77 %) and days to 50 % flowering (60.00 %). Similarly, low estimation of heritability value was recorded for days to maturity (19.80 %) and harvest index (12.8 %) whereas the remaining traits showed moderate heritability values which indicated that total variability was due to genetic causes as well as due to environment.

Chaudhary *et al.,* (2020) High heritability observed for grain yield per plant, number of pods per plant, biological yield per plant, 100 seed weight, harvest index, number of seeds per pod and plant height. While moderate heritability observed for days to 50% flowering and days to maturity, rendering them unsuitable for improvement through simple selection due to prevalence of non-additive gene action.

Biswal *et al.,*(2021) The estimates of high heritability (broad sense) was observed for 100-seed weight (91.9 %) followed by number of seeds per pod (86.6%), days to 50% flowering (86.3%), harvest index (86.1%), biological yield per plant (85.2%), number of effective pods per plant (84.4%), seed yield per plant (83.4%), total number of pods per plant (80.5 %), days to flower initiation (78.8%) and days to pod initiation (72.2%), plant height (66.9%) and number of secondary branches per plant (63.9%).

On the other hand, number of primary branches per plant (55.1%) and days to maturity (51.8%) exhibited medium heritability.

2.2.3 Genetic advance

Biru *et al.,* (2017) results show that traits such as 100 seed weight, no. of pods per plant, no. of seeds/pod and grain yield showed high heritability coalesced with high genetic advance as percent of mean.

Chopdar *et al.,* (2017) Recorded traits, primary branches per plant, number of seeds per pod and protein content with moderate to low heritability coupled with low genetic advance appear to be more affected by on non-additive gene action.

Aswathi *et al.,* (2019) observed that genetic advance as percent of mean was high for characters like single plant yield, 100 seed weight, number of secondary branches, number of pods per plant, number of seeds per plant, height of first pod.

Chaudhary *et al.,* (2020) high genetic advance observed for grain yield per plant, number of pods per plant, biological yield per plant, 100 seed weight, harvest index, number of seeds per pod and plant height.

Biswal *et al.,* (2021) High genetic advance as percentage of mean was noted for biological yield per plant (37.6%) followed by number of effective pods per plant (32.1%), number of seeds per pod (28.4%), total number of pods per plant (27.4%) and seed yield per plant (24.6%).

Bharathi *et al.,* (2022) observed that genetic advance as percent of mean recorded higher value in seed yield per plant.

2.3 Correlation and Path Coefficient Analysis in Chickpea

2.3.1Correlation coefficient analysis.

2.3.2 Path analysis.

2.3.1 Correlation coefficient analysis

Jayalakshmi *et al.,* (2020) remarked that plant height and 1st pod height exhibited a strong positive association between each other and with shoot biomass

Konduru *et al.,* (2021) found that the traits seed index, harvest index exhibited highly positive phenotypic and genotypic correlation for seed yield.

Meena *et al.,* (2021) manifested that seed yield per plant expressed highly significant positive correlation along with biological yield per plant, number of seeds per pod, number of pods per plant, harvest index and number of branches per plant.

Kamani *et al.,* (2022) results clearly showed the seed yield per plant showed positive and significant correlation with biological yield followed by harvest index, days to pod setting, number of seeds per plant and number of pods per plant, whereas seed yield per plant exhibited positive non-significant correlation with number of secondary branches.

Kandwal *et al.,* (2022) found days to maturity indicated a significant and positive correlation with seed yield and a substantial negative association was found for the quantity of seeds per pod.

Paul *et al.,* (2022) observed that the 100 seed weight showed high significant positive correlation with plant height and a significant negative correlation with no of seeds per pod.

Tengse SM *et al.,* (2022) Correlation studies showed that the traits *viz.* harvest index, 100 seed weight, number of pods per plant and number of secondary branches per plant recorded a highly positive significant correlation with seed yield at both genotypic and phenotypic level and days to 50% flowering at genotypic level with seed yield.

Ningwal *et al.,* (2023) revealed that seed yield per plant was positively and significantly correlated with biological yield, number of secondary branches per plant and number of pods per plant.

Tare *et al.,* (2023) noticed significant and positively associated with number of pods per plant, number of seeds per plant, biological yield per plant, harvest index, hundred seed weight and pollen fertility in all the environmental conditions.

2.3.2 Path analysis

Agrawal *et al.* (2018) Path analysis revealed that biological yield, effective pods per plant, harvest index, primary branches per plant and secondary branches per plant had high positive direct effect on grain yield per plant under normal condition while, chlorophyll index, effective pods per plant and 100 -seed weight would be quite effective in improving chickpea under late condition.

Babbar *et al.,* (2015) analysis by path analysis for understanding factors influencing seed yield revealed that flower initiation, biological yield and number of secondary branches have high positive and direct effect on seed yield per plant while a negative direct effect is exhibited on the same characters by harvest index and flower initiation while plant height and number of primary branches had indirect positive effects on harvest index.

Erdemci *et al.,* (2016) analysis by path coefficient analysis showed that the effects of no. of pods per plant and plant height on seed yield per plant is direct, positive and highest in magnitude compared to other traits. However, plant height and no. of primary branches per plant exhibited highest indirect effect on seed yield/plant through no. of pods per plant.

Chopdar *et al.,* (2017) Path coefficient analysis revealed that days to maturity, primary branches per plant, biomass per plant, harvest index, protein content and number of seeds per pod were major characters influencing seed yield directly and indirectly.

Agrawal *et al.,* (2018) Path analysis revealed that revealed that biological yield, effective pods per plant, harvest index, primary branches per plant and secondary branches per plant had high positive direct effect on grain yield per plant under normal condition while, chlorophyll index, effective pods per plant and 100-seed weight would be quite effective in improving chickpea under late condition.

Kerketta *et al.,* (2018) observed that biological yield had direct and high positive effect on seed yield per plant at both genotypic and phenotypic levels from which it can be surmised that the aforementioned character can be used as an effectual parameter for direct selection in yield improvement programs.

Chaudhary *et al.,* (2020) Path coefficient analysis revealed that among the various traits studied, biological yield per plant had high positive direct effect followed by harvest index at both genotypic and phenotypic levels on grain yield per plant. This indicated that biological yield per plant and harvest index are most important characters in influencing grain yield per plant.

Biswal *et al.,* (2021) Genotypic path coefficient exhibited that the highest positive direct effect on seed yield per plant was found by days to flower initiation followed by biological yield per plant, number of effective pod per plant and days to pod initiation.

Tengse *et al.,* (2022) conclude that from path coefficient analysis it is indicated that the characters *viz.,* 100 seed weight, harvest index, number of pods per plant, days to 50% flowering and number of secondary branches per plant showed a positive direct effect on seed yield.

Singh *et al.,* (2023) Biological yield per plant (g) and the Harvest index were found to be significant direct components of seed yield per plant by path analysis.

2.4 D^2 Analysis for Genotype Clustering

Babbar *et al.,* (2015) grouped their 31 chickpea genotypes into 13 clusters with the aid of Mahalanobi's D^2 statistics. Cluster IX exhibited high cluster mean of 51.07 cm for plant height (cm), while cluster X showed a high mean of 22.93 g for seed yield per plant.

Geethanjali *et al.,* (2018) conducted an experiment to analyse the genetic diversity. The analysis resulted in genotypes being grouped into five clusters where, maximum diversity is contributed by 100-seed weight.

Mahmood *et al.,* (2018) evaluated 15 genotypes and have grouped them into 3 clusters on the basis of similarity of characters by cluster analysis. Based on the distance between clusters, the dendrogram depicted that members of clusters I and III are the most diverse and cluster I exhibited higher values for plant height and 50% flowering while cluster II expressed higher values for days to 90% maturity and cluster III showed higher values for pods per plant, harvest index and seed yield.

Vishnu *et al.,* (2018) observed Inter cluster average D^2 values stretched between 7.42 and 20.11 under rain fed condition, while it was slightly higher and varied from 8.64 to 28 under irrigated condition. The most divergent clusters were IV and V under both the situations.

Dasari *et al.,* (2022) found that D^2 values showed adequate genetic diversity among the genotypes studied. Maximum number of genotypes was grouped into cluster II which included 13 genotypes. The cluster II, IV and VIII were found more diverse to each other.

Kamani *et al.,* (2022) by cluster mean revealed high variability among the clusters for the traits, plant height, days to maturity, days to 50 percent flowering, biological yield, seed yield per plant, number of pods per plant.

Kumar *et al.,* (2022) based on D^2 analysis 53 chickpea genotypes were grouped into seven clusters. Among the VII clusters, cluster I consists of 30 genotypes forming the largest cluster followed by cluster II with 16 genotypes, cluster VII with three genotypes and cluster III, IV, V and VI with one genotype each. Inter cluster distance were found to higher than intra cluster distance.

Saxena *et al.,* (2023) experimented with Ninetynine genotypes were grouped into ten clusters. Maximum inter cluster distance was observed between clusters VI and IX; VI and VII and IV and VI. The genotypes of these clusters are suggested for utilization in the crossing programs to breed varieties of chickpea for high yield with amenability to nutrients

Vikram *et al.,* (2023) observed 64 genotypes that were grouped into six clusters. Maximum inter cluster distance was found between cluster IV and cluster V followed by Cluster II and Cluster IV. Maximum intra cluster distance was observed within cluster IV followed by Cluster V.

CHAPTER III

MATERIALS AND METHODS

The present investigation **"Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (*Cicer arietinum* L.)."** was carried out during 2022-23 at field of All India Coordinated Research Project on Chickpea, R.A.K. College of Agriculture, Sehore (M.P.).

3.1 Experimental site:

The experiment was conducted at the experimental site of the All-India Coordinated Research Project on Chickpeas at R.A.K. College of Agriculture, Sehore (M.P.). Geographically, Sehore is situated at $27^{0}12$ north latitude and $77^{0}0$ east longitude at an altitude of 498.77 meters from mean sea level in the Vindhya Plateau of Madhya Pradesh.

Plate 3.1 Experimental site R. A. K. College of agriculture, Sehore M.P.

3.2 Experimental soil

The soil texture in the field was clay loam vertisol with 52% clay, 41.3% silt, and 6.6% sand, with a pH range from 7.2 to 7.8. Available nitrogen (N), phosphorus (P), and potassium (K) levels were low in the soil.

3.3 Climate and Season

The mean yearly rainfall varies from 1000 to 1200 mm and is mostly occur from June to September. The weather conditions prevailing during the period of crop growth (*rabi* season of 2022-23) are presented in Table 3.1 and depicted in Fig. 3.1.

3.4 Experimental material:

The base material for current research comprised of 55 genetically diverse genotypes of chickpeas obtained from a voluntary center, all India coordinated research project (AICRP) on chickpeas, R. A. K. College of Agriculture, Sehore given in table 3.2.

Table 3.1 -: Meteorological data during the crop season of 2022-23 at R.A.K. College of Agriculture, Sehore (M.P.)

Month	Standard Week	Week	Temperature (^0C)		Rainfall in mm	No. of rainy days
			MAX	MIN		
Nov.	45.00	07 Nov – 13 Nov	31.91	14.93	0.00	0.00
	46.00	14 Nov – 20 Nov	28.10	10.77	0.00	0.00
	47.00	21 Nov – 27 Nov	26.61	8.39	0.00	0.00
	48.00	28 Nov – 04 Dec	13.86	27.27	0.00	0.00
	Average		**25.12**	**15.34**		
Dec.	49.00	05 Dec – 11 Dec	26.00	9.91	0.00	0.00
	50.00	12 Dec-18 Dec	25.59	14.39	5.60	1.00
	51.00	19 Dec – 25 Dec	26.91	10.77	0.00	0.00
	52.00	26 Dec – 01 Jan	24.56	9.27	0.00	0.00
	Average		**25.76**	**11.09**		
Jan.	1.00	02 Jan – 08 Jan	20.44	6.06	0.00	0.00
	2.00	09 Jan – 15 Jan	24.30	5.76	0.00	0.00
	3.00	16 Jan – 22 Jan	23.11	8.59	0.00	0.00
	4.00	23 Jan – 29 Jan	26.73	14.46	2.60	1.00
	5.00	30 Jan – 05 Feb	25.71	7.74	0.00	0.00
	Average		**24.06**	**8.52**		
Feb.	6.00	06 Feb – 12 Feb	29.50	9.81	0.00	0.00
	7.00	13 Feb – 19 Feb	29.03	8.69	0.00	0.00
	8.00	20 Feb – 26 Feb	33.24	11.17	0.00	0.00
	9.00	27 Feb – 05 Mar	34.46	15.63	0.00	0.00
	Average		**31.56**	**11.33**		
March	10.00	06 Mar – 12 Mar	30.50	13.53	7.65	2.00
	11.00	13 Mar – 19 Mar	33.04	16.71	3.65	2.00
	12.00	20 Mar – 26 Mar	32.19	16.59	0.00	0.00
	13.00	27 Mar – 02 Apr	35.11	18.16	0.00	0.00
	Average		**32.71**	**16.25**		

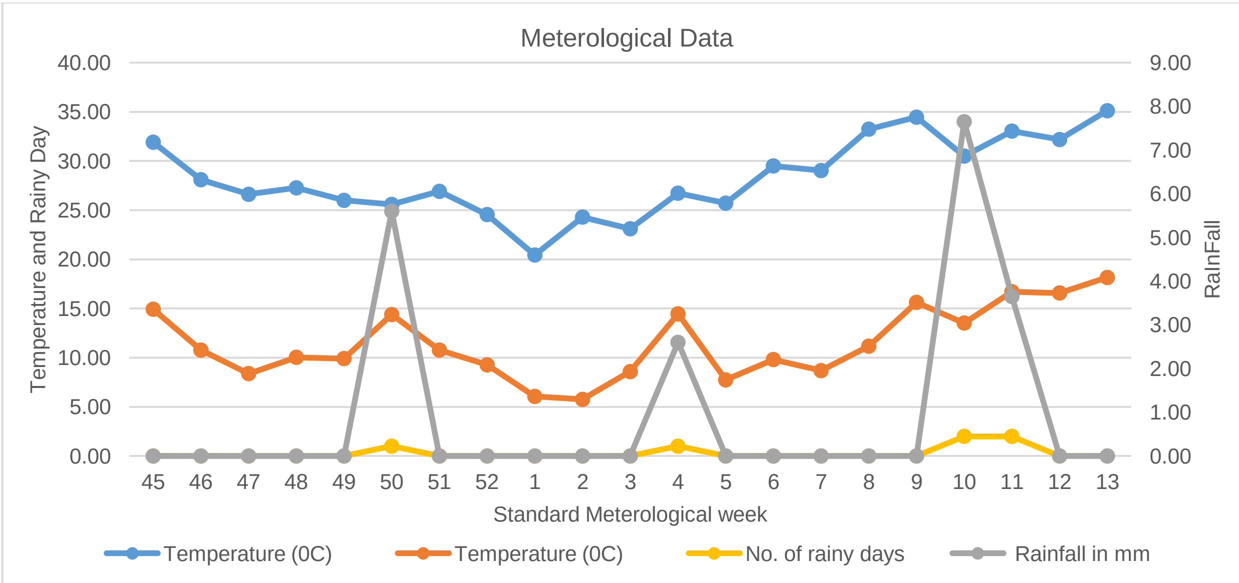

Fig 3.1-: Meteorological data during the crop season November to March, 2022-23 at R.A.K. College of Agriculture, Sehore (M.P.)

3.5 Experimental design and layout

A total of 55 genotypes were estimated for traits related to mechanical harvesting in a randomized block design with three replications under field conditions. Each entry was planted in a plot of four rows with an intra-row spacing of 22.5 cm and inter-row spacing of 7 cm. The crop was raised under rainfed conditions, and all recommended practices were followed to grow the crop. The genotypes used in this study are listed in Table 3.2.

3.6 Experimental detail:

Season	Rabi, 2022-23
Experimental Design	R.B.D. (Randomization Block Design)
Number of genotypes	55
Replications	03
Row length	4.0 m
Row to row distance	22.5 cm
Plant to plant distance	7 cm

3.7 Observations Recorded

Qualitative and quantitative observations were documented as indicated in the chickpea manual.

3.7.1. Early Plant Vigour

It was evaluated at the seedling stage at 30 days after sowing. Genotypes were categorized as, poor, medium and good.

3.7.2 Plant Growth Habit

It was recorded after completion of vegetative stage. On the basis of plant growth habit, the genotypes were classified into five categories *viz.,* 1. Erect ($0-15^{o}$from vertical), 2. Semi-erect ($16^{0}-45^{o}$ from vertical) 3. Semi Spreading ($46^{0}-60^{0}$) 4. Spreading ($60^{0}-80^{0}$) 5. Prostrate ($>80^{0}$) according to the DUS descriptor of chickpea at the stage of 50% plants with one open flower.

A B C

Plate no: 3.2 Showing variation based on plant growth habit. A. Erect, B. Semi erect and C. Spreading.

Table 3.2 List of the genotypes used in variability, correlation and diversity studies for the traits related to mechanical harvesting, yield and yield attributing traits in chickpea.

S.NO	ENTRY NAME
1	C-22925
2	C-22928
3	C-22929
4	C-22930
5	C-22931
6	C-22933
7	C-22934
8	C-22935
9	C-22936
10	C-22937
11	C-22938
12	C-22939
13	C-22940
14	C-22944
15	C-22945
16	C-22946
17	C-22947
18	C-22948
19	C-22949
20	C-22950
21	C-22952
22	C-22955
23	C-22956
24	C-22957
25	C-22958
26	C-22959
27	C-22960
28	C-22961
29	C-22962
30	C-22963
31	C-22964
32	C-22967
33	C-22968
34	C-22969
35	C-22970
36	C-22971
37	C-22972
38	C-22973
39	C-22974
40	C-22975
41	C-22976
42	C-22977
43	C-22978
44	C-22979
45	C-22980
46	C-22981
47	C-22982
48	RVG 204
49	RVSSG 96
50	RVSSG74
51	RVG205
52	RVG 202
53	RVSSG 68
54	RVKG 111
55	RVKG 121

3.7.3 Days to 50 Percent Flowering

Number of day bagged from sowing to the stage where 50 percent of plants have been to flower.

3.7.4 Days to Maturity

Number of day taken from sowing to the stage was over 90 per cent of pods have maturated and turned yellow.

3.7.5 Plant Height (cm)

The height of the plant was documented in cm from the ground level to the tip of main stem at the time of maturity.

