

**EXPLORATION OF GENETIC VARIABILITY IN
OKRA (*Abelmoschus esculentus* (L.) Moench) UNDER
SUBTROPICAL REGIONS OF HIMACHAL PRADESH**

Thesis

**by
SRISTI
(NH-2021-45-M)**

Submitted to



**DR. YASHWANT SINGH PARMAR UNIVERSITY
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This is to certify that the thesis titled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” submitted in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (HORTICULTURE) VEGETABLE SCIENCE** in the discipline of **VEGETABLE SCIENCE** of Dr. Yashwant Singh Parmar University of Horticulture and Forestry, Nauni, Solan (HP) – 173 230 is a bonafide research work carried out by **Ms. SRISTI (NH-2021-45-M)** daughter of Sh. Lekh Raj under my supervision and that no part of this thesis has been submitted for any other degree or diploma.

The assistance and help received during the course of investigation has been fully acknowledged.

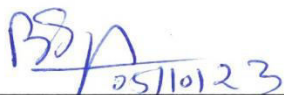
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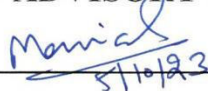


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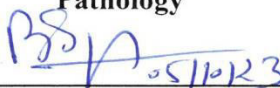
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**DEDICATED TO
MY PARENTS FOR
THEIR ENDLESS
LOVE, SUPPORT
AND
ENCOURAGEMENT**

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Sristi

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ABBREVIATIONS

L.	: Linnaeus
%	: Per cent
=	: Equal to
X	: Multiplication
°C	: Degree Celsius
/	: Per
>	: Greater than
<	: Less than
ANOVA	: Analysis of Variance
CV	: Coefficient of Variation
CD	: Critical Difference
<i>et al.</i>	: Co-workers
H.P.	: Himachal Pradesh
via	: by way of
SE	: Standard error
COH&F	: College of Horticulture and Forestry
<i>viz.,</i>	: Videlicet (namely)
PCV	: Phenotypic coefficient of variation
GCV	: Genotypic coefficient of variation
RH	: Relative humidity
NPK	: Nitrogen, Phosphorus, Potassium
pH	: Potential of Hydrogen
mt	: Metric tonnes
m	: Meter
cm	: Centimeter
mm	: Millimetre
g	: Gram
kg	: Kilogram
°B	: Degree brix
var.	: Variety
RCBD	: Randomized Complete Block Design
FYM	: Farm Yard Manure
GAM	: Genetic advance over mean
DAS	: Days after sowing
P	: Phenotypic
G	: Genotypic
YVMV	: Yellow vein mosaic virus
CSKHPKV	: Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya
NHB	: National Horticulture Board
AVRDC	: Asian Vegetable Research and Development Center

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Chapter-1

INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) commonly known as lady's finger or bhindi is an amphi-diploid crop having somatic chromosome number $2n=130$ (Joshi and Hardas, 1953; Schippers, 2000). In tropical and subtropical regions of the world, it is one of the most extensively farmed vegetable (Tattanakorn and Prabhat, 2004; Phathiz We and Ekpo, 2011). It is an important fruit vegetable, belongs to the family Malvaceae (Mallow family) and had captured prominent position among different vegetables in the world. It is earlier said to be the native of Ethiopia but according to recent investigations, it is considered to be African or Asiatic origin (Markose and Peter, 1990). India is considered as secondary centre of origin of okra (Vavilov, 1951). Earlier okra was known as *Hibiscus esculentus* but renamed as *Abelmoschus esculentus* (L.) Moench because in okra calyx, corolla and staminal column are fused together at the base and fall together after anthesis. This makes okra different from Hibiscus, whose calyx is persistent (Thamburaj and Singh, 2001). It is an often-cross pollinated crop with an extent of natural cross pollination upto 9.61 per cent. India is the leading producer of okra in the world having 72% of the total world production. In North India, it is widely cultivated as summer season crop and a winter crop in Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. In India, it is cultivated on an area of 531 thousand hectares with annual production of 6466 thousand tonnes and productivity 12.17 tonnes per hectare (NHB, 2021). In Himachal Pradesh, it is grown during summer and rainy season in low and mid-hills in 3.92 thousand hectares area with production of 60.95 thousand tonnes (Anonymous, 2021-22). Okra accounts for thirty percent of the foreign exchange among fresh vegetables (Bose and Ranjan, 1988).

The tender immature green fruits of okra are rich in vitamins (A, B and C), minerals, proteins, carbohydrates, iron, iodine and antioxidants (Jha and Dubey, 1998). Mucilage and fibre content present in okra are good for diabetic patients. The okra fruits have excellent medicinal values with antispasmodic, demulcent, diaphoretic, diuretic, emollient, stimulant and vulnerary properties. Okra fruit is a capsule (pod) which may be light green, green or red in color. The crop is grown

for its tender green fruits, which are mucilaginous and are used in various ways as cooked vegetable, boiled or fried, soups, sauces, stews, frozen, canned and dehydrated products. Apart from its importance as a vegetable, okra has several other economic uses also. The oil from its seeds is utilized in perfume industries and stem containing crude fibre and dried fruit shells are used in paper industry. The roots and stems are used as a clearing agent of cane juice in the manufacturing of jaggery and sugar.

Okra is herbaceous annual plant with bisexual flowers having erect or spreading growth habit. It is hardy crop which can be successfully grown on a wide range of soil and under variable environmental conditions. In Northern Indian plains, usually two crops of okra i.e. spring-summer and rainy season crop are taken in a year. The sowing of spring-summer crop is started from the beginning of February to the end of March while the rainy season crop is sown during May-July. Mid and low hills conditions are more suitable for okra cultivation due to longer harvesting period and lesser incidence of yellow vein mosaic virus. It grows well in areas where day temperature remains between 25 °C to 40°C and that of night over 22°C. Due to quick growing habit and heat tolerance okra fits well under sequential cropping systems either as a sole crop or an intercrop.

Presence of adequate genetic variability is the first and foremost requirement in the successful execution of any breeding programme. The crop improvement is directly proportional to the magnitude of genetic variability present in the germplasm (Dhankhar and Dhankhar, 2002). Selection is said to be effective in a population having a large heritable variability. The knowledge of pattern of inheritance of various characters is important consideration for determining the most appropriate breeding procedure for crop improvement. Phenotypic variation results from both genetic and environmental factors, thus phenotype are often not true indicator of its genotype. Variability, heritability, genetic advance, genetic gain, correlation and path correlation analysis are genetic tools for effective selection. Presence of genetic variability in the base population for yield and yield contributing characters is an important tool for successful crop improvement (Allard, 1960). The knowledge about genetic variability and association among yield and yield contributing characters obtained through

estimating genotypic and phenotypic correlation is important in order to determine suitable selection criteria (Miller et al., 1958). Phenotypic and genotypic coefficient of variation (PCV and GCV) is useful for estimating the extent of variability present in the available germplasm.

The index of transmission of characters from parents to their off springs is known as heritability. It alone does not depict the true picture of genetic improvement thus, study of genetic advance coupled with heritability are more powerful in predicting the resultant effect of selection (Johnson et al., 1955). Genetic advance reveal the improvement in the mean genotypic values of the selected progenies over the parental population thereby, helps the breeder to select the progenies in the earlier generation itself. Correlation studies are of great significance in plant breeding. If significant correlation values are established among yield and yield contributing traits, considerable improvement could be made through selective plant breeding technique. Study of correlation alone is not sufficient to generate an accurate view of direct and indirect influence of yield contributing traits on crop yield. Therefore path correlation analysis divides the total correlation coefficients into direct and indirect effects of independent variable on dependent variable.

A huge variability for qualitative as well as quantitative attributes in okra is present in Himachal Pradesh. Breeding and seed production are very feasible due to the presence of diverse germplasm and favourable microclimate. On the degree of genetic diversity and heritability of the yield and its contributing factors in okra grown in mid-hill environments in Himachal Pradesh, very little information is known. Old cultivars have low yields and are susceptible to serious diseases and pests. Hybrids are also quite expensive; the marginal and poor farmers in hilly regions cannot afford the price of F₁ hybrids. Therefore, it is necessary to investigate that how newly introduced open-pollinated genotypes perform in Himachal Pradesh mid-hill environmental conditions and to select elite genotypes for quality and quantity attributes.

Keeping in view the above facts, the present investigation entitled **“Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.)**

Moench) under subtropical regions of Himachal Pradesh” including thirty two genotypes was carried out with the following objectives:

OBJECTIVES

- To study the performance of okra genotypes under sub-tropical regions of Himachal Pradesh.
- To estimate the extent of genetic variability, heritability and genetic advance.
- To work out correlation among the various yield and yield contributing characters.
- To identify the promising genotype(s) with desirable horticultural traits.

**REVIEW OF
LITERATURE**

Chapter-2

REVIEW OF LITERATURE

The success of any crop improvement programme predominantly depends upon the selection of appropriate material and its skilful management. It is only possible, if we are possessing knowledge about previous work done in the concern field. A number of studies have been conducted with regards to variability for important characters of okra. Estimating parameters of variability, especially heritability and genetic gain are important indicators for improvement of characters through selection. Selection for highly heritable characters is more effective. Therefore, heritability along with other parameters of variability can be used in predicting effectiveness of selection. Genetic gain reflects the extent of improvement in characters through selection.

Selection for yield and quality traits can be better achieved if information about the association of different horticultural traits is available. Yield is a variable trait. Direct and indirect effects of different traits can be better utilized for effective selection through path coefficient analysis. In the past few years, substantial contribution has been made to the literature regarding genetics and breeding of okra. The relevant literature related to various aspects of present investigation entitled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” has been reviewed under following sub heads:

2.1 Genetic variability

2.2 Heritability and genetic advance

2.3 Correlation coefficient analysis

2.4 Path coefficient analysis

2.1 GENETIC VARIABILITY

Genetic variability is a pre-requisite for any breeding programme (Azam et al., 2013). It is considered as most important attribute in crop improvement (Oppong-Sekyere et al., 2011). The importance of genetic variability was

perceived by Vavilov (1951) for the first time and he supported that wide range of variability provides better scope for selection. Genetic evaluation and selection of superior genotypes is the most important aspects in plant improvement programme and the effectiveness of the selection depends upon the extent of genetic variability within or among the population subjected to the selection (Dixit et al., 1971; Rao, 1972; Tikka et al., 1974; Patnaik and Tak, 1974). For the improvement of yield and other quantitative characters the information regarding genetic variability is necessary. The studies conducted in okra related to genetic variability are reviewed below:

Dhall et al. (2001) evaluated forty eight advance generations of okra for genetic variability in ten quantitative characters. Significant differences were observed among the genotypes for all traits under study. Estimates of PCV and GCV were high for plant height (30.37%, 25.88%), yield per plant (30.19%, 20.47%), marketable yield per plant (30.07%, 20.10%) and fruits per plant (26.57%, 21.98%).

Bendale et al. (2003) studied a wide range of genetic variability for internodal length, number of branches per plant, first flowering node, pod length, pod weight, plant height, nodes per plant, fruiting period, number of pods per plant and yield per plant. The Phenotypic coefficient of variation for all the 15 attributes was higher than the genotypic coefficient of variance.

Mehta et al. (2006) studied genetic variability in twenty-two diverse genotypes of okra for all the characters. The genotypic coefficient of variation was higher for fruit yield, average fruit weight, plant height and fruit length which might be attributed to additive gene action. Simultaneously variations were noticed for number of primary branches per plant showing maximum variability among the different okra genotypes.

Dakahe et al. (2007) observed genetic variability in twenty five genotypes of okra and reported magnitudinal difference between phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV). The estimate was maximum for fruit length followed by number of fruits per plant and fruit girth, suggesting the influence of environment on these traits.

Singh et al. (2008) assessed genetic variability in 34 advanced breeding lines of okra, including their parents. The number of branches per plant, plant height, number of nodes per plant, number of seeds per fruit, length of the fruit, number of fruits per plant and fruit production were found to have the highest phenotypic and genotypic coefficients of variance.

Akotkar et al. (2010) evaluated 50 genotypes of okra to study genetic variability among different horticultural traits. The relative contribution of different characters towards the expression of genetic variability showed that plant height contributed the maximum (19.59%) followed by number of nodes on main stem (17.71%), number of locules per fruit (16.82%) and number of fruiting nodes (13.14%).

Morey et al. (2012) evaluated twenty two genotypes of okra for different morphological characters and observed significant variations for all the characters under study. The phenotypic coefficient of variation (PCV) was higher than genotypic coefficient of variation (GCV) for all characters indicating the role of environment for the expression of these traits. The high values of GCV and PCV was observed for moisture content (67.34%, 78.92%), diameter of fruit (26.45%, 27.35%), number of fruits per plant (23.93%, 25.73%) and yield per plant (22.29%, 22.93%).

Duggi et al. (2013) studied thirty-one genotypes of okra for yield and yield attributing characters. Both phenotypic and genotypic variations were in very close association for most of the traits which showed less environmental influence on the expression of the characters under study. High variability were observed for number of primary branches and number of fruits per plant which indicated the presence of substantial variability for these characters thus suggesting good scope for improvement through selection.

Koundinya et al. (2013) evaluated forty genotypes of okra and recorded moderate phenotypic and genotypic coefficient of variation for plant height, intermodal length, branches per plant, fruits per plant, seeds per fruit, test weight and fruit yield per plant.

Ijjaj et al. (2014) studied 25 okra genotypes to determine the genetic variability for 10 yield and quality related traits. There was minor difference between genotypic as well as phenotypic variance which indicated low environmental variance. Khajuria et al. (2015) observed sixty genotypes of okra and revealed that the estimates of phenotypic coefficient of variation (PCV) were higher than genotypic coefficient of variation (GCV) for all the characters indicating the role of environment for the expression of these traits. The phenotypic and genotypic coefficient of variability were found to be high for seed yield per plant (37.26 %, 36.60 %) and number of fruits per plant (31.10 %, 30.61 %).

Yonas et al. (2014) evaluated genetic variability among 25 okra accessions for quantitative morphological traits and results revealed significant differences ($p < 0.01$) among the genotypes for all quantitative traits. The estimated values of phenotypic and genotypic coefficients of variations indicated the presence of variability among the genotypes for majority of the yield contributing characters.

Muluken et al. (2016) evaluated 23 local okra collections and two exotic varieties for 25 quantitative and 10 qualitative traits and exhibited presence of significant differences among genotypes for all traits except for internodal length. Genotypic coefficient of variation was observed minimum for number of epicalyx per flower (3.08) and maximum for primary branches per plant (27.19%), while phenotypic coefficient of variation was minimum for number of epicalyx per flower (5.5%) and maximum for mature pod per plant (34.14%).

Kerure et al. (2017) observed fifty-two okra genotypes and reported significant differences among the genotypes for different morphological characters. High GCV and PCV were observed for yield per plant, number of fruits per plant and number of seeds per fruit whereas moderate GCV and PCV was observed for average fruit weight.

Patra et al. (2018) studied 14 genotypes along with 3 checks (Arka Abhay, Arka Anamika, and VRO-6). The coefficient of variation showed low variability of less than 5% for plant height (4.84 cm), fruit girth (2.86 cm), plant girth (2.62 cm) and leaf length (2.40 cm). High (>10%) was observed for fruit length (10.68),

total yield (kg plot-1) (17.63), incidence of YVMV at 30, 45, 60, 75 and 90 DAS (48.01, 34.70, 36.28 and 34.12%), respectively.

Vishnu et al. (2018) studied genetic variability on twenty nine genotypes of okra and revealed high magnitude of genetic variability for most of the characters under study. High magnitude of genotypic coefficient of variation were observed for number of marketable fruits per plant, marketable yield per plant and yellow vein mosaic virus infestation indicated high degree of genetic variability offering greater scope for selection of these characters.

Agbowuro et al. (2019) studied twenty okra accessions and reported high values of phenotypic and genotypic coefficient of variances in days to 50% flowering (46.09%, 39.09%) followed by weight of 100 seeds (36.65%, 36.39%) and final plant height (33.75%, 32.66%) while fresh fruit length showed minimum phenotypic and genotypic coefficient of variances (16.16%, 14.87%), respectively.

Kumari et al. (2019) evaluated the extent of genetic variability for yield and yield contributing attributes in thirty one hybrids of okra showing significant differences for different horticultural traits under study. High values of phenotypic and genotypic coefficients of variation were observed for yield per plant, number of fruits per plant and primary branches per plant.

Alam et al. (2020) studied forty genotypes of okra and revealed high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for number of primary branches while moderate for internodal length, number of nodes per plant, plant height, number of fruits per plant, fruit yield per plant and fruit yield per plot.

Kumar et al. (2020) evaluated 30 genotypes of okra including three checks (Parbhani Kranti, Pusa Sawani and Pusa Makhmali) and revealed that magnitude of phenotypic coefficients of variations (PCV) were higher than the genotypic coefficient of variation (GCV) for all the characters indicating the role of environment for the expression of these traits. Moderate to high values of PCV were observed for number of fruits per plant (16.44%) followed by number of nodes per plant (16.02%), number of branches per plant (15.53%) average fruit

weight (15.02), marketable fruit yield per plant (14.74), total soluble solid (14.52), plant height (13.48), total fruit yield per plant (12.73) and fruit length (11.48).

Melaku et al. (2020) observed 25 okra genotypes for 9 qualitative and 29 quantitative traits and revealed that the values of PCV and GCV was ranged from 7% to 35.27% and 5.69% to 33.31%, respectively. Number of primary branches, tender fruit weight, tender fruit yield (tender fruit yield per plant, per plot, and per hectare), number of matured pods, dry weight of matured pod and tender fruit mucilage had high values for both coefficient of variations.

Singh et al. (2020) observed 59 genotypes including 15 parents (11 lines, 4 testers) and 44 crosses of okra for thirteen characters showing significant differences for different horticultural traits under study and revealed that the phenotypic coefficient of variation was greater than genotypic coefficient of variation for all the characters. Moderate to high PCV and GCV estimates were observed for first fruit producing node, average fruit weight, number of primary branches per plant, stem diameter, inter-nodal length, plant height, number of seeds per fruit, number of fruits per plant and fruit yield per plant.

Bhardwaj et al. (2021) observed twenty genotypes of okra for agro-morphological traits and showed higher value of genotypic and phenotypic coefficients of variation for 100 seed weight (38.68%, 40.14%) followed by days to first flowering node (37.47%, 37.56%) and yield per plant (32.50%, 32.66%). While lower values of PCV and GCV were observed for fruit girth, plant height and fruit length.

Chetana et al. (2021) observed 42 accessions of okra for twelve yield and yield contributing attributes and reported that the phenotypic coefficient of variation was greater than genotypic coefficient of variation for all the traits studied and there was a little difference between the values of PCV and GCV thereby indicating the less effect of environment on the expression of these characters.

Sravanthi et al. (2021) analyzed genetic variability in 32 genotypes of okra and revealed significant differences among the genotypes for different horticultural traits. Values of genotypic and phenotypic coefficients of variation

were observed higher for plant height (41.552%, 41.853%), number of fruits per plant (22.213%, 22.845 %) and number of fruits per plot (47.872%, 48.986%), respectively.

Vani et al. (2021) evaluated 12 okra genotypes to study the genetic variability for 17 yield and yield-attributing characters. Maximum genotypic and phenotypic coefficient of variations was observed for number of branches per plant (18.97%, 19.08%) followed by fruit yield per plant (11.80%, 12.93%), fruit yield per hectare (11.80%, 12.93%), number of nodes on main stem (8.64%, 11.02%) and node at which first flower appears (8.04%, 8.99%), respectively.

Alemu (2022) studied 35 okra landraces for 22 agro-morphological and eight qualitative traits and observed that the estimates of genotypic and phenotypic coefficients of variation were in the range of 2.95% to 54.92% and 4.96% to 55.22%, respectively. Plant height, number of primary branches, internodes length, number of matured fruits per plant, weight of matured fruits per plant, dry weight of matured fruits, number of seeds per fruit, number of tender fruits per plant and yield per hectare had high estimates of PCV and GCV. Moderate values of GCV and PCV were recorded for days to 50% flowering, days to maturity, leaf length, leaf width, peduncle length, fruit length, average fruit weight and 100 seed weight.

