

**EVALUATION AND GENETIC VARIABILITY IN  
ADVANCED BREEDING LINES OF OKRA [*Abelmoschus  
esculentus* (L.) Moench] UNDER VARANASI CONDITIONS**



THESIS SUBMITTED IN PARTIAL FULFILMENT OF  
THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF

**Master of Science (Agriculture)**  
in  
**Horticulture**

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2013

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*Dedicated to*  
*My Beloved Parents*



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**Through:** The Head, Department of Horticulture, Institute of Agricultural Sciences, BHU,  
Varanasi.

Dear Sir,

I have great pleasure in forwarding the thesis entitled “**Evaluation and genetic variability in advanced breeding lines of okra [*Abelmoschus esculentus* (L.) Moench] under Varanasi conditions**” submitted by **Mr. Bhukya Narshima Swamy, I.D. No.- H-11098**, in partial fulfilment of the requirements for the degree of **Master of Science (Agriculture) in Horticulture**, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P.) and placing on record that he has completed the requisite residential requirements as contained in the statutes of the University.

I certify that the entire scheme of investigation presented herein was planned and carried out solely by the candidate under my guidance and supervision. The data present in thesis, to the best of knowledge and belief, are genuine and original.

Thanking you,

Yours faithfully,

Dr. Anand Kumar Singh  
(Supervisor)

FORWARDED

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By

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## ACKNOWLEDGEMENTS

---

*I am one among the few fortunates to be a part of Banaras Hindu University, the seat of learning, which with good grace provided me the most peaceful atmosphere for study and overall improvement. I bow my head with great reverence to late Mahamana Pandit Madan Mohan Malviya Ji.*

*I express my heartiest recognition to my advisor, **Dr. Anand Kumar Singh**, Associate Professor, Department of Horticulture, Institute of Agricultural Sciences, for his perfect supervision, incredible support, timely advice and guidance, never-ending encouragement and bestowing me with all freedom which helped to accomplish the present dissertation. I am blessed to have him as my mentor. I am indebted to him for his ceaseless and unselfish help and utter confidence in me. Thank you for letting me experiences the incessant flow of knowledge and wisdom that I shall treasure forever.*

*I am highly grateful to members of my advisory committee Dr. Binod Kumar Singh, Professor, Department of Horticulture and Dr. (Mrs.) Bandana Bose, Professor, Department of Plant Physiology, Institute of Agricultural Sciences, for their never ending encouragement, valuable suggestions and help during the course of investigation.*

*I express my sincere thanks to Dr. Anil Kumar Singh, Professor and Head, Department of Horticulture, Institute of Agricultural Sciences, for their encouragement, valuable suggestions and help during the course of investigation.*

*I also express my sincere thanks to Prof. B. P. Singh, Prof. M.M. Syamal, Prof. S. P. Singh, Dr. A. K. Pal, and the staff members Shri Barun, Shri Ram Nath , Shri Sukant Ghosh, Shri Shiv Dhani and Shri Lal ji Yadav for extending their help me during strenuous period.*

*I thank all the field workers and farm in-charge for their conscious help for letting me complete successfully the field work assigned to me.*

*I am obliged to all my seniors and my special thanks to Mr. Rahul, Mr. Prashanth, Mr. Sunil, Mr. Ramchandrya, Mr. Job Suresh, Mr. Tirupathi, Mr. Sarvesh, Ms. Manjuvani, Rajkumar, Neeraj, Omprakash, Venu, Harit, Rajender, Venkateswarlu, Veera Singh, Navakishore, Nabard Chandu, Rajasekhar, Amarnath, Reddayya, Siddu, Akhilendra, Joru for their valuable guidance and encouragement.*

*It will be unfair not to mention the names of my friends; Rajendra Prasad, Vijay, Natraj, Balram, Raghu, Satyanarana, Ram Kumar, Raju, Shanti, Sravan, Devi, Ajit, Swathi, Nagesh,*

*Laxmi, Shafiq, Bush, Sivaprasad, Sudhaker, Sivaramulu, Sahitya, Saichand, Sainath, Venkanna, Venu Madhv, Tirupathi, Murthi, Rajesh, Nirosha, Chandana, Bindu, Aliya, Shama, Srujana, Ashwini, Bhukya Sravanthi, Shilu, Likitha, Ravi Naik, Lakpathi, Munna, Shanti Priya, Vishnu, Amala, Patibha, Prashanth, Kilash, Akilesh, Rajesh, Janak, Kulvir, Hada, Keshav, Deepender, Dutta, Deepak, Ranjeet, Amresh, Sana, Abha, Rakchi and Smitha and my juniors Laxman, Vivek, Vibhavv, Saroj, Madhu, Rambabu and Suresh for their crucial assistance throughout my course work that made me grow more stronger while I request others their forgiveness for not indicating them hereby name, who will always remember in my heart.*

*I allocate my highest respect and heartfelt regards from my inner core of heart to my ever loved parents, **Sri. Ganya Naik** and **Smt. Badramma**; who have given me life and taught the concepts of life and their dedicated efforts to educate me to this level, with boundless affection, I owe an encompassing debt to my beloved sisters Vijaya-Hussain, Dr.Suma, China, Saroja-Veeru, Raja-Balu, Chitti, Sunitha, and my brother Dr. Komal, Naveen, Veeranna, N.Singh, D.Singh, Tiru, Rammanna, and V.V Naik and my sweet heart Sravanthi and my niece Sonu and Gabbar for their constant encouragement throughout my career.*

*I also allocate my highest respect to my teachers Prof. Manohar Rao, Prof. Veeranna Goud, Prof. Amarender Reedy, Prof. Srihari, Prof.RVSK Reddy, Prof. Ravinder Reddy, Prof. Hari Prasad, Prof. Rajkumar and Venkatalaxmi medam for their constant encouragement throughout my life.*

*At last I bow my head with devotion to lord Laxmi Narasimha Swamy, Venkateswara and Kashi Vishwanath who in unison are the sole owner of everything I have.*

*Place: Varanasi*

*Date:*

**(Bhukya Narshima Swamy)**

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### LIST OF SYMBOLS AND ABBREVIATIONS

ANOVA	:	Analysis of variance
CD	:	Critical difference
Cm	:	Centimetre
°C	:	Degree centigrade
Df	:	Degrees of freedom
<i>et al.</i> ,	:	and other workers
etc.	:	Etcetera
Fig.	:	Figure
G	:	Gram
Ha	:	Hectare
GA	:	Genetic advance
GCV	:	Genotypic Coefficient of Variation
$h^2$	:	Heritability in broad sense
<i>i.e.</i> ,	:	that is
IIVR	:	Indian Institute of Vegetable Research
M	:	metre
$m^2$	:	Square metre
Mg	:	Milligram
MSL	:	Mean sea level
MSS	:	Mean Sum of Squares
No.	:	Number
PCV	:	Phenotypic Coefficient of Variation
Q	:	Quintal
RBD	:	Randomised Block Design
S.Ed $\pm$	:	Standard error of difference
S.Em $\pm$	:	Standard error of mean
<i>viz.</i> ,	:	Namely
@	:	At the rate of
%	:	Per cent
$\sigma$	:	Standard deviation
Via	:	Through

## **INTRODUCTION**

---

Vegetables are herbaceous plant material with generally low calorific value providing micro nutrients, vitamins, antioxidants, fibres and induce alkaline reaction inside human body. Vegetables play major role in national developmental programs to alleviate hunger and malnutrition.