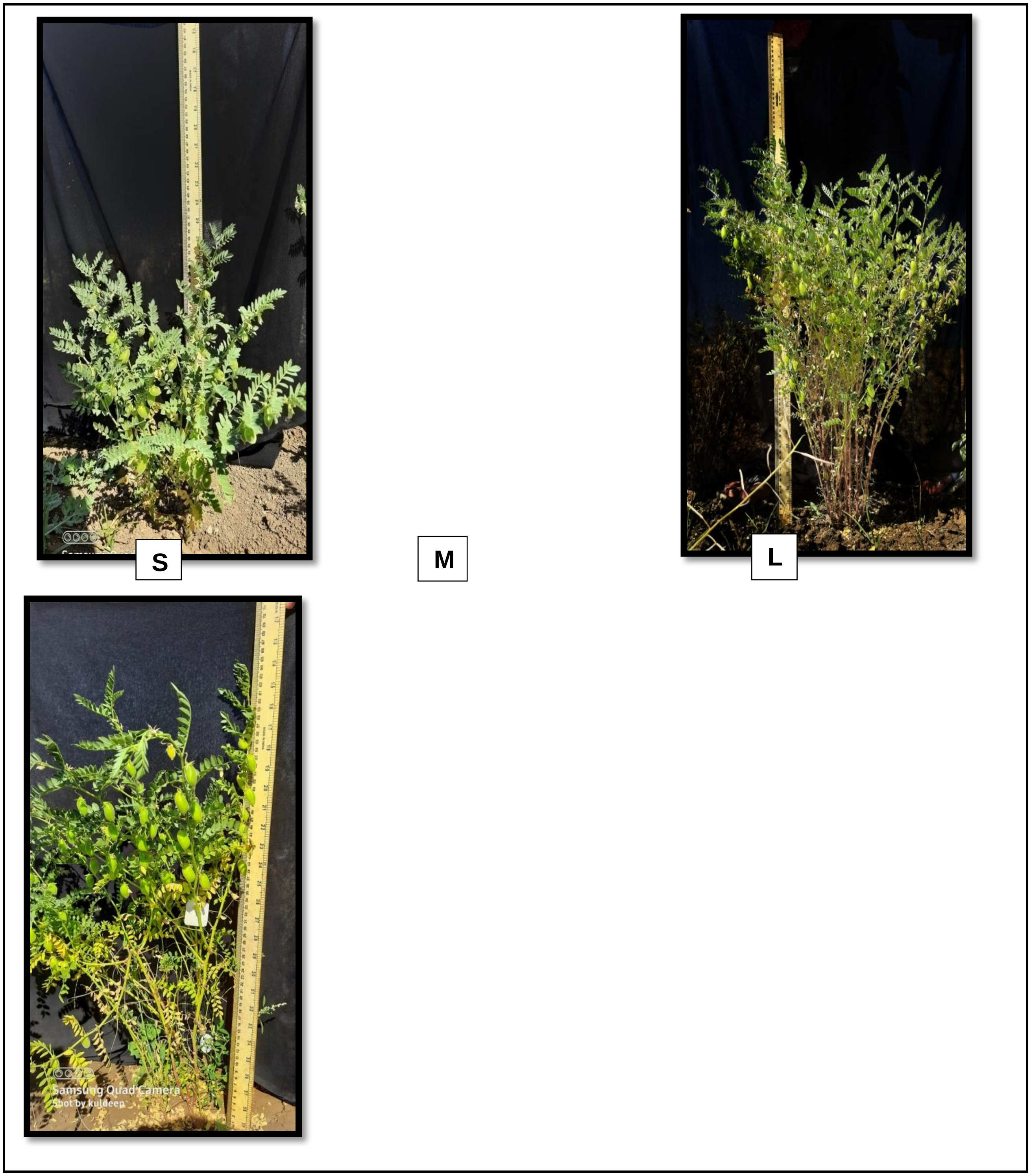

Plate no: 3.3 Showing variations based on plant height Short, medium and long

3.7.6 Height of First Pod from Soil Surface (cm)

The height of first pod from soil surface was noted above cm from the ground level at the time of maturity

3.7.7 Pods per Plants

The number of effective pods of 3 representative plants from each particular plot were counted and averaged.

3.7.8 Seeds per Plant

The number of seeds of all effective pods of 3 selected plants were counted and averaged.

3.7.9 100 Seed Weight (g)

After threshing and proper drying (air-dry), the seed index was recorded at 10% moisture content by weighing 100 seeds in grams.

3.7.10 Biological Yield per Plant (g)

The total dry weight of hand-pulled plants from each genotype was recorded after harvest and measured in grams per plant.

3.7.11 Seed Yield Per Plant (g)

The seed yield per plant was recorded from each selected plant after harvest and measured in grams.

3.7.12 Harvest Index (%)

The value of harvest index was obtained by dividing the total seed yield by biological yield and expressed in percentage.

3.8 Statistical Analysis

Analysis of Variance

Analysis of variance (ANOVA) for individual character was carried out on the basis of mean value per entry per replication as suggested for Randomized Block Design (RBD).

The model of analysis of variance is as given below.

Sources	df	SS	MSS	F-ratio
Replication	r-1	RSS	M_r	M_r/E
Genotype	t-1	Treatment SS	M_t	M_t/E
Error	(r-1)(t-1)	Error SS	E	
Total	(rt-1)	Total SS		

Where

r = number of replications

t = number of genotypes

Significance of the treatments was tested at 5 and 1 per cent level of probability.

Genetic Analysis

The mean, range, component of variance, genotypic and phenotypic coefficient of variation and heritability in broad sense, genetic advance were calculated as per procedure mentioned below. (Singh and Choudhary, 1985).

3.8.1. Mean

$$\bar{X} = \frac{\Sigma X}{N}$$

Where,

$\bar{X}$ = simple mean

ΣX = summation of all observation

N = number of observations

3.8.2. Range

It was the range of lowest and highest values of each trait taken in the observation.

$$R = X_{max} - X_{min}$$

3.8.3. Genotypic Variance

$$\text{Genotypic variance } (\sigma^2 g) = \frac{MSSg - MSSe}{r}$$

Where,

MSSg = mean square due to genotypes

MSSe = mean square due to error

r = number of replication

3.8.4. Phenotypic Variance

Phenotypic variance (σ^2p) = (σ^2g) + (σ^2e)

Where,

(σ^2g) = Genotypic variance

(σ^2e) = Environmental variance

3.8.5. Estimation of Genotypic and Phenotypic Coefficient of Variation

It was calculated by using the following formula

$$GCV = \frac{\sqrt{\sigma^2 g}}{\bar{X}} \times 100$$

Where,

GCV = Genotypic coefficient of variation

$\sigma^2 g$ = Genotypic variance

x = General mean of the characters.

$$PCV = \frac{\sqrt{\sigma^2 p}}{\bar{x}} \times 100$$

Where,

PCV = Phenotypic coefficient of variation

$\sigma^2 p$ = Phenotypic variance

x = General mean of the characters.

The PCV and GCV values are ranked as low, medium and high are mentioned below:

0-10% - Low

10-20% - Medium

>20% - High

3.8.6. Estimation of Heritability and Genetic Advance:

Heritability in percent in broad sense was calculated by the procedure suggested by Allard (1960) and outline by the following formula given by Singh and Choudhary (1977).

$$\text{Heritability \% } (h^2) \; \frac{\textit{Genotypic variance}}{\textit{Phenotypic variance}} \times 100 =$$

Heritability values are categorized on the basis of range of percentage as low, moderate and high (Robinson *et.al.* 1949) and are given below.

(h^2) <50% - Low

(h2) 50-70% - Moderate

(h^2) >70% and above - High

The estimates of expected genetic advance from selection, G(s), was obtained by Dewey and Lu (1959) and formula suggested by Robinson *et.al.* (1949).

$$G(s) = k\, h^2\, \sigma p$$

Where,

k = selection differential in standard deviation units which is 2.06 for 5% selection intensity

h^2 = heritability in broad sense, and

σp = phenotypic standard deviation

Genetic advance was expressed as percentage of mean by using the formula suggested by Johnson *et.al*. (1955).

Genetic advance as percentage of mean $\frac{Genetic\ advance}{grand\ mean} \times 100$ =

Genetic advance as percentage of mean was classified as low, moderate and high (Johnson *et.al*. 1955) and values are given below

GA% of mean	<25%	- Low
GA% of mean	25-35%	- Moderate
GA% of mean	>35% and above	- High

3.8.7 Estimation of correlation coefficients

Correlation analysis measures the degree and direction of association between two or more variables. It estimates the mutual relationships between the various plant character pairs and determines the component character based on which the selection is based for yield improvement. Simple correlation is the association between two variables and it is estimated by the following formula,

$$\mathbf{r_{xy}} = \frac{\boldsymbol{Cov.}(\boldsymbol{xy})}{\sqrt{(\boldsymbol{Var.xX\,Var.y})}}$$

Where,

r_{xy} = Correlation coefficient between characters x and y

Cov. (xy) = Covariance between characters x and y.

Var. (x) = Variance for character x.

Var. (y) = Variance for character y.

Correlation coefficients were calculated at phenotypic and genotypic level using the formulae suggested by Falconer (1964).

Phenotypic coefficient of correlation (rp) = r (X_i. X_j) p = $\frac{\boldsymbol{Cov.(Xi.Xj)p}}{\sqrt{\boldsymbol{V(Xi)p.V(Xj)p}}}$

Where,

r (X_i. X_j) p is phenotypic correlation between i^{th} and j^{th} characters

Cov. (X_i. X_j) p is phenotypic covariance between i^{th} and j^{th} characters

V (X_i) p is phenotypic variance of i^{th} character

V (X_j) p is phenotypic variance of j^{th} character

Testing significance of correlation coefficient

The phenotypic correlations are tested for their significance by the following formula on t-test

$$t_{(Cal)} = \frac{|r|}{\sqrt{1-r^2}} \cdot \sqrt{n-2}$$

Where,

n = number of treatments

r = correlation coefficient

if $t_{(Cal)}$ is equals or greater than $t_{(tab)}$ at (n - 2) degrees of freedom value then it is significant at a given probability level. If the $t_{(Cal)}$ value is less than t tabulated value then it is non-significant

3.8.8 Path coefficient analysis

The indirect and direct effects at both the phenotypic and genotypic levels were measured by considering the seed yield per plant as a dependent variable, using path coefficient analysis, as proposed by Wright (1921) and Dewey and Lu (1959).

For estimating the different direct and indirect effects, the following equation were created and solved concurrently

$r_{1y} = P_{1y}.r_{11} + P_{2y}.r_{12} + P_{3y}.r_{13} + \ldots\ldots\ldots\ldots + P_{ny}.r_{1n}$

$r_{2y} = P_{1y}.r_{21} + P_{2y}.r_{22} + P_{3y}.r_{23} + \ldots\ldots\ldots\ldots + P_{ny}.r_{2n}$

$r_{ny} = P_{1y}.r_{n1} + P_{2y}.r_{n2} + P_{3y}.r_{n3} + \ldots\ldots\ldots\ldots + P_{ny}.r_{nn}$

Where,

1,2……..n = Independent variable

y = Dependent variable

$r_{1y}.r_{2y}\ldots..r_{ny}$ = Coefficient of correlation between casual factors ‘1’ to ‘n’ on dependent character

$P_{1y}, P_{2y}, \ldots\ldots. P_{ny}$ = Direct effect of characters ‘1’ to ‘n’ on the character ‘y’

Now the path coefficients are estimated as

$\mathbf{P}_{1y} = \sum i\ \mathbf{B}_{1i}\ \mathbf{r}_{iy}$, $\mathbf{P}_{2y} = \sum i\ \mathbf{B}_{2i}\ \mathbf{r}_{iy}$, etc.

The influence of the residual factor (z), which evaluates the contribution of remaining qualities that were not included in the route coefficient analysis, is calculated as follow;

$$P_{zy} = \sqrt{1 - R^2}$$

Where,

$R^2 = \sum i \; p^2{}_{iy} + \sum i \sum i < j \; P_{iyrij}$

R^2 is the coefficient of multiple determination.

3.8.10. Genetic Diversity

Genetic divergence was calculated as suggested by Mahalanobis (1928) as follows.

$$pD^2 = b_2d_2 + b_2d_2 + \ldots\ldots\ldots\ldots\ldots\ldots + bpdp$$

Where, the b_1 values are to be estimated such that the ratio of variance between the populations to the variance within the population is maximized. In terms of variance and covariance, the D^2 values is obtained as follows.

$$pD^2 = W_{ij} \, (\bar{x}\,1_i - \bar{x}\,2_i)\,(\bar{x}\,1_j - \bar{x}\,2_j)$$

Where,

W_{ij} = inverse of estimated variance covariance matrix.

Grouping of genotype into various clusters by canonical roots analysis:

In the analysis vectors or canonical roots were calculated to represent the varieties in the graphical from (Rao, 1952). The various steps are given below.

1. Calculate sum of square and sum of products.

The sum of square and sum of products were computed from Y values (Transformed mean values) for each character and each character combination.

2. Cluster Averages

The clusters were formed on the basis of the graph made by plotting the values of Z1 against Z2 and clusters were formed by making groups of genotypes that were very near with one another.

i). Average Intra Cluster Distances: The measure of intra cluster distance was calculated by using the formula

$$\Sigma D^2_i/n$$

Where $\Sigma Di^2/n$ was the sum of distance between all possible combinations (n) of the population included in a cluster.

ii). Average Inter-cluster Distances. The procedure for calculating the inter cluster distance was first to measure the distance between cluster I and II, between I and III and so on.

Similarly the distance between II and III, between II and IV and so on were taken. Thus the clusters are taken one by one and their distance from other clusters were calculated.

The average inter cluster distance was calculated by the formula given as

$$\Sigma D^2_{(i,j)} / (n_i . n_j)$$

Where,

$\Sigma D^2_{(i,j)}$ = the total sum of distance between the populations of cluster i and j.

n_i = number of population in cluster i.

n_j = number of population in cluster j.

CHAPTER IV

RESULTS

The analysis for the experiment titled "**Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea *(Cicer arietinum L.)***" have been conducted on 55 genotypes. Observations were recorded on randomly tagged three plants from each genotype in each replication. The presence of genetic variability is confirmed through analysis of variance (ANOVA). Genetic variability present in the material was analyzed through various genetic variability estimates such as PCV, GCV, h^2bs, and GAM. Correlation studies provided information on how the component variables affect the seed yield. Path analysis divides the correlation estimates into direct and indirect components, thus giving an idea on how the component traits affects the dependent trait. Cluster analysis grouped the genotypes into clusters based on their diversity. The results of the experiment are discussed below under the following headers:

4.1 Analysis of Variance
4.2 Genetic variability studies
4.3 Correlation analysis
4.4 Path coefficient analysis
4.5 Cluster analysis
4.6 Classification of genotypes based on plant vigour, plant growth habit and height of first pod.

4.1 Analysis of variance:

Analysis of variance showed significant values in the mean sum of squares for ten characters namely days to 50% flowering, days to maturity, height of first pod, plant height, number of pods per plant, biological yield, harvest index, hundred seed weight and seed yield. The presence of significant levels of variation implies the presence of variability in the observed characters. This variability can be tapped into and be used in further development of the genotypes. The ANOVA for all ten characters is encapsulated in table 4.1.

Table 4.1: Analysis of Variance for Seed Yield and its Contributing Character in Chickpea for mechanical harvesting.

Source of Variations	Degree of freedom	Day to flowering	Day to maturity	Plant height (cm)	Height of first pod	Number of Pod Per plant	Number of Seed Per Plant	Biological. Yield.	Harvesting index	100 Seed Weight	Seed Yield.
MEAN SUM OF SQUARE											
REPLICATION	2	1.33	13.79	8.66	0.487	82.93	160. 90	14.25	2.51	2.67	2.25
GENOTYPE	54	**38.71****	**35.46****	**195.84****	**98.56****	**1297.64****	**2064.60****	**552.86****	**172.38****	**43.15****	**116.95****
ERROR	108	1.809	4.94	2.03	1.571	33.71	47.24	4.45	16.12	2.08	1.116

**** = significant at 1% level of significance.**

***   = significant at 5% level of significance.**

4.2 Genetic variability:

Genetic variability is said to exist in a population when individual genetic traits in the said population have a proclivity to differ from each other. Any breeding effort must be built on this foundation. Estimating the said genetic diversity contained in a population may be done using a variety of approaches like range, genotypic and phenotypic coefficient of variations (GCV % and PCV %) and the probability of their transfer to the next generations through heritability analysis (h2bs) and GA%.

Genetic variability parameters were estimated for 10 quantitative traits *viz.,* days to 50% flowering, days to maturity, plant height (cm), height of first pod (cm), number of seeds per plant, number of pods per plant, biological yield(g), harvest index (%), hundred seed weight (g) and seed yield per plot (g).

4.2.1 Mean and Range: The mean and range values for the ten characters are encapsulated in tables 4.2.

Days to 50% flowering: The range of days to 50% flowering varied from the least being 63 days and the highest being 80 days with a mean value of 70 days. Among the 55 genotypes studied, two genotypes namely C-22974 and C-22956 had flowered at 63 days while C-22978 took 80 days, which is the highest among the studied genotypes.

Days to maturity: Days to maturity ranged from 113 days to 130 days with an average of 120 days.

Height of first pod: The lowest and highest height noted for 1^{st} pod height is 18.83 cm for C-22947 and 40.7 cm for RVSSG-96, respectively with the mean being 29.36 cm.

Plant height (cm): The tallest genotype among the study material recorded 76.6 cm (RVSSG-96) while the shortest genotypes recorded a height of 33.22 cm (C-22952) with a mean height of 56.00 cm.

Number of seeds per plant: The mean numbers of seeds per plant are 70.13 while the range lies between 14.66 to 131 seeds per plant.

Number of pods per plant: The lowest numbers of pods observed is for C-22934 with 11 pods per plant while the highest number was observed for C-22967 with 119 pods per plant with a mean value of 53 pods per plant.

Biological yield: The least biological yield observed is 8.88g for C-22934 while the highest observed is 72.44g for C-22969. Mean value for biological yield is 35.34 g.

Harvest Index: Harvest index ranged from a minimum of 23.16% for C-22969 to a highest of 57.04% for C-22980 averaging 43.28%.