Awasthi et al. (2022) studied eighteen genotypes of okra and reported maximum phenotypic and genotypic coefficient of variation for plant height at 45 days (20.08%, 19.79%), number of fruits per plant (17.37%, 17.24%), number of seeds per fruits (17.34%, 17.38), diameter of fruits (14.99%, 14.16%), first flowering node (12.02%, 11.3%) and fruit yield per plant (13.74%, 13.66%).

Barman and Marboh (2022) observed genetic variability on ten okra accessions and reported maximum phenotypic and genotypic coefficient of variation for fruit yield per plant (36.5%, 36.3%) followed by plant height (32.2%, 32.2%), number of fruit per plant (25.0%, 24.0%), 100 seed weight (22.4%, 22.1%) and first fruit producing node (21.3%, 14.5%), respectively.

Kumar et al. (2022) evaluated 20 genotypes of okra and revealed that the phenotypic coefficient of variation was greater than the genotypic coefficient of

variation. The values of GCV and PCV were higher for number of primary branches per plant (23.55%, 24.59%) while moderate for plant height (10.70%, 10.79%), internodal length (18.98%, 19.09%), number of nodes per plant (15.78%, 15.95%), number of fruits per plant (18.96%, 19.15%), fruit length (15.86%, 16.01%), number of seeds per fruit (12.23%, 12.44%), weight of 100 seed (14.08%, 14.09%) and fruit yield per plant (19.45%, 19.62%), respectively.

Shwetha et al. (2022) evaluated forty-eight accessions of okra and reported high values of phenotypic and genotypic coefficient of variation for number of leaves per plant (21.51%, 22.90%), pod diameter (22.16%, 22.72%), average pod weight (24.57%, 25.81%), total yield per plant (24.79%, 26.45%), number of branches per plant (25.09%, 26.28%) and total yield per plot (28.05%, 29.55%), respectively.

Srivarsha et al. (2022) observed genetic variability in 26 okra genotypes for 14 yield and yield contributing traits and revealed higher PCV and GCV estimates for plant height, fruit length, fruit yield per plant, shoot and fruit borer incidence on fruits, number of fruits per plant and yellow vein mosaic virus percent disease incidence. Moderate PCV and GCV estimates were recorded for fruit weight, internodal length, fruit diameter and number of nodes at first flowering while days to 50% flowering, number of locules per fruit and number of ridges per fruit recorded low PCV and GCV.

2.2 HERITABILITY AND GENETIC ADVANCE:

Heritability is an index of transmission of characters from the parent to their off springs. The feasibility and scope of improvement that can be brought about by selection are shown by heritability. It is typically expressed in percentage and is a valuable tool for evaluating the proportion of genetic variance to all variance. Lush (1940) defined heritability as the ratio of the total genotypic variance to the total phenotypic variance which provides a measure of the overall importance of hereditary determination of a trait.

The genetic gain is the product of heritability and selection differential expressed in term of phenotypic standard deviation of the characters. Heritability

and genetic advance/genetic gain both are the component of direct selection. It is necessary to utilize heritability estimate in the conjunction with selection differential, which would indicate the expected genetic gain. The studies conducted in okra concerning heritability and genetic advance are reviewed below:

Patro and Ravisankar (2004) studied genetic variability for 17 characters in 41 genotypes of okra collected from various sources. High heritability was observed for branches per plant and yield per plant whereas high genetic advance was recorded for yield per plant, plant height and germination percentage. Highest genetic advance as per cent of mean was recorded for branches per plant indicating that the trait is more reliable for improvement through selection.

Indurani and Veeraragavathatham (2005) observed high heritability coupled with higher genetic advance for plant height at first flower bud appearance, number of fruits per plant, fruit weight and yield per plant.

Jaiprakashnarayan et al. (2006) studied the genetic variation among various okra genotypes for different growth and earliness characters and reported high heritability coupled with high genetic advance over mean (GAM) for plant height, internodal length, number of nodes on main stem, number of nodes at first flowering and number of leaves after 45 days. High heritability with low GAM was observed for days to 50% flowering.

Singh et al. (2007) reported high heritability for plant height, number of fruits per plant, fruit yield, fruit length, fruit girth and number of branches per plant. High heritability coupled with moderate genetic advance was recorded for all the characters except for nodes at which first flower appears indicating that additive gene affects were more important for these characters.

Singh et al. (2008) observed 34 advanced breeding lines of okra including their parents to assess genetic variability and reported high heritability along with high genetic gain in number of branches per plant, plant height, number of seeds per fruit, number of nodes per plant, fruit length, fruit yield and number of fruits per plant which indicated that there were higher number of additive factors

involved in the expression of these characters and further improvement could be brought about by selection.

Sengupta and Verma (2009) reported high heritability coupled with high genetic advance for yield per plant, days to first picking, days to 50 per cent flowering, fruits per plant and flowering nodes per plant which indicated the involvement of additive gene action for these traits.

Nasit et al. (2010) revealed high estimates of heritability coupled with high genetic advance expressed as per cent of mean for number of nodes per plant, fresh fruit crude protein content, fruit yield per plant and plant height which may be attributed to the preponderance of additive gene action showing the importance of selection for improvement of these characters.

Pal et al. (2010) observed high heritability estimates for edible fruit yield per plant, plant height, number of fruits per plant, days to flowering and length of fruiting node in both the consecutive generations. The genetic advance as per cent of mean was high for plant height and edible fruit yield per plant in both the generations. On the basis of variability parameters selection criteria based on edible fruit yield per plant, plant height, days to flowering, length of first fruiting node, width of fruit, length of fruit and number of fruits per plant may be useful for further developing high yielding okra varieties.

Ramanjinappa et al. (2011) observed high heritability coupled with high genetic advance over mean for plant height, number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant, number of seeds per fruit, harvest index and total yield per plant.

Nwangburuka et al. (2012) studied genetic variability of 29 okra cultivars for 8 yield related traits. High heritability in broad-sense coupled with high genetic advance observed for plant height, pod length, pod width and pod weight suggesting the effect of additive genes and reliability of selection based on phenotype of these traits for crop improvement.

Shaikh et al. (2013) observed 25 okra accessions and revealed significant differences among genotypes for all the characters. Plant height (cm), number of seeds per fruit and number of fruits per plant recorded high heritability coupled

with high genetic advance as per cent of mean which indicates that selection could be effective for improvement in these characters.

Kumar and Kumar (2014) studied 55 diverse genotypes including 10 parents and 45 crosses of okra for fruit yield and its component traits and reported high heritability coupled with high genetic advance as per cent of mean for first fruiting node, days of first picking, number of branches per plant, plant height, number of fruits per plant and yield per plant which might be indicative of effectiveness of selection for such characters.

Patel et al. (2014) evaluated heritability and genetic advance in thirty genotypes of okra and reported high heritability coupled with high genetic advance as per cent of mean for fruit yield per plant and fruit yield per plot suggesting the preponderance of additive genes. It also indicated higher response for selection of high yielding genotypes as these characters are governed by additive gene actions.

Khajuria et al. (2015) studied 60 okra accessions and reported heritability in broad sense varied from 4.1% (number of ridges per fruit) to 99.2 % (number of seeds per fruit). High heritability accomplished with moderate genetic advance as per cent mean was recorded for petal size, fresh fruit weight, dry fruit weight and seed weight per fruit.

Krishna et al. (2015) evaluated 30 okra accessions for 18 quantitative characters and reported high heritability coupled with high genetic advance for plant height, inter nodal length, nodes on main stem, first fruiting node and number of pickings whereas days to first flowering, days to 50 per cent flowering, fruit width and average fruit weight exhibited the high heritability coupled with moderate genetic advance.

Bagwale et al. (2016) observed 40 genotypes of okra and revealed that high heritability coupled with high expected genetic advance as per cent of mean was observed for plant height and yield per plant. Muluken et al. (2016) reported high heritability coupled with high genetic advance as per cent of mean for fruit yield, fruit length, fruit weight and yield related traits.

Kerure et al. (2017) estimated high heritability coupled with high genetic advance as per cent of mean for plant height, stem girth, number of branches per plant, first fruit producing node, fruit length, fruit diameter, number of fruits per plant, average fruit weight, number of seeds per fruit, 100 seed weight and yield per plant except days to 50% flowering and days to 80 % maturity which shows low heritability with low genetic advance as per cent of mean. The yield per plant, plant height and number of seeds per fruit showed high genetic advance that helped in effective and reliable selection through these characters for crop improvement.

Ullangula et al. (2017) studied twenty one accessions of okra for 12 characters and reported high heritability coupled with high genetic advance as per cent of mean for yield per plant, fruit weight and number of fruits per plant suggesting that they can be improved through selection.

Sharma et al. (2018) studied twenty five genotypes of okra and reported high heritability in broad sense for crude fibre content (98%) followed by leaves per plant (94%) and plant height (93%) whereas minimum for branches per plant (42%). High genetic advance as per cent of mean was observed for leaves per plant (64.30%) and crude fibre content (48.73%).

Kumar et al. (2019) evaluated sixty-eight okra accessions and reported high heritability coupled with high genetic advance as per cent of mean for plant height and pod yield per plant indicated the involvement of additive gene action and more chances of improvement in these traits by selection.

Rambabu et al. (2019) reported high estimates of heritability coupled with high genetic advance as per cent of mean for plant height, number of branches per plant, inter nodal length, days to 50% flowering, days to first harvest, days to last harvest, fruit length, fruit girth, fruit weight, number of fruits per plant, number of seeds per fruit, fruit yield per plant, 100 seed weight, number of pickings, crude fiber content, iodine content and iron content.

Ashraf et al. (2020) studied 14 diverse genotypes of okra and reported heritability estimates in broad sense ranged from 28.60% for fruit weight to

87.96% for fruits per plant. The genetic advance as per cent of mean ranged from 5.00% for days to first flowering to 52.08% for yield per hectare.

Walling et al. (2020) observed twenty eight genotypes of okra and reported high heritability coupled with high genetic advance as per cent of mean for plant height, size of leaf, number of leaves per plant and yield per plant which suggested that these traits can be improved through selection.

Yadav et al. (2020) evaluated thirty-six genotypes of okra and reported high heritability coupled with high genetic advance as per cent of mean for number of branches per plant (84.54%, 28.27%) followed by total fruit yield per plant (99.13%, 19.11%) and average fruit weight (93.86%, 14.29%) indicating the importance of selection for improvement.

Chetana et al. (2021) revealed that high heritability coupled with high genetic advance as per cent of mean was observed for plant height, internodal length, number of nodes on main stem, number of branches per plant, 100 seed weight and fruit yield per plant.

Tudu et al. (2021) studied twenty two genotypes of okra and reported high heritability estimates for plant height, number of branches per plant, length of internodes, number of nodes to first flowering, days taken to first flowering, days taken to first picking, fruiting span, fruit length, fruit width, fruit weight and number of fruits per plant. The genetic advance as per cent of mean was recorded highest for plant height (48.02%), number of branches per plant (30.10%), fruiting span (25.88%), fruit length (32.68%), fruit width (35.53%) and fruit weight (55.24%).

Vani et al. (2021) evaluated heritability and genetic advance for 17 characters of okra. The heritability estimates in broad sense was observed maximum for number of branches per plant (99%) followed by fruit yield per plant (83%), fruit yield per hectare (83%), node at which first flower appears (80%) and plant height (69%). The genetic advance as a per cent of mean was observed highest for fruit yield per plant, fruit yield per hectare, plant height and number of branches per plant.

Awasthi et al. (2022) reported very high heritability estimates for number of seeds per fruit (99.70%), days to 50% flowering (99.0%), yield per plant (98.80%), number of fruits per plant (98.50%) and plant height at 45 days. Genetic advance as per cent of mean was high for plant height at 45 days (40.18), number of seeds per fruit (35.63), number of fruits per plant (35.25), plant height at 90 days (29.94), fruit yield per plant (27.97), diameter of fruits (27.55) and first flowering node (21.87).

Baghel et al. (2022) evaluated genetic variability among 16 okra accessions for yield and its contributing traits. High heritability coupled with high genetic advance as a per cent of mean (GAM) was observed for fruit yield per plant, fruit yield per plot, fruit yield per hectare, number of branches per plant at 60 DAS and 90 DAS, plant height at 60 DAS, number of leaves per plant at 30 DAS, number of nodes to 1st flowering, and length of internodes.

Jadhav et al. (2022) evaluated 26 accessions of okra for seventeen traits and reported high heritability estimates for days to 50% flowering (98.86) followed by fruits per plant (98.26) and plant height (97.90). The highest genetic advance as per cent of mean was observed for plant height (43.69) followed by the incidence of fruit and shoot borer (43.22) and leaf area (39.11).

Mohammed and Shiferaw (2022) evaluated heritability and genetic advance in 36 okra genotypes for 29 agro morphological and biochemical traits. Heritability values ranged between 33.63% and 99.81%, while the genetic advance as percentage of mean ranged between 4.29% and 95.45%. High broad sense heritability was coupled with high genetic advance as per cent of mean for plant height, branch, internodal length, fruit length, panicle length, fresh fruit weight, number of fruits per plant, number of mature pods, seed yield per plant, seed yield per hectare, and fibre and protein content.

Reddy et al. (2022) studied 60 genotypes of okra using 20 quantitative traits and revealed high heritability coupled with high genetic advance as per cent of mean for plant height (13.68, 13.48), internodal length (16.61, 13.98), first fruiting node (13.00, 10.89), number of fruits per plant (13.19, 11.91), number of marketable fruits per plant (13.36, 11.97) and fruit yield per plant (13.75, 12.29).

2.3 CORRELATION COEFFICIENT ANALYSIS

Correlation coefficient analysis describes the association between different traits. The correlation between yield and its contributing traits gives an idea for selection, which could profitably be exercised to obtain increase in yield. As such, it is important to estimate the correlation coefficients, as it aids in estimating the true associations due to genetic causes. The studies conducted in okra related to correlation analysis are reviewed below:

Niranjan and Mishra (2003) revealed that the genotypic correlations were higher than their corresponding phenotypic correlations. Fruit yield was positively and significantly correlated with edibility period of fruits, fruits per plant, fruit length, seeds per fruit, fruit weight, plant height and branches per plant at both genotypic and phenotypic levels. Associations were significant at the genotypic level only between edibility period of fruits and branches per plant. All characters had positive and significant association among each other at both levels.

Jaiprakashnarayan and Mulge (2004) studied correlation in 69 okra genotype and observed that total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 days after sowing and number of leaves on 45 and 100 days after sowing. While total yield per plant had negative and significant association with number of locules per fruit and number of nodes to first fruiting.

Alam and Hossain (2006) studied correlation in different genotypes of okra and reported that yield of green pods had a highly significant and positive association with weight of green pods per plant and weight of individual green pods.

Verma et al. (2007) revealed that yield per plant exhibited positive and significant correlation with fruits per plant, fruit weight, fruit length and fruit girth while negative and significant association with 100 seed weight, days to 50% flowering and days to first flowering.

Pal et al. (2008) studied correlation for yield and yield contributing components and reported that the number of nodes on the main stem was

positively and significantly associated with number of fruits per plant and marketable fruit yield per plant. The number of fruits per plant had a significant and positive correlation with marketable fruit yield per plant.

Shashank et al. (2009) observed that the single fruit weight ($P = 0.720$, $G = 0.826$) exhibited highest positive and significant correlation followed by number of fruits per plant ($P = 0.642$, $G = 0.722$) with number of seeds per fruit and number of seeds per fruit ($P = 0.634$, $G = 0.772$) with fruit yield per plant. However, the highest negative and significant correlation was found in number of nodes per plant ($P = -0.777$, $G = -0.818$) with internodal length.

Balakrishnan and Sreenivasan (2010) revealed that fruit yield was positively and significantly associated with number of fruits, internodal length, fruit weight and fruit length while shoot and fruit borer infestation recorded negative and significant association with plant height, flowering period, number of fruits per plant, fruit yield and internodal length.

Das et al. (2012) reported significant and positive correlation of fruit yield per plant with number of nodes on main stem, fruit length, fruit diameter, fruit weight and number of fruits per plant while negative and significant correlation was found with days to first flowering and node number at first flowering.

Ahiakpa et al. (2013) revealed a strong positive correlation between total fruit production and first fruit producing node, first fruit producing node and first flowering node, and fruits per plant and stem diameter.

Duggi et al. (2013) revealed that yield per plant had positive and significant association with fruit weight and significantly negative correlation with days to 50% flowering. Plant height and crop duration had positive and significant genotypic correlation while significant and negative correlation was found between number of fruits per plant and fruit weight both at genotypic and phenotypic levels.

Koundinya et al. (2013) studied 30 genotypes of okra. The result revealed that seed yield per plant had significant and positive association with plant height (0.210), fruits per plant (0.631), fruit yield per plant (0.606) and seeds per fruit (0.596) whereas, it exhibited significant and negative association with days to

50% flowering (-0.308). Fruit yield per plant was having significant positive association with plant height (0.365), fruits per plant (0.912) and fruit weight (0.328) while it had significant and negative association with days to 50% flowering (-0.271).

Reddy et al. (2014) evaluated fifty seven inbred lines and seven checks for yield and yield related components, screened for reaction to okra yellow vein mosaic virus, nature of association among different yield attributes and their direct and indirect contribution towards yield. Results revealed that the fruit yield per plot had significantly positive correlation with number of branches, inter-nodal length, fruit length, fruit diameter, number of fruits per plant, fruit weight and disease incidence to yellow vein mosaic virus (YVMV) at both genotypic and phenotypic level, whereas negative correlation with days to 50 per cent flowering and plant height.

Saryam et al. (2015) reported that yield per plant had highly significant and positive correlation with number of fruits per plant, fruit diameter, fruit length, number of seeds per fruit, days to maturity, fruit weight, leaf blade width, 100 seed weight, flower diameter, fruiting span, petiole length and stem diameter.

Umrao et al. (2015) studied eleven characters in fifty genotypes of okra. Fruit yield per plant showed positive and significant association with number of first fruiting nodes per plant, final plant height, no. of fruiting nodes per plant, length of fruit, weight per fruit and number of fruits per plant.

Chandramouli et al. (2016) reported that fruit yield per plant exhibited positive correlation with plant height, primary branches per plant, nodes on main stem, internodal length, fruits per plant, fruit length, fruit girth, number of pickings and picking duration. Kumar and Reddy (2016) observed that fruits per plant and total yield per plant had positive and significant association with marketable pod yield per plant.

Badiger et al. (2017) revealed that plant height, internodal length, branches per plant, average fruit weight, fruits per plant and marketable yield per plant were positively and significantly correlated with total yield per plant. Pithiya et al. (2017) reported that nodes at first flowering, days to 50 per cent flowering, fruit

length, fruit diameter and fruits per plant had positive and significant correlation with plant height.

Dwivedi et al. (2017) observed 20 genotypes of okra and result showed significant and positive correlation of plant height at 30 DAS with plant height at 60 DAS (0.66), plant height at 90 DAS (0.58), fruiting span (0.56), number of branches per plant at 60 DAS (0.479), length of internode (0.39), yield per plant, number of branches per plant at 30 DAS (0.34), number of leaves per plant (0.31) and number of fruits per plant (0.26). However, significant and negative association was observed with days to first picking (-0.53), days to 50% flowering (-0.44) and number of seeds per fruit (-0.39).

Prasath et al. (2017) studied 30 lines of okra. The result revealed that number of fruits per plant showed positive and significant correlation with number of seeds per fruit, 100 seed weight, number of pickings and ascorbic acid content. Number of seeds per fruit showed positive and significant correlation with 100 seed weight, number of pickings and iodine content.

Shuirkar et al. (2018) studied fourteen diverse genotypes of okra. Plant height had positive and significant correlation with length of internode (0.2871), days to 50% flowering (0.1882) and fresh fruit weight (0.3387). A high significant and negative association of plant height was observed with first fruiting node (-0.3138). Length of internode recorded positive and significant correlation with days to 50% flowering (0.4420), days to first picking (0.1753) and fruit weight (0.5021). While, days to 50% flowering expressed a significant and positive association with first fruiting node (0.2019), days to first flowering (0.2132), days to first picking (0.3118), fruit length (0.1943) and fresh fruit weight (0.2525).