At present India is second largest producer of vegetables in the world with a total production of 146.554 million tons from an area of 8.495 million hectares with the productivity 11.6 tonnes per hectare is next to China. The present production is far below the requirement of rapidly growing population of our country. The per capita availability of 195 g per day is due to low productivity levels in vegetables (Anon., 2011).

The crops used for vegetable purpose in the world belonging to 1200 species under 78 families and out of them, more than 860 species under 59 families belong to dicots and about 340 species under 90 families belong to monocots. In the tropical and sub tropical parts of world, about 90 species of vegetable crops are cultivated but hardly 40 of them are commercially important.

Vegetables are chief and rich source of carbohydrates, proteins, vitamins and minerals. Vegetables like tapioca, sweet potato, potato, peas, cluster bean, carrot and sugar beet are rich source of carbohydrates. Peas, cow pea, leaves of methi, mustard, spinach, pointed guard and beans are rich source of proteins. All leafy vegetables are rich in vitamin A and B and carrot, tomato are rich in vitamin A. Brussels sprout, leaves of coriander, bitter gourd, chillies, sweet pepper, tomato, cauliflower, cabbage and sugar beet are rich source of minerals. Many of the vegetable crops possess high medical value for curing certain diseases. For instance, onion and garlic are found to possess anti bacterial properties and are also involved in controlling blood sugar and act as blood purifier. White brinjal is found to be useful against diabetes.

Among numerous vegetables grown in our country, okra [*Abelmoschus esculentus* (L.) Moench] is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. It belongs to family Malvaceae with  $2n = 8x = 72$  or 130 chromosomes and is a polyploid. There are 30 species under genus *Abelmoschus* in the old world and four in the new world. Out of them, *A. esculentus* is the only species known to be cultivated extensively and is known by many local names in different parts of the world. It is called lady's finger in England, gumbo in The United States of America, guino-gombo in Spanish, guibeiro in Portuguese and bhindi in India. It is quite popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions. Even within India, different names have been given in different regional languages (Chauhan, 1972).

Okra is one of the most acceptable vegetable crops cultivated in the subcontinent. Presently it occupies an area of 498 thousand hectares with the production of 5784 thousand metric tonnes (Anon., 2011). Its productivity level of 11.6 tonnes per ha falls far behind the productivity level of other countries. In India, area (78.9 thousand ha), production (1184.2 thousand MT) and productivity (15.0 MT per ha) under okra cultivation is highest in the state of Andhra Pradesh (Anon., 2011).

Okra is suitable for cultivation as a garden crop as well as on large scale commercial farms. It is grown commercially in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopian, Cyprus and the Southern United States. Okra is cultivated for its fibrous fruits or pods containing round, white seeds. The fruits are harvested when immature and eaten as a vegetable. Okra fruit can be cooked in a variety of ways.

The fruits contain 6.60 to 10.00 per cent crude fibre, 84.60 to 90.50 per cent edible portion, 14.40 to 18.60 per cent protein and 8.20 to 9.15 per cent ash of the total weight (Singh *et al.*, 1974). Among minerals, Calcium ranged from 99 to 198; P from 34.50 to 56.00 and Fe 0.80 to 2.40 mg per 100g of edible portion and rich source of vitamin B<sub>6</sub> and folic acid.

The superior fibre found in okra helps to stabilize blood sugar as it curbs the rate at which sugar is absorbed from the intestinal tract. Many alternative health practitioners believe all disease begins in the colon. The okra fibre, absorbing water and ensuring bulk in stools, helps prevent and improve constipation. Unlike harsh wheat bran, which can irritate or injure the intestinal tract, okra's mucilage soothes, and okra facilitates elimination more comfortably by its slippery characteristic many people abhor. In other words, this incredibly valuable vegetable not only binds excess cholesterol and toxins (in bile acids) which cause numerous health problems if not evacuated, but then assures easy passage out of the body of same. Unlike some prescription and over-the-counter drugs for this, the veggie is completely non-toxic, non-habit forming (except for the many that greatly enjoy eating it), has no adverse side effects, is full of nutrients, and is economically within reach of most. Further contributing to the health of the intestinal tract, okra fiber (as well as flax and psyllium) has no equal among fibers for feeding the good bacteria (probiotics). To retain most of okra's nutrients and self-digesting enzymes, it should be cooked as little as possible, e.g. with low heat or lightly steamed. Some eat it raw.

Okra is often grown as a perennial in many tropical areas. It is a tall- growing plant characterized by indeterminate growth. Plant height averages between 3 to 6 feet or more with varieties for both temperate and tropical areas. Indigenous African varieties can grow to 12 feet tall with a base stem 4 inches in diameter. It is a warm-season, annual vegetable, leaves are alternate and usually palmately five lobed, with long stems attached to a thick woody stem with or without branches. Its lobed leaves are generally hairy and may reach 11 inches in length. Okra has large, attractive, *Hibiscus* like flowers which are auxiliary and solitary. Flowering is continuous but highly dependent upon biotic and abiotic stress. Flowers are 5-8 cm diameter, with five white to yellow petals, often with a red or purple spot at the base of each petal and flower lasts only one day. The flower structure combines hermaphroditism and self compatibility. Flower bud initiation, flowering, anthesis and stigma receptivity are influenced by genotype and climatic factors like temperature and humidity (Venkatramini, 1952). The fruit, a long generally ribbed fuzzy pod developing in the leaf axil, grows rapidly after flowering. The edible part is the fruit pod which varies

in colour from yellow to red to green. Cultivars vary in plant height, shape and colour of the pod. Most cultivars are adapted to high temperatures and a wide range of soil types. Average temperatures of 25-35°C are best for growth, flowering and pod development. Okra is tolerant to wide variation in rainfall.

Okra is basically a self pollinated crop but natural crossing up to an extent 8.75 per cent may occur so, it is an often cross pollinated crop (Purewall and Randhava, 1947). It has several good features, which help the breeders and geneticists to have quick, genetic results. Among these features its growing habits, short life span and adaptability to wide range of soil and climatic conditions. It has also the features, which would save a lot of time and labour in achieving quick genetic results, for example, the monoadelphous condition of the emasculation work. Further, a large number of seeds per capsule provide many crossed and self seeds. Thus, it is one of the best suited crops for genetic studies.

### **Purpose of this research**

The availability of per capita vegetables is less than the per capita required recommendation. So, it is necessary to develop high yielding and better quality varieties of vegetables, which can provide more production from a small piece of land within a minimum period of time. This can be achieved by improvement in breeding programmes of vegetables. Breeding programmes are done for the improvement in the qualitative and quantitative traits of the prescribed crops. A breeding programme can only be called as a successful one, when it is associated with diversity of parents with better chance of improving its economic characters.