Hundred seed weight: The hundred seed weight ranged from 13.91 g to 33.3 g with an average of 22.13 g. C-22971 had the least weight i.e., 13.91 g, while C-22956 recorded the highest hundred seed weight i.e. 33.4 g.

Seed yield per plant (g): The plant yield ranged from 3g to the highest of 33.4g while averaging at 15.19g. The lowest plant yield (g) was recorded for C-22934 (3g) while the highest was recorded by C-22967 (33.4g).

Table 4.2: Descriptive statistics and genetic parameters of 55 genotypes for ten yield and yield attributing and machine harvestable traits during Rabi 2022-23

Character	Mean	Range		SEm±	GCV	PCV	h^2	GAM%
		MIN.	MAX.					
DF	70.5636	63.00	80.00	0.7765	4.97	5.32	87.18	9.56
DM	120.3152	113.00	130.00	0.7720	2.78	2.99	86.26	5.32
PH (cm)	56.5701	32.22	76.55	0.8234	14.20	14.42	96.97	28.81
Height of first pod	29.3210	18.8	40.8	0.7237	19.38	19.85	95.36	39.00
NPP	53.4000	10.00	119.00	3.3508	38.25	39.95	92.60	76.21
NSPP	70.1394	14.66	131.33	3.9681	36.97	38.24	93.43	73.61
BIO.Y.	35.3432	8.88	72.44	1.218	38.25	38.71	97.62	77.86
HI	43.2799	23.16	57.03	2.317	16.62	19.03	76.25	29.90
HSW	22.1313	13.91	33.40	0.8323	16.72	17.94	86.82	32.09
SY.	15.1970	3.07	33.44	0.6098	40.89	41.47	97.19	83.04

DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height (cm); NPP = No. of pods per plant; NSP = No. of seeds per plant; Bio.Y. = Biological yield (g); HI = Harvest index (%); HSW = Hundred seed weight (g); SY = Seed yield per plant (g)

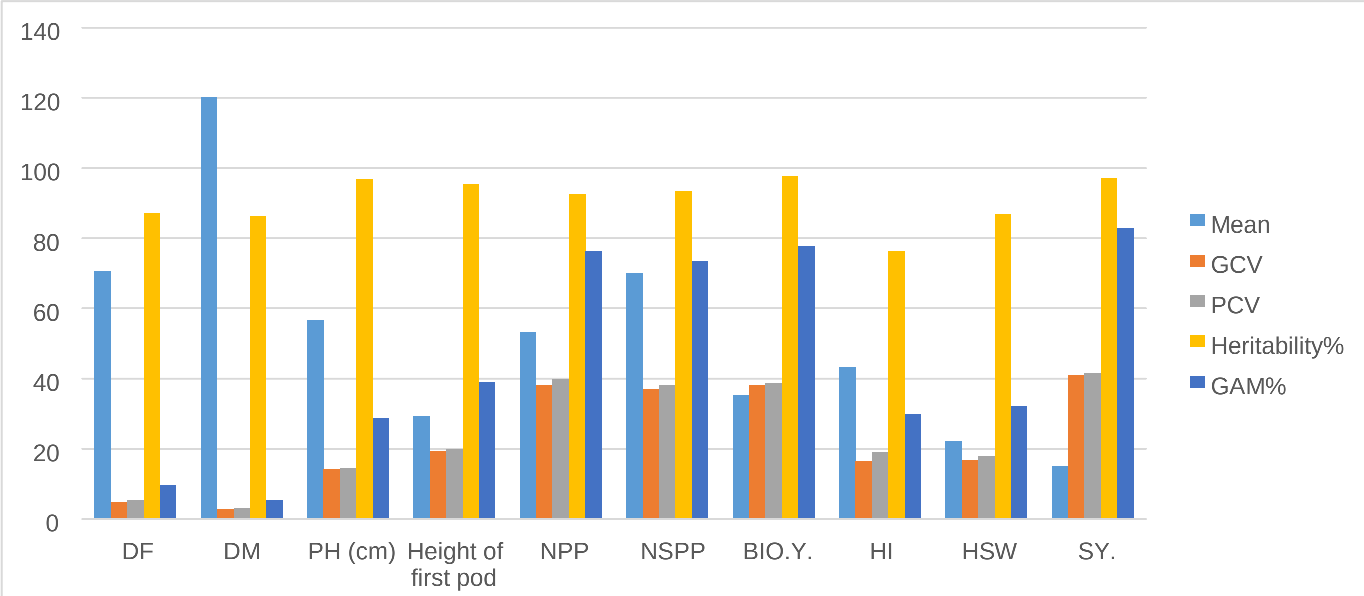

Fig 4.1 Genetic parameter presentation for machine harvesting and seed yield attributing characters

4.2.2 Phenotypic and genotypic coefficient of variation (%):

The division of variation into components attributed to various sources (genetic and environment) is the basic notion behind the study of variation. The relative quantity of these components can influence a population's genetic makeup. A number of analytical approaches for evaluating genetic variability have been provided by statistics. GCV and PCV are two of the most frequent procedures for determining the degree of heritable and non-heritable variation in the material under study.

According to Siva Subramanian and Madhavamenon (1973), genotypic and phenotypic coefficients of variance are classified as "**Low (10%), Moderate (10 to 20%) and Large (>20%)".** The PCV and GCV estimates for the character under study are provided in Table 4.2.

The magnitudes of PCV were higher than the magnitudes of GCV. This indicated the impact of role of the environment over the genotypic effect, finally influencing the phenotypic effect. The results are presented in table 4.2. The inference made from the study is that biological yield, number of pods per plant, number of seeds per plant and seed yield per plant were the traits which showed high PCV coupled with high GCV.

Days to 50% flowering

The study revealed that phenotypic coefficient of variation and genotypic coefficient of variation were low i.e., 5.32 and 4.97 respectively.

Days to maturity

In this trait genetic parameters such as phenotypic coefficient of variation and genotypic coefficient of variation were low i.e., 2.99, 2.78.

Plant height

The analysis reveals that phenotypic coefficient of variation (14.42) & genotypic variation (14.20) was moderate.

Height of first pod

In this trait phenotypic coefficient of variation (19.58) was moderate along with moderate genotypic coefficient of variation (19.38).

Number of pods per plant

In this trait phenotypic coefficient of variation (39.95) was high along with high genotypic coefficient of variation (38.25).

Number of seeds per plant

In this trait phenotypic coefficient of variation (38.24) was high along with high genotypic coefficient of variation (36.97).

Seed yield per plant

Seed yield per plant estimates high phenotypic coefficient of variation (41.47), genotypic coefficient of variation (40.81).

Biological yield

In this trait both phenotypic coefficient of variation, genotypic coefficient of variation was high i.e., 38.71 and 38.25.

Hundred or 100 seed weight

The study reveals that phenotypic coefficient of variation (17.94) and genotypic coefficient of variation (16.72) were moderate.

Harvest index

Harvest index estimates moderate phenotypic coefficient of variation (19.03) & genotypic coefficient of variation (16.62).

4.2.3 Heritability (h2bs) percent and Genetic Advance as percent of mean (GAM)%:

The degree of variation in a phenotypic trait in a population that is due to genetic variability between individuals in that population is estimated by heritability. It determines how much of a trait's variance may be attributable to hereditary causes rather than environmental influences. Broad sense heritability estimated from the ratio of total genetic variance to that of phenotypic variance. Genetic advance as percent of mean (GAM) estimates the increment in the mean genotypic value of the chosen plants over the parental population.

Interpretations based on both the heritability estimates and GAM estimates would give a better insight into the mode of gene action and the passing over of the character under study to the subsequent generations rather than the interpretations derived based on either one of these estimates. A high heritability value combined with a high GAM percent implies additive gene action, whereas a high heritability value combined with a low GAM percent implies non-additive gene action. Low heritability combined with low GAM percent values shows additive gene action, although low heritability values were caused by environmental influences. Low heritability and GAM values show non additive gene action and also the prevalence of environmental influence in the manifestation of the character under study. The heritability and GAM values have been encapsulated in table 4.2. Highest heritability estimate was shown by Biological yield (97.62), followed by seed yield per plant (97.19), plant height (96.97), height of first pod (95.36), number of seeds per plant (93.43) and number of pods per plant (92.60). Harvesting index showed comparable low heritability (76.25) values among all character. High genetic advance as percent of mean (GAM) values were exhibited by seed yield per plant, biological yield, number of pods per plant, number of seeds per plant and height of first pod. Rest all other traits showed moderate to low magnitudes of GAM. High values for both heritability and genetic advance can be seen in characters such as seed yield per plant, number of pods per plant, number of seeds per plant and biological yield. Day to 50% flowering and Days to maturity showed high heritability coupled with low genetic advance values indicating the presence of non-additive gene action on this trait.

High heritability was manifested by the environmental effects rather than the genotype. Seed yield per plant, biological yield, number of pods per plant and number of seeds per plant were the traits presenting high values of PCV, GCV coupled with high heritability and high GAM.

4.3 Correlation studies

The degree of association between two variables, such as a complicated character and an associated trait, as well as the direction of change, is measured using correlation analysis. It proposes a strategy for selecting and improving specific associated trait in order to increase a complicated attribute like seed yield. Correlation studies aid in the comprehension of yield components and the effects of other characters on the same (Robinson *et al.*, 1951 and Johnson *et al.,* 1955). Correlation is calculated at three levels: genotypic, phenotypic, and environmental, while the first two estimates indicate the magnitude of the underlying association. The phenotypic correlations of different yield traits are provided in Table 4.3.1. The relationship was studied and found that the genotypic correlation values were high in magnitude as compared to the phenotypic correlation values, indicating the less influence of environment.

4.3.1 Days to 50% flowering

Day to 50% flowering showed negative and non-significant correlation with plant height (-0.020) hundred seed weight (-0.123). It exhibited positive and non-significant with day of maturity (0.224), height of first pod (0.129).

4.3.2 Days to maturity

The character exhibited positive and non-significant correlation with plant height (0.169), seed yield (0.098), height of first pod (0.206) and 100 seed weight (0.055).

4.3.3 Plant height

Plant height showed positive and significant correlation with height of first pod (0.680**), biological yield (0.270*). Positive and non-significant correlation was observed for pod per plant (0.176), seed yield (0.236).

4.3.4 Height of first pod from soil surface

Height of first pod showed positive and significant correlation with plant height (0.680**). It exhibited positive and non-significant correlation with days to maturity (0.206), day to flowering (0.129) and hundred seed weight (0.111).

4.3.5 Number of pods per plant

Number of pods per plant showed positive and significant relation with number of seed per plant (0.931**), biological yield (0.788**), and with seed yield (0.814**).

4.3.6 Number of seeds per plant

Number of seeds per plant held positive and significant co-relation with number of pods per plant (0.788**), biological yield (0.779**), harvest index (0.394**), and seed yield (0.893**).

It exhibited negative and non-significant correlation with hundred seed weight (-0.026).

4.3.7 Biological yield per plant

Biological yield per plant exhibited positive and significant relation with Plant height (0.270*), number of pods per plant (0.788**), number of seeds per plant (0.779**), 100 seed weight (0.367**), seed yield (0.894**) and showed negative and non-significant with harvest index (-0.058).

4.4.8 Harvest index

Harvest index was positive and significantly correlated with number of seeds per plant (0.394**), pod per plant (0.316*) and seed yield (0.361*). It exhibited negative and non-significant correlation with days to 50% flowering (- 0.058), days to maturity (-0.028).

4.4.9 100 Seed weight

100 Seed weight exhibited positive and significantly correlated with harvest index (0.367**) and seed yield (0.395**). It exhibited negative and non-significant correlation with days to 50% flowering (-0.123), days to maturity (-0.086) and seed per plant (-0.026).

4.4.10 Seed yield

Seed yield per plant exhibited positively significant correlation number of pods per plant (0.874**), number of seeds per plant (0.893**), biological yield (0.894**), harvest index (0.361**). It was positively non-significant with day to maturity (0.098) and days to 50% flowering (0.013).

4.4 Path analysis:

Path analysis gives information about how a component trait affects the dependent trait i.e. through direct effect and through other characters i.e. indirect effects. This shows whether the association with the dependent trait is due to the effect via other component traits. Residual effect provides insight into other significant traits that are not explored in this study and their impacts on the dependent variable. The genotypic and phenotypic path analysis on various traits with seed yield per plot as dependent traits are discussed below in the tables 4.4.1a and 4.4.1b. The path analysis is done for characters seed yield per plant as dependent traits individually at both genotypic and phenotypic levels.

4.4.1 Genotypic direct and indirect effects on seed yield per plant as dependent variable:

The data regarding path analysis was given in table 4.4.1a.

Days to 50% flowering

This trait had (0.0007) negligible positive direct effect on seed yield per plant.

Days to maturity

Days to maturity had positive direct effect (0.0059) on seed yield per plant, whereas positive indirect effects were observed through, plant height (0.0009), height of first pod (0.0012).

Plant height

This character had negative direct effect (-0.0184) on seed yield per plant. Days to flowering (0.0004) only positive indirect effect, whereas major negative indirect effects were observed by height of first pod (-0.0125) and biological yield (-0.0048).

Height of first pod

Height of first pod showed positive direct effect (0.0250) on seed yield per plant. Rest all character has positive indirect effect like plant height has more (0.0170), days to maturity (0.0051) and day to flowering (0.0032) positive indirect effect.

Number of pods per plant

Number of pod per plant also had positive direct effect (0.0457) on seed yield. Positive indirect effect was observed by number of seeds per plant (0.0425), biological yield (0.0360).

Number of seeds per plant

Positive direct effect (0.422) by number of seeds per plant on seed yield per plant was observed, whereas positive indirect effect by number of pods per plant (0.393), biological yield (0.329) and for hundred seed weight negative indirect effect (-0.0109) were recorded.

Biological yield

Biological yield had positive direct effect (0.462) on seed yield per plant. Positive indirect effects were observed for days to 50% flowering (0.0045) and hundred seed weight (0.169). Negative indirect effects were observed for harvest index (-0.027)

Hundred or 100-Seed weight

This trait exhibits positive direct effect (0.2179) on seed yield per plant whereas positive indirect effects were seen for biological yield (0.080) and harvest index (0.018). Days to 50% flowering (-0.0327) Days to maturity (-0.025), and number of seeds per plant (-0.0013) exhibits negative indirect effects.

Harvest index

Harvest index had positive direct effect (0.189) on seed yield per plant, whereas positive indirect effects were viewed for, days to maturity (0.0012), plant height (0.0005), number of seeds per plant (0.074), and hundred seed weight (0.0002). Negative indirect effects were seen for biological yield (-0.011)

4.4.2 Phenotypic direct and indirect effects on seed yield per plant as dependent variable:

The data regarding path analysis was given in table 4.4.1b

Days to 50% flowering

Days to 50% flowering trait had negative direct effect (-0.0061) on seed yield per plant. Similarly negative indirect effect showed by days to maturity (-0.0016), height of first pod (-0.0008), whereas positive indirect effect observed by plant height (0.0001) and hundred seed weight (0.0006).

Days to maturity

Days to maturity had positive direct effect (0.0193) on seed yield per plant, whereas positive indirect effects were observed through, plant height (0.0029), height of first pod (0.0038), whereas negative indirect effect observed by hundred seed weight (-0.0012).

Plant height

This character had negative direct effect (-0.0405) on seed yield per plant. Days to flowering (0.0006) and harvest index (0.00003) were only positive indirect effect, whereas major negative indirect effects were observed by height of first pod (-0.0267) and biological yield (-0.0105).

Height of first pod

Height of first pod showed positive direct effect (0.0539) on seed yield per plant. Rest all character has positive indirect effect most were plant height (0.0355), days to maturity (0.0105) and day to flowering (0.007).

Number of pods per plant

Number of pods per plant also had positive direct effect (0.0350) on seed yield. Positive indirect effect major were also observed by number of seeds per plant (0.0324), biological yield (0.0265).

Number of seeds per plant

Positive direct effect (0.205) by number of seeds per plant on seed yield per plant was observed, whereas most positive indirect effect by number of pods per plant

(0.189), biological yield (0.154) and for hundred seed weight negative indirect effect (-0.006) were recorded.

Biological yield

Biological yield had positive direct effect (0.691) on seed yield per plant. Positive indirect effects were also observed for days to 50% flowering (0.0080), days to maturity (0.0516), plant height (0.180), pod per plant (0.523), number of seeds per plant (0.519) and 100-seed weight (0.243). Negative indirect effects were observed for harvest index (-0.0622)

Hundred or 100-Seed weight

This trait exhibits positive direct effect (0.110) on seed yield per plant whereas positive indirect effects were seen for biological yield (0.039) and height of first pod (0.0117). Days to 50% flowering (-0.0115), Days to maturity (-0.0072), and number of seeds per plant (-0.0032) exhibit negative indirect effects.

Harvest index

Harvest index had positive direct effect (0.333) on seed yield per plant, whereas positive indirect effects were viewed for, days to 50% flowering (0.0070), days to maturity (0.0099), number of seeds per plant (0.113), and hundred seed weight (0.024). Negative indirect effects were seen for biological yield (-0.030) and plant height (-0.0003)

Positive correlation at phenotypic correlation level and negative correlation at genotypic correlation level and vice versa and positive direct effects in phenotypic path analysis and negative direct effects in genotypic path analysis and vice versa indicate the effects of the environment and genotype x environment interactions (G X E) to be reasons for the aforementioned changes.