Singh et al. (2018) studied fourteen diverse genotypes of okra. Number of fruits per plant, plant height, average fruit weight, number of seeds per fruit, fruit length, first flower producing node, first fruit producing node, 50 percent flowering and stem diameter had significantly positive association with fruit yield, indicating mutual association of these traits.

Syfullah et al. (2018) revealed that fruit yield per plant showed significant and positive correlation with average fruit weight, number of fruit per plant and

plant height while significantly negative correlation with seeds per fruit at genotypic and phenotypic level which can be considered for selection of a good variety.

Rathava et al. (2019) observed 31 genotypes of okra. The fruit yield per plant exhibited positive and highly significant correlation with plant height, number of fruits per plant, average fruit length and fiber content at both genotypic and phenotypic levels, indicating mutual association of these traits.

Raval et al. (2019) studied correlation coefficient and path analysis using parents (female VRO - 6 and male AOL - 09 – 02) and their F1 and F2 generations. Observations were recorded on thirteen yield and its contributing characters. The fruit yield per plant exhibited positive and highly significant correlation with number of fruits per plant, plant height at final harvest, fruit weight, number of branches per plant, fruit girth, number of seeds per fruit, internodal length and 100 seed weight.

Yadav et al. (2019) studied 44 accessions of 6 okra wild species along with 4 check cultivars viz., Pusa Sawani, Pusa A-4, Pusa Bhindi 5 and DOV-92. The results revealed significant positive association of fruit weight (0.85), number of fruits per plant (0.532), stems diameter (0.088), plant height (0.069) and fruit diameter (0.046) with fruit yield per plant.

Nuksungla et al. (2020) observed twenty eight genotypes of okra. The yield per plant had highly significant and positive correlation with leaf area index, leaf size, number of leaves, number of fruits per plant, fruit weight, fruit length, number of ridges per fruit, number of seeds per fruit and fruit diameter signifying the importance of these traits in selection for yield.

Rana et al. (2020) observed seventeen genotypes of okra. The fruit yield per plant had significant and positive correlation with average fruit weight followed by plant height at 45 DAS, number of leaves at 45 DAS, number of fruits per plant and number of primary branches at 45 DAS.

Walling et al. (2020) studied twenty eight genotypes of okra. The yield per plant showed highly significant and positive genotypic correlation coefficients with leaf area index, leaf size, number of leaves, number of fruits per plant, fruit

weight, fruit length, number of ridges per fruit, number of seeds per fruit and fruit diameter.

Samiksha et al. (2021) revealed that the total fruit yield per plant had exhibited highly significant and positive correlation with number of fruits per plant followed by plant height.

Tudu et al. (2021) evaluated 22 accessions of okra. Genotypic and phenotypic coefficient analysis revealed that fruit yield per plant showed positive and significant association with plant height, internodal length, days to first picking, number of nodes to first flowering and fruit yield per hectare.

Barman and Marboh (2022) observed thirteen quantitative traits of okra. Plant height and number of fruits per plant showed highly positive significant association with fruit yield per plant both at phenotypic and genotypic level.

Neeraja et al. (2022) studied nineteen characters in thirty seven okra genotypes. The fruit yield per plant registered positive and significant correlation with plant height (0.7038 P, 0.7191 G), number of primary branches (0.6308 P, 0.6529G), internodal length (0.5986 P, 0.6255 G), fruit length (0.3727 P, 0.3883 G), number of seeds per fruit (0.4039 P, 0.4258 G), number of fruits per plant (0.7977 P, 0.8229 G) and seed weight per fruit (0.3750 P, 0.3942 G).

Ranga and Darvhankar (2022) reported that yield per plant showed a highly significant and positive correlation with first flowering node, fruit length, number of fruits per plant and number of seeds per fruit. Yield per hectare showed highly significant and positive correlation with 1000 seed weight.

2.4 PATH COEFFICIENT ANALYSIS

For categorizing correlation coefficients into direct and indirect effects, path coefficient analysis is a reliable statistical technique. It analyses the relationships between several yield-related parameters. The technique of path coefficient was originally developed by Wright (1921). He defined the path coefficient technique as the ratio of the standard deviation of the effect to the total standard deviation where all causes are constant, except that one in question. The

path coefficient analysis in okra has been studied by several investigators and the same is reviewed below:

Akinyele and Osekita (2006) reported high positive direct effects of number of pods per plant and height at flowering on seed yield indicating that, with other variables held constant, an increase in number of pods per plant and height at flowering might increase seed yield per plant.

Reddy et al. (2013) evaluated one hundred germplasm lines of okra. Path coefficient analyses revealed that fruit weight, total number of fruits per plant and number of marketable fruits per plant not only had positively and significant association with marketable pod yield per plant, but also had positively high direct effect on marketable pod yield per plant and are regarded as the main determinants of marketable pod yield per plant.

Balai et al. (2014) studied 27 genotypes and observed that yield per plant had highest positive direct effect *via* average weight of edible pod followed by number of pods per plant and number of leaves per plant.

Yonas et al. (2014) studied path coefficient analysis at genotypic level on twenty five genotypes of okra and revealed that internodes number had high positive direct effect on fruit yield ($p=6.90$) followed by average fruit weight ($p=6.89$) which had positive genotypic correlation with yield.

Sharma and Prasad (2015) studied path coefficient analysis in twenty diverse genotypes of okra and reported that number of fruits per plant and fruit weight contributed maximum direct effect to yield per plot, whereas number of branches per plant and days to first harvest showed highest negative direct effect on yield per plot.

Ishfaq et al. (2016) studied the direct and indirect contribution of plant traits with pod yield per plant in 25 genotypes of okra. The path analysis revealed that pod weight per plant, number of pods per plant, plant height at maturity and 100 seed weight contributed largely to pod yield and maximum emphasis would be given to these traits for selection of high yielding okra genotypes.

Kumar et al. (2016) reported that positive and direct effect on fruit yield per plant exerted by number of fruits per plant followed by stem diameter, fruit weight, number of days taken to flower, number of leaves per plant, number of fruits per branch and number of branches per plant. However, negative and indirect effect on fruit yield was observed in order to isolate superior plant types for improvement of fruit yield.

Yadav et al. (2017) evaluated twenty diverse okra genotypes to estimate the correlation and path analysis for fruit yield and its contributing characters. Path coefficient analysis on various yield contributing characters revealed that fruits per plant, fruit length, number of seeds per fruit, number of branches per plant, plant height, fruit weight and number of flowers per plant showed direct positive effect towards yield.

Singh et al. (2018) observed path coefficient analysis in fourteen diverse genotypes of okra and revealed that fruit width (1.431) had maximum direct contribution towards fruit yield followed by number of fruits per plant (0.834), first fruit producing node (0.221) and average fruit weight (0.145). However, 100 seed weight exhibited highest negative direct effect (-1.732) followed by first flower producing node (-0.222), days to 50 per cent flowering (-0.097), intermodal length (-0.062) plant height at 45 days after sowing (-0.065) and days to first flowering (-0.040).

Kelemoge et al. (2019) studied 28 hybrids of okra. The path coefficient analysis revealed that number of primary branches per plant (0.795), number of nodes per plant (0.594), fruit length (0.765), fruit girth (1.106), leaf chlorophyll content (1.533) and mucilage content (0.352) exerted a high positive direct effect on fruit yield per plant.

Kumari et al. (2019) studied path analysis using 20 diverse okra genotypes along with four checks (Kashi Pragati (VRO 6), Kashi Kranti (VRO-22), Kashi Lalima and Arka Anamika). Observations were recorded on eleven quantitative morphological and qualitative biochemical traits on yield per plant in okra. Average fruit weight (0.716) exhibited maximum positive direct effect on fruit yield per plant followed by number of fruits per plant (0.686) and fruit diameter (0.066). Path coefficient analysis carried out at genotypic level revealed that

number of primary branches, plant height, fruit diameter, number of fruits per plant, average fruit weight and moisture percentage recorded positive direct effect on fruit yield per plant.

Rathava et al. (2019) evaluated 31 genotypes of okra to determine the nature of association among different yield attributes and their direct and indirect contribution towards yield. Path coefficient analysis revealed that number of fruit per plant had maximum direct contribution towards fruit yield followed by average fruit weight, average fruit diameter and plant height. However, average fruit length had the higher negative direct effect on fruit yield per plant followed by days to 50% flowering, number of branches, internodal length and fiber content.

Rathod et al. (2019) studied path coefficient analysis on 3 parents AOL-09-02, AOL-10-22 and GAO-5, two hybrids viz., AOL-09-2 x AOL-10-22 and AOL-09-2 x GAO-5 and their F₂ generations. Positive direct effect on fruit yield per plant was recorded for number of fruits per plant, fruit weight, 100 seed weight and fruit girth in F₂ populations of both crosses. Direct selection practiced on these characters will result in improvement in yield.

Raval et al. (2019) observed thirteen yield and its contributing characters. The path coefficient analysis revealed that number of fruits per plant, fruit weight, days to first picking, internodal length, 100 seed weight and fruit length recorded positive direct effect on fruit yield per plant.

Alam et al. (2020) estimated path coefficient analysis in 40 genotypes of okra and reported high positive direct effect for fruit yield per plant contributed by plant height, days to first flower initiation, number of primary branches and days to first fruit picking whereas, high but negative direct effect exhibited by length of internode, number of nodes per plant, number of fruits per plant, fruit length, days to 50% flowering, days to second fruit picking, duration of crop and days to first fruit set on fruit yield.

Rynjah et al. (2020) observed the path coefficient analysis in thirty six okra genotypes for fourteen traits and revealed that yield per plant had maximum

positive direct effect contributed by fruit girth followed by plant height, fruit weight, fruit length and number of branches per plant.

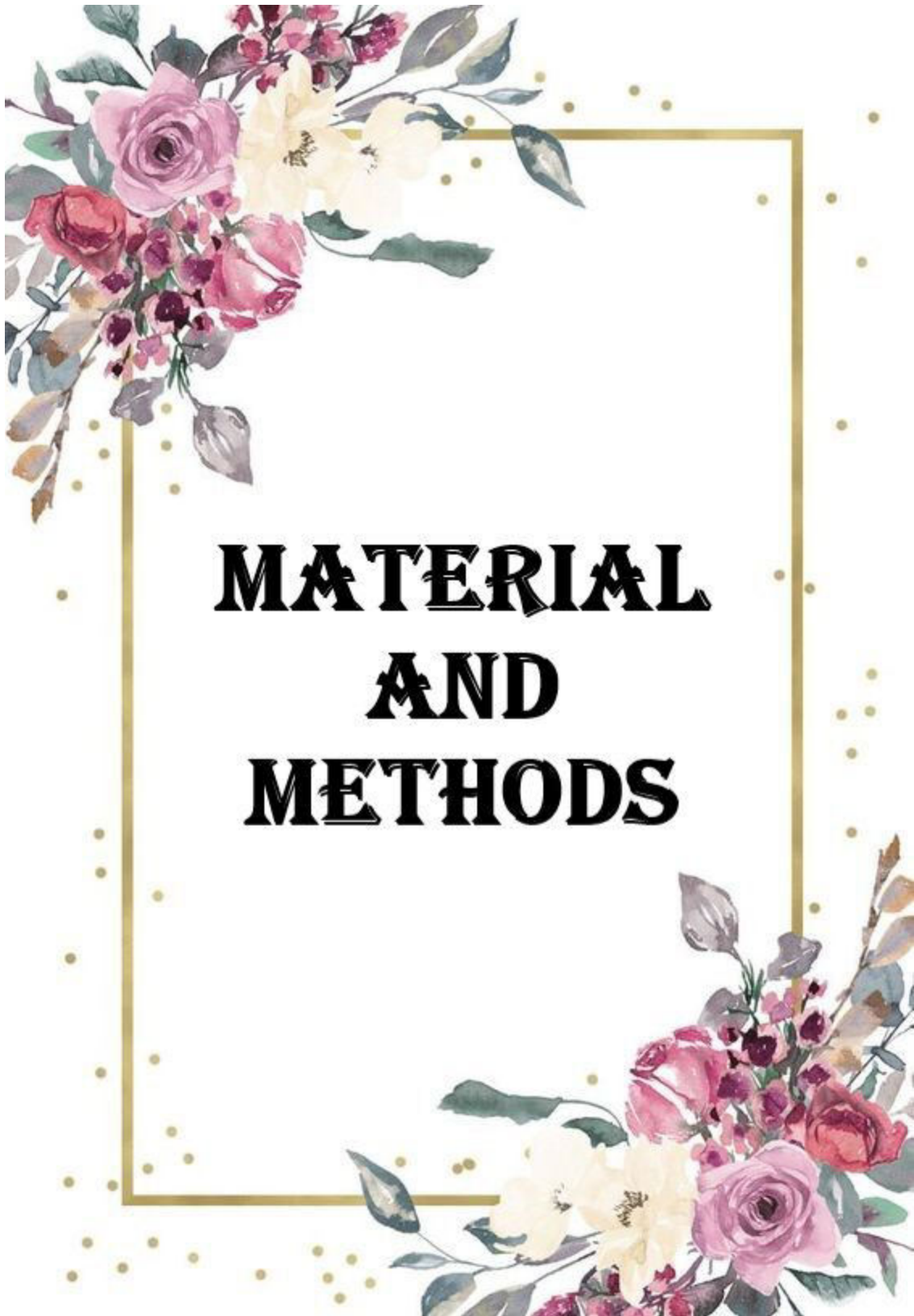
Verma and Singh (2020) estimated path coefficient analysis in fifty genotypes of okra to determine direct and indirect effects of traits on fruit yield. Maximum direct positive effect on fruit yield per plant was observed by number of fruits per plant followed by number of branches per plant, plant height, length of internode and number of first fruiting node.

Samiksha et al. (2021) studied path coefficient analysis on seventeen genotypes of okra and observed that number of fruits per plant showed highest positive direct effect on total fruit yield per plant followed by fruit circumference, TSS, acidity and fruit length. While highest negative direct effect was shown by leaves per plant. The maximum positive indirect effect on total fruit yield per plant were exhibited by number of fruits per plant followed by average fruit weight, fruit length and plant height.

Sravanthi et al. (2021) studied thirty two okra genotypes for the analysis of correlation and path coefficient and revealed that days to initiation for first flowering, number of branches per plant, fruit length, weight of fruit and number of fruits per plant have positive direct effect on yield.

Komolafe et al. (2022) evaluated forty accessions of okra and path coefficient analysis revealed that number of pod per plant had the highest positive direct effect on pod yield per plant with its largest indirect effect with days to 50% flowering and reduction in days to maturity. Due to close associations among these traits, they could be used as basis of selection for higher yield.

Rajani et al. (2022) studied path analysis using parents (VRO-3, VRO-6, 440-10-1, TCR-1674, JPM-20-16-39 and HRB-9-2) and their F₁. Observations were recorded on 18 yield and yield contributing characters. Path coefficient analysis revealed that traits like plant height, number of fruits per plant, fruit length, fruit girth, fruit weight, number of seeds per fruit and test weight exhibited high and positive direct effect on fruit yield per plant indicating that selection based on these traits would result in improved fruit yield per plant.



MATERIAL AND METHODS

Chapter-3

MATERIALS AND METHODS

This chapter comprises the detail about the material used and methodologies employed during the course of present investigation entitled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” which was carried out at the Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, Dr Y.S. Parmar University of Horticulture and Forestry, Solan, during rainy season 2022.

3.1 SITE OF EXPERIMENT

3.1.1 Location

The Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P.) is located at an altitude of about **650 meters** above mean sea level, lying between **31°41’47.6” North** latitude and **72°28’6.3” East** longitude under low hill zone of Himachal Pradesh, India.

3.1.2 Climate and soil conditions

The experimental farm has subtropical climate with an annual rainfall of **60-100 cm**. The climate is generally characterized as sub humid, hot summers with mild winters. May-June and December-January are the hottest and coldest months, respectively. Maximum rainfall takes place during July-August. The meteorological parameters during the cropping season such as maximum and minimum temperature, relative humidity and rainfall were taken at the Meteorological observatory, College of Horticulture and Forestry, Neri, Hamirpur (H.P.) during the genotypes evaluation (June to October, 2022) has been presented in Appendix-I. Graphical representation of meteorological data during the growing season is depicted in Fig. 3.1. The soil of the experimental block was sandy loam having good drainage capacity, uniform texture having pH 6.5-7.5 and medium NPK status.

3.2 EXPERIMENTAL MATERIALS

The experimental materials for the present investigation comprises of thirty two diverse genotypes of okra (*Abelmoschus esculentus* (L.) Moench) including one check variety (P-8). These genotypes were selected from the germplasm collected from low hill zone of H.P. and maintained at the experimental farm, Neri. The genotypes under study have been enlisted in Table 3.1.

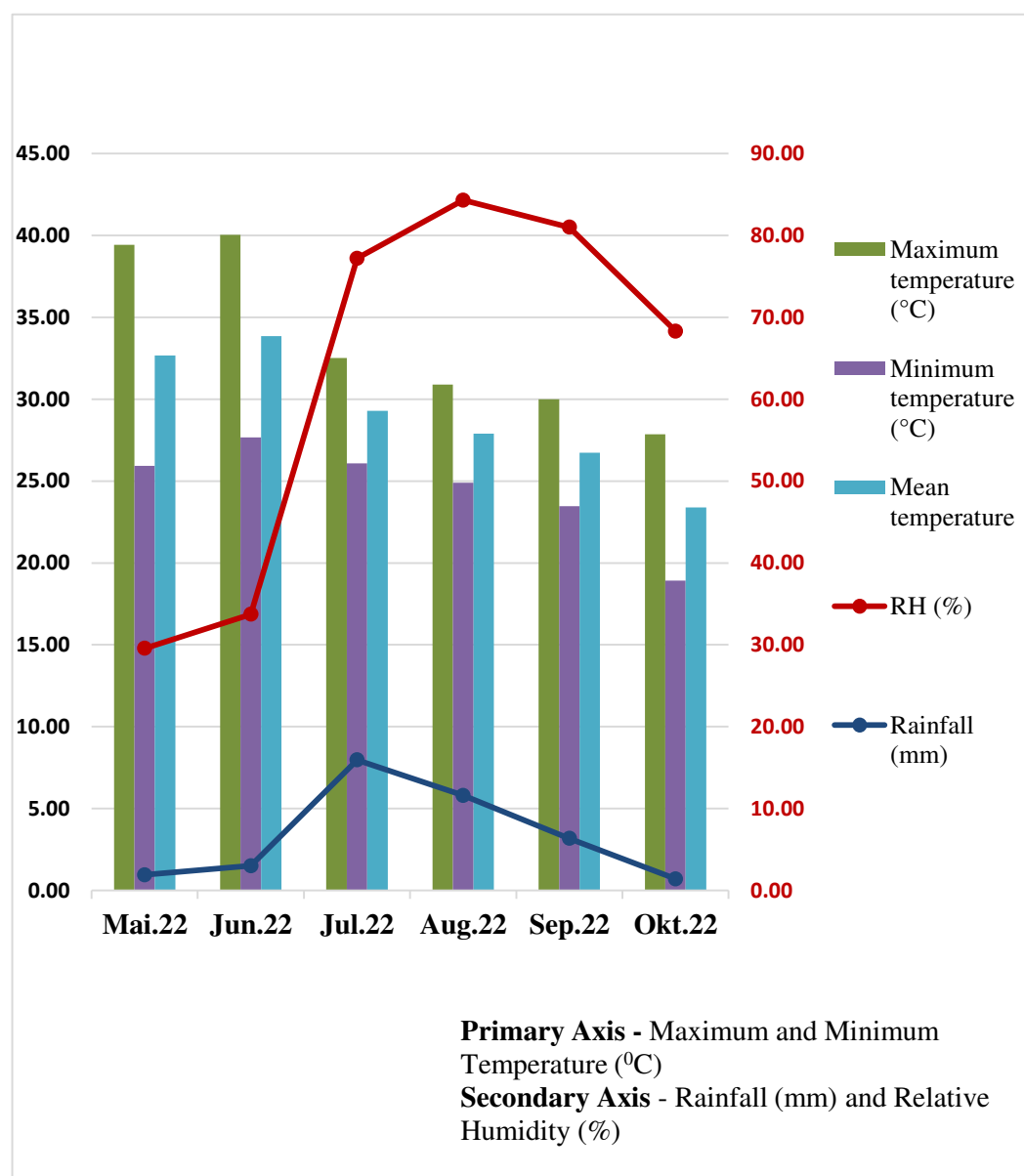


Fig. 3.1 Agro meteorological data during cropping period (June to October, 2022)