The major traits of interest for breeders in okra are yield and its component traits. The success of breeding programme is essentially a manifestation of efficiency of selection. Since yield depends upon several components, selection based on yield alone is not likely to be efficient. The component characters are also interrelated among themselves and also influence the yield to a great extent. For the development of effective breeding programme the existence of variability is of primary importance.

The efficiency of selection largely depends upon the magnitude of significant variability present in the plant production.

Heritability and genetic advance are important selection parameters. Heritability is a good index of transmission of characters from parents to their offspring (Falconer, 1960). Genetic advance is the measure of genetic gain under selection. Thus, genetic advance denotes the improvement in the mean genotypic value of selected population over the parental population. Heritability estimates along with genetic advance are more helpful in predicting the improvement that can be made in a crop by selecting the elite genotypes for various characters.

The understanding of correlation usually helps in finding out the phenotypic marker characters which are closely associated with yield. Such correlation coefficient provide information by themselves. Estimation of correlation co-efficient among the yield contributing variables is useful during selection and would maximize yield in the shortest period of time. Correlation co-efficient between a pair of characters is either positive or negative and high or low. This value indicates the relative importance of character (s) on which greater emphasis should be made during selection for yield. However, as a number of variables in the correlation study increases the direct and indirect association between yield and a particular component character becomes complex.

The efficiency of selection based on estimates of character association can be enhanced by ascertaining direct and indirect effects component traits towards the expression of yield using path coefficient analysis. Wright (1921) gave description and technique of path coefficient analysis, which provide an effective measure of direct and indirect association of characters contributing to pod yield. It determines the cause and effect relationship and has been found useful in partitioning the correlation coefficient into its direct and indirect effects contributing to yield. Dewey and Lu (1959) first applied the technique of path coefficient analysis in a plant breeding programme.

Keeping all the above points in mind, the present investigation based on evaluation of thirty two genotypes of okra for fourteen yield and other related traits was undertaken with the following objectives:

1. To work out the mean performance with respect to yield and yield attributing traits in okra genotypes.
2. To estimate genotypic and phenotypic coefficient of variability in the okra genotypes under evaluation.
3. To study the heritability and genetic advance of the evaluated characters.
4. To estimate genotypic and phenotypic correlation co-efficient among the yield and yield contributing traits.
5. To study the path coefficient analysis for demonstrating the impact of direct and indirect effects of yield contributing traits on yield.

## **REVIEW OF LITERATURE**

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Vegetable breeder is primarily concerned with the improvement of both quantitative and qualitative plant characters. Hence, adequate knowledge of genetics of various traits is very essential in vegetable breeding program for obtaining desired results in the generation. The genes required for crop improvement are present in different lines, strains, varieties or population of the crop species and their relatives and wild relative, which constitute the germplasm of a crop. However, the success of vegetable breeding depends on the extent and the magnitude of variability existing in the germplasm. At the same time, improvement is possible on the basis of heritable variation. Hence, for the improvement of okra yield traits are necessary. Therefore, detailed information about genetic architecture of pod yield and its attributes should be the main concern.

Keeping in view the objectives of the present investigation, the review of literature concerned to the studies on genetic variability in okra through character association, correlation and path coefficient analysis conducted for this dissertation is outlined under the following major 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**

For a successful crop improvement program, information on the nature and magnitude of genetic variability, degree of transmission of the traits is of immense importance. The variability available in the population can be partitioned into heritable and non-heritable components viz., phenotypic and genotypic coefficients of variation, heritability and genetic advance on which selection can be effectively

carried out. High heritability alone is not enough to make efficient selection in segregating generations, unless information is accompanied for substantial amount of genetic advance (Johnson *et al.*, 1955).

A detailed summary of methods for estimating genetic variance is presented by Cockerham (1963). In an earlier study, Rao (1972) evaluated 12 genotypes of okra and reported high GCV for plant height and number of days to flowering.

According to Reddy *et al.* (1985) high genotypic and phenotypic variances were recorded for pod yield per plant and plant height indicating wide variability. The GCV was maximum for pod yield per plant and minimum for days to flowering. Number of branches and plant height also showed comparatively high genotype coefficient of variability. Days to flowering, pod length and first podding node have low GCV indicating that they were more influenced by the environment.

Balakrishnan and Balakrishnan (1988) conducted studies on variability in okra for eleven quantitative characters and observed high phenotypic and genotypic variances for yield per plant, low GCV for number of ridges per pod. Later, Vijay and Manohar (1990) reported maximum range of variation for number of ridges on pod. They further reported that GCV was highest in number of pods per plant, number of branches per plant and pod yield per plant. In another study, Jeyapandi and Balakrishnan (1992) evaluated eighteen genotypes of okra and reported high PCV and GCV for pod weight, pod length and number of pods per plant, a close correspondence between the estimates of phenotypic coefficients of variation and genotypic coefficients of variation indicating the fact that environmental influence is very low.

In a study with 7 okra genotypes and 21 diallel crosses in Anand region, Patel and Dalal (1992) reported relatively high GCV for pod yield, number of pods per plant, plant height, number of branches per plant and pod weight, whereas high PCV for number of branches per plant. They observed narrow range of variability for days to first flowering and pod girth.

According to Bindhu *et al.* (1994) there were significant differences for all the characters studied in bhindi except leaf axil bearing the first flower and podding phase suggesting considerable variability between them. Similarly, a panel of authors conducted experiments on genetic variability in different genotypes of okra and confirmed high GCV and PCV for plant height (Mahto, 1996; Dash and Mishra, 1998; Jaiprakashnarayan *et al.*, 2006; Singh and Singh, 2006; Singh *et al.*, 2006 and Magar and Madrap, 2009), number of branches per plant (Mahto, 1996; Bindhu, *et al.*, 1997 and Singh and Singh, 2006), number of nodes per plant (Singh and Singh, 2006), node at which first flowering appeared (Magar and Madrap, 2009), first podding node length (Singh and Singh, 2006), inter nodal length (Singh and Singh, 2006), leaf area (Bindhu, *et al.*, 1997), number of pods per plant (Mahto, 1996; Bindhu *et al.*, 1997; Indurani and Veeraragavathatham, 2005; Khan *et al.* (2005), Singh and Singh, 2006; Singh *et al.*, 2006 and Magar and Madrap, 2009), weight of pods per plant (Bindhu *et al.*, 1997), length of pod (Bindhu *et al.*, 1997; Singh and Singh, 2006), width of pod (Mahto, 1996), weight of single pod (Bindhu *et al.*, 1997; Magar and Madrap, 2009), pod yield per plant (Singh and Singh, 2006; Indurani and Veeraragavathatham, 2005; Khan *et al.*, 2005), number of seeds per pod (Mahto, 1996; Singh and Singh, 2006) and 100-seed weight (Mahto, 1996).

Sood *et al.* (1995) stated the phenotypic and genotypic coefficients of variability, heritability and genetic advance, along with correlations between all combinations of 12 characters. Existence of wide variation was supported by different estimates. Ridges/pod had high genotypic and phenotypic coefficient of variation, heritability and genetic advance, whereas moderate heritability coupled with high to moderate genetic advance was recorded for the node at which the first pod set, plant height and nodes per plant. Duration of availability of edible pods, plant height and pod length had positive and strong correlations with yield.