Table 4.3.1. Phenotypic correlation of yield and yield attributes in chickpea

	DF	DM	PH	HFP	PPP	SPP	BioY	HI	HSW	SY(g)
DF	1									
DM	0.224	1								
PH	-0.020	0.169	1							
HFP	0.129	0.206	0.680**	1						
PPP	0.019	0.104	0.176	0.0665	1					
SPP	0.068	0.157	0.217	0.0707	0.931**	1				
BioY	0.0098	0.078	0.270*	0.0568	0.788**	0.779**	1			
HI	0.001	0.006	0.003	0.0314	0.316*	0.394*	-0.058	1		
HSW	-0.123	-0.086	0.072	0.1113	0.058	-0.026	0.367*	0.081NS	1	
SY(g)	0.013	0.098	0.236	0.1031	0.874**	0.893**	0.894**	0.361*	0.395*	1

- DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height (cm); NPP = No. of pods per plant; NSP = No. of seeds per plant; Bio.Y. = Biological yield (g); HI = Harvest index (%); HSW = Hundred seed weight (g); SY = Seed yield per plant (g)

Table 4.4.1a Genotypic path coefficient yield and yield components in chickpea

	DF	DM	PH	HFP	PPP	SPP	BioY	HI	HSW
DF	**0.00069**	0.00131	0.00038	0.00323	0.00089	0.02860	0.00455	0.00020	-0.02685
DM	0.00016	**0.00587**	-0.00311	0.00517	0.00476	0.06639	0.03611	0.00122	-0.01865
PH	-0.00001	0.00099	**-0.01845**	0.01704	0.00803	0.09186	0.12024	0.00048	0.01579
HFP	0.00009	0.00121	-0.01255	**0.02505**	0.00304	0.02986	0.02623	0.00594	0.02425
PPP	0.00001	0.00061	-0.00324	0.00167	**0.04571**	0.39321	0.36387	0.05980	0.01259
SPP	0.00005	0.00092	-0.00401	0.00177	0.04254	**0.42252**	0.36022	0.07439	-0.00567
BioY	0.00001	0.00046	-0.00480	0.00142	0.03600	0.32945	**0.46198**	-0.01106	0.08000
HI	0.00000	0.00004	-0.00005	0.00079	0.01446	0.16631	-0.02704	**0.18901**	0.01770
HSW	-0.00009	-0.00050	-0.00134	0.00279	0.00264	-0.01099	0.16963	0.01535	**0.21789**

Residual value = 0.0168

- DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height (cm); NPP = No. of pods per plant; NSP = No. of seeds per plant; Bio.Y. = Biological yield (g); HI = Harvest index (%); HSW = Hundred seed weight (g); SY = Seed yield per plant (g)

Table 4.4.1b Phenotypic path coefficient yield and yield components in chickpea

	DF	DM	PH	HFP	PPP	SPP	Bio. Y	HI	HSW
DF	**-0.00614**	0.00506	0.00064	0.00701	0.00048	0.01099	0.00802	0.00703	-0.01149
DM	-0.00161	**0.01928**	-0.00606	0.01059	0.00301	0.02779	0.05169	0.00987	-0.00716
PH	0.00010	0.00289	**-0.04050**	0.03550	0.00583	0.04299	0.17975	-0.00027	0.00781
HFP	-0.00080	0.00379	-0.02667	**0.05392**	0.00164	0.01144	0.03794	0.01647	0.01177
PPP	-0.00008	0.00166	-0.00674	0.00253	**0.03502**	0.18991	0.52356	0.09197	0.00559
SPP	-0.00033	0.00261	-0.00849	0.00301	0.03242	**0.20510**	0.51962	0.11300	-0.00325
BioY	-0.00007	0.00144	-0.01053	0.00296	0.02653	0.15422	**0.69107**	-0.03003	0.03912
HI	-0.00013	0.00057	0.00003	0.00266	0.00966	0.06953	-0.06227	**0.33334**	0.00810
HS	0.00064	-0.00125	-0.00285	0.00572	0.00176	-0.00601	0.24374	0.02433	**0.11091**

Residual value = 0.0282

- DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height (cm); NPP = No. of pods per plant; NSP = No. of seeds per plant; Bio.Y. = Biological yield (g); HI = Harvest index (%); HSW = Hundred seed weight (g); SY = Seed yield per plant (g)

4.5 Genetic divergence

To estimate genetic divergence values, correlated means of different characters were transformed to the standard uncorrelated means. The statistical distance (Mahalanobis D^2 distance) between different pairs of the genotypes were obtained as the sum of squares of difference between the pairs of the corresponding uncorrelated value of any of the two genotypes considered at a time.

4.5.1 Grouping of genotypes into various clusters

Fifty - five Chickpea genotypes were categorized into 13 clusters, based on the divergence analysis. Distributions of the genotypes into different clusters were exhibited in table 4.5.1. Cluster I was the largest, among all the clusters consisted 19 genotypes followed by cluster II consisted 9 genotypes. Cluster III comprised 3 genotypes and cluster IV, V, VI comprised 7, 3, 4 genotype in respectively. And cluster VII, VIII consisted 2 and 3 genotypes respectively and remains 5 cluster namely IX, X, XI, XII and XIII consist 1-1 genotype.

4.5.2 Inter and intra cluster divergence D^2

The intra and inter cluster D^2 mean values are exhibited in table 4.4.2. On the basis of D values, 55 chickpea genotypes were grouped into 13 clusters. The intra cluster distance varied from 0.00 to 187.8834. Cluster IV showed highest intra cluster value (187.8834), while cluster I had 140.5076 intra cluster value, cluster II had 149.1163, cluster III had 142.402, cluster V had 86.9967, cluster VI had 114.7406 intra cluster value, VII had 100.612 and VIII had 166.2542 intra cluster values. Whereas, cluster IX, X, XI XII and XIII had one genotype in each so, showed zero value for the intra cluster distance.

The highest inter cluster distance was observed between the genotypes of cluster X and cluster XIII (1885.148) followed by cluster XII and cluster XIII (1549.497). Inter cluster distance was found lowest between cluster V and cluster XI (166.423).

In order to show actual positions of cluster according to their inter cluster values, 55 chickpea genotypes grouped into 13 different clusters. The accordance similarities or the dissimilarities also found with variations from cluster to cluster. With the aim of get better Perceptions regarding to closeness of various clusters, 13 clusters arranged based on their inter cluster distance (Table 4.5.2).

Table 4.5.1 Distribution of 55 chickpea genotypes into 13 clusters

	Name of genotype
I.	C-22925, C-22928, C-22931, C-22933, C-22937, C-22938, C-22946, C-22948, C-22950, C-22955, C-22961, C-22962, C-22963, C-22972, C-22975, C-22976, RVG 202, RVKG 111
II.	C-22929, C-22930, C-22947, C-22958, C-22960, C-22982, RVG-205, RVSSG 68, RVKG 121
III.	C-22934, C-22957, RVSSG74
IV.	C-22935, C-22945, C-22973, C-22979, C-22980, C-22981, RVG 204
V.	C-22936, C-22959, C-22964
VI.	C-22939, C-22949, C-22952, C-22971
VII.	C-22940, C-22977
VIII.	C-22944, C-22968, C-22978
IX.	C-22956
X.	C-22967
XI.	C-22969
XII.	C-22970
XIII.	RVSSG 96

Table 4.5.2 Average inter and intra cluster divergence D^2

CLUSTER	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	XIII
I	**140.5**	226.04	324.65	247.56	279.44	318.13	361.41	303.15	282.34	649.31	471.46	423.89	567.61
II		**149.11**	181.74	296.97	515.08	275.77	689.27	296.12	213.88	1024.48	789.81	629.21	526.43
III			**142.4**	378.66	761.6	319.69	978.26	333.38	327.60	1406.32	1182.57	793.42	478.17
IV				**187.88**	500.07	627.23	557.28	215.96	255.97	977.64	645.05	800.17	278.09
V					**86.99**	528.85	237.25	706.87	505.70	398.02	166.32	266.40	1068.24
VI						**114.74**	696.52	590.76	450.86	904.84	852.47	374.88	1102.12
VII							**100.61**	728.13	603.09	182.95	228.38	342.25	1177.9
VIII								**166.25**	349.64	1185.3	824.19	969.28	267.28
IX									**0**	877.95	699.08	637.54	543.80
X										**0**	324.82	543.04	1816.68
XI											**0**	543.22	1254.7
XII												**0**	1549.76
XIII													**0**

4.5.3 Cluster Mean

Cluster mean of 10 different yield-attributing traits is presented in Table 4.5.3. The mean values for trait days to 50% flowering ranged from 63.00 to 75.22, reflected in cluster IX and cluster VIII respectively. Mean values for days to maturity varied from 117.33 to 124.66, represented by cluster XIII and cluster VIII. Means values for plant height were extended from 39.75 (cluster VI) to 76.55 (cluster XIII). Cluster XII (20.66) had a minimum and cluster XIII (40.66) showed a maximum means value for the height of first pod from soil surface. Cluster III had a minimum (22.44) and cluster X (119.0) showed a maximum mean value for the trait number of pods per plant. Trait number of seeds per plant was lowest in cluster III and highest mean value in cluster X which were 29.66 and 131.0, respectively. Biological yield per plant ranged from 14.56 to 72.44, reflected in cluster III and cluster XI respectively. Seed yield per plant varied from 6.26 to 33.44 was represented by cluster III land cluster X. Cluster VI (18.53) had minimum and cluster IX (33.40) showed maximum mean value for hundred seed weight and harvest index were ranged from 33.66 to 53.44, reflected in cluster VI and cluster IX respectively.

Table. 4.5.3. Cluster means of advance breeding lines for seed yield and yield components of chickpea

CLUSTER	DF	DM	PH (cm)	HFP	NPP	NSP	BY	HI	100SW	SY
	71.2456	119.0175	57.6586	28.6265	59.6667	78.1404	37.0991	44.2191	21.7688	16.3005
2	68.5556	121.5185	51.9244	26.9356	40.7407	48.7037	26.3026	37.7422	20.4867	9.6244
3	71.5556	119.1111	53.2556	26.3889	22.4445	29.6667	14.5689	41.2078	21.0267	6.2678
4	69.5238	121.6667	65.8871	35.4586	51.9048	69.3809	34.6328	48.1081	24.0205	16.4271
5	70.4444	119.7778	60.0689	24.1844	63.8889	81.0000	59.9967	35.0044	25.9589	20.9200
6	72.0000	118.5834	39.7575	21.8334	40.9167	56.9167	24.1358	44.5542	18.5350	10.1192
7	70.8334	122.6667	58.6084	32.3667	90.0000	125.0000	56.2684	53.8334	23.5084	30.2200
8	75.2222	124.0000	61.2200	38.5000	53.6667	76.5556	28.6889	43.2878	19.4811	12.4867
9	63.0000	122.3333	52.5500	34.2333	34.3333	41.6667	33.1067	45.3167	33.4000	14.9967
10	70.3333	119.6667	49.5533	31.1000	119.000	131.0000	65.9967	50.6767	27.0600	33.4400
11	68.6667	120.6667	60.4433	32.2333	85.6667	110.3333	72.4433	33.6633	22.7433	24.3700
12	72.3333	122.3333	48.3333	20.6000	38.6667	79.6667	46.2233	47.9867	27.9800	22.0967
13	68.0000	117.3333	76.5533	40.6667	32.0000	47.0000	23.2233	41.7667	19.3533	9.6700

- DF = Days to 50% flowering; DM = Days to maturity; PH = Plant height (cm); NPP = No. of pods per plant; NSP = No. of seeds per plant; Bio.Y. = Biological yield (g); HI = Harvest index (%); HSW = Hundred seed weight (g); SY = Seed yield per plant (g)