Table 3.1: List of genotypes and their source of collection

S.NO.	GENOTYPE	SOURCE
1.	LC-21	Department of Vegetable Science, COH&F, Neri, Hamirpur
2.	LC-23	Department of Vegetable Science, COH&F, Neri, Hamirpur
3.	LC-24	Department of Vegetable Science, COH&F, Neri, Hamirpur
4.	LC-25	Department of Vegetable Science, COH&F, Neri, Hamirpur
5.	LC-28	Department of Vegetable Science, COH&F, Neri, Hamirpur
6.	LC-33	Department of Vegetable Science, COH&F, Neri, Hamirpur
7.	LC-34	Department of Vegetable Science, COH&F, Neri, Hamirpur
8.	LC-35	Department of Vegetable Science, COH&F, Neri, Hamirpur
9.	LC-36	Department of Vegetable Science, COH&F, Neri, Hamirpur
10.	LC-37	Department of Vegetable Science, COH&F, Neri, Hamirpur
11.	LC-38	Department of Vegetable Science, COH&F, Neri, Hamirpur
12.	LC-40	Department of Vegetable Science, COH&F, Neri, Hamirpur
13.	LC-42	Department of Vegetable Science, COH&F, Neri, Hamirpur
14.	LC-43	Department of Vegetable Science, COH&F, Neri, Hamirpur
15.	LC-44	Department of Vegetable Science, COH&F, Neri, Hamirpur
16.	LC-45	Department of Vegetable Science, COH&F, Neri, Hamirpur
17.	LC-47	Department of Vegetable Science, COH&F, Neri, Hamirpur
18.	LC-49	Department of Vegetable Science, COH&F, Neri, Hamirpur
19.	LC-50	Department of Vegetable Science, COH&F, Neri, Hamirpur
20.	LC-51	Department of Vegetable Science, COH&F, Neri, Hamirpur
21.	LC-52	Department of Vegetable Science, COH&F, Neri, Hamirpur
22.	LC-53	Department of Vegetable Science, COH&F, Neri, Hamirpur
23.	LC-55	Department of Vegetable Science, COH&F, Neri, Hamirpur
24.	LC-56	Department of Vegetable Science, COH&F, Neri, Hamirpur
25.	LC-57	Department of Vegetable Science, COH&F, Neri, Hamirpur
26.	LC-58	Department of Vegetable Science, COH&F, Neri, Hamirpur
27.	LC-60	Department of Vegetable Science, COH&F, Neri, Hamirpur
28.	LC-62	Department of Vegetable Science, COH&F, Neri, Hamirpur
29.	LC-65	Department of Vegetable Science, COH&F, Neri, Hamirpur
30.	Punjab Suhabani	Punjab Agriculture University, Ludhiana
31.	Palam Komal	CSKHPKV, Palampur
32.	P-8 (check)	Punjab Agriculture University, Ludhiana

Source: Department of Vegetable Science, COH&F, Neri, Hamirpur

3.3 FIELD OPERATIONS

The experimental field was prepared and ploughed thoroughly with the help of power tiller to bring it to the fine tilth and planked for levelling. Manures and fertilizers (N, P & K) were applied to the crop as per recommendations of package of practices. After levelling, plots of 1.80m × 1m dimensions were made and seeds of different genotypes of okra were directly sown in the plots at 60cm × 20cm spacing on 21st May, 2022. Thinning was done 7-10 days after seed germination to retain 15 plants per plot. The crop was raised as per package of practices of vegetable crops (Anonymous, 2014).

3.4 EXPERIMENTAL DESIGN AND LAYOUT

The details of experimental layout are given below:

Location	Experimental Farm of Vegetable Science, Neri, Hamirpur
Design	Randomized Complete Block Design
Name of crop	Okra (<i>Abelmoschus esculentus</i> (L.) Moench)
Season & year	Rainy or Kharif, 2022
Date of sowing	21 May, 2022
No. of genotypes	32 (including check)
Plot size	1.80m×1m
Replications	Three (03)
Spacing	60 cm×20cm
Total number of plant per plot	15
Check variety	P-8

3.5 OBSERVATIONS TO BE RECORDED

Five plants in each plot were selected randomly and tagged for recording data for various plant characters. The data recorded on various parameters during the period of experiment are as follow:



Plate 1: Field preparation and seed sowing

3.5.1 Plant height at first flowering node (cm)

Height of plant was recorded from the crown portion to the first flowering node with the help of meter scale.

3.5.2 Days to 50% flowering

Number of days taken from the date of sowing to the date of 50% flowering was counted.

3.5.3 Plant height (cm)

Height of plant was recorded from the base just above the soil surface to growing point of the plant at the end of the season with the help of meter scale.

3.5.4 Internodal length (cm)

The inter-nodal length of the five randomly selected plants was recorded. The length between two nodes from different places was measured (base, middle and top) with the help of scale and average was worked out.

3.5.5 Fruit length (cm)

The length of randomly selected five fruits from the tagged plants was measured and average was worked out.

3.5.6 Fruit girth (cm)

The diameter of the randomly selected five fruits from the tagged plants was measured with the help of Vernier calipers and average was worked out.

3.5.7 Fruit weight (g)

The individual weight of five randomly selected fruits from the tagged plants was recorded separately with the help of weighing balance and average was worked out.

3.5.8 Number of seeds per pod

Seeds were extracted and counted carefully from the five dried fruits and average number of seeds per fruit was worked out.

3.5.9. 100 seed weight (g)

Seeds from five randomly selected fruits were extracted and hundred seeds were counted and their seed weight was recorded.

3.5.10 Number of fruits per plant

The number of fruits harvested from five randomly selected plants in each genotype were counted after each picking and summed up together. The average number of fruits per plant was calculated.

3.5.11 Fruit yield per plant (g)

Total yield from all the five tagged plants were calculated by adding all the pickings and average was worked out.

3.5.12 Fruit yield per plot (kg)

Total weight of marketable fruits harvested from each plot was recorded and expressed as yield per plot of each genotype.

3.5.13 Number of ridges

Number of ridges per fruit was observed from fruits of randomly tagged plants.

3.5.14 Plant growth habit

The plant growth habit was recorded as per branching habit under following categories:

- i. Spreading
- ii. Non-spreading

3.5.15 Fruit color

The color of the fruit as per AVRDC record-sheet was recorded at marketable stage in following categories:

- i. Dark Green
- ii. Green

- iii. Yellow green
- iv. Green with red specks
- v. Red

3.5.16 Stem color

Stem color was measured after plants entered into the stage of full foliage and was recorded in the following categories:

- i. Green
- ii. Green with red patch
- iii. Red

3.5.17 Leaf color

The color of mature leaves was recorded in following categories:

- i. Green
- ii. Green with red veins

3.5.18 Incidence of diseases if any

The disease incidence was calculated by counting the number of plants affected in each replication and were expressed in percentage.

3.6 STATISTICAL ANALYSIS

Analysis of variance was done as suggested by Gomez and Gomez (1984).

3.6.1 ANOVA for RCBD

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	F _{cal}
Genotypes	(g-1)	S _g	M _g = S _g / (g-1)	M _g / M _e
Replications	(r-1)	S _r	M _r = S _r / (r-1)	M _r / M _e
Error	(r-1)(g-1)	S _e	M _e = S _e / (r-1)(g-1)	
Total	(rg-1)	S _T		

Where,

r	=	Number of replications
g	=	Number of genotypes
S_r	=	Sum of squares due to replications
S_g	=	Sum of squares due to genotypes
S_e	=	Sum of squares due to error
S_T	=	Total sum of squares
M_r	=	Mean sum of squares due to replications
M_g	=	Mean sum of squares due to genotypes
M_e	=	Mean sum of squares due to error

The replication and entries mean sum of squares was tested against error mean squares by 'F' test at $(r-1)$, $(r-1) (g-1)$ and $(g-1)$, $(r-1) (g-1)$ degree of freedom for RCBD at 5% level of significance.

The calculated F-values were compared with tabulated F- value. When F-test found significant, critical differences were calculated to find out the superiority of one genotype over the others.

The standard error (SE) and critical difference (CD) was calculated as follows:

$$\begin{aligned} SE(d) \pm &= \sqrt{2 Me/r} \\ SE(m) \pm &= \sqrt{Me/r} \\ CD_{0.05} &= S.E. (d) \times t_{(0.05) (r-1) (g-1) df} \end{aligned}$$

Where,

$SE(m) \pm$	=	Standard error of mean
$SE(d) \pm$	=	Standard error of difference
$CD_{0.05}$	=	Critical difference at 5 per cent level of significance

3.6.2 Parameters of variability

Parameters of variability were estimated as per formula given by Burton and De Vane (1953) as follows:

3.6.2.1 Phenotypic coefficient of variation (PCV)

$$\text{PCV (\%)} = \frac{\sqrt{\text{Phenotypic variance (Vp)}}}{\text{General mean of population (GM)}} \times 100$$

3.6.2.2 Genotypic coefficient of variation (GCV)

$$\text{GCV (\%)} = \frac{\sqrt{\text{Genotypic variance (Vg)}}}{\text{General mean of population (GM)}} \times 100$$

Where,

$$V_e = M_e$$

$$V_g = \text{Genotypic variance } (M_g - M_e) / r$$

$$V_p = \text{Phenotypic variance } (V_g + V_e)$$

3.6.2.3 Heritability

Heritability in broad sense was calculated as per formula given by Burton and Devane (1953) and Allard (1960).

$$H (\%) = \frac{V_g}{V_p} \times 100$$

Where,

$$H = \text{Heritability (\%)}$$

$$V_g = \text{Genotypic variance } [V_g = (M_g - M_e) / r]$$

$$V_p = \text{Phenotypic variance } (V_g + V_e)$$

3.6.2.4 Genetic advance

The expected genetic advance resulting from selection of five percent superior individuals was calculated as per Allard (1960):

$$GA = H \times \sigma_p \times K$$

Where,

$$H = \text{Heritability (\%)}$$

$$\sigma_p = \text{Phenotypic standard deviation}$$

K = Selection differential at 5% selection index (K = 2.06)

3.6.2.5 Genetic gain (GG)

Genetic advance expressed as per cent of population mean was calculated by the method given by Johnson et al. (1955).

$$GG = \frac{GA}{GM} \times 100$$

Where,

GG = Genetic gain

GA = Genetic advance

GM = Population mean

For categorization of magnitude of different parameters, following limits were used (Warshamana, 2005)

PCV and GCV

PCV and GCV	>30%	High
	15-30%	Moderate
	<15%	Low

Heritability

Heritability	>80%	High
	50-80%	Moderate
	<50%	Low

Genetic gain

Genetic advance as per cent of mean (Genetic gain)	>50%	High
	25-50%	Moderate
	<25%	Low

3.7 CORRELATION ANALYSIS

The correlations between all characters under study, at genotypic and phenotypic level were estimated as per the method described by Al-Jibouri et al. (1958).

Source of variation	Degree of freedom	Mean sum of square		Mean sum of square	Variation ratio (F-value)
		X	Y		
Replications (r)	r-1				
Genotypes (t)	g-1	$M_g X$	$M_g Y$	$M_g XY = MP_1$	MP_1 / MP_2
Error (r)	(r-1)(g-1)	$M_e X$	$M_e Y$	$M_e XY = MP_2$	

Genotypic, phenotypic and environmental co-variance between X and Y characters worked out as under:

$$\begin{aligned}
 \text{Environmental covariance (V}_e \text{ XY)} &= MP_2 \\
 \text{Genotypic covariance (V}_g \text{ XY)} &= (MP_1 - MP_2)/r \\
 \text{Phenotypic covariance (V}_p \text{ XY)} &= V_g \text{ XY} + V_e \text{ XY}
 \end{aligned}$$

Where,

$$\begin{aligned}
 V_e \text{ XY} &= \text{Environmental covariance between X and Y} \\
 V_g \text{ XY} &= \text{Genotypic covariance between X and Y} \\
 V_p \text{ XY} &= \text{Phenotypic covariance between X and Y}
 \end{aligned}$$

Coefficients of correlation:

3.7.1 Phenotypic correlation between characters X and Y:

$$r_p = \frac{V_p \text{ XY}}{\sqrt{V_p \text{ X} \times V_p \text{ Y}}}$$

3.7.2 Genotypic correlation between characters X and Y:

$$r_g = \frac{V_g \text{ XY}}{\sqrt{V_g \text{ X} \times V_g \text{ Y}}}$$

3.7.3 Environmental correlation between characters X and Y:

$$r_e = \frac{V_{eXY}}{\sqrt{V_{eX} V_{eY}}}$$

Where,

V_{pXY} , V_{gXY} , V_{eXY} denotes phenotypic, genotypic and environmental covariances between characters X and Y, respectively.

V_{pX} , V_{gX} , V_{eX} denotes phenotypic, genotypic and environmental variances between characters X, whereas, V_{pY} , V_{gY} , V_{eY} denotes phenotypic, genotypic and environmental variances between characters Y.

3.8 PATH COEFFICIENT ANALYSIS

The following formula was used for calculating path coefficient analysis suggested by Dewy and Lu (1959). The path coefficient was obtained by the simultaneous selection of following equations, which express the basic relationship between genotypic correlation (r) and path coefficient (P)

$$r_{14} = P_{14} + r_{12} P_{24} + r_{13} P_{34}$$

$$r_{24} = r_{21} P_{14} + P_{24} + r_{23} P_{34}$$

$$r_{34} = r_{31} P_{14} + P_{32} + r_{24} P_{34}$$

Where, r_{14} , r_{24} and r_{34} are genotypic correlation of components characters with yield (dependent variable) and r_{13} , r_{23} and r_{24} are genotypic correlations among the component characters (independent variable) and $r_{12} P_{24}$, $r_{13} P_{34}$, $r_{21} P_{14}$, $r_{23} P_{34}$, $r_{31} P_{14}$ and $r_{24} P_{34}$ indirect effects.

The direct effects were calculated by the following set of equations:

$$P_{14} = C_{11} r_{14} + C_{12} r_{24} + C_{13} r_{34}$$

$$P_{24} = C_{21} r_{14} + C_{22} r_{24} + C_{23} r_{34}$$

$$P_{34} = C_{31} r_{14} + C_{32} r_{24} + C_{33} r_{34}$$

Where, C_{11} , C_{12} , C_{23} and C_{33} are constants and P_{14} , P_{24} and P_{34} are the estimates of direct effects.

3.8.1 Residual effect:

It measures the role of other possible independent variables which were not included in the study on dependent variable. The residual effect was estimated with the help of direct effect and simple correction coefficient as given below:

$$I = P^2_{x_4} + P^2_{14} + P^2_{24} + P^2_{34} + 2P_{14}r_{12}P_{24} + 2P_{14}r_{13}P_{34} + 2P_{24}r_{22}P_{34}$$



Plate 2: General view of the experiment at Vegetable Research Farm, COH&F, Neri



Plate 2: General view of the experiment at Vegetable Research Farm, COH&F, Neri

**RESULTS
AND
DISCUSSION**

Chapter-4

RESULTS AND DISCUSSION

The present investigation entitled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” on 32 accessions of okra including check (P-8) was conducted during kharif season in the year 2022 with the following objectives:

1. To study the performance of okra genotypes under sub-tropical regions of Himachal Pradesh.
2. To identify the promising genotype(s) with desirable horticultural traits.
3. To estimate the extent of genetic variability, heritability and genetic advance.
4. To work out correlation among the various yield and yield contributing characters.

The results obtained from the present investigation are presented under following headings:

4.1 Variability studies

4.1.1 Mean performance of genotypes

4.1.2 Parameters of variability

4.1.2.1 Coefficient of variation

4.1.2.2 Heritability

4.1.2.3 Genetic advance (as % of mean)

4.2 Correlation studies

4.2.1 Phenotypic correlations

4.2.2 Genotypic correlations

4.3 Path coefficient analysis

4.1 VARIABILITY STUDIES

4.1.1 Mean performance of genotypes

The analysis of variance depicting high significant differences among all the genotypes for various parameters of okra is shown in Appendix-II, which revealed the presence of abundant genetic variability in the germplasm. For all the characters the value of mean sum of square was highly significant. The findings are similar to that of Chaukhande et al. (2011), Vani et al. (2012), Saryam et al. (2015), More et al. (2018), Kumar et al. (2019), Sravanthi et al. (2021) and Shwetha et al. (2022). The mean performances of the thirty two genotypes of okra for various characters are presented in Table 4.1, 4.2 and 4.3.

4.1.1.1 Plant height at first flowering node (cm)

Minimum plant height at first flowering is an indicative of more number of fruits per plant which directly contributes towards yield. Significant variation was observed among all the genotypes for plant height at first flowering node (Appendix- II) ranging from 29.55 cm to 44.17 cm with a population mean of 35.92 cm (Table 4.1). The genotype LC-65 exhibited minimum plant height at first flowering node which was statistically at par with LC-33 (30.33 cm) followed by LC-28 (30.63 cm) and LC-51 (30.73 cm), while maximum was observed in LC-42 which was statistically at par with LC-58 (43.94 cm). Twenty three genotypes resulted in higher plant height at first flowering node than the check cultivar P-8 (32.83 cm).

4.1.1.2 Days to 50% flowering

Less number of days to 50% flowering is an indicative of early production. Data pertaining to days to 50% flowering is presented in Table 4.1. A wide range of variability for days to 50% flowering was observed among various genotypes of okra (Appendix-II) ranging from 45.32 to 53.64 days being minimum in LC-51 and maximum in LC-42. Fourteen genotypes were earlier in 50% flowering than the overall mean (50.60). LC-33 (45.42), LC-65 (45.45) and LC-28 (45.47) were found statistically at equivalence with LC-51. The standard check P-8 took 52.66 days which was statistically at par with LC-56 (53.42), LC-60 (53.35), LC-58 (52.50), LC-55 (52.42), LC-34 (52.42), LC-62 (52.34), LC-44 (52.30), LC-52 (52.22) and LC-23 (51.97). Twenty seven genotypes have taken lesser number of

days to 50% flowering than the standard check P-8. These results were similar with the earlier findings of Sharma et al. (2016), Mishra et al. (2018), Agbowuro et al. (2019) and Mohammed and Shiferaw (2022).

4.1.1.3 Plant height (cm)

Plant height is strongly associated with plant vigour and yield. All the genotypes studied revealed significant variations for plant height (Appendix-II) ranged from 141.69 cm to 274.60 cm in LC-42 and LC- 65, respectively with the mean performance of 194.27 cm (Table 4.1). Genotype LC-65 was found statistically at par with LC-51 (274.25 cm), LC-33 (273.91) and LC-28 (273.33 cm), whereas the genotype LC-42 was statistically at par with LC-58 (141.74 cm) and LC-25 (142.36 cm). Four genotypes viz., LC-28 (273.33 cm), LC-33 (273.91), LC-51 (274.25 cm) and LC-65 (274.60) resulted in higher plant height than the check cultivar P-8 (222.20 cm). These results are in agreement with the findings of Prakash and Pitchaimuthu (2010), Narkhede et al. (2015), Kumar et al. (2021), Choudhary et al. (2022) and Prakash et al. (2022).

4.1.1.4 Internodal length (cm)

Internodal length is an indicative of plant vigour and has direct impact on plant spacing. Moreover, genotypes with more plant height had longer internodal length and more number of nodes per plant which directly contributes towards yield. Analysis of variance revealed significant differences among genotypes for internodal length (Appendix-II). Maximum internodal length was observed in LC-33 (16.51 cm) which was statistically at equivalence with LC-65 (16.30 cm), LC-51 (16.25 cm) and LC-28 (16.12 cm), while minimum was recorded in LC-36 (4.25) followed by LC-42 (4.55 cm), LC-52 (4.65 cm), LC-25 (4.73 cm) and LC-58 (4.78 cm). P-8 (standard check) recorded internodal length of 6.25 cm which was statistically at par with eight genotypes. The variation for internodal length has also been reported by Sundaram and Rajkumar (2015), Sood et al. (2018), Alam et al. (2020), Vani et al. (2021) and Jadav et al. (2022).