Yassin and Anbu (1997) observed wide variability in bhendi among the genotypes for many characters *viz.*, plant height, number of branches, and number of pods, pod weight and yield per plant which were very important, whereas two characters plant height and weight of pod were less important.

Rajani and Manju (1997) observed high PCV and GCV for pod yield per plant followed by leaf area, moderate to high PCV as well as GCV were observed for almost all the characters except incidence of yellow vein mosaic, days to first flowering, first podding node, podding phase and pod length which recorded low values. However, Mathew *et al.* (1993) observed significant differences among the varieties of okra for yield and resistance to YVMV.

Singh *et al.* (1998) conducted an experiment in three genotypes of okra *viz.*, Parbhani Kranti, Hissar Unnat and Satdhari were treated with gamma rays (15, 30, 45, and 60 kR) and ethyle methane sulphonate (0.25, 0.50, 0.75 and 1.00%). Estimates of variability were carried out in induced mutants of okra for eleven characters. The highest GCV and PCV were observed for number of pods per plant, yield per plant and plant height suggested the importance of these characters in selection programme of okra.

Gandhi *et al.* (2001) studied that, in okra the characters like number of branches per plant, seed yield per plant, pod yield per plant and height at first pod set have higher plant height, number of nodes per plant, inter nodal length and pod length had moderate and for the characters 100 seed weight, days to maturity and days to 50 per cent flowering had very low GCV and PCV estimates suggesting high narrow and least scope for selection, respectively.

Dhankhar and Dhankhar (2002) evaluated sixty-two lines of okra for genetic variation in yield and yield components. Higher range of variation was recorded for the number of pods per plant, days to 50% flowering, and number of branches per plant during the rainy season, and for pod yield and plant height during the spring-summer season. The non-significant variation between phenotypic and genotypic coefficients of variation for pod yield and plant height indicated that the environment did not significantly affect the expression of these traits.

In another study Sarkar *et al.* (2004) also reported that pod yield per plant, number of pods per plant, pod weight, pod dry weight and number of leaves per plant at first flower showed high value of GCV and PCV.

The genetic variability of 69 okra cultivars in terms of different pod and yield parameters was studied by Mulge *et al.* (2004). The genotypic and phenotypic variation (GV and PV, respectively) and genotypic and phenotypic coefficients of variations (GCV and PCV, respectively) were high for total yield per plant and number of seeds per pod. Moderate GCV and PCV was observed for number of ridges per pod, number of locules per pod, number of pods per plant, pod length, pod diameter and average pod weight, whereas pod circumference exhibited low GCV and PCV.

Jaiprakashnarayan *et al.* (2006) evaluated 69 genotypes for different growth and earliness characters in okra. High genotypic and phenotypic variation was observed for plant height at 100 days after sowing (DAS). High GCV and PCV were observed for number of branches per plant, plant height at 100 DAS and inter nodal length. Moderate GCV and PCV were observed for number of nodes on main stem, number of nodes at first flower and number of leaves at 100 DAS. Days to first flowering and days to 50 per cent flowering exhibited low GCV and PCV.

Mehta *et al.* (2006) studied genetic variability, correlation and path coefficients analyses in 22 diverse genotypes of okra for pod yield and its component traits. The values of phenotypic coefficients of variation (PCV) were higher than that of genotypic coefficients of variation (GCV) values for all the seven traits indicating the influence of environment in the expression of these traits.

Mitra *et al.* (2006) stated that phenotypic and genotypic variances were similar in magnitude for days to 50% flowering and yield for *A. esculentus*, but phenotypic variances were higher than genotypic variances for all the remaining characters. The maximum genotypic variances were noted for plant height, and minimum for yield per plant. PCV values were invariably slightly higher than the corresponding GCV values for all the characters due to environmental influence.

Genetic variability, heritability and genetic advance of 15 quantitative characters in 19 diverse okra genotypes were also studied by Singh *et al.* (2006). Estimates of phenotypic and genotypic coefficient of variation were high for inter

nodal length, number of branches per plant, number of pods per plant, number of seeds per pod and pod yield per plant.

Thirty-four advanced breeding lines including parents of okra were evaluated for genetic variability by Singh *et al.* (2008). The highest genotypic and phenotypic coefficients of variation were observed for number of branches per plant, plant height, node at which first flower, number of nodes per plant, number of seeds per pod, pod length, number of pods per plant and pod yield.

Magar and Madrap (2009) studied on 41 genotypes of okra to assess the genotypic and phenotypic variability, heritability, genetic advance and to determine the nature of association among different yield attributes and their direct and indirect contribution towards yield. Phenotypic co-efficient of variability was higher than the genotypic ones. GCV and PCV were of higher magnitude for pod yield per plant followed by number of pods per plant, node at which first flower appear, plant height and pod weight. The magnitudinal difference between PCV and GCV estimate was maximum for node at which first flower appear and number of pods per plant suggesting influence of environment on these traits.

Saifulla and Rabbani (2009) characterized and evaluated one hundred and twenty one okra genotypes for different quantitative and qualitative traits. Significant variations among the genotypes were observed for different characters studied. The GCV and the PCV were very close in most of the characters which indicated less environmental influence on the expression of those characters.

High genotypic and phenotypic coefficients of variation were noticed for number of primary branches per plant indicating maximum variability among the different genotypes okra (Jindal *et al.*, 2010).

In a study twenty five genotypes of okra were evaluated to study the variability for 15 different characters by Chaurasiya *et al.* (2010). The treatment mean squares were significant for all 15 characters studied. The characters number of

branches per plant, pod yield per plant and day's first flowering at pod set should high GCV and PCV estimates.

Akotkar *et al.* (2010) stated that high values of GCV, PCV observed for number of podding nodes, number of ridges per pod, plant height and number of podding nodes indicated these characters might be controlled by additive genes. Plant height had the highest contribution towards the total genetic divergence.

Prakash *et al.* (2011) evaluated 44 genotypes of okra for 15 quantitative characters and they revealed that the phenotypic variances for all the fifteen characters were found to be higher than the genotypic variance. High GCV and PCV was observed for plant height, inter-nodal length, first flowering node, first pod producing node, height of first flowering node, average pod weight and number of seeds per pod and they suggested selection based on these characters are advisable for improvement.

Ramanjinappa *et al.* (2011) studied genetic variability of 13 quantitative characters in 17 okra genotypes and they revealed that significant differences among genotypes were observed for all the characters under study, the characters plant height and number of branches per plant showed high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV), selection based on these characters are suggested for further improvement.

Nwangburuka *et al.* (2012) evaluated Twenty-nine okra accessions from different agro-ecological regions in Nigeria to determine their genetic variability from eight yield related characters. The experiment was laid out in a Randomized Complete Block Design with five replications. There was high genotypic coefficient of variability recorded in traits such as plant height (26.2), fresh pod length (23.9), fresh pod width (23.9), mature pod length (28.6), branching per plant (29.3) and pod weight per plant (33.9), suggesting the effect of additive genes and reliability of selection based on phenotype of these traits for crop improvement.