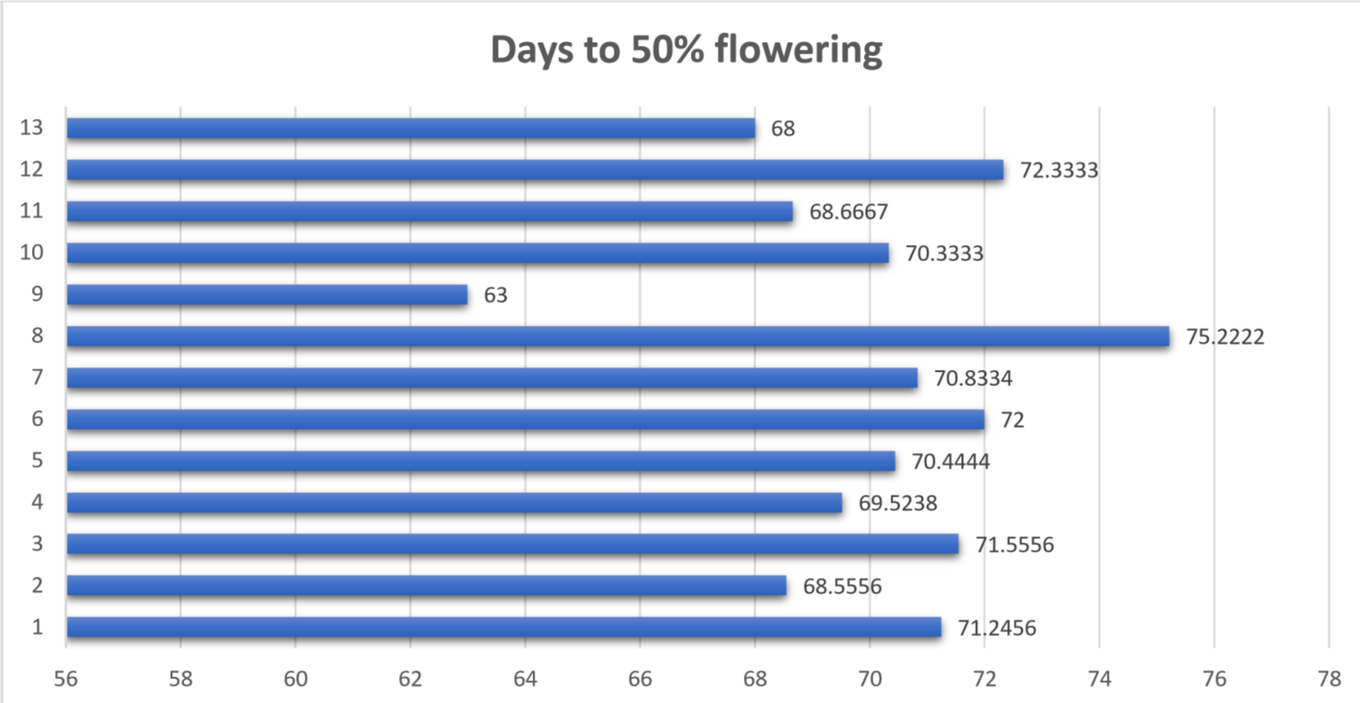

Fig 4.2 Showing mean of Day to 50% flowering in different clusters

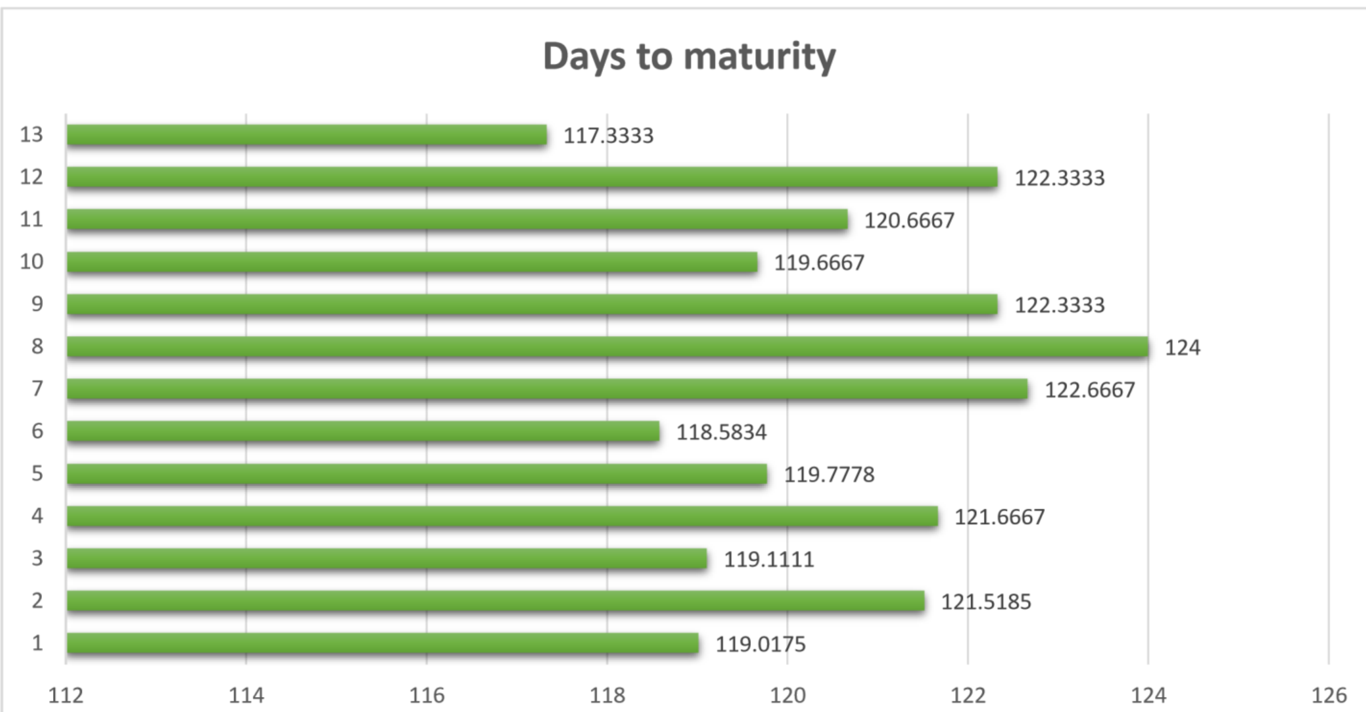

Fig 4.3 Showing mean of Day maturity in different clusters

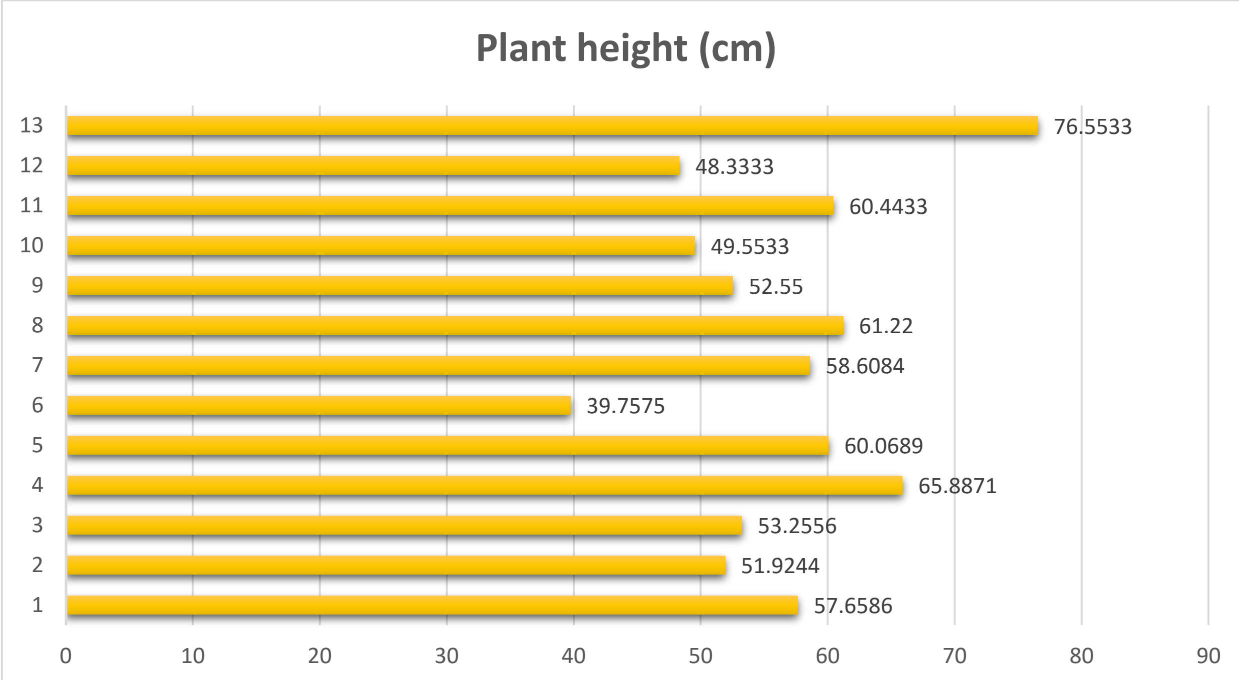

Fig 4.4 Showing mean of Plant height (cm) in different clusters

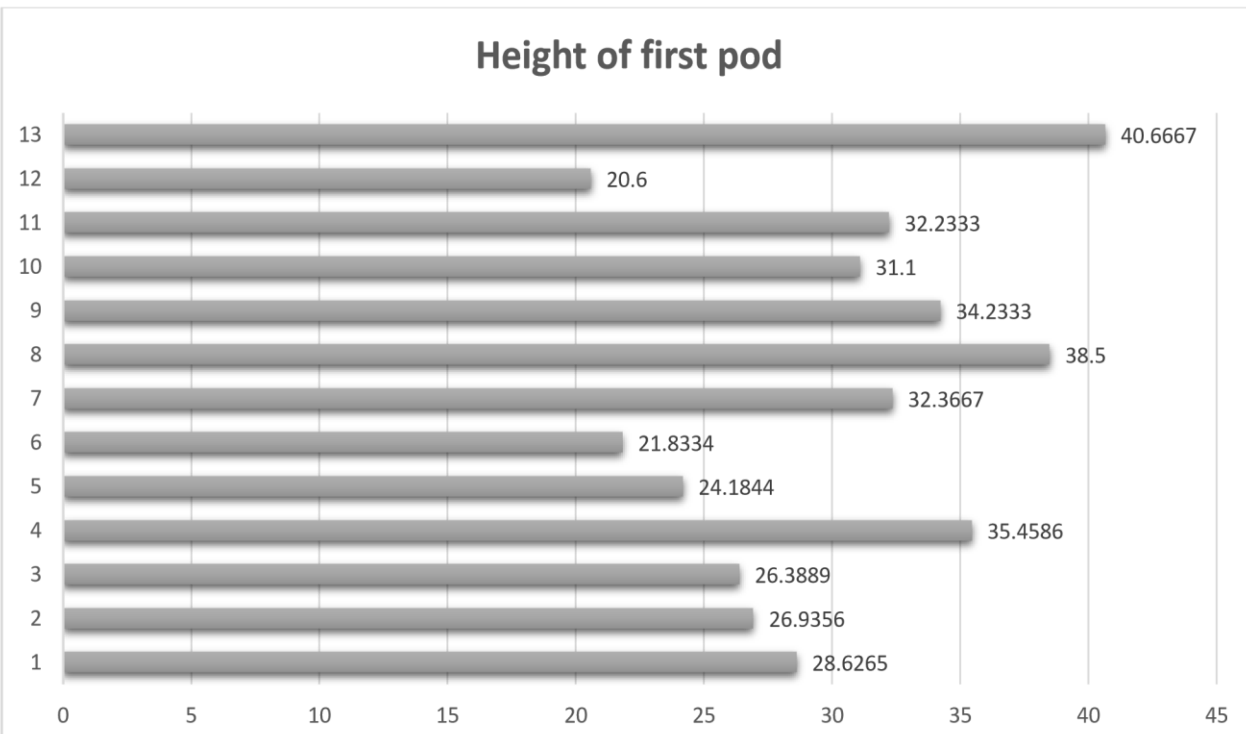

Fig 4.5 Showing mean of height of first pod in different clusters

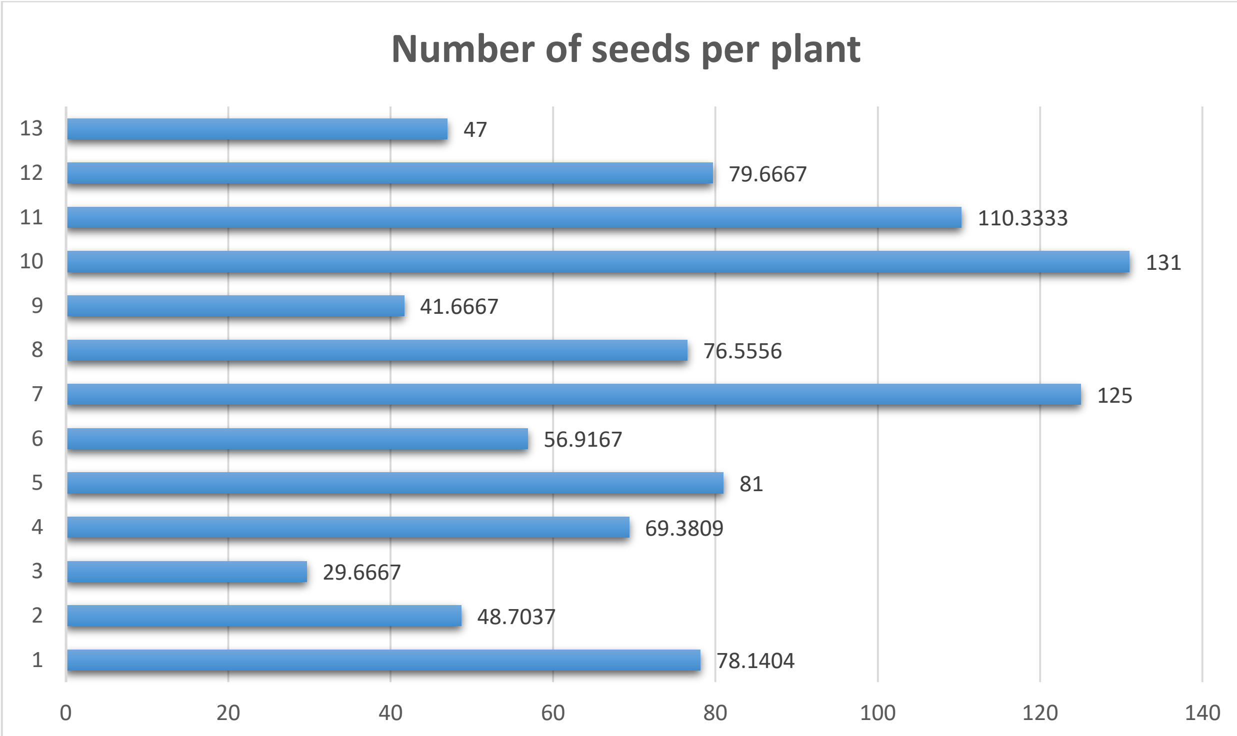

Fig 4.6 Showing mean of Number of seeds per plant in different clusters

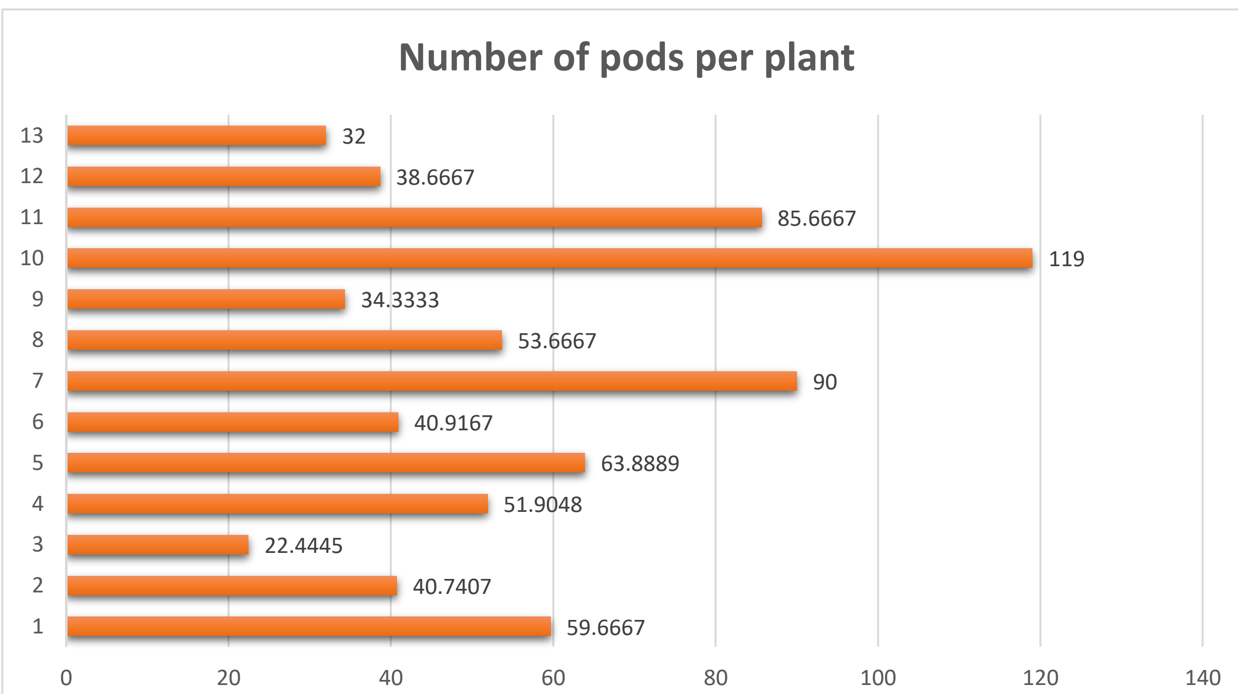

Fig 4.7 Showing mean of Number of pods per plant in different clusters

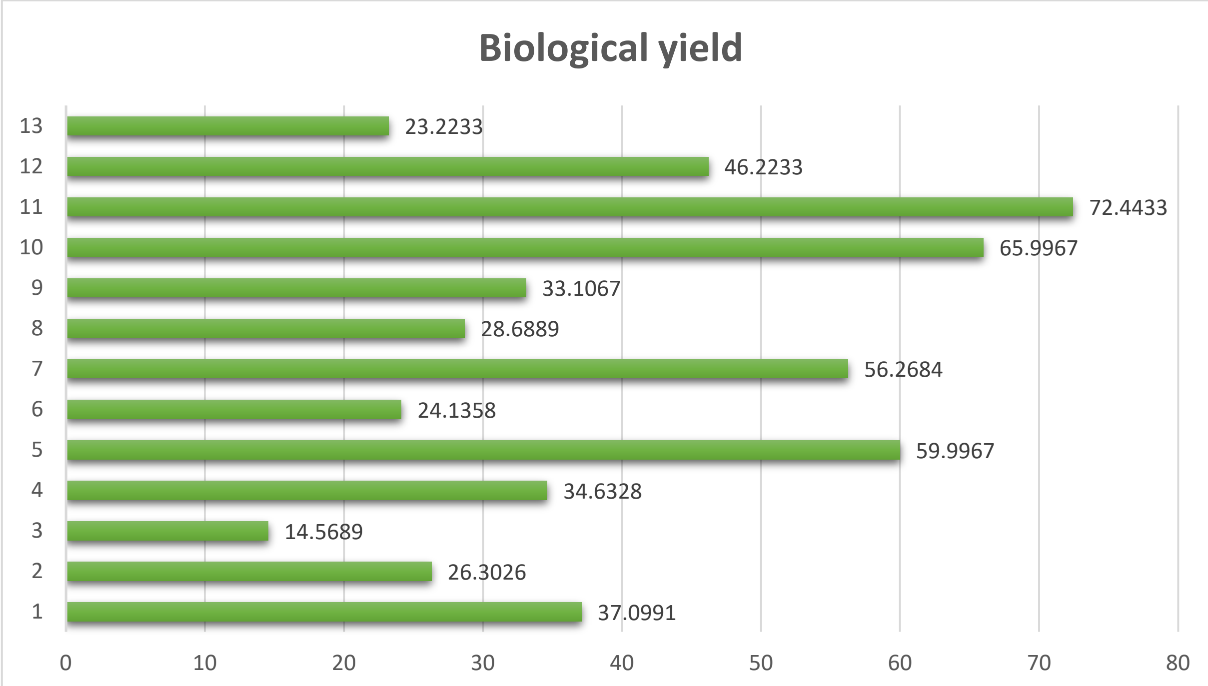

Fig 4.8 Showing mean of Biological yield per plant in different clusters

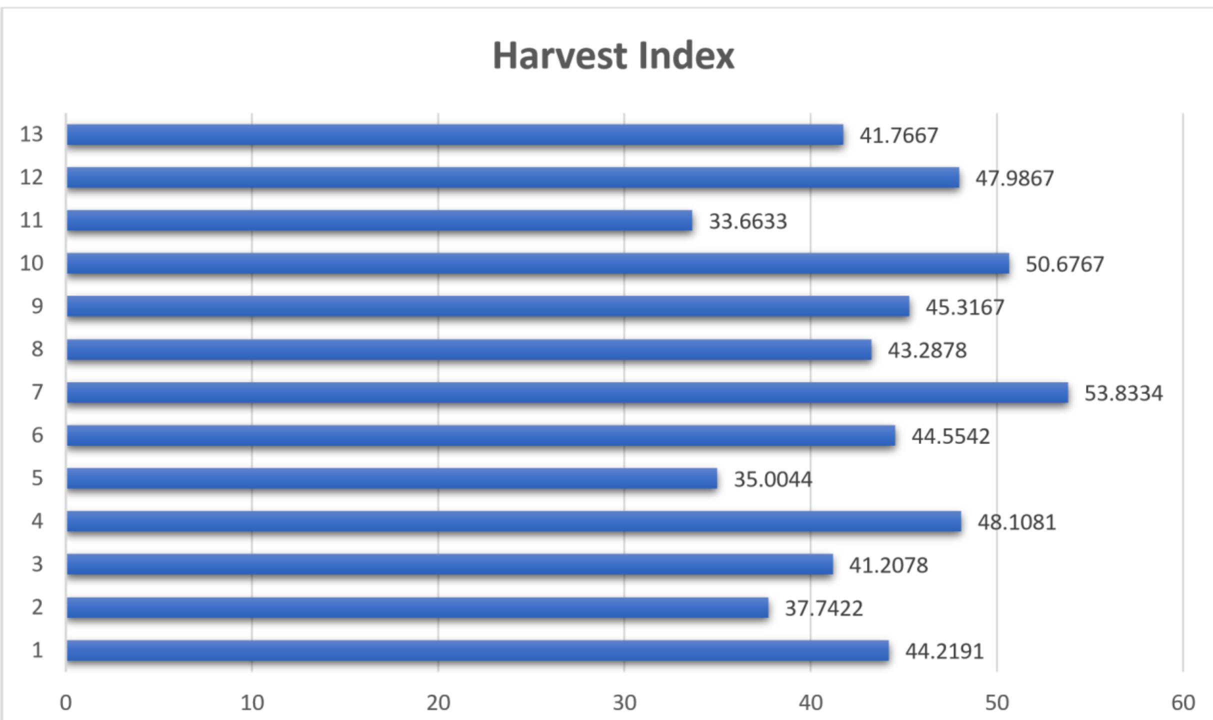

Fig 4.9 Showing mean of Harvest index in different clusters

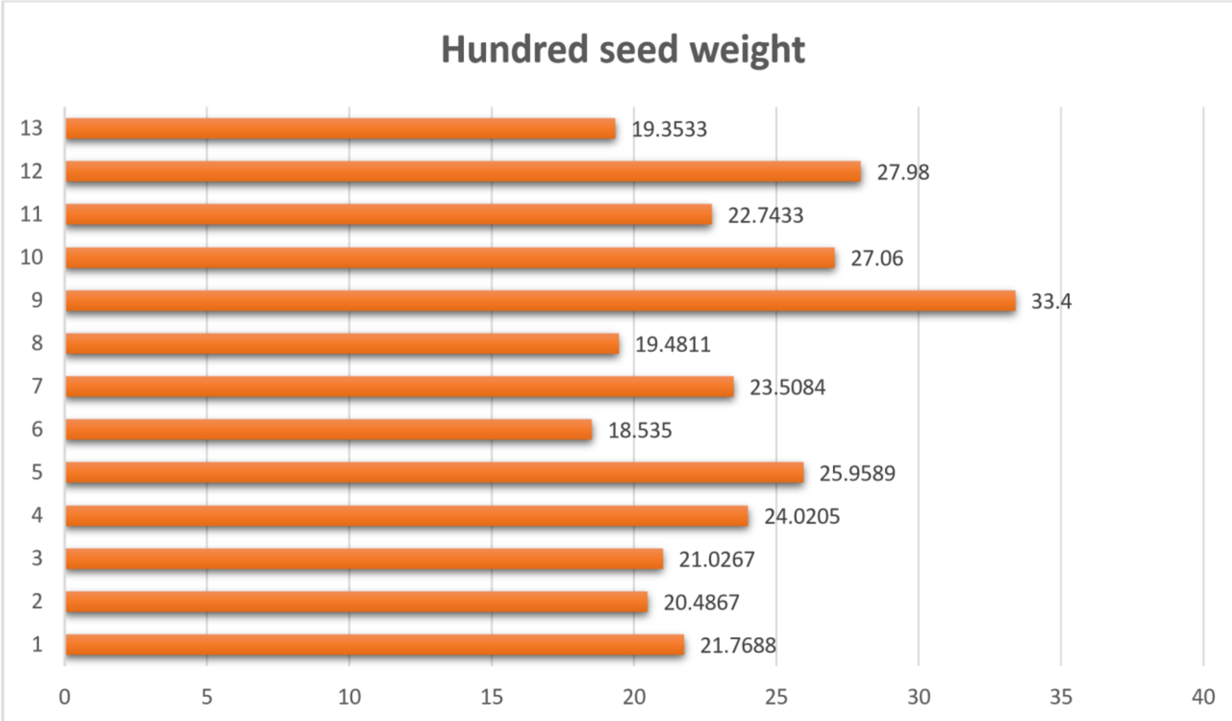

Fig 4.10 Showing mean of hundred seed weight in different clusters

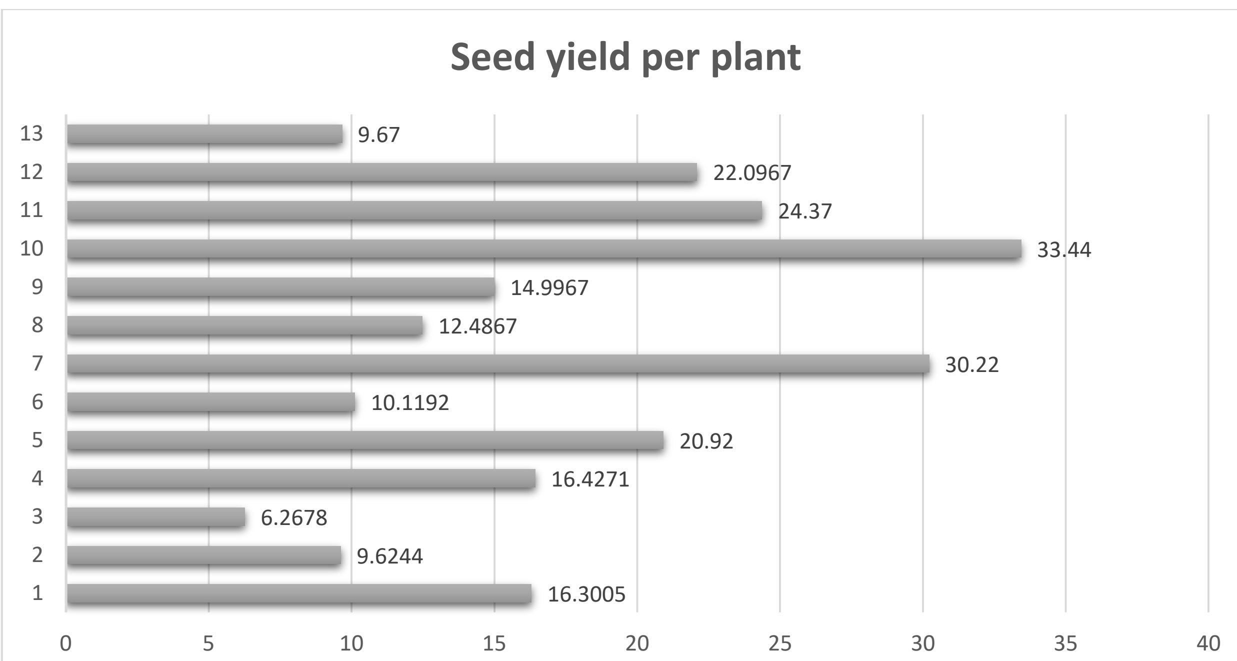

Fig 4.11 Showing mean of seed yield per plant in different clusters

4.6 Classification of genotypes:

4.6.1 Based on Plant growth habit:

Plant growth habit helps in the development of chickpea cultivars suitable for mechanical harvesting along with seed yield. Chickpea cultivars with erect and semi erect growth habits are considered suitable for mechanical harvesting.

Based on plant growth habit genotypes are classified into five types *viz.,* erect, semi erect, semi spreading, spreading and prostrate. Knowledge of the type of plant growth habit plays an important role in identifying genotypes suitable for mechanical harvesting. Erect and semi erect type plant growth habits are suitable for mechanical harvesting varieties. Out of 55 genotypes, a maximum number of 38 genotypes showed semi erect growth habit, 10 genotypes showed semi spreading and the remaining 7 showed erect type growth habit. Prostrate and spreading growth habits were not observed in any genotype.

Table 4.6.1 Classification of genotype based on Plant growth habit:

Plant growth habit	Relative frequency	Genotype
Erect	7	C-22930, C-22934, C-22970, C-22971, C-22972, C-22980, RVSSG 96
Semi Erect	38	C-22925 C-22928 C-22931 C-22935 C-22936 C-22937 C-22938 C-22939 C-22940 C-22944 C-22945 C-22947 C-22948 C-22950 C-22952 C-22956 C-22957 C-22958 C-22960 C-22961 C-22962 C-22967 C-22968 C-22969 C-22973 C-22974 C-22975 C-22976 C-22977 C-22979 C-22981 RVG 204 RVSSG74 RVG205 RVG 202 C-22978, RVKG 111 RVKG 121
Semi Spreading	10	C-22929, C-22933, C-22946, C-22949, C-22955, C-22959, C-22963, C-22964, C-22982, RVSSG 68
Spreading	0	-
Prostrate	0	-
Total	55	

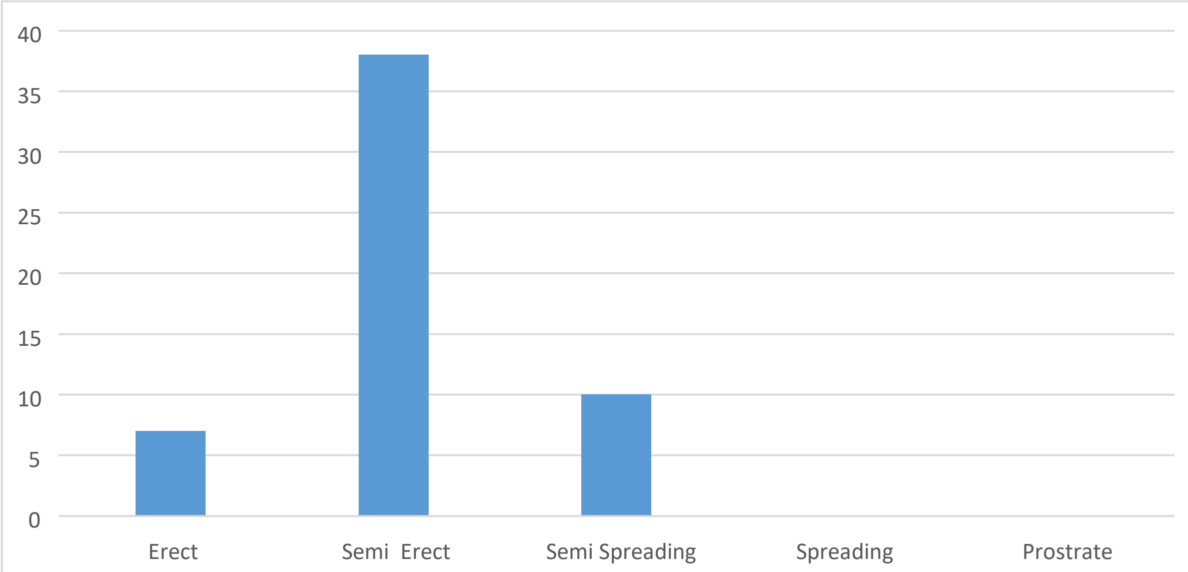

Fig 4.12 Classification of genotype based on Plant growth habit

4.6.2 Based on Early Plant vigour:

Based on plant vigour genotypes are classified into three types *viz.,* good, medium, and poor. Knowledge of the type of plant vigour play an important role in identifying genotype growth. Out of 55 genotypes, a maximum number of 26 genotypes showed medium plant vigour, 22 genotypes showed good vigour and the remaining 7 showed poor type early plant vigour listed in table 4.6.2.

Table 4.6.2 Classification of genotype based on Early Plant vigour:

Plant growth habit	Relative frequency	Genotype
Good	22	C-22925 C-22928 C-22930, C-22935, C-22936, C-22940, C-22944, C-22944, C-22945, C-22946, C-22962, C-22963, C-22964, C-22973, C-22974, C-22975, C-22976, C-22978, C-22982 RVG-204 RVG-205 RVG-202 RVKG-111
Medium	26	C-22929 C-22931 C-22933 C-22938 C-22939 C-22948 C-22949 C-22950 C-22952 C-22955 C-22956 C-22958 C-22959 C-22961 C-22967 C-22968 C-22969 C-22972 C-22977 C-22979 C-22980 C-22981, RVSSG-96 RVSSG-74 RVG 205 RVSSG-68 RVKG-121
Poor	7	C-22934, C-22937, C-22947, C-22957, C-22960, C-22970, C-22971
Total	55	

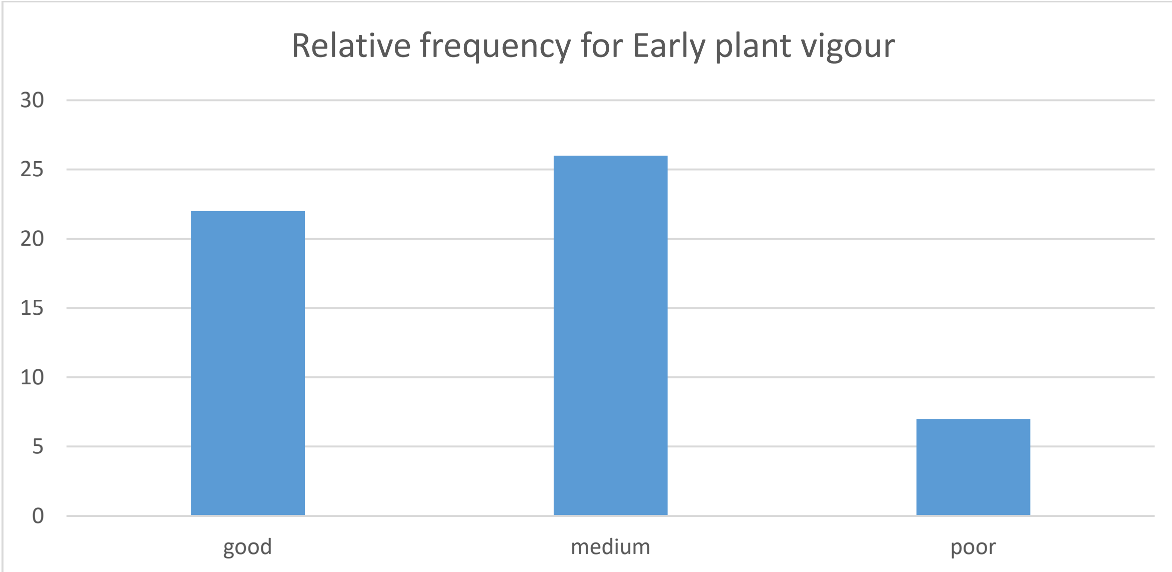

Fig 4.13 Classification of genotype based on Early plant vigour

4.6.3 Classification of genotypes suitable for machine harvesting

Chickpea genotypes having the height of first fruiting pod from soil surface of more than 25 cm are considered as best suited for mechanical harvesting. Although, genotypes exhibiting height of first fruiting pod from the soil surface between 21 cm - 25 cm can be also useful for machine harvest but if height of first fruiting pod from soil surface is less than 20 cm then those genotypes are not suitable for the mechanical harvesting.

Table 4.6.3: Frequency of genotypes on the basis of plant growth habit and height of first pod from soil surface in chickpea

Height of first pod from soil surface	**No. of genotype having plant growth habit**				
	Erect	**Semi erect**	**Semi spreading**	**Spreading**	**Prostrate**
Above 25cm	**5**	**33**	**5**		
Between 20-25 cm	**1**	**4**	**5**		
Less than 25 cm	**1**	**1**	**0**		
total	**7**	**38**	**10**		

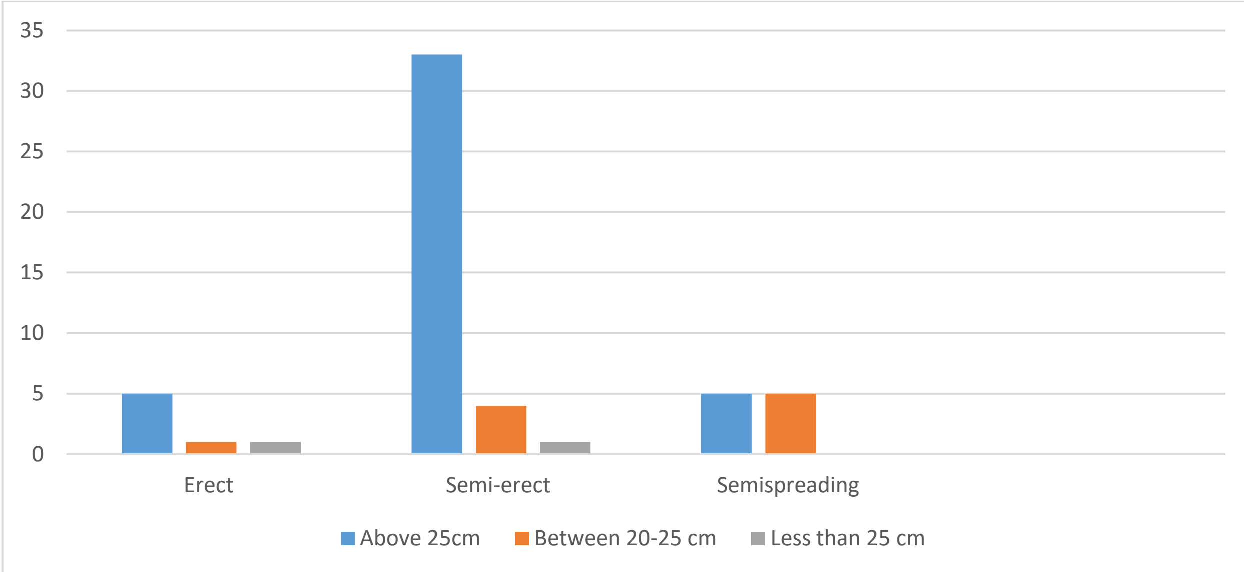

Fig 4.14 Frequency of genotypes on the basis of plant growth habit and height of first pod from soil surface in chickpea

As exhibited In Table 4.6.3 a total of 43 chickpea genotypes were found suitable for mechanical harvesting. 38 genotypes are best suited (5 erect type growth habit and 33 with semi erect type growth habit).

CHAPTER -V

DISCUSSION