Table 4.1: Mean performance of okra genotypes for plant height at first flowering node, days to 50% flowering, plant height and internodal length

S. No.	Genotypes	Plant height at first flowering node (cm)	Days to 50% flowering	Plant height (cm)	Internodal length (cm)
1.	LC-21	39.65	51.74	172.30	6.25
2.	LC-23	32.44	51.97	163.37	5.63
3.	LC-24	39.68	49.08	147.33	11.85
4.	LC-25	40.27	50.10	142.36	4.73
5.	LC-28	30.63	45.47	273.33	16.12
6.	LC-33	30.33	45.42	273.91	16.51
7.	LC-34	32.23	52.42	179.07	4.97
8.	LC-35	34.87	50.00	208.88	5.22
9.	LC-36	33.78	50.39	189.70	4.25
10.	LC-37	38.83	50.00	181.63	10.50
11.	LC-38	39.30	50.25	177.53	12.72
12.	LC-40	32.55	47.35	196.30	8.25
13.	LC-42	44.17	53.64	141.69	4.55
14.	LC-43	38.33	53.55	173.58	5.45
15.	LC-44	35.99	52.30	168.60	5.97
16.	LC-45	35.63	50.66	200.89	8.08
17.	LC-47	39.93	51.27	174.40	5.55
18.	LC-49	35.00	50.46	206.41	6.50
19.	LC-50	33.00	51.85	217.60	9.05
20.	LC-51	30.73	45.32	274.25	16.25
21.	LC-52	35.22	52.22	170.57	4.65
22.	LC-53	36.27	51.85	195.70	10.25
23.	LC-55	31.99	52.42	169.13	6.06
24.	LC-56	38.00	53.42	190.07	6.47
25.	LC-57	37.65	49.85	194.40	5.87
26.	LC-58	43.94	52.50	141.74	4.78
27.	LC-60	37.80	53.35	192.54	11.83
28.	LC-62	38.23	52.34	190.17	12.27
29.	LC-65	29.55	45.45	274.60	16.30
30.	Punjab Suhabani	34.70	48.84	213.96	15.71
31.	Palam Komal	35.80	50.98	198.49	11.63
32.	P-8 (check)	32.83	52.66	222.20	6.25
	Mean	35.92	50.60	194.27	8.82
	Range	29.55-44.17	45.32-53.64	141.69-274.60	4.25-16.51
	C.D.(0.05)	1.34	0.77	4.71	0.70
	SE(m)	0.47	0.27	1.66	0.25
	C.V. %	2.28	0.93	1.48	4.84

4.1.1.5 Fruit length (cm)

Fruit length is an important parameter which decides the choice of consumers for consumption purpose and also affects the marketable fruit yield. Data recorded for fruit length showed significant differences among all the genotypes (Appendix-II). It ranged from 9.84 cm to 20.05 cm with a population mean of 14.48 cm (Table 4.2), being maximum in LC-65 which was found to be statistically at par with LC-33 (19.35 cm), LC-51 (19.03 cm) and LC-28 (18.95 cm). Standard check P-8 recorded fruit length of 16.79 cm which was statistically at par with Punjab Suhabani (17.00 cm), LC-50 (16.92 cm) and LC-35 (15.93 cm). Minimum fruit length of 9.84 cm recorded for LC-58 which was statistically at par with LC-23 (10.36 cm) and LC- 25 (10.92 cm). Hazem et al. (2013), Narkhede et al. (2015), Khajuria et al. (2016), Doddanakatte et al. (2016), Kumari et al. (2017) and Vishnu et al. (2018) has also reported wide range of variability for fruit length in okra.

4.1.1.6 Fruit girth (cm)

Fruit girth is a major yield contributing as well as quality trait of fruits. A wide range of variability was observed among all the genotypes under study for fruit girth ranging from 1.43 cm to 2.47 cm (Table 4.2). Maximum fruit girth was recorded in LC-55 which was statistically at par with LC-60 (2.40 cm), LC-40 (2.39 cm), LC-65 (2.38 cm), LC-33 (2.38 cm), LC-28 (2.37 cm), LC-51 (2.36 cm) and LC-50 (2.35 cm). P-8 (check) recorded fruit girth of 1.67 cm which was statistically at par with LC-52 (1.78 cm), LC-44 (1.74 cm), LC-34 (1.74 cm), LC-36 (1.71 cm), LC-62 (1.63 cm), LC-37 (1.58 cm) and LC-23 (1.56 cm). Minimum fruit girth was observed in LC-42 (1.43 cm), found to be statistically at equivalence with LC-56 (1.49 cm). Similar findings are also reported by Muluken et al. (2016), Chandramouli et al. (2016), Verma et al. (2018), Chetana et al. (2021), Ranga and Darvhankar (2022) and Jadhav et al. (2022).

Table 4.2: Mean performance of okra genotypes for fruit length, fruit girth, fruit weight and number of seeds per pod

S. No.	Genotypes	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of seeds per pod
1.	LC-21	12.13	1.89	15.55	94.93
2.	LC-23	10.36	1.56	16.80	69.97
3.	LC-24	12.43	1.87	16.73	90.93
4.	LC-25	10.92	1.93	15.83	76.80
5.	LC-28	18.95	2.37	29.41	96.80
6.	LC-33	19.35	2.38	29.54	100.57
7.	LC-34	12.82	1.74	18.49	82.40
8.	LC-35	15.93	2.01	19.69	123.94
9.	LC-36	13.88	1.71	22.20	77.13
10.	LC-37	13.41	1.58	18.86	105.10
11.	LC-38	15.54	1.80	21.84	81.43
12.	LC-40	15.44	2.39	19.61	110.43
13.	LC-42	11.21	1.43	10.80	72.23
14.	LC-43	12.43	1.91	19.21	109.63
15.	LC-44	13.54	1.74	18.21	105.57
16.	LC-45	15.53	1.93	21.02	111.70
17.	LC-47	12.74	1.96	20.56	90.50
18.	LC-49	15.29	2.03	20.91	81.70
19.	LC-50	16.92	2.35	20.68	108.13
20.	LC-51	19.03	2.36	28.87	123.22
21.	LC-52	12.25	1.78	11.80	85.67
22.	LC-53	15.06	1.87	19.53	85.87
23.	LC-55	11.57	2.47	12.97	112.60
24.	LC-56	13.94	1.49	17.75	70.33
25.	LC-57	15.36	1.91	21.76	99.60
26.	LC-58	9.84	2.03	20.11	70.23
27.	LC-60	14.52	2.40	22.47	123.13
28.	LC-62	13.78	1.63	17.64	95.53
29.	LC-65	20.05	2.38	30.00	124.67
30.	Punjab Suhabani	17.00	2.23	16.41	90.63
31.	Palam Komal	15.18	1.94	19.54	98.47
32.	P-8 (check)	16.79	1.67	29.02	89.17
	Mean	14.48	1.96	20.12	95.59
	Range	9.84-20.05	1.43-2.47	10.80-30.00	69.97-124.67
	C.D.(0.05)	1.16	0.12	1.16	1.75
	SE(m)	0.41	0.04	0.41	0.62
	C.V. %	4.88	3.80	3.53	1.12

4.1.1.7 Fruit weight (g)

Fruit weight has direct contribution towards marketable yield. Analysis of variance showed significant differences among different genotypes for fruit weight (Appendix-II). Data pertaining to this trait is presented in Table 4.2. Maximum fruit weight of 30.00 g was recorded in LC-65 and it was found statistically at par with four genotypes including standard check viz., LC-33 (29.54 g), LC-28 (29.41 g), P-8 (29.02 g) and LC-51 (28.87 g), while minimum fruit weight of 10.80 g was recorded in LC-42 which was statistically at par with LC-52 (11.80 g). Thirteen genotypes gave higher average fruit weight than the population mean (20.12 g). These results are in agreement with the earlier findings of Reddy et al. (2014), Doddanakatte et al. (2016), Kerurel et al. (2017), Raval et al. (2018), Singh et al. (2019), Walling et al. (2020) and Prakash et al. (2022).

4.1.1.8 Number of seeds per pod

The number of seeds per fruit is directly correlated with the number of ridges per fruit as well as fruit length. Therefore, the fruits having larger fruit length and more number of ridges had more number of seeds. The perusal of data presented in (Appendix-II) recorded significant variation among genotypes for number of seeds per pod ranging from 69.97 to 124.67 with the population mean of 95.59 (Table 4.2). Maximum value was recorded in LC-65 followed by LC-35 (123.94), LC-51 (123.22) and LC-60 (123.13). Twenty genotypes had more number of seeds per pod than standard check P-8 (89.17), whereas minimum number of seeds per pod was observed in LC-23 which was statistically at par with LC-58 (70.23) and LC- 56 (70.33). These findings are in agreement with results obtained by Jindal et al. (2009), Koundinya et al. (2013), Koundinya and Dhankhar (2013), Kerure et al. 2017), Rambabu et al. (2019) and Shwetha et al. (2022).

4.1.1.9 100 seed weight (g)

Analysis of variance showed significant variability among all the genotypes for 100 seed weight (Appendix-II). The genotype LC-33 exhibited maximum 100 seed weight of 8.59 g which was statistically at par with LC-55 (8.51 g), Punjab Suhabani (8.48 g) and LC-51 (8.45 g) while minimum 100 seed

weight was recorded in LC-56 (5.02 g) followed by LC-58 (5.05 g). P-8 (check) recorded 100 seed weight of 6.71 g which was found to be statistically at par with LC-25 (6.87 g) and Palam Komal (6.62 g). Fourteen genotypes had higher 100 seed weight than population mean (Table 4.3). Wide range of variation with respect to this trait are also reported by Dhankar and Dhankar (2002), Verma et al. (2004), Ramgiry et al. (2017), Barman and Marboh (2022) and Kumar and Chakraborti (2023).

4.1.1.10 Number of fruits per plant

Number of fruits per plant is an important component which contributes towards yield. The data recorded for this parameter showed significant variability among all the genotypes (Appendix-II). The data pertaining to number of fruits per plant is presented in Table 4.3. Maximum number of fruits per plant was recorded in genotype LC-65 (15.49) which was found to be statistically at par with LC-33, LC-51, LC-28 and P-8 (check). While minimum number of fruits per plant (6.45) was observed in LC-47 which was found to be statistically at par with LC-55 (6.50), LC-25 (6.65), LC-44 (6.65), LC-58 (6.69), LC-42 (6.78) and LC-34 (6.83). Bello and Aminu (2017), Verma et al. (2018), Melaku et al. (2020), Ashraf et al. (2020), Yadav et al. (2020) and Prakash et al. (2022) also reported wide variation for this trait.

4.1.1.11 Fruit yield per plant (g)

Fruit yield per plant is one of the utmost important parameter that directly contributes towards total yield. All the genotypes studied revealed significant differences for fruit yield per plant (Appendix-II), which was ranged from 103.67 g to 483.23 g with a population mean of 242.25 g. Twelve genotypes gave higher fruit yield per plant than general mean (Table 4.3). Highest fruit yield per plant was recorded in genotype LC-28 followed by LC-65, LC-51, LC-33 and P-8 (Check). While minimum fruit yield per plant was recorded in LC-42 which was statistically different from other genotypes. Similar findings are also reported by Reddy et al. (2013), Thulasiram et al. (2017), Sravanthi (2017), Raval et al. (2018), Syfullah et al. (2018), Kumari et al. (2019), Kumar et al. (2019), Alam et al. (2020) and Shwetha et al. (2022).

Table 4.3: Mean performance of okra genotypes for 100 seed weight, number of fruits per plant, fruit yield per plant and fruit yield per plot

S. No.	Genotypes	100 seed weight (g)	Number of fruits per plant	Fruit yield per plant (g)	Fruit yield per plot (kg)
1.	LC-21	5.35	7.70	159.33	1.51
2.	LC-23	5.23	7.15	198.04	1.68
3.	LC-24	6.26	8.55	193.65	2.18
4.	LC-25	6.87	6.65	170.06	1.86
5.	LC-28	7.76	15.29	483.23	6.53
6.	LC-33	8.59	15.48	480.84	6.47
7.	LC-34	5.52	6.83	187.20	1.85
8.	LC-35	5.92	10.95	291.64	3.80
9.	LC-36	6.36	7.92	294.70	3.12
10.	LC-37	5.55	7.51	163.96	2.25
11.	LC-38	7.29	7.86	155.74	2.84
12.	LC-40	6.38	9.95	206.11	2.82
13.	LC-42	5.36	6.78	103.67	1.70
14.	LC-43	7.28	7.35	235.88	2.21
15.	LC-44	5.77	6.65	126.47	1.72
16.	LC-45	7.73	9.44	304.14	3.05
17.	LC-47	6.29	6.45	127.01	2.75
18.	LC-49	6.21	9.06	198.69	2.92
19.	LC-50	6.13	11.45	210.97	3.38
20.	LC-51	8.45	15.32	482.32	6.60
21.	LC-52	7.66	10.78	122.49	2.09
22.	LC-53	7.63	8.86	159.47	2.91
23.	LC-55	8.51	6.50	125.69	1.46
24.	LC-56	5.02	8.10	187.87	2.29
25.	LC-57	5.35	9.72	272.22	2.84
26.	LC-58	5.05	6.69	184.44	2.03
27.	LC-60	5.72	7.99	168.25	2.59
28.	LC-62	7.36	8.94	254.25	3.24
29.	LC-65	5.63	15.49	482.89	6.84
30.	Punjab Suhabani	8.48	11.51	254.11	2.41
31.	Palam Komal	6.62	10.61	286.55	4.91
32.	P-8 (check)	6.71	15.04	479.97	6.02
	Mean	6.56	9.52	242.25	3.15
	Range	5.02-8.59	6.45-15.49	103.67-483.23	1.46-6.84
	C.D.(0.05)	0.14	0.48	9.99	1.00
	SE(m)	0.05	0.17	3.52	0.35
	C.V. %	1.33	3.05	2.52	19.39

4.1.1.12 Fruit yield per plot (kg)

Fruit yield per plot is one of the most important characters in any research programme. Data pertaining to fruit yield per plot is presented in the Table 4.3. The observations revealed significant variations among various genotypes (Appendix-II) ranged from 1.46 kg to 6.84 kg with a population mean of 3.15 kg. Highest fruit yield of 6.84 kg per plot was recorded in L-65, which was found to be statistically at par with LC-51 (6.60 kg), LC-28 (6.53 kg), LC-33 (6.47 kg) and standard check P-8 (6.02 kg). The genotype LC-55 recorded minimum fruit yield per plot (1.46 kg) which was found to be statistically at par with thirteen genotypes viz., LC-21 (1.51 kg), LC-23 (1.68 kg), LC-42 (1.40 kg), LC-44 (1.72 kg), LC-34 (1.85 kg), LC-25 (1.86 kg), LC- 58 (2.03 kg), LC-52 (2.09 kg), LC-24 (2.18 kg), LC-43 (2.21 kg), LC-37 (2.25 kg), LC-56 (2.29 kg) and Punjab Suhabani (2.41 kg). Wide range of variation for fruit yield per plot are also reported by Senapati et al. (2011), Ahamed et al. (2015), Ramgiry and Ramgiry (2020), Baghel et al. (2022) and Shwetha et al. (2022).

4.1.1.13 Number of ridges

Data based on visual observations is presented in Table 4.4 which showed variation with respect to number of ridges. All the genotypes under study showed less variation for this parameter ranging from 5 to 8 ridges per fruit. Maximum number of ridges (8.00) was observed in LC-35, LC-40, LC-44, LC-55 and LC-60 while minimum number of ridges (5.00) was observed in thirteen genotypes including check P-8. Eight genotypes i.e. LC-21, LC-23, LC-24, LC-37, LC-47, LC-49, LC-50 and LC-65 showed seven ridges per fruit. These results are similar to the previous findings of Akotkar et al. (2010), Das et al. (2012), Simon et al. (2013), Singh et al. (2017) and Mohammed and Shiferaw (2022).

4.1.1.14 Plant growth habit

Data based on visual observations is presented in Table 4.4 and is categorized as spreading and non-spreading growth habit. Nineteen genotypes including check had non-spreading growth habit, while the genotypes viz., LC-21, LC-23, LC-34, LC-35, LC-36, LC-40, LC-43, LC-44, LC-47, LC-52, LC-55, LC-57 and LC-58 had spreading growth habit. Verma et al. (2004) and Reddy et al. (2013) also reported similar findings.

4.1.1.15 Fruit color

Fruit color is an important parameter which decides the consumer preference. All the genotypes under study revealed wide variations for fruit color. The perusal of data based on visual observations is presented in Table 4.4 and is categorized as dark green, green, yellow green, green with red specks and red. Six genotypes *viz.*, LC-28, LC-53, LC-62, Punjab Suhabani, Palam Komal and P-8 (check) exhibited dark green fruit color whereas fourteen genotypes had green color fruits. Six genotypes had yellow green fruits, whereas fruits of five genotypes were green with red specks. While one genotype (LC-65) had red color fruits. These results are in agreement with the earlier findings of Reddy et al. (2012), Ahiakpa et al. (2013), Muluken et al. (2016), Tesfa and Yosef (2016) and Bashir and Aminu (2017).

4.1.1.16 Stem color

Data based on visual observation is presented in Table 4.4 and is categorized as green, green with red patch and red. Twenty four genotypes had green stem color, whereas seven had green with red patch stem. While LC-65 had red color stem. Salameh (2014) and Asare et al. (2016) had also reported similar findings.

4.1.1.17 Leaf color

Leaf color was observed as green and green with red veins as depicted in Table 4.4. Seven genotypes *viz.*, LC-50, LC-51, LC-57, LC-60, Punjab Suhabani, Palam Komal and P-8 (check) had green leaf color, whereas remaining twenty five genotypes had green leaf with red veins. Results of the present study are in accordance with the findings of Alam and Hossain (2008), AdeOluwa and Kehinde (2012), Temam (2020) and Mohammed and Shiferaw (2022).

4.1.1.18 Incidence of diseases if any

No incidence of disease was found during the cropping period.

Table 4.4: Mean performance of okra genotypes for different morphological trait.

S. No.	Genotypes	Number of ridges	Plant growth habit	Fruit color	Stem color	Leaf color
1.	LC-21	7.00	Spreading	Green with Red Specks	Green with Red Patch	Green with Red Vein
2.	LC-23	7.00	Spreading	Green	Green with Red Patch	Green with Red Vein
3.	LC-24	7.00	Non-Spreading	Green	Green	Green with Red Vein
4.	LC-25	5.00	Non-Spreading	Green	Green	Green with Red Vein
5.	LC-28	5.00	Non-Spreading	Dark Green	Green	Green with Red Vein
6.	LC-33	5.00	Non-Spreading	Green	Green	Green with Red Vein
7.	LC-34	6.00	Spreading	Yellow Green	Green with Red Patch	Green with Red Vein
8.	LC-35	8.00	Spreading	Yellow Green	Green	Green with Red Vein
9.	LC-36	5.00	Spreading	Green	Green	Green with Red Vein
10.	LC-37	7.00	Non-Spreading	Green with Red Specks	Green with Red Patch	Green with Red Vein
11.	LC-38	6.00	Non-Spreading	Yellow Green	Green	Green with Red Vein
12.	LC-40	8.00	Spreading	Green	Green	Green with Red Vein
13.	LC-42	5.00	Non-Spreading	Green	Green	Green with Red Vein
14.	LC-43	6.00	Spreading	Green	Green	Green with Red Vein
15.	LC-44	8.00	Spreading	Yellow Green	Green	Green with Red Vein
16.	LC-45	6.00	Non-Spreading	Green	Green	Green with Red Vein
17.	LC-47	7.00	Spreading	Yellow Green	Green	Green with Red Vein
18.	LC-49	7.00	Non-Spreading	Green with Red Specks	Green with Red Patch	Green with Red Vein
19.	LC-50	7.00	Non-Spreading	Green	Green	Green
20.	LC-51	5.00	Non-Spreading	Green	Green	Green
21.	LC-52	5.00	Spreading	Yellow Green	Green	Green with Red Vein
22.	LC-53	5.00	Non-Spreading	Dark Green	Green	Green with Red Vein

23.	LC-55	8.00	Spreading	Green with Red Specks	Green with Red Patch	Green with Red Vein
24.	LC-56	5.00	Non-Spreading	Green with Red Specks	Green with Red Patch	Green with Red Vein
25.	LC-57	6.00	Spreading	Green	Green	Green
26.	LC-58	6.00	Spreading	Green	Green	Green with Red Vein
27.	LC-60	8.00	Non-Spreading	Green	Green	Green
28.	LC-62	5.00	Non-Spreading	Dark Green	Green	Green with Red Vein
29.	LC-65	7.00	Non-Spreading	Red	Red	Green with Red Vein
30.	Punjab Suhabani	5.00	Non-Spreading	Dark Green	Green	Green
31.	Palam Komal	5.00	Non-Spreading	Dark Green	Green	Green
32.	P-8 (check)	5.00	Non-Spreading	Dark Green	Green	Green

4.1.2 Parameters of variability

4.1.2.1 Coefficient of variation

The observations are recorded on magnitude of both genotypic as well as phenotypic variability. All the genotypes under studies revealed a wide range of variation for yield and its contributing characters (Table 4.5). As per observations, the phenotypic coefficient of variation was greater in magnitude than the genotypic coefficient of variation for all the parameters, which revealed that there was noticeable variability in the genetic material used. The narrow difference between genotypic and phenotypic coefficients of variation indicated less environmental interference, whereas the wide differences indicated their sensitivity to environmental fluctuations towards the expression of these characters. Parameters with higher phenotypic as well as genotypic coefficient of variation have wider scope of improvement through selection.