Singh *et al.* (2012) studied different genotypes of okra for phenotypic and genotypic coefficient of variation and they revealed that number of branches per plant and length of first podding node showed the highest phenotypic and genotypic coefficient of variation closely followed by number of seeds per pod. The GCV and PCV values for most of the characters were found to be very distant to each-other, indicated that characters much influenced by environmental factors.

Reddy *et al.* (2012) studied genetic variability on 100 genotypes of okra revealed high magnitude of genetic variability and high degree of transmission of majority of the growth, earliness and yield associated traits under study. High magnitude of genotypic coefficient of variation (>20.00%) for number of branches per plant, total number of pods per plant, number of marketable pods per plant, total yield per plant (g), marketable yield per plant (g) and yellow vein mosaic virus infestation on plants (%) indicated high degree of genetic variability offering great scope for selection of these characters.

Vani *et al.* (2012) conducted variability studies in 157 genotypes of okra and revealed that the characters viz., plant height, pod weight, seeds per pod, yield per plant and pod yield per hectare, to some extent pod length and inter nodal distance exhibited high genetic gain along with high variability, while pod weight and number of pods per plant recorded low genetic gain coupled with low or moderate variability. The characters like number of branches per plant, pod width and node at which first flower appeared showed low GCV and high PCV values highlighted the usefulness of selection based on the phenotypic performance of the genotypes.

## **2.2 HERITABILITY AND GENETIC ADVANCE**

The success of breeding programme is achieved by the efficient utilization of heritability and variability available in the population. Padda *et al.* (1970) reported that the heritability in broad sense was high for all the characters *i.e.*, plant height, yellow vein mosaic infection, number of days to flower, yield of green pods per plant, number of dry seeds per pod and weight of 1000 dry seeds and in the case of seeds

per pod, it was very high. The magnitude of genetic advance in per cent of mean was moderate to high for all the characters under study in okra.

Rao and Ramu (1975) observed that heritability in broad sense was highest for length of pod and expected genetic advance was more for pod girth in bhendi. However, Reddy *et al.* (1985) recorded a high genetic advance, heritability for plant height, pod yield per plant, number of branches and a high heritability estimates of 90.9% to 99.9% were recorded for pod width and pod length respectively in okra.

According to Agarwal *et al.* (1984) a fair heritability for pods per plant, seed yield per plant, nodes on the main stem, girth of edible pod and length of edible pod and maximum genetic advance as percentage of mean in case of primary branches per plant in okra were observed. But, Balakrishnan and Balakrishnan (1988) reported that in bhendi high heritability coupled with high genetic advance as per cent of mean were recorded for plant height, number of pods per plant, pod weight, number of seeds per pod, yield per plant confirming the preponderance of additive genes in controlling the expression of these traits. Among all the above pod weight and number of pods per plant and yield per plant is high and they served as the most reliable index for improving the yield. On other hand, Veeragavathatham and Irulappan (1990) found that plant height in okra, exhibited low narrow sense heritability.

Randhawa and Sharma (1988) recorded high heritability and genetic advance in okra for number of pods per plant, number of branches per plant in F<sub>3</sub> generation and confirmed that okra breeders should follow selections based on these characters in early generations (F<sub>3</sub>) to develop high yielding and YVMV resistant cultivars. Similarly, Rath *et al.* (1991) evaluated 12 cultivars of okra for 10 yield components. Highly significant differences between cultivars were found for all characters. Heritability estimates ranged from 99.7% for number of seeds per pod to 69.7% for number of branches per plant. Similar results were also reported by Chourasiya *et al.* (2010) revealing that the characters pod length number of ridge per pod (100%), days of first flowering (89%), plant height (86%) and plant per cent affect by YVMV (84%) showed high heritability estimate. However, these characters were coupled

with varied genetic advance *i.e.* high, medium and low respectively suggesting complexity of genetic mechanism in expression of those traits. The additive genetic variance was reported by traits like plant height, no of branches per pod, pod length, pod diameter and no. of pod per plant.

Jeyapandi and Balakrishnan (1992) recorded that the heritability and genetic advance in okra were higher for yield per plant, number of pods per plant, pod weight and pod length, hence these characters can effectively be used as criteria for selection in the improvement of bhendi. This study was further confirmed by many workers like Mahto (1996), Yassin and Anbu (1997), Panda and Singh (1997), Dash and Mishra (1998), Dhall *et al.* (2000), Patro and Sankar (2004), Khan *et al.* (2005), Dakahe *et al.* (2007), Manivannan *et al.* (2007) and Pal *et al.* (2010).

Sood *et al.* (1995) stated that the phenotypic and genotypic coefficients of variability, heritability and genetic advance, along with correlations between all combinations of 12 characters. Existence of wide variation was supported by different estimates. Ridges per pod had high genotypic and phenotypic coefficient of variation, heritability and genetic advance, whereas moderate heritability coupled with high to moderate genetic advance was recorded for the node at which the first pod set, plant height and nodes per plant.

Singh *et al.* (1998) conducted an experiment in three genotypes of okra *viz.* Parbhani Kranti, Hissar Unnat and Satdhari were treated with gamma rays (15, 30, 45, and 60 kR) and ethyle methane sulphonate (0.25, 0.50, 0.75 and 1.00%). Estimates of heritability and genetic advance were carried out in induced mutants of okra for eleven characters. High heritability and genetic advance were observed for number of pods per plant, yield per plant, plant height and number of seeds per pod suggested the importance of these characters in selection programme of okra.

Gandhi *et al.* (2001) stated that the high heritability estimates of height at first pod set and dry pod yield per plant were coupled with high magnitude of expected genetic advance indicating existence of additive gene action in the expression of these characters and improvement of characters can be done through direct selection in okra.

Dhankhar and Dhankhar (2002) evaluated sixty-two lines of okra for genetic variation in yield and yield components. High genetic advance coupled with high heritability was recorded for all characters except days to 50% flowering during the spring-summer season.

The genetic variability of 69 okra cultivars in terms of different pod and yield parameters was studied by Mulge *et al.* (2004). High heritability with high genetic advance over mean (GAM) was observed for total yield per plant, number of seeds per pod, number of ridges per pod, number of locules per pod and number of pods per plant. High heritability with low GAM was observed for pod circumference.

In another study Sarkar *et al.* (2004) reported that high heritability coupled with high genetic advance was recorded for number of pods per plant, pod weight and dry weight as well as pod yield per plant, indicating that these characters are controlled by additive action of polygenes.

Khan *et al.* (2005) recorded moderate heritability with moderate to low genetic advance for days to first pod set and pod diameter which was attributed to the fact that the parental genotypes might have possessed both additive and/or non additive genes for these traits in different magnitudes. On the other hand Singh and Singh (2006) reported high heritability estimates with moderate genetic advance for first podding node, number of branches per plant, tapering length and pod yield per plant in comparison to other characters, which indicated the additive gene effects. Days to first flower, plant height, pod length, number of pods per plant and width of the pod showed high to moderate heritability with low genetic advance which indicates high environmental effects and selection may be ineffective for such traits.