Chickpea (*Cicer arietinum* L) is an important and well-known leguminous crop grown in India. It is popular because it is most preferred for human consumption in various forms and it is widely grown under diverse conditions in most of the states of the country. In India, the chickpea crop is harvested manually however, with non-time availability of labours and increasing labour costs, manual harvesting has become an expensive field operation. Hence, the farmers are increasingly opting for mechanical harvesting wherever it is feasible. Traditional chickpea varieties are short and semi-spreading, which means their machine harvesting, is difficult or practically less feasible. This necessitates the development of cultivars suited to mechanical harvesting. The ideotype for mechanized harvesting is the one which has tall (>50 cm), erect growth habit with short internodal length, low branching angle, pod bearing above 25 cm from ground level and combined with higher productivity. Further, these lines have to be characterized by early maturity, disease resistance and good seed quality to satisfy other requirements of consumers and the farming community. Hence, in this context, a genetic improvement strategy may be implemented for developing chickpea lines suited for mechanized harvesting, which is a new direction in chickpea breeding.

Different chickpea plant types exist in nature. For mechanical harvesting semi erect and compact plant types are suitable. Earlier workers have proposed many chickpea ideotypes for different agro-climatic situations like drought, hot environments, high input conditions and late sown rainfed conditions. Efforts have also been put into breeding for erectness in chickpea. For instance, Bahl (1980) derived tall progenies from a cross between spreading and tall however, there was no gain in harvest index because most of the photosynthetic assimilates were spent on producing long internodal length. Compact growth habit with short internodal length in chickpea has been emphasised by several researchers (Ramanujan 1975; Sinha 1977; Gupta and Lal 1981; Dahiya *et al.,* 1990). A spontaneous brachytic mutant with short internodes and compact growth habit, E100YM, has been identified (Dahiya *et al.* 1984) and used in ideotype breeding by Lather (2000), who obtained promising progenies with compact growth habit which can be grown at higher plant density and also found an elite tall breeding line with upright growth habit and suitable for mechanical harvesting as the fruiting zone started at about 20 cm from the base.

Keeping in view, the importance of mechanized harvesting in chickpea, the present investigation was designed to understand and elicit information on genetic variability, inter character association, diversity and the nature of genetic components governing the inheritance of the traits related to mechanical harvesting and yield and yield attributing traits. Based on combining ability analysis, an effort was also made to identify the potential population for combining productivity and the traits related to mechanical harvesting in chickpea. The results obtained from the present study are discussed under the following heads.

5.1 Variability

All the 55 genotypes under the study displayed considerable amount of differences in their mean performance with respect to the traits related to mechanical harvesting as well as yield and yield attributing characters. An assessment of heritable and non-heritable components in the total variability is indispensable in adopting a suitable breeding procedure. The heritable portion of the overall observed variation can be ascertained by studying the components of variation such as coefficients of genotypic and phenotypic variability, heritability and predicted genetic advance. The magnitude of the phenotypic coefficient of variation (PCV) in general was found to be higher than the genotypic coefficient of variation (GCV) for all the characters studied indicating the influence of environment on the manifestation of these characters. However, the presence of a narrow gap between PCV and GCV for all the characters under study suggested low environmental influence on the expression of traits under study.

The genotypes exhibited higher PCV and GCV values for a few of the mechanical harvesting-related traits like seed yield per plant, biological yield, and number of pods per plant. However, for the height of first pod, plant height, harvest index and hundred seed weight, the PCV and GCV values were moderate. These results are in accordance with Kandwal *et al.* (2022), and Singh *et al.* (2014). The remaining traits like days to 50 per cent flowering and days to maturity exhibited low PCV and GCV values. These results are in consonance with Mohamed *et al.* (2015) Srivastava *et al*. (2017), and Gautam *et al.* (2021) in chickpea.

5.2 Heritability and Genetic Advance

Heritability estimates reveal the heritable portion of variability present in different characters. The knowledge of heritability enables the plant breeder to decide the course of selection procedure to be followed under a given situation. However, heritability values coupled with genetic advance would be more reliable (Johnson *et al.,* 1955) and useful in formulating selection procedures. In the present study, heritability estimates in the broad sense and genetic advance as per cent of the mean were estimated.