Table 4.5: Estimates of range, phenotypic and genotypic coefficients of variation, heritability and genetic advance as % of mean among fruit yield and its attributing traits in okra

Characters	Mean	Range		Coefficient of variations (%)		Heritability (%)	Genetic Advance as % of mean (%)
		Minimum	Maximum	Genotypic	Phenotypic		
Plant height at first flowering node (cm)	35.92	29.55	44.17	10.45	10.69	95.47	21.03
Days to 50% flowering	50.60	45.32	53.64	4.85	4.93	96.47	9.80
Plant height (cm)	194.27	141.69	274.60	19.12	19.18	99.41	39.27
Internodal length(cm)	8.82	4.25	16.51	46.47	46.73	98.93	95.22
Fruit length (cm)	14.48	9.84	20.05	18.14	18.78	93.24	36.08
Fruit girth (cm)	1.96	1.43	2.47	15.19	15.66	94.11	30.36
Fruit weight (g)	20.12	10.80	30.00	24.36	24.62	97.95	49.67
Number of seeds per pod	95.59	69.97	124.67	17.40	17.43	99.59	35.77
100 seed weight (g)	6.56	5.02	8.59	16.90	16.96	99.39	34.71
Number of fruits per plant	9.52	6.45	15.49	30.86	31.01	99.03	63.27
Yield per plant (g)	242.25	103.67	483.23	48.54	48.60	99.73	99.85
Yield per plot (kg)	3.15	1.46	6.84	50.42	54.01	87.12	96.94

The coefficients of variation under study are categorized as high (>30%), moderate (15-30%) and (low <15%) as per Warshamana, 2005.

Phenotypic and genotypic coefficient of variation ranged from 4.93% to 54.01% and 4.85% to 50.42%, respectively. High magnitude of GCV and PCV were observed for fruit yield per pot (50.42%, 54.01%) followed by fruit yield per plant (48.54%, 48.60%), internodal length (46.47%, 46.73%) and number of fruits per plant (30.86%, 31.01%). High values of GCV and PCV for fruit yield per plot have also been reported by Bagwale et al. (2016), Melaku et al. (2020) and Shwetha et al. (2022). Nasit et al. (2009), Reddy et al. (2012), Ranga et al. (2021) and Prakash et al. (2022) observed high GCV and PCV for fruit yield per plant. Prakash and Pitchaimuthu (2010) and Mohammed and Shiferaw (2022) reported high GCV and PCV for internodal length. High GCV and PCV for number of fruits per plant are similar to the findings of Sravanthi (2017), Kumar et al. (2020), Ranga et al. (2021) and Prakash et al. (2022).

Moderate magnitude of GCV and PCV were recorded for fruit weight (24.36%, 24.62%) followed by plant height (19.12%, 19.18%), fruit length (18.14%, 18.78%), number of seeds per pod (17.40%, 17.43%), 100 seed weight (16.90%, 16.96%) and fruit girth (15.19%, 15.66%), respectively. Moderate GCV and PCV for fruit weight are similar to the findings of Kerure et al. (2017) and Jangde et al. (2019). Thulasiram et al. (2017), Verma et al. (2018), Ashraf et al. (2020) and Prakash et al. (2022) reported moderate GCV and PCV for plant height. Pachiyappan and Saravanan (2013) and Mohammed and Shiferaw (2022) reported moderate values of GCV and PCV for fruit length whereas, Verma et al. (2018) and Melaku et al. (2020) revealed moderate GCV and PCV for number of seeds per pod. Similar findings for 100 seed weight were reported by Makhdoomi et al. (2018) and Reddy et al. (2022). Moderate GCV and PCV for fruit girth are similar to the findings of Makhdoomi et al. (2018), Kavya et al. (2019) and Jadav et al. (2022).

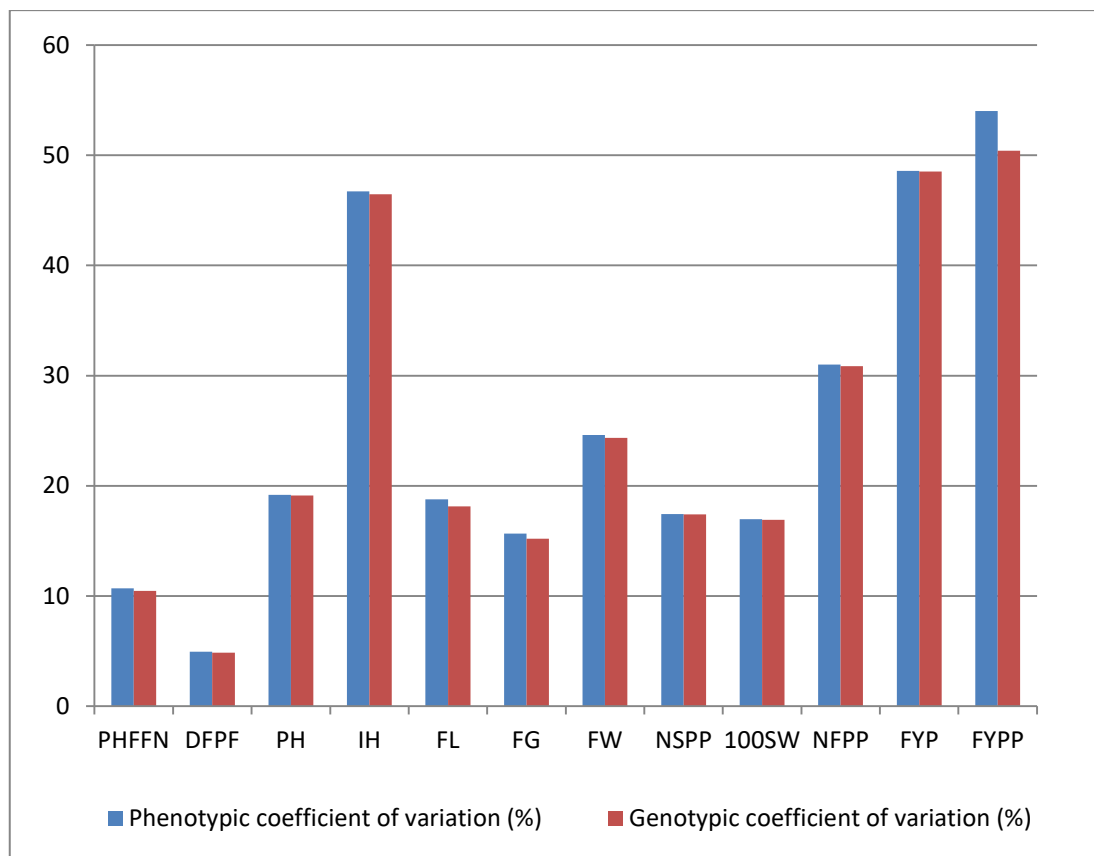


Figure 4.1: Graphical presentation of Genotypic and Phenotypic coefficients of variation (%)

Where,

PHFFN = Plant height at first flowering node (cm)	FW = Fruit weight (g)
DFPP =Days to 50% flowering	NSPP =Number of seeds per pod
PH = Plant height (cm)	100 SW = 100 seed weight (g)
IH = Internodal length (cm)	NFPP = Number of fruits per plant
FL = Fruit length (cm)	FYP = Fruit yield per plant (g)
FG = Fruit girth (cm)	FYPP = Fruit yield per plot (kg)

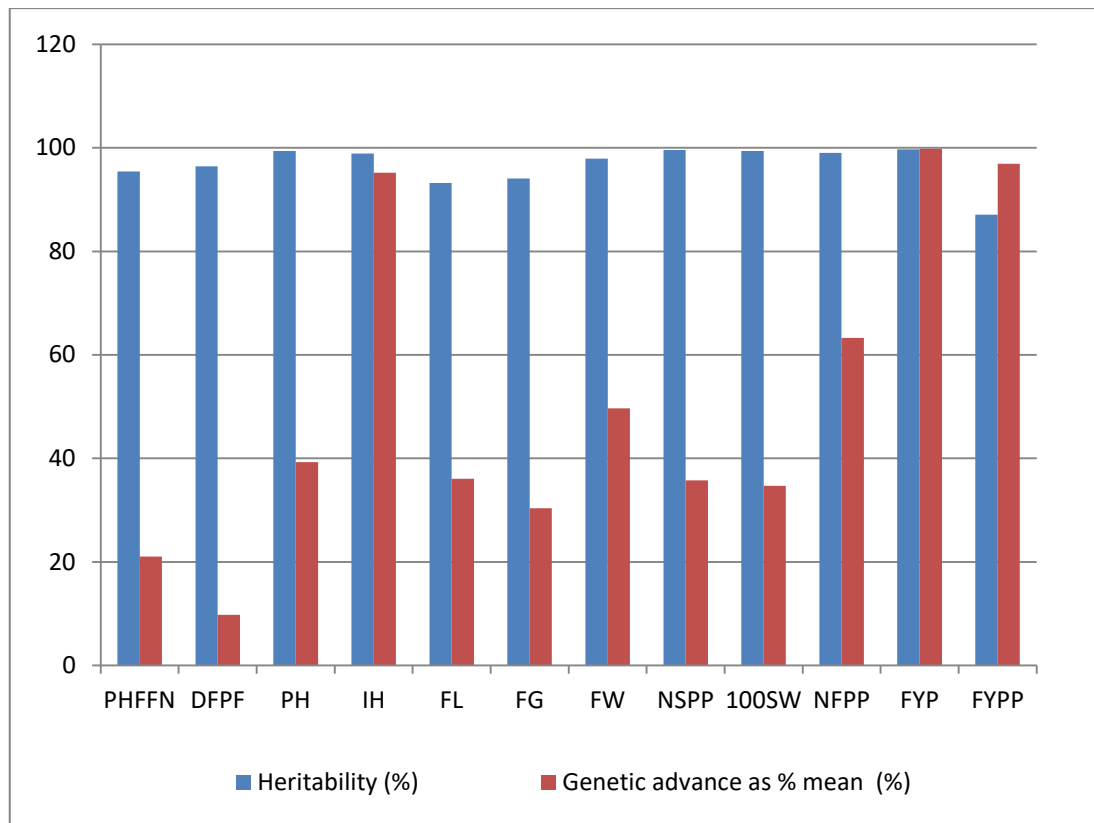


Figure 4.2: Graphical presentation of heritability (%) and genetic advance as % mean

Where,

PHFFN = Plant height at first flowering node (cm)	FW = Fruit weight (g)
DPPF =Days to50% flowering	NSPP =Number of seeds per pod
PH = Plant height (cm)	100 SW = 100 seed weight (g)
IH = Internodal length (cm)	NFPP = Number of fruits per plant
FL = Fruit length (cm)	FYP = Fruit yield per plant (g)
FG = Fruit girth (cm)	FYPP = Fruit yield per plot (kg)

Low magnitude of GCV and PCV were recorded for plant height at first flowering node (10.45%, 10.69%) and days to 50% flowering (4.85%, 4.93%). Kumar et al. (2015), Sharma et al. (2016), Kerure et al. (2017), Mohammed and Shiferaw (2022), Reddy et al. (2022), Shwetha et al. (2022) and Setu (2023) reported low PCV and GCV for days to 50% flowering in okra.

4.1.2.2 Heritability

Heritability in broad sense is an important parameter to the breeders, as its magnitude indicates the reliability with which a genotype can be recognized by its phenotypic expression. Genetic variability alone cannot be sufficient to determine heritable variation. According to Burton and De Vane (1953) heritability is an estimation of heritable variation and it is helpful in predicting the expected amount of improvement, which can be achieved through selection together with the genotypic coefficient of variation. Selection is more effective for the improvement of parameters having higher heritability.

Heritability estimates for the parameters under study are categorized as high (>80%), moderate (50-80%) and low (<50%) as per Warshamana, 2005. In the present analysis, the range of heritability (broad sense) for various parameters was varied from 87.12% to 99.73% (Table 4.5). All the genotypes showed high heritability, being maximum for fruit yield per plant (99.73%) followed by number of seeds per pod (99.59%), plant height (99.41%), 100 seed weight (99.39%), number of fruits per plant (99.03%), internodal length (98.93%), fruit weight (97.95%), days to 50% flowering (96.47%), plant height at first flowering node (95.47%), fruit girth (94.11%), fruit length (93.24%) and fruit yield per plot (87.12%). Parameters having high heritability are less influenced by the prevailing environmental conditions therefore selection is more effective for improvement of such traits.

High heritability for plant height, internodal length, fruit length and fruit diameter has been reported by Prakash et al. (2022). Reddy et al. (2022) reported high heritability estimates for plant height, internodal length, days to 50% flowering, fruit length, fruit weight, number of fruits per plant, fruit yield per plant. For the traits *viz.*, plant height, internodal length, 100 seed weight and fruit yield per plant high heritability has been recorded by Chetana et al. (2021) while, Rambabu et al. (2019) reported high estimates of heritability for plant height, inter

nodal length, days to 50% flowering, fruit length, fruit girth, fruit weight, number of fruits per plant, number of seeds per fruit, fruit yield per plant and 100 seed weight.

Singh et al. (2006) and Mohapatra et al. (2007) reported similar findings for days to 50% flowering whereas Patel et al. (2014) observed high heritability for fruit yield per plot. Hazara and Basu (2000), Chaukhande et al. (2011) and Nagre (2011) reported similar findings for fruit length and plant height.

4.1.2.3 Genetic advance (as % of mean)

The superiority of selected plants in phenotypic expression over the original population is not only due to their genotype superiority but also due to favorable environmental conditions. Heritability estimates alone are not sufficient therefore heritability along with genetic advance is more useful tool for improvement. Genetic advance is the improvement in mean genotypic value of selected plant over base population. Genetic gain is the genetic advance as per cent of mean. Genetic advance depends upon heritability of parameter under selection, genetic variability of genotype and intensity of selection. The characters with high heritability coupled with high genetic advance would response to selection better than those with high heritability with low genetic advance. High heritability along with high genetic advance shows that parameters were governed mainly due to additive gene effect and therefore selection might be effective in improvement of these traits as suggested by Johnson et al. (1955).

Genetic advance as per cent of mean for the parameters under study are categorized as high (>50%), moderate (25-50%) and low (<25%). Genetic advance was calculated as % mean for yield and its contributing characters which are presented in Table 4.5 and shown in Fig. 4.2. Genetic advance (expressed as % of population mean) ranged from 9.80% to 99.85%. Maximum value was recorded for fruit yield per plant (99.85%) followed by fruit yield per plot (96.94%), internodal length (95.22%) and number of fruits per plant (63.27%). High genetic gain for fruit yield per plot has also been reported by Baghel et al. (2022). Mohammed and Shiferaw (2022) reported high genetic gain for internodal length and number of fruits per plant whereas, Reddy et al. (2022) reported high genetic advance as percent of mean for internodal length, number of fruits per

plant and fruit yield per plant. Priyanka et al. (2018) reported high genetic gain for number of fruits per plant and fruit yield per plant.

Moderate genetic advance was recorded for fruit weight (49.67%), plant height (39.27%), fruit length (36.08%), number of seeds per pod (35.77%), 100 seed weight (34.71%) and fruit girth (30.36%). Moderate genetic gain for plant height has also been reported by Awasthi et al. (2022). Chetana et al. (2021) reported moderate genetic advance for fruit length. Phanikrishna et al. (2015) reported moderate genetic gain for fruit girth and fruit weight. Moderate genetic gain for fruit girth has also been reported by Hazra and Basu (2000).

Low genetic advance as per cent mean was observed for plant height at first flowering node (21.03%) and days to 50% flowering (9.80%) which indicates the preponderance of non-additive gene action and improvement in these characters may be brought about by hybridization. Low genetic gain for days to 50% flowering has also been reported by Khan et al. (2023), Shwetha et al. (2022) and Melaku et al. (2020).

4.2 CORRELATION STUDIES

Correlation is a statistical measure that shows the extent to which two variables are linearly related i.e. they changes together at a constant rate. More closely a parameter is associated with yield, more effective will be the selection for yield improvement. It gives an idea about the inter relation among the various parameters and determines the component characters for which selection can be done for genetic improvement in the fruit yield. The effect of the yield contributing characters on yield can be studied by correlation analysis programme for bringing crop improvement. Knowledge about the association of characters serves an important purpose for the breeders as, all the phenotypic traits are the result of interplay of various genetic factors among themselves and combined interaction with the environmental factors.

Table 4.6: Estimates of phenotypic correlation coefficient between yield and its component characters in okra (*Abelmoschus esculentus* (L.) Moench)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
Y1	1											
Y2	0.535**	1										
Y3	-0.746**	-0.722**	1									
Y4	-0.406**	-0.689**	0.725**	1								
Y5	-0.639**	-0.693**	0.923**	0.741**	1							
Y6	-0.498**	-0.560**	0.555**	0.494**	0.512**	1						
Y7	-0.534**	-0.622**	0.823**	0.591**	0.776**	0.423**	1					
Y8	-0.417**	-0.369**	0.510**	0.403**	0.519**	0.615**	0.372**	1				
Y9	-0.395**	-0.377**	0.410**	0.488**	0.390**	0.433**	0.187	0.252*	1			
Y10	-0.658**	-0.691**	0.902**	0.689**	0.860**	0.472**	0.746**	0.409**	0.420**	1		
Y11	-0.626**	-0.681**	0.863**	0.610**	0.777**	0.375**	0.855**	0.366**	0.344**	0.891**	1	
Y12	-0.577**	-0.661**	0.859**	0.654**	0.793**	0.407**	0.839**	0.386**	0.338**	0.871**	0.889**	1

**Significance at 1% level *Significance at 5% level

Where, Y1= Plant height at first flowering node (cm), Y2= Days to 50% flowering, Y3= Plant Height (cm), Y4= Internodal Length (cm), Y5= Fruit Length (cm), Y6= Fruit Girth (cm), Y7= Fruit Weight (g), Y8= Number of seeds per pod, Y9=100 seed weight (g), Y10= Number of fruits per plant, Y11= Fruit yield per plant (g) and Y12= Fruit yield per plot (kg).

In the present investigation, the observed correlation coefficients among the different characters were worked out at both genotypic as well as phenotypic levels. In general, genotypic correlation coefficients were higher in magnitude than phenotypic correlation coefficients for all the parameters, indicating lesser role of environment in governing the phenotype of the okra genotypes. The correlation coefficients between the parameters at both phenotypic and genotypic levels were estimated and are presented in Table 4.6 and 4.7, respectively.