Kumar *et al.* (2006) reported high heritability and low genetic advance as per cent of mean was found with respect to plant height and 100 seed weight, which indicated the predominance of non additive gene effects. Judicious application of pure line selection may prove effective for exploiting these traits in this crop.

Mehta *et al.* (2006) studied genetic variability, correlation and path coefficients analyses in 22 diverse genotypes of okra for pod yield and its component traits. The heritability and genetic advance as percentage of mean were higher for pod yield, average pod weight, plant height and pod length, which might be attributed to additive gene action resulting into their inheritance.

Mitra *et al.* (2006) stated that the estimates of heritability in broad sense varied from 99.8% for yield per plant to 44.7% for pod girth. Except number of branches per plant, inter nodal length and pod girth other character expressed high heritability values, *i.e.* above 83%. Heritability in narrow sense was found to be highest for plant height (44.8%), only suggesting thereby the more or less important role of additive gene effect. Genetic advance was the highest (38.306) for plant height and the lowest (0.530) for yield per plant. The higher estimates of GCV and heritability coupled with higher genetic advance for pods per plant, number of nodes per plant, plant height, inter nodal length and pod length indicated that heritability of these traits is mainly due to additive effects and selection for these characters will be most effective in West Bengal environmental condition. High heritability accompanied with medium to low genetic advance for yield per plant is indicative of non-additive gene action playing a vital role.

Genetic variability, heritability and genetic advance of 15 quantitative characters in 19 diverse okra genotypes were also studied by Singh *et al.* (2006). The characters viz., number of seeds per pod, inter nodal length, number of branches per plant, pod yield per plant, number of pods per plant, plant height and 100-seed weight exhibited high heritability along with high genetic advance, which indicated that there was more number of additive factors and, therefore, further improvement could be brought about by selection.

Kumar *et al.* (2007) conducted experiment on diallel study in okra, involving 28 F<sub>1</sub>s and 8 parents. The 8 parents were AB-1, AB-2, KS-305, KS-312, BO-2, Arka Anamika, Pusa Sawani and IIHR-4. Data were recorded on 10 characters, *i.e.* days to flowering, plant height, number of node per plant, number of first podding node, inter nodal length, pod length, pod width, tapering length of pod, number of pods per plant

and yield per plant. High heritability coupled with moderate to high genetic advance over mean were observed for days to flowering, node number per plant, inter nodal length, pod number per plant, and yield per plant. High heritability coupled with low genetic advance were observed for plant height; low heritability coupled with high genetic advance for pod width and tapering length of pod; and low heritability coupled with low genetic advance for pod length.

Kumar *et al.* (2007) observed high heritability coupled with moderate to high genetic advance over mean for days to flowering, number of nodes per plant, length of internodes, number of pod per plant and yield per plant.

In an experiment, Yadav *et al.* (2007) conducted experiments on evaluating 51 treatments in 15 okra parents, KS-423, KS-440, KS-447, KS-441, KS-453, KS-455, KS-420, BO-2, KS-437, KS-448, KS-439, KS-427, Prabhani Kranti, KS-10 and KS-404. High heritability coupled with high genetic advance was observed for the number of pods per plant, yield per plant and number of branches per plant, indicating that most likely, heritability is due to additive gene effects and selection may be effective. The maximum value of genetic advance in percent of mean was observed for the number of pods per plant followed by inter nodal length, pod length, plant height, days to flowering, pod width, tapering length of pod, number of first podding node and minimum value observe for length of first podding node.

Thirty-four advanced breeding lines including parents of okra were evaluated for genetic variability, character association and path coefficients by Singh *et al.* (2008). The number of branches per plant, plant height, number of seeds per pod, number of nodes per plant, pod length, pod yield and number of pods per plant exhibited high heritability along with high genetic gain, 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 their selection.

Magar and Madrap (2009) studied on 41 genotypes of okra to assess the genotypic and phenotypic variability, heritability, genetic advance and to determine the nature of association among different yield attributes and their direct and indirect

contribution towards yield. Heritability estimates were of high magnitude for pod length, total pod yield per plant indicating major role of genotype with less environmental influence.

Saifulla and Rabbani (2009) characterized and evaluated one hundred and twenty one okra genotypes for different quantitative and qualitative traits. Significant variations among the genotypes were observed for different characters studied. The high heritability estimates along with considerable genetic advance were noticed in days to first flowering, plant height, number of primary branches per plant, number of internodes per plant, number of pods per plant, pod weight, number of seeds per pods and pod yield per plant provided the basis for selection for development of new variety of okra based on phenotypic performance. Genotypes AE009, AE024, AE036, AE061, AE080 and AE087 possessed desirable characters and were selected for further evaluation.

Twenty five genotypes of okra were evaluated to study the variability for 15 different characters by Chaurasiya *et al.* (2010). Medium to high and high heritability was recorded for all the characters studied. The characters pod length no. of ridge per pod (100%), days of first flowering (89%), plant height (86%) and plant per cent affect by YVMV (84%) showed high heritability estimate, however these characters were coupled with varied genetic advance *i.e.* high, medium and low respectively suggesting complexity of genetic mechanism in expression of those traits. The additive genetic variance was reported by traits like plant height, no of branches per pod, pod length, pod diameter and number of pods per plant.

Jindal *et al.*, (2010) stated that high estimates of heritability coupled with high genetic advance obtained for number of branches per plant, total yield per plant and marketable yield per plant indicating presence of additive gene effects which indicated the effectiveness of selection for these traits. Presence of high heritability coupled with low genetic advance for days to pod picking, average pod weight, plant height, inter nodal length, number of pods per plant, pod diameter and average pod length revealed that straight selection has limited scope for further improving these traits.

Prakash *et al.* (2011) evaluated 44 genotypes of okra for 15 quantitative characters and they revealed that high heritability coupled with high genetic advance as per cent of mean (GAM) were observed for all most all the characters studied, except for days to 50% flowering and days to 80% maturity, which showed high heritability with low GAM. Plant height, average pod weight, number of seeds per pod and total yield per plant showed high genetic advance that helped in effective and reliable selection through these characters for further improvement in okra.

Ramanjinappa *et al.* (2011) studied heritability and genetic advance of 13 quantitative characters in 17 okra genotypes and revealed that high heritability was recorded for all the characters studied except days to 50 per cent flowering which exhibited moderate heritability. The characters viz, plant height, number of branches per plant, number of nodes per plant, inter nodal length, number of pods per plant, number of seeds per pod, harvest index and total yield per plant exhibited high heritability coupled with high genetic advance over mean (GAM) which indicated that there was more number of additive factors and therefore, further improvement could brought by selection.

Nwangburuka *et al.* (2012) evaluated twenty-nine okra accessions from different agro-ecological regions in Nigeria to determine their heritability and genetic advance from eight yield related characters. The experiment was laid out in a Randomized Complete Block Design with five replications. There was high % broad-sense heritability and genetic advance in traits such as plant height (90.7, 51.5), fresh pod length (98.5, 48.8), fresh pod width (98.5, 48.8), mature pod length (98.5, 52.3), branching per plant (82.3, 54.8) and pod weight per plant (90.0, 63.3), suggesting the effect of additive genes and reliability of selection based on phenotype of these traits for crop improvement.