All mechanical harvesting-related characteristics, as well as yield and yield-attributing traits, had strong heritability estimates. High heritability coupled with high genetic advance as per cent over mean was observed for the mechanical harvesting-related trait height at first pod. A similar trend was also observed for yield and yield components *viz.,* number of seeds per plant, number of pods per plant and seed yield per plant. High PCV and GCV values for the traits indicate the existence of vast variability among the genotypes taken for study and the possibility of genetic improvement through direct selection for these traits. The findings of Srivastava *et al.* (2017) and Aswathi *et al.* (2019) are comparable to those of the current results. However, most of the traits related to mechanical harvesting showed moderate PCV and GCV values which might be due to less variability for these traits among the genotypes as in the present study genotypes were obtained from different research centers considering the important mechanical harvesting-related traits.

Whereas high heritability with high genetic advance for most of the traits related to mechanical harvesting, yield and yield attributing traits indicate the lesser influence of environment in the expression of these characters and prevalence of additive gene action in their inheritance, hence are amenable for simple selection. The low genetic advance over mean coupled with high heritability for days to maturity and days to 50% flowering suggested the importance of non-additive gene action for these traits. Chauhan *et al.* (2023) found a similar conclusion for days to 50% flowering and days to maturity. Therefore, selection based on the traits related to mechanical harvesting, yield and yield components could be more effective in realizing high genetic gain.

5.3 Correlation analysis

The association of one or more characters influenced by a large number of genes is elaborated statistically by correlation coefficients. As yield is a very complex character depending on a number of component characters, the knowledge of the association between the yield and its components and among the components is of immense practical value in making selections. In the present study, the interrelationship among the yield and characters related to mechanical harvesting is of immense help in breeding programs aimed at developing high-yielding genotypes with suitability for machine harvesting.

A positive significant relationship was observed between seed yield per plant with other traits. The positive association between the two traits indicates that a hike in one of the traits will certainly increase the values for another trait. Likewise, a negative association tells that an increase in one trait will lead to a decrease in another trait. Hundred seed weight showed a positive association with all the traits except days to 50% flowering, days to maturity and number of seeds per plant and negative association with day to maturity and seed per plant. The number of seeds per plant showed a high positive significant association with the number of pods per plant and significant positive relationship with plant height. The number of pods per plant had significant positive associations with plant height. Seed yield per plant exhibited positively significant correlation number of pods per plant number of seeds per plant, biological yiel and harvest index. It was positively non-significant with day to maturity and days to 50% flowering. Similar results were also reported by Ali *et al.,* (2011), Padmavathi *et al.,* (2013) and Kuldeep *et al.,* (2014). A similar kind of association between plant height and seed yield was reported by Babbar *et al.,* (2012).

5.4 Path analysis:

Path analysis gives information about how a component trait affects the dependent trait i.e., through direct effects and through other characters i.e., indirect effects. This shows whether the association with the dependent trait is due to the effect via other component traits. The residual effect provides insight into other significant traits that are not explored in this study and their impacts on the dependent variable.

5.4.1 Genotypic path

In genotypic path analysis for the 10 characters, it is observed that plant height had a negative direct effect (-0.0184) on seed yield per plant as similar findings were also described by Sözen *et al.,* (2018). Days to flowering (0.0007) had a positive indirect effect, whereas major negative indirect effects were observed by the biological yield (-0.0270) and hundred seed weight (-0.0267). The height of the first pod showed a positive direct effect (0.0250) on seed yield per plant. The rest of all characters had a positive indirect effect like plant height had more (0.0170), days to maturity (0.0051) and day to flowering (0.0032) through height of first pod on seed yield.

The number of pods per plant also had a positive direct effect (0.0457) on seed yield and through this a positive indirect effect was observed by the number of seeds per plant (0.0425), and biological yield (0.0360). A positive direct effect (0.422) by number of seeds per plant on seed yield per plant was observed, whereas a positive indirect effect by number of pods per plant (0.425), biological yield (0.360) through number of seed per plant observed and for hundred seed weight negative indirect effect (-0.0268) through day to 50% flowering were recorded for seed yield.

5.4.2 Phenotypic path

Days to 50% flowering trait had a negative direct effect (-0.0061) on seed yield per plant. Similarly, a negative direct effect was shown by plant height (-0.0405), whereas a positive direct effect was observed by harvest index (0.333), biological yield (0.691) and hundred seed weight (0.110). Height of first pod showed positive direct effect (0.0539) on seed yield per plant. Rest all character has positive indirect effect most were plant height (0.0355), days to maturity (0.0105) and day to flowering (0.007).

Positive direct effect (0.205) by number of seeds per plant on seed yield per plant was observed, whereas most positive indirect effect by number of pods per plant (0.189), biological yield (0.154) and for hundred seed weight negative indirect effect (-0.006) were recorded.

Biological yield had positive direct effect (0.691) on seed yield per plant. Positive indirect effects were also observed for days to 50% flowering (0.0080), days to maturity (0.0516), plant height (0.180), pod per plant (0.523), number of seeds per plant (0.519) and 100-seed weight (0.243). Negative indirect effects were observed for harvest index (-0.0622). Similarly, Vaghela *et al*. (2009), Ali *et al*. (2009), and Yucel & Anlarsal (2010) found the number of seeds per plant and number of pods per plant both has a positive direct effect on seed yield.

5.5 Genetic divergence

To estimate genetic divergence values, correlated means of different characters were transformed into the standard uncorrelated means. The statistical distance (Mahalanobis D^2 distance) between different pairs of the genotypes was obtained as the sum of squares of difference between the pairs of the corresponding uncorrelated value of any of the two genotypes considered at a time.

On the basis of D values, 55 chickpea genotypes were grouped into 13 clusters. The intra cluster distance varied from 0.00 to 187.8834. Cluster IV showed the highest intra cluster value (187.8834), while cluster I had 140.5076 intra cluster value, cluster II had 149.1163 intra cluster values, cluster III had 142.402 intra cluster values, cluster V had 86.9967 intra cluster values, cluster VI had 114.7406 intra cluster value, cluster VII had 100.612 intra cluster values and cluster VIII had 166.2542 intra cluster values. Whereas, clusters IX, X, XI XII and XIII had one genotype in each so, showed zero value for the intra cluster distance.

And the highest inter cluster distance was observed between the genotypes of cluster X and cluster XIII (1885.148) followed by cluster XII and cluster XIII (1549.497). Inter cluster distance was found to be the lowest between cluster V and cluster XI (166.423). Genotypes with the highest cluster mean from these clusters for these traits were chosen and used as parents in future hybridization programmes. The range of inter cluster distance varied from 166.74 to 1816.22 which is higher than the range of Intra cluster distance varied from 0.00 to 187.88. Similar results were also reported by Syed *et al.,* (2012), Jain and Indapurkar (2013), Puri *et al.,* (2013), Jayalakshmi *et al.,* (2014), Singh *et al.,* (2016), Vijayakumar *et al.,* (2017), Gediya *et al.,* (2018).

CHAPTER VI
SUMMARY, CONCLUSION AND SUGGESTIONS FOR FURTURE WORKS

The primary focus of the current experiment titled "**Screening and clustering of ideal genotypes suitable for machine harvesting in advanced generation lines of Chickpea (*Cicer arietinum* L.)"** is to identify genotypes that are both high-yielding and amenable for machine harvesting. The research was carried out in the experimental field under the Department of Genetics and Plant Breeding, R. A. K. College of Agriculture, Sehore with 55 genotypes.

The investigation focused on 10 characters *viz.,* Days to 50% flowering, Days to maturity, Height of first pod (cm), Plant height, Number of seeds per plant, Number of pods per plant, Biological yield, Harvest index, hundred seed weight and Plant yield (g). The data obtained has been subjected to various statistical analyses such as genetic variability parameters, correlation analysis, path coefficient analysis, and cluster analysis in order to find out how various characters interact with each other in order to obtain the required genotype that matches the requirements of our research problem. The outcomes of the aforementioned research are summarized in the following paragraphs.

Observations were recorded on the physiological traits *viz.,* days to 50% flowering and days to maturity, eight other quantitative traits *viz.,* plant height (cm), height of first pod from soil surface (cm), number of pods per plant, number of seeds per plant, hundred seed weight, biological yield per plant, harvest index and seed yield per plant.

Genetic parameters *viz*, mean, range, phenotypic and genotypic coefficient of variation, heritability and genetic advance as percentage of mean, genotypic and phenotypic correlation coefficient and genetic diversity analysis were estimated for different characters *viz*. days to 50% flowering and days to maturity, eight other quantitative traits *viz.,* plant height (cm), height of first pod from the soil surface (cm), number of pods per plant, number of seeds per plant, hundred seed weight, biological yield per plant, harvest index and seed yield per plant

High genotypic and phenotypic coefficient of variation found for seed yield per plant followed by number of pods per plant, biological yield per plant, number of seeds per plant, height of first pod, harvest index and hundred seed weight showed large variation for such characters.

Characters exhibiting high heritability coupled with high genetic advance as a percentage of mean were seed yield per plant followed by biological yield number of pods per plant, and number of seeds per plant. High heritability coupled with moderate genetic advance showed the height of first pod, hundred seed weight, harvest index and plant height. Seed yield per plant showed a significant and positive correlation with plant height, number of pods per plant, number of seeds per plant, biological yield per plant and harvest index.

For morphological characterization of genotypes, data were recorded on the visual traits at the plant level *viz.,* plant growth habit and height of first pod from soil surface. Based on this selection of plants suitable for mechanical harvesting has been also done.

Erect and semi-erect type plant growth habits are suitable for mechanical harvesting varieties. Out of 55 genotypes, a maximum number of 38 genotypes showed semi erect growth habit, 10 genotypes showed semi spreading and the remaining 7 showed erect type growth habit. Prostrate and spreading growth habits were not observed in any genotype.

Based on D^2 (divergence) values, 55 chickpea genotypes were categorized into 13 clusters. Cluster I was the largest, among all the clusters consisting of 18 genotypes followed by cluster II consisting of 9 genotypes. Cluster III comprises 3 genotypes, cluster IV has 7, cluster V has 3, cluster VI has 4, cluster VII comprises 2 genotypes, cluster VIII comprise 3 genotypes and the rest comprise one genotype in each.

The mean value for traits days to 50% flowering were maximum in cluster VIII, mean value for days to maturity were also maximum in cluster VIII and the mean value for plant height was maximum in cluster XIII. Similarly for the height of first pod from soil mean value was maximum in cluster XIII and mean value for number of seed per pod and number of pod per plant was maximum for cluster X.

Conclusion

The research study was taken into account in order to assess the genotypes of chickpeas for high yield and machine harvest ability based on the first pod's height. The findings indicated that the characteristic, height of First pod is crucial since it indicate to use of a machine harvester for the chickpea crop's harvest. Eight promising genotypes were identified in our investigation *viz.,* C 22931, C 22940, C 22967, C 22969, C 22970 and C 22980, RVG 204 and RVG 205 and can raise for the good height of the initial pod coupled with high yield.

Suggestion for further work

1. The best first-generation breeding lines identified for qualitative traits should be used to improve suitable chickpea varieties for machine harvesting.
2. There is a need to evaluate genetic variability for different traits related to machine harvesting. Therefore, a large number of desi, chickpea and kabuli chickpea genotypes should be collected from different parts of the country to identify better plant architecture and yield potential for mechanical harvesting.
3. Hybridization between promising lines identified for machine harvesting in this study belonging to distant clusters must be used to exploit the heterotic effect and desirable genes to reach potential sergeants.
4. Diverse first-generation breeding lines grouped in different clusters should be further investigated for their stability under stress and favourable climatic conditions.

CHAPTER VII
BIBLIOGARPHY

Agrawal, T., Kumar, A., Kumar, S., Kumar, A., Ranjan, R., Kumar, S. and Singh, P. (2018). Correlation and Path Coefficient Analysis for Grain Yield and Yield Components in Chickpea (*Cicer arietinum* L.) under Normal and Late Sown Conditions of Bihar, India. *International Journal of Current Microbiology and Applied Sciences*, **7**: 1633-1642.

Ali M.A., Nawab N.N., Abbas A., Zulkiffal M. and Sajjad M. (2009) Evaluation of criteria in *Cicer arietinum L.* using correlation and path analysis. *Australian Journal of Crop Science* **3**(2): 65–70

Aswathi, P.V., Ganesamurthy, K. and Jayamani, P. (2019). Genetic variability for morphological and biometrical traits in chickpea (*Cicer arietinum* L.). *Electronic Journal of Plant Breeding,* **10**(2): 699-705.

Babbar, A., Bansal, V., Tiwari, P. and Iquebal, M., (2012). Genetic variability for chickpea (*Cicer Arietinum L*.) under late sown season. *Legume Research.* **35.** 1-7.

Babbar, A., Pandey, S. and Singh, R. (2015). Genetic studies on chickpea genotypes grown in late sown under rice fallow conditions of Madhya Pradesh. *Electronic Journal of Plant Breeding*, 6(3), 738 748.

Banik, M., Deore, G.N., Mandal, A.K. and Mhase, L.B. (2018). Genetic Variability and Heritability Studies in Chickpea (*Cicer arietinum* L.). *Current Journal of Applied Science and Technology,* **31**(1): 1-6.

Bharathi, Ch., Lavanya, G., Roopa Viswanatha and Reddy, Y. (2022) Genetic Variability and Association Analysis in Chickpea (*Cicer arietinum L.*) for Seed Yield Characters. *International Journal of Plant & Soil Science*. pp. 27-36. ISSN 2320-7035

Basha S.J., Jayalakshmi V., Ahammed S.K. and Kamakshi N. (2020). Studies on growth and yield characters of chickpea (*Cicer arietinum L.*) varieties suitable for mechanical harvesting. *Tropical Plant Research* **7**(3): 634–637

Biru, A., Kassahun, T., Teklehaimanot, H. and Dagnachew, L. (2017). Broad sense heritability and genetic advance for grain yield and yield components of chickpea (*Cicer arietinum* L.) genotypes in western Ethiopia. *International Journal of Genetics and Molecular Biology*, **9**(4): 21 25.

Biswal, M., Solanki, R.S., Prajapat, S.S., Krishnan, R.S.R. and Babbar, A. (2021). Dissection of Genetic Variability, Correlation and Path Analysis of Seed Yield and Yield Contributing Traits in Chickpea (*Cicer arietinum* L.) and their Implication in Selection. *Biological Forum – An International Journal,* **13**(4): 679-686.

Bukke, A.N., Singh, L., Parveen, S., and Gupta, P. (2022). Assessment of Genetic Variability Parameters and Character Association in Chickpea (*Cicer arietinum L.*). *International Journal of Environment and Climate Change*, **12**(11): 1654–1662.

Chaturvedi, S.K., Singh, N.P., Mishra, N., Gaur, P.M. and Varshney, R.K. (2016). Tailoring chickpea varieties for amenability to machine harvesting. *Joint PanAfrican Grain Legume and World Cowpea Conference,*

Chaudhary, N.C., Kumar, M., Chand, P., Singh, S.K., Yadav, M.K. and Gangwar, L.K. (2020). Estimation of Heritable Relationship and Variability of Yield and Yield Determinants in Chickpea (*Cicer arietinum* L.). *Int.J.Curr.Microbiol.App.Sci.* **9**(6): 2511-2519.

Chopdar, D.K., Bharti, B., Sharma, P.P., Dubey, Brajendra, R.B., Meena, B.L. (2017). Studies on genetic variability, character association and path analysis for yield and its contributing traits in chickpea (*Cicer arietinum* L.). *Legume Research*. **40**(5): 824-829.

Dasari, P., Padala, C. and Gaibriyal, M.L. (2022). Study on Genetic Diversity in Chickpea (*Cicer arietinum* L.) Germplasm under Normal Sown Conditions. *Int. J. Curr. Microbiol. App. Sci.,* **11**(4): 256-260.

Dahiya, B.S., Lather, V.S., Solanki, I.S. and Kumar, R., (1984), Useful spontaneous mutants in chickpea. *Int. Chickpea Newslett*, **11**: 5–7.

Erdemci, I., Yasar, M. and Koc, M. (2016). Evaluation of selection criteria in winter chickpea using correlation coefficient and path analysis. *Yuzuncu Yil Universitesi J. Agric. Sci.,* **26**(1): 1-6.

Gautam, Ashish & Panwar, R & Verma, Sanjay & Arora, Anju & Gaur, Amit & Chauhan, Charupriya. (2021). Assessment of Genetic Variability Parameters for Yield and its Components in Chickpea (*Cicer arietinum L*.). *Biological Forum –An International Journal* **13**(2). 651-655.

Gediya, L.N., Patel, D.A., Parmar, D.J., Patel, R and Parth, R. 2018. Assessment of genetic diversity of chickpea genotypes using D2 statistics. *International Journal of Chemical Studies*. **6**(4): 3177-3181.

Geethanjali, D., Sudha Rani, M. and Jayalakshmi, V. (2018). Genetic diversity analysis in chickpea (*Cicer arietinum* L.) grown under rainfed and irrigated conditions for quality and yield attributing traits*. Indian J. Agric. Res.,* **52**(6): 691-695.

Golpira, H., Tavakoli, T., and Baerdemaeker, J. D. 2013. Design and development of a chickpea stripper harvester. *Spanish Journal of Agricultural Research*, **11**(4), 929 934.

Gupta, M., Kaur, M., Singh, I and Gaur, P.M. (2015). Developing chickpea cultivars suitable for mechanical harvesting. *Brain Storming Meeting on Promotion of Pulses in Indo-Gangetic Plains of India*, Punjab Agricultural University, At Ludhiana, India.

Gupta, V. P. and Lal, S., 1981, Developmental allometry and plant type in chickpea*. Int. chickpea Newslett*, **4** : 8–9.

Jayalakshmi, V., Reddy, A.T., Vishnu, B., and Imran, M.M. 2020. Genetic variability and character association studies in chickpea (*Cicer arietinum* L.) with special reference to traits amenable to combine harvesting. *The Journal of Research ANGRAU.*

Jain, S.K. & Sharma, L. & Gupta, K.C. & Kumar, Vipen & Yadav, M.R. (2020). Variability and Character Association for Yield and Quantitative Traits under

Late Sown Conditions in Chickpea (Cicer arietinum L.). *Legume research - an international journal*. 10.18805/LR-4432.

Jain, S and Indapurkar, Y.M. 2013. Assesment of Genetic Divergence in Chickpea Genotypes (*Cicer arietinum L.*). *Trends in Biosciences.* 6(1): 68-69.