4.2.1 Phenotypic correlations

The phenotypic correlation coefficients among different parameters showed that fruit yield per plot had positive and significant association with fruit yield per plant (0.889), number of fruits per plant (0.871), plant height (0.859), fruit weight (0.839), fruit length (0.793), internodal length (0.654), fruit girth (0.407), number of seeds per pod (0.386) and 100 seed weight (0.338) while negative and significant association with plant height at first flowering node (-0.577) and days to 50% flowering (-0.661). Fruit yield per plant showed positive and significant association with number of fruits per plant (0.891), plant height (0.863), fruit weight (0.855), fruit length (0.777), internodal length (0.610), fruit girth (0.375), number of seeds per pod (0.366) and 100 seed weight (0.344) whereas negatively significant association with plant height at first flowering node (-0.626) and days to 50% flowering (-0.681).

Number of fruits per plant exhibited positive and highly significant association with plant height (0.902), fruit length (0.860), fruit weight (0.746), internodal length (0.689), fruit girth (0.472), 100 seed weight (0.420) and number of seeds per pod (0.409) while negative and significant correlation was obtained for plant height at first flowering node (-0.658) and days to 50% flowering (-0.691). 100 seed weight had positive and significant association with internodal length (0.488), fruit girth (0.433), plant height (0.410), fruit length (0.390) and number of seeds per pod (0.252) whereas it showed negative and significant association with days to 50% flowering (-0.377) and plant height at first flowering node (-0.395). Positive and significant correlation was exhibited by number of seed per pod with fruit girth (0.615), fruit length (0.519), plant height (0.510), internodal length (0.403) and fruit weight (0.372) while it expressed negative and

significant association with days to 50% flowering (-0.369) and plant height at first flowering node (-0.417).

Fruit weight exhibited positive and significant correlation with plant height (0.823), fruit length (0.776), internodal length (0.591) and fruit girth (0.423) while it was significantly and negatively associated with plant height at first flowering node (-0.534) and days to 50% flowering (-0.622). Fruit girth had positive and significant association with plant height (0.555), fruit length (0.512) and internodal length (0.494) while negative and significant correlation for plant height at first flowering node (-0.498) and days to 50% flowering (-0.560). Fruit length had positive and highly significant association with plant height (0.923) and internodal length (0.741) while negative and significant association with plant height at first flowering node (-0.639) and days to 50% flowering (-0.693). Internodal length had positive and significant association with plant height (0.725) and it expressed negative association with plant height at first flowering node (-0.406) and days to 50% flowering (-0.689). Plant height exhibited negative and significant correlation with days to 50% flowering (-0.722) and plant height at first flowering node (-0.746). Days to 50% flowering had positive and significant association with plant height at first flowering node (0.535).

4.2.2 Genotypic correlations

Genotypic correlations provide measures of genetic association between parameters and are more reliable than phenotypic correlation and this helps to identify the parameters to be utilized in breeding programme.

Perusal of data from (Table 4.7) expressed that fruit yield per plot was positively and significantly correlated with fruit yield per plant (0.955), number of fruits per plant (0.944), plant height (0.922), fruit weight (0.900), fruit length (0.892), internodal length (0.707), fruit girth (0.455), number of seeds per pod (0.412) and 100 seed weight (0.366) while plant height at first flowering node (-0.623) and days to 50% flowering (-0.720) showed negative and significant correlation with fruit yield per plot. Positive and significant correlation was exhibited by fruit yield per plant with number of fruits per plant (0.897), fruit weight (0.867), plant height (0.867), fruit length (0.805), internodal length (0.616), fruit girth (0.390), number of seeds per pod (0.367) and 100 seed weight

(0.346) while it expressed negatively significant association with plant height at first flowering node (-0.643) and days to 50% flowering (-0.695).

Number of fruits per plant had positive and highly significant association with plant height (0.907), fruit length (0.891), fruit weight (0.756), internodal length (0.696), fruit girth (0.489), 100 seed weight (0.423) and number of seeds per pod (0.412) while negative and significant correlation was obtained for plant height at first flowering node (-0.678) and days to 50% flowering (-0.716). 100 seed weight exhibited positive and significant association with internodal length (0.490), fruit girth (0.442), plant height (0.412), fruit length (0.406) and number of seeds per pod (0.253) while negative and significant association with days to 50% flowering (-0.385) and plant height at first flowering node (-0.405). Positive and significant correlation was revealed by number of seed per pod with fruit girth (0.639), fruit length (0.535), plant height (0.513), internodal length (0.406) and fruit weight (0.376) while negatively significant association with days to 50% flowering (-0.379) and plant height at first flowering node (-0.429).

Positive and significant correlation was exhibited by fruit weight with plant height (0.832), fruit length (0.809), internodal length (0.602) and fruit girth (0.446) whereas, it was significantly and negatively associated with plant height at first flowering node (-0.549) and days to 50% flowering (-0.642). Fruit girth had positive and significant association with plant height (0.570), fruit length (0.553) and internodal length (0.512) while negative and significant correlation for plant height at first flowering node (-0.510) and days to 50% flowering (-0.584). Fruit length had positive and highly significant association with plant height (0.960) and internodal length (0.768) whereas it had negative and significant association with plant height at first flowering node (-0.678) and days to 50% flowering (-0.735). Internodal length had positive and significant association with plant height (0.731) and it showed negative association with plant height at first flowering node (-0.422) and days to 50% flowering (-0.704).

Table 4.7: Estimates of genotypic correlation coefficient between yield and its component characters in okra (*Abelmoschus esculentus* (L.) Moench)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	Y12
Y1	1											
Y2	0.556**	1										
Y3	-0.763**	-0.739**	1									
Y4	-0.422**	-0.704**	0.731**	1								
Y5	-0.678**	-0.735**	0.960**	0.768**	1							
Y6	-0.510**	-0.584**	0.570**	0.512**	0.553**	1						
Y7	-0.549**	-0.642**	0.832**	0.602**	0.809**	0.446**	1					
Y8	-0.429**	-0.379**	0.513**	0.406**	0.535**	0.639**	0.376**	1				
Y9	-0.405**	-0.385**	0.412**	0.490**	0.406**	0.442**	0.191	0.253*	1			
Y10	-0.678**	-0.716**	0.907**	0.696**	0.891**	0.489**	0.756**	0.412**	0.423**	1		
Y11	-0.643**	-0.695**	0.867**	0.616**	0.805**	0.390**	0.867**	0.367**	0.346**	0.897**	1	
Y12	-0.623**	-0.720**	0.922**	0.707**	0.892**	0.455**	0.900**	0.412**	0.366**	0.944**	0.955**	1

**Significance at 1% level *Significance at 5% level

Where, Y1= Plant height at first flowering node (cm), Y2= Days to 50% flowering, Y3= Plant Height (cm), Y4= Internodal Length (cm), Y5= Fruit Length (cm), Y6= Fruit Girth (cm), Y7= Fruit Weight (g), Y8= Number of seeds per pod, Y9=100 seed weight (g), Y10= Number of fruits per plant, Y11= Fruit yield per plant (g) and Y12= Fruit yield per plot (kg).

Plant height expressed negative and significant correlation with days to 50% flowering (-0.739) and plant height at first flowering node (-0.763). Days to 50% flowering exhibited positive and significant association with plant height at first flowering node (0.556).

Corresponding to the results of present investigation, positive and significant correlation of yield per plot with number of fruits per plant, fruit weight and negative and significant correlation with days to 50% flowering at both phenotypic and genotypic levels has also been reported by Jadhav et al. (2022). Shinde et al. (2023) revealed positive and significant association of yield per plant with plant height, internodal length, number of fruits per plant, fruit weight, fruit length, and 100 seeds weight at both phenotypic as well as genotypic level. Similar results exhibiting significant positive association of yield per plant with plant height, number of fruits per plant, fruit length, fruit girth, fruit weight, and number of seeds per pod has been reported by Rajani et al. (2022). Kumar et al. (2022) revealed positive and significant association of number of fruits per plant with fruit length and fruit weight at both genotypic and phenotypic level. Pundir et al. (2022) recorded high positive and significant correlation of fruit yield per plant with plant height, fruit diameter, fruit length, fruit weight and number of fruits per plant. Fruit yield per plant exhibited positive and significant association with number of fruits per plant, plant height, fruit weight, number of seeds per pod and fruit length as reported by Singh et al. (2017). Negative and significant association of internodal length with days to 50 % flowering has been reported by Alam et al. (2020). Raval et al. (2019) recorded positive and significant correlation of yield per plant with number of fruits per plant, plant height, fruit weight, fruit girth, number of seeds per pod, internodal length and 100 seed weight.

Positive and significant correlation of fruit length with plant height and internodal length whereas, negative and significant association with days to 50% flowering has been reported by Sravanthi et al. (2021). Rynjah et al. (2020) recorded positive and highly significant correlation of yield per plant with fruit girth, fruit length, number of fruits per plant, plant height and fruit weight at both genotypic and phenotypic levels of correlation. Whereas, days to 50% flowering was found to have negative correlation with yield per plant. Fruit length showed

negative and significant correlation with days to 50% flowering which has been to the results obtained by Rathava et al. (2019). Prasath et al. (2017) recorded positive and significant correlation of fruit yield per plant with plant height, number of fruits per plant, internodal length, fruit length, fruit girth, fruit weight, number of fruits per plant, number of seeds per pod and 100 seed weight. Negative and significant correlation of plant height with days to 50% flowering has also been reported by Palve et al. (2021). Chavan et al. (2019) recorded positive and significant correlation of fruit yield per plant with plant height, internodal length, fruit length, fruit weight, number of fruits per plant, fruit yield per plot.

4.3 PATH COEFFICIENT ANALYSIS

Path coefficient analysis is a standardized partial regression coefficient which separates the genotypic correlation coefficient into direct and indirect effects on yield. It is used to find out whether the association of parameters with yield is due to their direct effects or is the consequences of their indirect effects via other component characters. In the present studies, yield per plot has been used as dependable variable with other traits. Since the values of genotypic path correlation coefficient are more reliable in predicting the correct idea about the direct and indirect effect of the component characters. The estimates of path coefficient analysis at genotypic level are shown in the (Table 4.8) which depicts the direct and indirect effects of various horticultural traits on yield per plot.

4.3.1 Plant height at first flowering node (cm)

Positive direct effect was observed on fruit yield per plot through plant height at first flowering node (0.1056). High positive indirect effects on fruit yield per plot was via fruit length (0.0994) followed by fruit girth (0.0350). Negative indirect effects were observed through days to 50% flowering (-0.0045), internodal length (-0.0123), number of seeds per pod (-0.0162), 100 seed weight (-0.0163), fruit yield per plant (-0.1059), plant height (-0.1826), fruit weight (-0.1912) and number of fruits per plant (-0.3344).

4.3.2 Days to 50% flowering

Negative direct effect of days to 50% flowering was observed on fruit yield per plot (-0.0081). Positive indirect effects were seen through fruit length (0.1077), plant height at first flowering node (0.0587), fruit girth (0.0401) and negative indirect effects were observed through number of seeds per pod (-0.0143), 100 seed weight (-0.0155), internodal length (-0.0206), fruit yield per plant (-0.1144), plant height (-0.1769), fruit weight (-0.2236) and number of fruits per plant (-0.3532). Similar findings are also reported by Reddy et al. (2013), Yonas et al. (2014), Kumar et al. (2015), Prakash et al. (2022) and Singh et al. (2022).

4.3.3 Plant height (cm)

Positive and direct effect was observed through plant height on fruit yield per plot (0.2393). Number of fruits per plant (0.4474), fruit weight (0.2898), fruit yield per plant (0.1428), internodal length (0.0214), number of seeds per pod (0.0194), 100 seed weight (0.0166) and days to 50% flowering (0.0060) showed positive indirect effects on fruit yield per plot. While negative indirect effects were observed for fruit girth (-0.0391) followed by plant height at first flowering node (-0.0806) and fruit length (-0.1405) as similar to the findings of Kumar et al. (2015), Mishra et al. (2018), Kumar et al. (2019) and Prakash et al. (2022).

4.3.4 Internodal length (cm)

Internodal length showed positive direct effect on fruit yield per plot (0.0293). Positive indirect effect was shown by number of fruits per plant (0.3431) followed by fruit weight (0.2094), plant height (0.1750), fruit yield per plant (0.1014), 100 seed weight (0.0197), number of seeds per pod (0.0153), days to 50% flowering (0.0057) and negative indirect effects through fruit girth (-0.0351), plant height at first flowering node (-0.0446) and fruit length (-0.1125) as similar to those of Thulasiram et al. (2017), Kelemoge et al. (2019) and Neeraja et al. (2022).

4.3.5 Fruit length (cm)

Negative direct effect of fruit length (-0.1465) was observed on fruit yield per plot. Positive indirect effects were seen via number of fruits per plant (0.4391), fruit weight (0.2816), plant height (0.2296), fruit yield per plant

(0.1325), internodal length (0.0225), number of seeds per pod (0.0202), 100 seed weight (0.0163) and days to 50% flowering (0.0060) whereas, fruit girth (-0.0379) and plant height at first flowering node (-0.0717) showed negative indirect effect on fruit yield per plot. Similar results are also reported by Rajkumar and Sundaram (2015), Rathava et al. (2019) and Nirosha et al. (2023).

4.3.6 Fruit girth (cm)

Fruit girth showed negative direct effect (-0.0686) on fruit yield per plot. Number of fruits per plant (0.2410), fruit weight (0.1554), plant height (0.1363), fruit yield per plant (0.0642), number of seeds per pod (0.0241), 100 seed weight (0.0177), internodal length (0.0150) and days to 50% flowering (0.0047) had positive indirect effects on fruit yield per plot. Negative indirect effect was observed through plant height at first flowering node (-0.0538) and fruit length (-0.0809) as similar to the findings of Rajkumar and Sundaram (2015), Mishra et al. (2018), Rambabu et al. (2019) and Rajani et al. (2022).

4.3.7 Fruit weight (g)

Fruit weight showed positive direct effect on fruit yield per plot (0.3482). Positive indirect effects were observed via number of fruits per plant (0.3726), plant height (0.1992), fruit yield per plant (0.1427), internodal length (0.0176), number of seeds per pod (0.0142), 100 seed weight (0.0077) and days to 50% flowering (0.0052). Negative indirect effects were observed through fruit girth (-0.0306), plant height at first flowering node (-0.0580) and fruit length (-0.1185) as similar to those of Alam and Hossain (2006), Adiger et al. (2011), Reddy et al. (2013), Yonas et al. (2014), Kumar et al. (2015), Neeraja et al. (2022) and Prakash et al. (2022).

4.3.8 Number of seeds per pod

Number of seeds per pod exhibited positive direct effect (0.0377) on fruit yield per plot. Positive indirect effects were observed by number of fruits per plant (0.2030) followed by fruit weight (0.1308), plant height (0.1227), fruit yield per plant (0.0604), internodal length (0.0119), 100 seed weight (0.0102) and days to 50% flowering (0.0031). Negative indirect effects were seen through fruit girth (-0.0438), plant height at first flowering node (-0.0453) and fruit length (-0.0783) as similar to the findings of Rambabu et al. (2019) and Rajani et al. (2022).

4.3.9 100 seed weight (g)

Positive direct effect of 100 seed weight was recorded for fruit yield per plot (0.0402). Number of fruits per plant (0.2087), plant height (0.0987), fruit weight (0.0667), fruit yield per plant (0.0570), internodal length (0.0143), number of seeds per pod (0.0096) and days to 50% flowering (0.0031) exhibited positive indirect effects on yield per plot. Negative indirect effect were recorded for fruit girth (-0.0303), plant height at first flowering node (-0.0428) and fruit length (-0.0594). These results are in line with Sindhumole et al. (2006), Akotkar et al. (2010), Adiger et al. (2011), Mishra et al. (2018) and Rajani et al. (2022).

4.3.10 Number of fruits per plant

Positive direct effects of number of fruits per plant were recorded for fruit yield per plot (0.4931). Fruit weight (0.2631), plant height (0.2172), fruit yield per plant (0.1476), internodal length (0.0204), 100 seed weight (0.0170), number of seeds per pod (0.0155) and days to 50% flowering (0.0058) showed indirect positive effects whereas, fruit girth (-0.0335), plant height at first flowering node (-0.0716) and fruit length (-0.1304) exhibited negative indirect effects on fruit yield per plot. Similar findings has also been reported by Saitwa et al. (2011), Kumar et al. (2015), Ranga et al. (2011), Mudhalvan and Senthilkumar (2021) and Prakash et al. (2022).

4.3.11 Fruit yield per plant (g)

Fruit yield per plant exhibited positive direct effect (0.1646) on fruit yield per plot. Positive indirect effects were shown by number of fruits per plant (0.4421), fruit weight (0.3018), plant height (0.2075), internodal length (0.0180), 100 seed weight (0.0139), number of seeds per pod (0.0139) and days to 50% flowering (0.0056). Negative indirect effects were shown by fruit girth (-0.0268), plant height at first flowering node (-0.0679) and fruit length (-0.1179). Similar results are also reported by Ashraf et al. (2020), Ranga et al. (2021), Awasthi et al. (2022), Choudhary et al. (2022) and Rajani et al. (2022).

Table 4.8: Estimates of direct and indirect effect of yield contributing characters towards fruit yield per plot in okra (*Abelmoschus esculentus* (L.) Moench)

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11	GCCTYP
Y1	0.1056	-0.0045	-0.1826	-0.0123	0.0994	0.0350	-0.1912	-0.0162	-0.0163	-0.3344	-0.1059	-0.623**
Y2	0.0587	-0.0081	-0.1769	-0.0206	0.1077	0.0401	-0.2236	-0.0143	-0.0155	-0.3532	-0.1144	-0.720**
Y3	-0.0806	0.0060	0.2393	0.0214	-0.1405	-0.0391	0.2898	0.0194	0.0166	0.4474	0.1428	0.922**
Y4	-0.0446	0.0057	0.1750	0.0293	-0.1125	-0.0351	0.2094	0.0153	0.0197	0.3431	0.1014	0.707**
Y5	-0.0717	0.0060	0.2296	0.0225	-0.1465	-0.0379	0.2816	0.0202	0.0163	0.4391	0.1325	0.892**
Y6	-0.0538	0.0047	0.1363	0.0150	-0.0809	-0.0686	0.1554	0.0241	0.0177	0.2410	0.0642	0.455**
Y7	-0.0580	0.0052	0.1992	0.0176	-0.1185	-0.0306	0.3482	0.0142	0.0077	0.3726	0.1427	0.900**
Y8	-0.0453	0.0031	0.1227	0.0119	-0.0783	-0.0438	0.1308	0.0377	0.0102	0.2030	0.0604	0.412**
Y9	-0.0428	0.0031	0.0987	0.0143	-0.0594	-0.0303	0.0667	0.0096	0.0402	0.2087	0.0570	0.366**
Y10	-0.0716	0.0058	0.2172	0.0204	-0.1304	-0.0335	0.2631	0.0155	0.0170	0.4931	0.1476	0.944**
Y11	-0.0679	0.0056	0.2075	0.0180	-0.1179	-0.0268	0.3018	0.0139	0.0139	0.4421	0.1646	0.955**

**Significance at 1% level

Where, Y1= Plant height at first flowering node (cm), Y2= Days to 50% flowering, Y3= Plant Height (cm), Y4= Internodal Length (cm), Y5= Fruit Length (cm), Y6= Fruit Girth (cm), Y7= Fruit Weight (g), Y8= Number of seeds per pod, Y9=100 seed weight (g), Y10= Number of fruits per plant, Y11= Fruit yield per plant (g), Y12= Fruit yield per plot (kg) and GCCTYP= Genotypic correlation coefficient with total yield per plot.