Singh *et al.* (2012) revealed that the heritability estimates in broad sense were high for days flowering to maturity, number of branches per plant and days to flowering, while low heritability estimates were observed for plant height, length of first podding node and pod diameter. The genetic advance as percentage of mean was high for number of branches per plant and days flowering to maturity. High

heritability coupled with high genetic advance was observed for days flowering to maturity and number of branches per plant indicating that they are governed by additive genes and could be effectively improved through selection.

Reddy *et al.* (2012) studied heritability and genetic advance in 100 genotypes of okra revealed that the characters plant height (cm), number of branches per plant, inter nodal length (cm), days to fifty per cent flowering, first flowering node, first podding node, pod length (cm), pod weight (g), total number of pods per plant, number of marketable pods per plant, total yield per plant (g), marketable yield per plant (g), yellow vein mosaic virus infestation on pods and plants (%) having high heritability (>60.00%) coupled with high expected genetic advance (>20.00%) revealed that a very significant improvement is possible through selection for all these characters.

Vani *et al.* (2012) studied heritability and genetic advance in 157 genotypes of okra and revealed that the characters viz., plant height, pod weight, seeds per pod, yield per plant and pod yield per hectare, to some extent pod length and inter nodal distance exhibited high genetic gain along with high heritability, while pod weight and number of pods per plant recorded low genetic gain coupled with low or moderate heritability. The characters showed low to moderate heritability and genetic gain thus the selection in these traits would not be effective.

### **2.3 CORRELATION COEFFICIENT ANALYSIS**

Correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for improvement in yield. Simple correlations are of three types viz., phenotypic, genotypic and environmental. Phenotypic correlation is the observable correlation between variables, measures the environmental deviation together with non additive gene action. Genotypic correlation on the other hand is the inherent association between two variables. They can be estimated from replicated data only.

The knowledge of the nature of association between characters is of great asset to plant breeders to formulate evaluation or work procedures. The magnitude

and direction of association is measured by correlation coefficients. Correlation studies provide information such that selection for one character results in progress for all positively correlated characters.

Padda *et al.* (1970) reported positive correlation of plant height with mosaic infection, yield per plant and seeds per pod, mosaic infection with days to flower, seeds per pod and 1000 seed weight, between days to flower and seeds per pod, between yield per plant and 1000 seed weight and between seeds per pod and 1000 seed weight. However correlation was significant between days to flower and seeds per pod.

Thamburaj and Kamalanathan (1973) studied association between yield components of okra and reported highest degree of positive correlation  $r=0.9327$  for weight of pods and  $r=0.9106$  for number of pods. Also, Rao and Ramu (1975) observed that the pod length has significant positive correlation with yield in bhendi.

Mishra and Singh (1985) in their study to establish correlation among the various traits to find out their direct and indirect effects on yield of okra revealed that the number of pods per plant, pod weight, pod length, 100 seed weight, plant height and number of nodes per plant showed high positive genotypic correlations with yield per plant, while yellow vein mosaic, seeds per pod and branches per plant showed negative significant associations with it.

Reddy *et al.* (1985) reported that the magnitude of genotypic correlations in okra were similar to the phenotypic estimates, showing that environmental influence less impact to alter the degree of association among the characters. Pod yield per plant showed significant and positive correlation with all the traits except first podding node. Among pod yield components significant positive correlations were observed for pods per plant, with all the traits; pod length and width with all except first podding node; number of branches with all except plant height and days to flower with all except first podding node.

Balakrishnan (1988) indicated that the number of nodes per plant, number of pods per plant and pod weight had highly significant positive association with yield. Number of seeds per pod had significant negative correlation with yield per plant in bhendi. Similarly, Randhawa and Sharma (1988) stated that in okra there was a positive and significant correlations for number of branches per plant, number of pods per plant, total yield per plant and days to seed maturity indicating that selection should be done in early generations for making improvement in yield and seed maturity and selection for YVMV should not be made in early generation as there was negative correlation.

Balakrishnan and Balkrishnan (1990) revealed that in bhendi the yield per plant recorded high correlation values for number of pods per plant and pod weight. A positive highly significant correlation observed between plant height with number of pods per plant, pod weight; pod length and pod weight; pod girth and pod weight, number of pods per plant with pod weight, 100 seed weight; pod weight and 100 seed weight.

Singh *et al.* (1998) conducted an experiment in three genotypes of okra *viz.* Parbhani Kranti, Hissar Unnat and Satdhari were treated with gamma rays (15, 30, 45, and 60 kR) and ethyle methane sulphonate (0.25, 0.50, 0.75 and 1.00%). Estimates of correlation were carried out in induced mutants of okra for eleven characters. Strong positive correlated response for yield per plant with number of pods per plant, pod length, pod width, number of seeds per pod and plant height suggested the importance of these characters in selection programme of okra.

It was reported by many workers in okra that the marketable yield per plant, pod weight, pod length, number of pods per plant and plant height had significantly positive correlation with total yield per plant Jeyapandi and Balakrishnan (1990); Bendale *et al.*, 2003; Khan *et al.*, 2005; Mehta *et al.*, 2006; Kumar *et al.*, 2007; Pal *et al.*, 2008; Magar and Madrap, (2009). On the other hand pod yield was negatively correlated with plant height, number of branches per plant and days to 50% flowering (Mehta *et al.*, 2006).

Gandhi *et al.* (2002) revealed association analysis in 44 genotypes of okra and indicated that dry pod yield was highly significant with plant height, nodes per plant, inter nodal length, number of pods per plant and seed yield per plant suggesting that dry pod yield depended on all these characters and each one of them have influenced the character dry pod yield in okra.

Dhankhar and Dhankhar (2002) evaluated sixty-two lines of okra for genetic variation in yield and yield components. The coefficient of variation at phenotypic and genotypic levels was high for the number of branches and pods per plant, pod yield, and plant height, suggesting that selection may be based on these traits. Pod yield was significantly and positively correlated with the number of pods and branches per plant, and plant height, but was negatively correlated with days to 50% flowering. The number of pods per plant was positively associated with the number of branches per plant and plant height, and was negatively correlated with days to 50% flowering. Pod yield can be improved through selection for higher number of pods and branches, and medium plant height.

It was reported that seed yield per plant in okra showed significant positive correlation with number of pods per plant, height at flowering, pod width and weight of hundred seeds. (Akinyele and Osekita, 2006 and Mahto, 1996).

Patro and Sankar (2006) observed that yield per plant recorded highly significant positive correlation with germination percentage, number of branches per plant, number of ridges per pod, pod weight, number of seeds per pod, 100 seed weight and ascorbic acid content.

In an experiment with okra, Ali *et al.* (2008) revealed that correlation coefficients between parental order of dominance and parental measurement were found to be negative for height of plant, number of branches per plant and width of pods per plant indicating that dominant genes governed the expression of these characters. The positive and significant values observed for days to flowering, length of pod, number of pods per plant and pod yield per plant suggested that these characters were governed by recessive genes. Correlation coefficients were estimated

at genotypic and phenotypic levels. The correlation coefficients were consistently significant and positive between pod yield per plant and number of pods per plant at both genotypic and phenotypic levels. Pod yield per plant showed significant and positive correlation between length of pod and width of pod at genotypic level.