Joshi, P. (2017). Genotypes suitable for mechanical harvesting identified from genetics stock of chickpea (*Cicer aritinum* L.). *M.P. Young Scientist Congress,* 10.

Joshi, P., Yasin, M. and Sundaram, P. (2018). Genetic Variability, Heritability and Genetic Advance Study for Seed Yield and Yield Component Traits in a Chickpea Recombinant Inbred Line (RIL) Population. *International Journal of Pure and Applied Bioscience*, **6**(2); 136 141.

Jukanti, A., Gaur, P., Gowda, C., & Chibbar, R. (2012). Nutritional quality and health benefits of chickpea (*Cicer arietinum L.*): *A review. British Journal of Nutrition*, **108**(S1), S11-S26

Kamani, V., Nandimandalam, H., Ellapu, G.R. and Praneeth, D. (2022). Exploring genetic diversity and analyzing seed yield characters through principle component analysis in chickpea (*Cicer arietinum* L.), **11;** 1727-1731.

Kerketta, A., Lavanya, G.R. and Kumar, P. (2018). Interrelationship between Seed Yield and Component Characters in Chickpea (*Cicer arietinum* L.). *International Journal of Current Microbiology and Applied Sciences,* **7**(7): 102-106.

Kandwal, N., Panwar, R.K., Verma, S.K., Arora, A., Chauhan, A., & Reddy, B.S. (2022). Assessment of genetic variability, correlation and path analysis for yield and its component traits in chickpea (*Cicer arietinum L.*). *The Pharma Innovation Journal*, **11**(11): 1231-1235.

Konduru, T., Lavanya, G., Nayan, R. and Brahmanjaneyulu, P. (2021). Estimation of Correlation and Path Coefficient Analysis for Quantitative Characters in Chickpea at Uttar Pradesh (*Cicer arietinum* L.). *International Journal of Plant & Soil Science,* **33**: 96-107.

Kumar, A., Kumar, A., Ravi, R.K., Kumar, S., Satyendra, Kumari, R. and Singh, P.K. (2019). Principal component analysis of Agro-morphogenetic traits in Desi chickpea (*Cicer arietinum* L.). *International Journal of Chemical Studies*, **6**: 362-365.

Kumar, A., Singh, B.P., Jamwal, B.S., Kumar, B., and Kumar, A. (2022). Genetic Diversity Analysis of Chickpea Genotypes (*Cicer arietinum* L.) for Seed Yield and Morphogenetic Traits. *Legume Research - An International Journal.*

Madhuri R.D. and Jayalakshmi V. (2020). Identification of high yielding mechanical harvestable chickpea (*Cicer arietinum* L.) genotypes under rainfed and irrigated conditions. *Int J Chem Stud* **8**(1): 368-375.

Mahmood, M.T., Ahmad, M., Ali, I., Hussain, M., Latif, A. and Zubair, M. (2018). Evaluation of Chickpea Genotypes for Genetic Diversity through Multivariate Analysis. *Journal of Environmental and Agricultural Sciences*, **15***:* 11-17.

Malhotra, R.S., Singh, K.B. and Saxena, M.C., (1997). Effect of irrigation on winter sown chickpea in a mediterranean environment. *J. Agron. Crop Sci.,* 178: 237-243.

Mannur D.M., kumar, S. and Sharanabasappa, B.Y. (2017). Estimates of genetic parameters of chickpea varieties suitable for mechanical harvesting across three locations. *Int. J. of Innovative and Applied Research*, **5**(9): 41-46.

Meena, V.K., Verma, P., Tak, Y. and Meena, D. (2021). Genetic Variability, Correlation and Path coefficient Studies in Chickpea (Cicer arietinum L.) Genotypes in South Eastern Rajasthan. *Biological Forum – An International Journal*, **13**(3a): 93-98.

Mohamed, A. A., Izzat, T. S. A. and Ashraf, E. M. A., 2015, Assessment of genetic variability and yield stability in chickpea (Cicer arietinum L.) cultivars in River Nile State, Sudan. *J. Plant Breed. Crop Sci*. **7**(7): 219-224.

Mundinamani, S.M. and Laxmi, N. (2014). Economics of production of major crops in dharwad districts. *Kranataka J. Agric. Sci.*, **27**(2): 165-169.

Ningwal, R., Tripathi, M.K., Tiwari, S., Yadav, R.K., Tripathi, N., Solanki, R.S., Asati, R. and Yasin, M. (2023). Assessment of genetic variability, correlation and path coefficient analysis for yield and its attributing traits in chickpea (*Cicer arietinum* L.). *The Pharma Innovation Journal*, **12**(3): 4851-4859.

Oram P & Belaie A (1990) Legumes in Farming Systems. ICARDA/IFI'RI Report. Aleppo, Syria: International Center for Agricultural Research in the Dry Areas. International Food Policy Research Institute. Washington DC, USA.

Osrnan AE, Ibrahirn MH & Jorres MA (1990) The role of legumes in the farming systems of the Mediterranean Areas. In: Proceedings of the Workshop, 20–24 Jun 1988, ICARDA, Aleppo, Syria. Dordrecht, Netherlands: *Kluwrr Academic Publishers*.

Patil S., Mansur C.P., Gaur P., Salakinkop S. and Alagundagi S. (2021). Planting Density Affected Dry Matter Production, Partitioning, and Yield in Machine Harvestable Chickpea Genotypes in the Irrigated Ecosystem. *International Journal of Plant Production*, **15**: 29-43.

Paul, P., Patil, S.S., Manojkumar, N., and Kumar, G.M. (2022). Study of Correlations and Path Evaluations to Find Yield Contributing Characters in Chickpea Genotypes. *International Journal of Environment and Climate Change*, **12**(8): 83–90.

Puri, M.K., Johnson, P.L and Sharma, R.N. 2013. Study of variability, diversity and association analysis of chickpea (Cicer arietinum L.) germplasm under normal and late sown condition of Chattisgarh state. *Trends in Biosciences.* 6(6): 723- 731.

Ramanujam, S., 1975, Genetic diversity, stability and plant type in pulse crops. In: Proceedings of the International Workshop on Grain Legumes, ICRISAT, Patancheru, AP, India, pp. 167 176.

Sajja, S. B., Samineni, S., and Gaur, P.M. 2017. Botany of Chickpea. *International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)* 13 24. https://doi.org/10.1007/978-3-319-66117-9_3

Saxena, M.C., Diekrnann, J., Erskine, W. and Singh, K.B., (1987). Mechanization of harvest in lentil and chickpea in semi-arid areas. Proceed. Conference on mechanization of field experiments in semi-arid areas, ICARDA. Aleppo, Syria, pp 211-228.

Saxena R.R., Nandedkar, K., Rawte, S., Porte, S.S., Xalxo, S.M., Parikh, M. and Saxena, R.R. (2023). Exploiting Genomic Resources for Efficient Utilization of Chickpea (*Cicer arietinum L*.) Crop Improvement based on Agro-morphological, Yield and Nutritional Traits. *Legume Research*. **46**(2): 134-140.

Shilpa, P.C., Mundinamani, S.M., And Rudrapur, S. 2017. Comparative economic analysis of chickpea cultivation in mechanized and non-mechanized farms of India. *Agriculture Update*, **12**(S-3): 770 776.

Sinha, S.K., 1977, Food legumes: distribution, adaptability and biology of yield. FAO, Rome, Paper No. 3, p. 124.

Singh, D.J., Singh, R and Kamble, M.S. 2016. Genetic diversity studies in chickpea (*Cicer arietinum L*.) in kolhapur region of Maharashtra. *Bangladesh Journal of Botany*. 45(3): 459-464.

Singh T.P., Raiger H.L., Kumari J., Singh A., Deshmukh P.S. (2014) Evaluation of chickpea genotypes for variability in seed protein content and yield components under restricted soil moisture condition. *Indian Journal of Plant Physiology*. 19(3):273280

Singh, U., Gaur, P. M., Chaturvedi, S.K., Hazra K. K. and Singh G. (2019). Changing Plant Architecture and Density can Increase Chickpea Productivity and Facilitate for Mechanical Harvesting. *Int. J. Plant Prod.* **13:** 193–202

Singh, P., Nath, S., Dubey, S., Mishra, P. and Kuswaha, C. (2023). Genetic Divergence on Chickpea (*Cicer arietinum* L.) Genotypes Grown under Late Sown Conditions. *International Journal of Environment and Climate Change.* **13**. 637-645.

Srivastava S, Lavanya GR, Lal GM. (2017) Genetic variability and character association for seed yield in chickpea (Cicer arietinum L.). *Journal of Pharmacognosy and Phytochemistry.* 6(4):748-750.

Sözen, Ömer and Karadavut, Ufuk. (2018). Correlation and path analysis for yield performance and yield components of chickpea (*Cicer arietinum L*.) genotypes cultivated in central Anatolia. *Pakistan Journal of Botany*. 50.

Syed, M.A., Islam, M.R., Hossain, M.S., Alam, M.M and Amin, M.N. 2012. Genetic divergence in chickpea (*Cicer arietinum L*.). *Bangladesh Journal of Agricultural Research*. 37(1): 129-136.

Tare, S., Yasin, M., Sikarwar, R. S., Puri, P., & Malik, V. (2023). Dissection of genetic variability, correlation of seed yield and yield contributing traits in chickpea (*Cicer arietinum L*.) in different temperature conditions. *The Pharma Innovation Journal*, **12**(2), 1702-1707.

Tamvar, M.R., Patel, S.R., Patil, S.S., Naik, A.J., & Patel, H.N. (2019). Variability, heritability and genetic advance for quantitative traits in chickpea (*Cicer arietinum L.* var. microsperma*). International Journal of Chemical Studies*, 7(4), 1764-1767.

Tengse SM, Sarode SB, Deshmukh SS, Shinde AV. Assessment of correlation and path analysis in chickpea (*Cicer arietinum* L.). *Pharma Innovation* **11**(1):184-188.

Ton, A. and Anlarsal, A. E. 2017. Estimation of genetic variability for seed yield and its components in chickpea (*Cicer arietinum L*.) genotypes. *Legume Res.An Int. J*., 40(6): 1133-1135.

Vaghela, M.D., Poshiya V.K., Savaliya J.J., Kavani R.H. and Davada B.K. (2009) Genetic studies in kabuli chickpea (*Cicer arietinum L*.). *Legume Research* **32**(3): 191–194

Vijayakumar, A.G., Boodi, I., Gaur, P., and Upadhyaya, H. D. (2017). Genetic diversity for yield and its component traits in chickpea *(Cicer arietinum L.). Electronic Journal of Plant Breeding.* **8.** 89-95.

Vikram, T.H., Haritha, H.N., Satyanarayana, M.S. and Jayalakshmi, V. (2023). Biochemical and morphological diversity of chickpea (*Cicer arietinum* L.). *Electronic Journal of Plant Breeding*, **14**(1): 296 – 302.

Vishnu, B., Jayalakshmi, V., RaniSudha, M. (2018). Genetic diversity studies among chickpea (*Cicer arietinum* L.) genotypes under rainfed and irrigated conditions for yield attributing and traits related to mechanical harvesting. *Legume Research*, **43**(2): 190-194.

Yadav, A.K., Chaubey, S.K., Pyare, R., Kumar, A., & Pyare, R. (2020). Correlation and path coefficient analysis of yield and its component in chickpea (*Cicer arietinum L.*). *Journal of Pharmacognosy and Phytochemistry*, **9**(Sp), 67-70.

Yucel D.O. and Anlarsal A.E. (2010) determination of Selection criteria with Path coefficient analysis in chickpea (*Cicer arietinum L*.). *Bulgerian Journal of Agricultural Sciences* **16**: 42–48.

APPENDICES

ENTRY NAME	Day to flowering	Days to maturity	Plant height (cm)	Height of first pod	No. of pod per Plant	No. Of seed per plant	Seed yield per plant	Biological yield per plant	100 Seed Weight (g)	Harvest index (%)
C-22925	75.00	118.67	57.00	29.33	56.00	70.33	15.97	40.78	23.27	39.17
C-22928	68.67	116.67	59.33	29.02	37.33	44.33	10.62	29.33	24.25	36.30
C-22929	64.33	118.33	49.00	24.22	43.33	50.00	7.77	33.66	17.22	23.16
C-22930	68.33	119.67	61.33	32.00	40.00	45.67	9.29	31.66	20.55	29.28
C-22931	70.33	123.00	55.33	30.21	89.33	109.67	24.19	45.22	22.90	53.50
C-22933	69.33	123.67	59.00	25.11	69.33	100.00	16.00	36.44	16.91	43.95
C-22934	71.00	119.67	49.00	28.77	10.67	14.67	3.00	8.89	19.44	33.24
C-22935	65.67	118.67	69.22	30.11	53.33	72.33	15.44	28.00	22.78	55.17
C-22936	68.33	120.00	56.11	20.22	60.33	69.33	18.87	53.00	27.62	35.63
C-22937	78.33	119.33	60.11	32.33	50.00	65.67	16.26	37.66	23.37	43.24
C-22938	73.33	124.33	56.44	24.37	72.33	79.00	15.82	41.00	20.29	38.59
C-22939	74.67	120.00	39.15	26.60	32.00	42.67	8.85	24.44	22.46	36.19
C-22940	69.67	125.33	61.22	32.07	80.67	119.67	28.66	53.66	23.28	53.47
C-22944	72.33	123.33	56.44	34.43	79.33	115.67	16.04	30.52	15.44	52.60
C-22945	68.33	123.33	62.66	31.73	64.67	73.67	21.00	46.55	30.00	45.19
C-22946	67.67	121.00	63.77	26.70	57.33	87.00	17.53	35.88	20.22	48.86
C-22947	70.00	124.33	42.33	18.83	40.67	48.33	9.61	20.55	21.74	47.06
C-22948	76.33	123.33	57.77	35.60	40.33	55.67	13.66	35.66	23.60	38.18
C-22949	71.00	115.67	45.55	20.20	49.67	66.33	12.55	35.66	18.98	35.27
C-22950	69.00	116.67	53.00	25.57	54.67	91.67	16.55	42.66	20.72	38.81
C-22952	69.00	118.00	33.22	20.87	39.33	50.33	9.56	18.11	18.79	53.06
C-22955	71.67	115.00	51.00	22.50	43.67	59.67	13.89	30.89	21.89	45.17
C-22956	63.00	122.33	52.55	34.23	34.33	41.67	15.00	33.11	33.40	45.32
C-22957	74.67	124.67	55.88	24.93	26.67	31.33	6.11	13.89	18.33	43.96
C-22958	70.67	124.33	54.77	31.13	40.00	42.00	10.00	22.89	23.44	43.60

C-22959	72.67	120.67	64.55	23.73	58.33	77.67	21.56	65.66	25.41	32.93
C-22960	65.00	119.00	53.44	29.27	24.67	35.67	6.44	21.89	17.35	29.54
C-22961	72.67	119.67	59.67	32.73	92.33	99.00	17.89	44.11	19.22	40.56
C-22962	73.67	122.67	58.44	25.87	58.33	99.33	18.11	37.55	22.55	48.14
C-22963	73.67	121.00	54.77	24.83	60.00	79.33	13.63	29.55	18.00	46.34
C-22964	70.33	118.67	59.55	28.60	73.00	96.00	22.33	61.33	24.85	36.46
C-22967	70.33	119.67	49.55	31.10	119.00	131.00	33.44	66.00	27.06	50.68
C-22968	73.67	123.67	61.89	40.67	40.00	47.33	9.89	26.77	24.70	37.18
C-22969	68.67	120.67	60.44	32.23	85.67	110.33	24.37	72.44	22.74	33.67
C-22970	72.33	122.33	48.33	20.60	38.67	79.67	22.10	46.22	27.98	47.99
C-22971	73.33	120.67	41.11	19.67	42.67	68.33	9.52	18.33	13.91	53.70
C-22972	72.00	119.33	58.22	27.77	58.00	82.33	18.67	40.11	22.78	46.49
C-22973	66.67	115.33	52.67	28.67	47.00	55.33	13.67	26.11	25.68	52.67
C-22974	63.00	123.33	70.00	39.33	41.00	69.00	13.11	29.00	19.70	45.10
C-22975	67.67	116.33	66.22	30.63	54.33	65.67	16.22	37.33	24.80	43.53
C-22976	68.67	117.33	59.55	33.00	67.67	90.67	16.11	45.20	17.09	35.80
C-22977	72.00	120.00	56.00	32.67	99.33	130.33	31.78	58.88	23.74	54.20
C-22978	79.67	125.00	65.33	40.40	41.67	66.67	11.54	28.77	18.30	40.09
C-22979	75.33	124.00	70.55	39.00	61.67	88.67	20.00	46.55	21.11	43.00
C-22980	72.33	118.00	59.33	40.20	40.67	60.33	15.78	27.66	24.45	57.04
C-22981	77.33	124.00	67.67	39.33	41.67	51.33	12.33	29.44	24.41	42.01
C-22982	71.00	122.00	46.00	25.20	37.00	41.00	9.11	25.67	24.63	35.47
RVG 204	64.67	120.33	61.78	28.50	60.33	70.33	17.33	35.22	25.71	49.24
RVSSG 96	68.00	117.33	76.55	40.67	32.07	47.00	9.67	23.22	19.35	41.77
RVSSG74	69.00	113.00	54.89	25.47	30.03	43.00	9.70	20.93	25.31	46.43
RVG 205	67.67	124.33	57.11	29.97	48.97	66.67	14.33	34.96	19.37	41.00
RVG 202	69.00	115.33	57.22	28.67	89.33	102.00	23.89	47.33	23.68	50.59
RVSSG 68	69.33	120.00	57.11	25.10	59.67	70.67	10.40	20.13	14.67	51.87
RVKG 111	70.00	112.67	56.00	31.00	36.43	48.00	11.04	22.07	22.39	50.27
RVKG 121	70.67	116.00	46.22	26.70	32.40	38.33	9.66	25.32	25.41	38.70

VITA

The author of this thesis **Mr. Jai Singh Yadav** S/O **Gopal Lal Yadav** was born on 23th June 1998 at District. Jaipur (Raj.). He completed his High School (10th) in 2013 and Higher Secondary (12th) in 2015 from Rajasthan Board of Secondary Education (RBSE) Ajmer Rajasthan.

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Higher Secondary	Mathematics	2015	BSER Ajmer	80.40 %
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