Residual effect = 0.01409

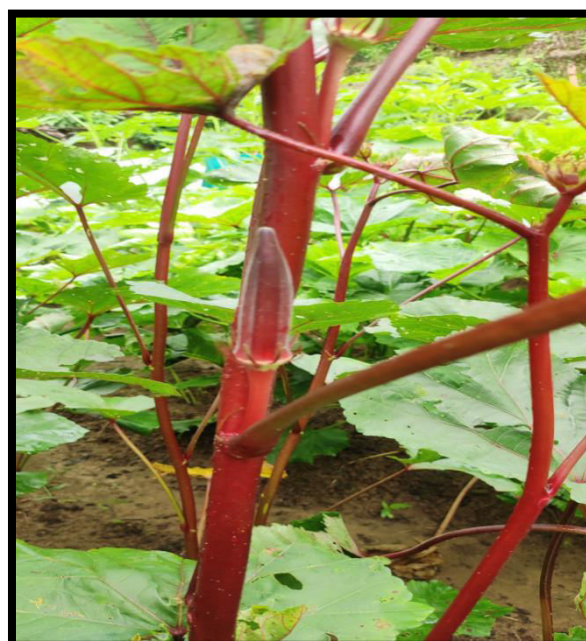
Diagonal figures represent the direct effect.



Green



Green with red patch

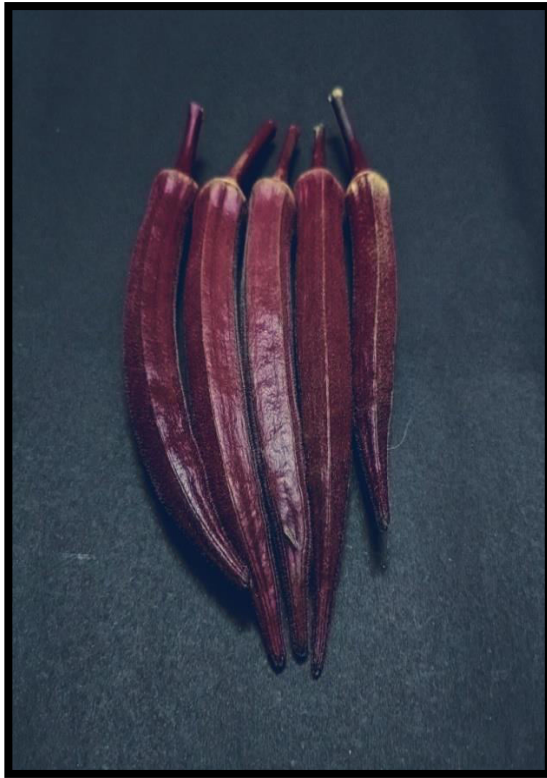


Red

Plate 3: Variability with respect to stem color and fruit color



Plate 4: Variability among different genotypes of okra



LC-65



LC-51



LC-28

Plate 5: Promising genotypes

**SUMMARY
AND
CONCLUSION**

Chapter-5

SUMMARY AND CONCLUSION

The present investigation entitled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” was carried out during kharif season 2022-2023 at the Experimental Farm of Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur, Dr YS Parmar University of Horticulture and Forestry, Solan.

The genetic material comprising of thirty two genotypes including check variety ‘P-8’ was assessed in Randomized Complete Block Design with three replications. The okra genotypes were directly sown in the field on 21st May, 2022 at a spacing of 60 cm × 20 cm with a plot size of 1.80 m × 1m containing 15 plants per plot. The observations were recorded on plant height at first flowering node (cm), days to 50% flowering, plant height (cm), internodal length (cm), fruit length (cm), fruit girth (cm), fruit weight (g), number of seeds per pod, 100 seed weight (g), number of fruits per plant, fruit yield per plant (g), fruit yield per plot (kg), number of ridges, plant growth habit, fruit color, stem color, leaf color and incidence of diseases if any. Morphological characterization of genotypes was done on visual observations. The data was subjected to statistical analysis for estimation of all the parameters of variability i.e. phenotypic and genotypic coefficient of variation, heritability, genetic advance and correlation. Path coefficient analysis was also carried out for yield per plot with other horticultural traits to know the direct and indirect effects.

The major findings of the study are as follow:

- Analysis of variance (ANOVA) revealed highly significant differences among all the genotypes for all the parameters indicating the presence of wide range of variability.
- Based upon the overall mean performance of all the genotypes, LC-65 (6.84 kg) recorded highest fruit yield per plot which was statistically at par with LC-51 (6.60 kg), LC-28 (6.53 kg) and check variety P-8 (6.02 kg). The genotype LC-65 was also found superior with respect to other traits

like plant height at first flowering node, plant height, fruit length, fruit weight, number of seeds per pod and number of fruits per plant.

- Minimum plant height at first flowering node was recorded in LC-65 (29.55 cm) which was statistically at par with LC-33 (30.33 cm) and LC-28 (30.64 cm). Minimum days to 50% flowering were assessed in LC-51 (45.32) followed by LC-33 (45.42) and LC-65 (45.45). However, maximum plant height was recorded in LC-65 (274.60 cm) which was statistically at equivalence with LC-51 (274.25 cm) and LC-33 (273.91 cm). Internodal length was recorded maximum in LC-33 (16.51 cm) followed by LC-65 (16.30 cm) and LC-51 (16.25 cm), while maximum fruit length was observed in LC-65 (20.05 cm) followed by LC-33 (19.35 cm) and LC-51 (19.03 cm). Fruit girth was recorded maximum in LC-55 (2.47 cm) which was statistically at par with LC-60 (2.40 cm) and LC-40 (2.39 cm), maximum fruit weight was observed in LC-65 (30.00 g) followed by LC-33 (29.54 g) and LC-28 (29.41 g). Number of seeds per pod was recorded maximum in LC-65 (124.67) which was found to be statistically at par with LC-35 (123.94) and LC-51 (123.22) whereas, 100 seed weight was maximum in LC-33 (8.59 g) followed by LC-55 (8.51 g) and Punjab Suhabani (8.48 g). Number of fruits per plant was recorded maximum in LC-65 (15.49) which was statistically at equivalence with LC-33 (15.48) and LC-51 (15.32), while fruit yield per plant was observed maximum in LC-28 (483.23 g) followed by LC-65 (482.89 g) and LC-51 (482.32 g). Therefore, these genotypes can be used effectively for further breeding strategies after seeing their performance in other statistical genetic tools such as parameters of genetic variability, correlation and path coefficient analysis.
- The difference between genotypic and phenotypic coefficients of variation was less but values of phenotypic coefficients of variation were slightly higher in magnitude than that of genotypic coefficients of variation for all the parameters which indicates that the phenotypic expression of the traits was less influenced by the environment. High phenotypic and genotypic coefficients of variation (PCV and GCV) were observed for fruit yield per plot (54.01%, 50.42%) followed by fruit yield per plant (48.60%, 48.54%),

internodal length (46.73%, 46.47%) and number of fruits per plant (31.01%, 30.86%). Moderate magnitude of PCV and GCV were recorded for fruit weight (24.62%, 24.36%), plant height (19.18%, 19.12%), fruit length (18.78%, 18.14%), number of seeds per pod (17.43%, 17.40%), 100 seed weight (16.96%, 16.90%) and fruit girth (15.66%, 15.19%) whereas, low magnitude of PCV and GCV were recorded for plant height at first flowering node (10.69%, 10.45%) and days to 50% flowering (4.93%, 4.85%). Thus, indicating the role of environmental factors for the expression of these characters.

- Among all the parameters studied, high heritability coupled with high genetic advance as per cent of mean were recorded for fruit yield per plant (99.73%, 99.85%), fruit yield per plot (87.12%, 96.94%), internodal length (98.93%, 95.22%) and number of fruits per plant (99.03%, 63.27%) indicating that the heritability for these parameters is due to additive gene effects, showing the importance of selection for crop improvement through these traits.
- High heritability coupled with moderate genetic advance was recorded in fruit weight (97.95%, 49.67%), plant height (99.41%, 39.27%), fruit length (93.24%, 36.08%), number of seeds per pod (99.59%, 35.77%), 100 seed weight (99.39%, 34.71%) and fruit girth (94.11%, 30.36%) which may be attributed to additive and non-additive gene effects. High heritability coupled with low genetic advance as per cent mean was observed for plant height at first flowering node (95.47%, 21.03%) and days to 50% flowering (96.47%, 9.80%) which indicates the preponderance of non-additive gene action and improvement in these traits can be brought about by hybridization.
- Genotypic correlation coefficients were slightly higher in magnitude than phenotypic correlation coefficients for all the parameters, which indicated that environment played lesser role in governing the phenotype of the genotypes.

Table 5.1: Top three promising genotypes for different characters studied in okra (*Abelmoschus esculentus* (L.) Moench)

CHARACTERS	GENOTYPES
Plant height at first flowering node (cm)	LC-65
	LC-33
	LC-28
Days to 50 % flowering	LC-51
	LC-33
	LC-65
Plant height (cm)	LC-65
	LC-51
	LC-33
Internodal length (cm)	LC-33
	LC-65
	LC-51
Fruit length (cm)	LC-65
	LC-33
	LC-51
Fruit girth (cm)	LC-55
	LC-60
	LC-40
Fruit weight (g)	LC-65
	LC-33
	LC-28
Number of seeds per pod	LC-65
	LC-35
	LC-51

100 seed weight (g)	LC-33
	LC-55
	Punjab Suhabani
Number of fruits per pant	LC-65
	LC-33
	LC-51
Fruit yield per plant (g)	LC-28
	LC-65
	LC-51
Fruit yield per plot (kg)	LC-65
	LC-51
	LC-28

Results revealed that fruit yield per plot was positively and significantly correlated with fruit yield per plant (0.955), number of fruits per plant (0.944), plant height (0.922), fruit weight (0.900), fruit length (0.892), internodal length (0.707), fruit girth (0.455), number of seeds per pod (0.412) and 100 seed weight (0.366) while negatively significant association was observed with plant height at first flowering node (-0.623) and days to 50% flowering (-0.720). From the correlations studies, it is concluded that selection should be made on the basis of lesser pant height at first flowering node, early in appearance of 50% flowering, higher plant height, maximum internodal length, higher fruit length, girth and fruit weight, more number of seeds per pod having higher 100 seed weight, more number of fruits per plant with higher yield per plant can bring yield improvement in okra.

- Path coefficient analysis at genotypic level indicated that the positive direct effect on fruit yield per plot was observed by plant height at first flowering node (0.10562), plant height (0.23929), internodal length (0.02925), fruit weight (0.34816), number of seeds per pod (0.03774), 100

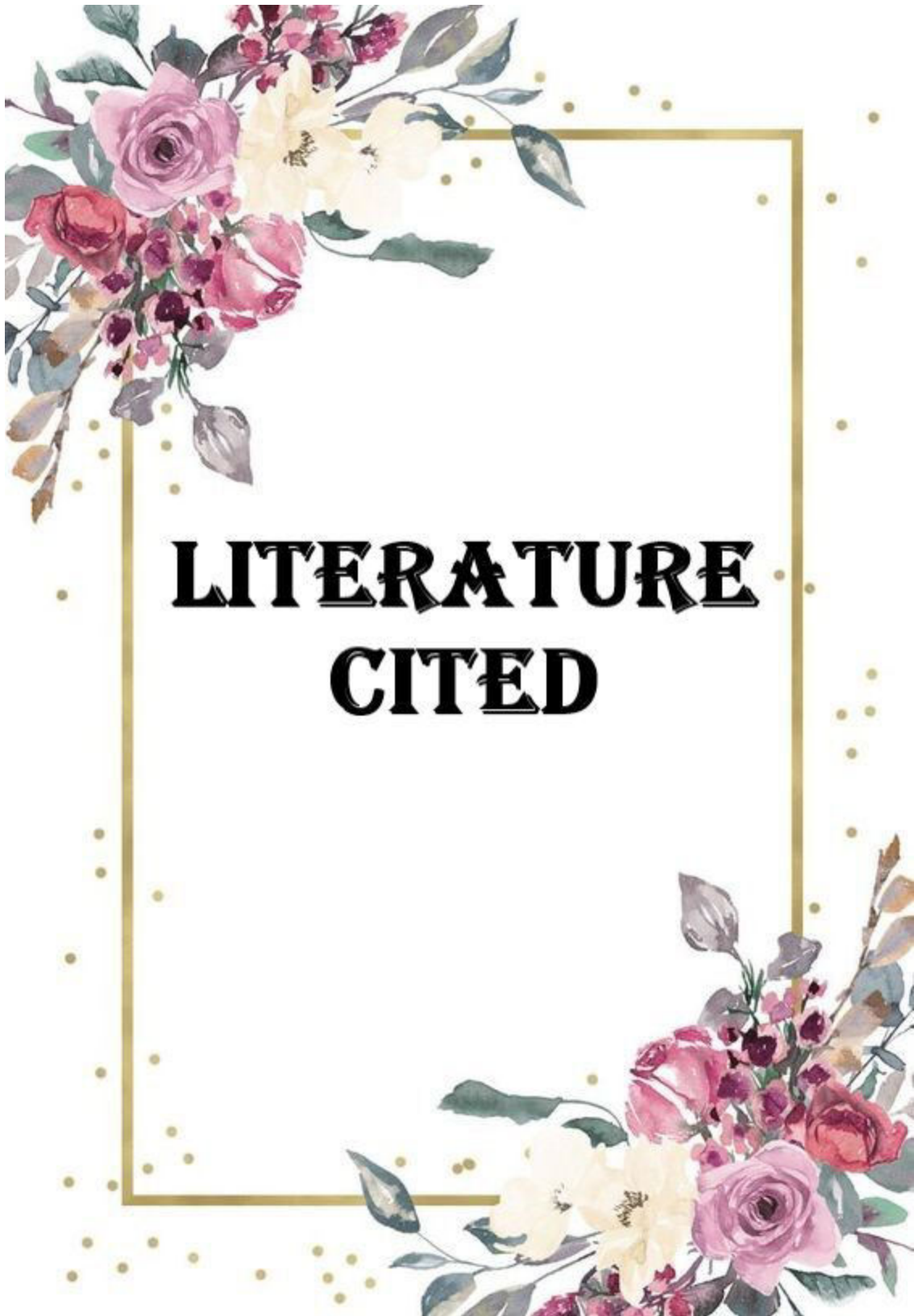
seed weight (0.04015), number of fruits per plant (0.49305) and fruit yield per plant (0.16464). So, selection based on these traits will be worthwhile for any breeding programme whereas, highest and negative direct effect was recorded for days to 50% flowering, fruit length and fruit girth. Thus, indicating the importance of selection for making improvement in yield.

CONCLUSIONS:

- ✓ On the basis of overall mean performance of the genotypes, it is concluded that the genotypes LC-65, LC-51 and LC-28 were found superior over the check P-8 in terms of fruit yield per plot. These genotypes were also promising for other traits like plant height at first flowering node, days to 50% flowering, plant height, internodal length, fruit length, fruit girth, fruit weight, number of seeds per pod, 100 seed weight, number of fruits per plant, fruit yield per plant. Thus these genotypes can be recommended for cultivation after multi-location testing in different regions of state. Further, all these genotypes can also be exploited in future breeding programme for their superior characters.
- ✓ Higher estimates of genotypic (GCV) and phenotypic coefficient of variation (PCV) were observed for fruit yield per plot, fruit yield per plant, internodal length and number of fruits per plant reflecting presence of high genetic variability among all the genotypes for these traits and offered better scope for improvement.
- ✓ High heritability was observed for plant height at first flowering node, days to 50% flowering, plant height, internodal length, fruit length, fruit girth, fruit weight, number of seeds per pod, 100 seed weight, number of fruits per plant, fruit yield per plant, fruit yield per plot.
- ✓ The highest genetic advance as per cent mean was recorded for fruit yield per plant, fruit yield per plot, internodal and number of fruits per plant indicating the presence of additive gene effect which in turn offers good scope for reliable and effective selection.
- ✓ Positive and significant correlation of fruit yield per plot was recorded with fruit yield per plant, number of fruits per plant, plant height, fruit

weight, fruit length, internodal length, fruit girth, number of seeds per pod and 100 seed weight. Hence, selection for these traits would be much effective for yield improvement.

- ✓ The path coefficient analysis indicated that number of fruits per plant had maximum positive direct effect on pod yield per plot followed by fruit weight, plant height, yield per plant, plant height at first flowering node, 100 seed weight, number of seeds per pod and internodal length. Therefore, selection for these traits would be more effective for improvement of fruit yield in okra.



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APPENDIX-I

Agro-meteorological data during cropping period

Month	Average Monthly Temperature (°C)		Mean Temperature (°C)	Average Relative Humidity (%)	Rainfall (mm)
	Max	Min			
May-22	39.42	25.92	32.67	29.56	1.91
Jun-22	40.04	27.67	33.86	33.73	3.00
Jul-22	32.51	26.07	29.29	77.21	15.94
Aug-22	30.89	24.89	27.89	84.31	11.60
Sep-22	29.99	23.47	26.73	81.00	6.34
Oct-22	27.85	18.91	23.38	68.30	1.41

Source: Metrological observatory, Department of Soil Science and Water Management, College of Horticulture and Forestry, Neri, Hamirpur H.P. – 177001

APPENDIX-II

Analysis of variance (ANOVA) for various horticultural traits in okra (*Abelmoschus esculentus* (L.) Moench)

	CHARACTER	MEAN SUM OF SQUARES		
		Replication	Genotype	Errors
		2 (Degree of freedom)	31 (Degree of freedom)	62 (Degree of freedom)
1.	Plant height at first flowering node (cm)	0.706	42.899	0.667
2.	Days to 50% flowering	0.323	18.249	0.22
3.	Plant Height (cm)	3.255	4146.493	8.257
4.	Internodal Length (cm)	0.15	50.565	0.182
5.	Fruit Length (cm)	0.61	21.175	0.5
6.	Fruit Girth (cm)	0.004	0.272	0.006
7.	Fruit Weight (g)	0.393	72.591	0.503
8.	Number of seeds per pod	0.845	830.938	1.144
9.	100 seed weight (g)	0.015	3.70	0.008
10.	Number of fruits per plant	0.129	25.973	0.084
11.	Yield per plant (g)	1.529	41509.39	37.263
12.	Yield per plot (kg)	0.366	7.951	0.373



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Title of the thesis : Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh

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Admission Number : NH-2021-45-M

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ABSTRACT

The present investigation entitled “**Exploration of genetic variability in okra (*Abelmoschus esculentus* (L.) Moench) under subtropical regions of Himachal Pradesh**” was carried out during rainy season 2022-2023 at Experimental Research Farm, Department of Vegetable Science, College of Horticulture and Forestry, Neri, Hamirpur (H.P). Thirty two genotypes including check variety P-8 were evaluated in Randomized Complete Block Design with three replications to estimate the extent of variability, heritability, genetic advance, correlation and path coefficient analysis for yield and other horticultural traits. Analysis of variance showed significant differences among all the genotypes with respect to the characters studied. The genotypes LC-65(6.84 kg, 482.89 g, 15.49, 30.00 g), LC-51 (6.60 kg, 482.32 g, 15.32, 28.87 g) and LC-28 (6.53 kg, 483.23 g, 15.29, 29.41 g) were recorded superior over the check P-8 for fruit yield per plot, fruit yield per plant, number of fruits per plant and fruit weight, respectively. The estimates of PCV and GCV were high for fruit yield per plot, fruit yield per plant, internodal length and number of fruits per plant. High heritability coupled with high genetic advance as per cent mean was observed in fruit yield per plant, fruit yield per plot, internodal length and number of fruits per plant. The correlation studies at genotypic and phenotypic levels revealed that pod yield per plot had significant and positive correlation with fruit yield per plant, number of fruits per plant, plant height, fruit weight, fruit length, internodal length, fruit girth, number of seeds per pod and 100 seed weight. The path coefficient analysis indicated that number of fruits per plant had maximum positive direct effect on pod yield per plot followed by fruit weight, plant height, yield per plant, plant height at first flowering node, 100 seed weight, number of seeds per pod and internodal length. Therefore, selection for these traits would be more effective for improvement of fruit yield in okra.

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BRIEF BIO-DATA

BRIEF BIO-DATA

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10+2	2016	Mahavir Public School, Sunder Nagar	C.B.S.E	78.8 %	First
Graduation	2021	Dr YS Parmar University of Horticulture and Forestry, Nauni, Solan (HP)	Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan (HP)	82.4%	First

Whether sponsored by some state/Central Govt./Univ./SAARC Scholarship/ Stiped/ Fellowship, any other financial assistance received during the study period : NA
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