Singh *et al.* (2008) conducted an experiment on thirty four advanced breeding lines including parents of okra to estimate correlation among the characters under study. They revealed that pod yield had a strong and positive genotypic and phenotypic correlation with number of pods per plant, number of nodes per plant, number of branches per plant, plant height and average pod weight. Selection on these traits is useful in further crop improvement programme.

Koujalagi *et al.* (2010) also revealed that pod yield of okra genotypes was positively and significantly associated with plant height, number of branches, internode length, pod weight and number of pods per plant both at genotypic and phenotypic levels. Further, the magnitude of genotypic correlation coefficient was invariably higher than phenotypic correlation coefficient, suggesting strong inherent traits (Kumar *et al.*, 2009). The most important trait, number of flowers per plant was positively and significantly correlated with number of leaves per plant, diameter of stem and number of days to flower at genotypic and phenotypic levels. The data also revealed that number of pods per branch, number of pods per plant and number of days to flower was positively and significantly correlated at genotypic and phenotypic levels.

Saifulla and Rabbani (2010) evaluated 121 okra genotypes collected from different parts of Bangladesh. Genotypic and phenotypic coefficient of correlation revealed that pod yield per plant had positive significant correlations with internodes per plant, length and diameter of pod, pods per plant, average weight of pod and seeds per pod but pod yield had significant negative correlation with days to first flowering.

Ramanjinappa *et al.* (2011) evaluated 17 genotypes of okra and revealed that the estimates of phenotypic coefficient of variation and genotypic coefficient of variation were found to be higher for plant height and number of branches per plant.

Pod yield for plant was positively and significantly correlated with plant height, number of nodes per plant, number of pods per plant and harvest index.

Nwangburuka *et al.* (2012) evaluated twenty-nine okra accessions from different agro-ecological regions in Nigeria from eight yield related characters. The experiment was laid out in a Randomized Complete Block Design with five replications and they revealed that the positive and significant phenotypic and genotypic correlation between plant height at maturity, fresh pod width, seeds per pod and pods per plant, branches per plant with seed weight per plant and pod weight per plant, suggests that selection on the basis of the phenotype of these characters will lead to high seed and pod yield in okra.

Vani *et al.* (2012) conducted correlation studies in 157 genotypes of okra and revealed that pod yield per plant recorded significant positive correlation with plant height, number of branches per plant, pod length, number of pods per plant, average pod weight and yield per hectare. In the same manner pod yield per hectare also recorded significant positive correlation with plant height, number of branches per plant, pod length, average pod weight, number of pods per plant, pod yield per plant and seeds per pod.

Thus, an overview of the available literature on the test crop clearly indicates that in okra the success of breeding program depends on the quantum of genetic variability available for exploitation. A previous knowledge of the structure of the genetic diversity within a large collection of germplasm may be of great help to make decisions on management procedures as well as on breeding strategies to use in current and future breeding programs. The information on the type of variation in the available genetic material and the part played by the environment on the expression of plant characters is of prime importance for the appraisal of rate and magnitude of possible improvement.

#### **2.4 PATH COEFFICIENT ANALYSIS**

The study of genotypic and phenotypic correlation does not provide an exact picture of relative importance of direct and indirect influence of each of the

component character towards the desired character. So, the plant breeder tries to partition the correlation coefficient into components of direct and indirect effects by employing the path coefficient analysis, which involves measurement of influence of one trait upon the set of other traits through standardized partial regression coefficient to increase the efficiency of selection.

Dhall *et al.* (2000) conducted path coefficient analysis in 48 advanced generation lines of okra and revealed that the marketable yield per plant, number of pods per plant, pod weight, pod length and plant height had the highest direct effect on the total yield, indicating that emphasis should be given on such characters to improve the yield potential.

Dhankhar and Dhankhar (2002) evaluated sixty-two lines of okra for genetic variation in yield and yield components and they recorded pod yield was significantly and positively correlated with the number of pods and branches per plant, and plant height, but was negatively correlated with days to 50% flowering. The number of pods per plant was positively associated with the number of branches per plant and plant height, and was negatively correlated with days to 50% flowering. Pod yield can be improved through selection for higher number of pods and branches, and medium plant height.

Gandhi *et al.* (2002) conducted trial on the interdependency of various morphological characters *viz.*, plant height, inter nodal length and height at pod set, pod length and girth, 100-seed weight and number of days to 50% flowering and maturity and dry pod yield of 44 okra cultivars and revealed that path coefficient analysis showed that inter nodal length had the highest positive direct effect, whereas plant height had the highest negative direct effect on dry pod yield.

Kamal *et al.* (2003) evaluated path analysis in thirty divergent genotypes of okra and revealed that number of pods per plant and width of pod had high positive direct effect on yield per plant indicating that these characters may be given due weightage while making selection for crop yield improvement.

Sarkar *et al.* (2004) evaluated twenty- five genotypes of okra and indicated path coefficient analysis with partitioning of phenotypic correlation revealed that number of pods per plant and pod weight had positive and high direct effect on pod yield, indicating their importance as reliable selection criteria for improvement of yield in okra.

Bali *et al.* (2005) evaluated thirty-one lines of okra and reported as path analysis showed that number of pods per plant, average pod weight, inter nodal distance and plant height had the highest positive direct effect on total yield per plant.

Mehta *et al.* (2006) were studied path coefficients analyses in 22 diverse genotypes of okra for pod yield and its component traits and revealed that pod girth had the maximum direct effect followed by pod length towards pod yield. Thus, the pod yield in okra can be improved by selecting for higher pod length, pod girth and average pod weight simultaneously.

Patro and Sankar (2006) observed path coefficient analyses of 15 characters in 41 bhendi genotypes. Yield per plant was positively and directly affected at both phenotypic and genotypic levels by germination percentage, number of branches per plant, number of pods per plant, pod weight, number of seeds per pod, 100 seed weight and ascorbic acid content, at the genotypic level by plant weight, pod volume and longevity of tenderness, and at the phenotypic level by number of nodes per plant. Germination percentage revealed high positive indirect effects on yield through number of days for first pod setting, pod weight, number of seeds per pod, 100 seed weight and ascorbic acid content.

Adeniji and Aremu (2007) evaluated direct and indirect effects of agronomic and reproductive characters on pod and seed yield of the West African okra, *Abelmoschus caillei* in Nigeria and indicated that the path analysis identified plant height at maturity, ridges per pod, pods per plant, mature pod length and seed per ridge as selection indicators for pod and seed yield improvement in West African okra.

Singh *et al.* (2008) conducted path coefficient studies in thirty four advanced breeding lines including parents of okra and results indicated that number of pods per plant had the highest direct contribution towards yield followed by average pod weight. Therefore, direct selection for these traits will be effective in enhancing the productivity per plant while indirect selection for plant height, number of branches per plant and number of nodes per plant is suggested for designing of productive plant canopy of okra.

Koujalagi *et al.* (2010) evaluated the interrelationship and path co-efficients for pod yield and its attributes on 56 genotypes of okra. The results revealed that pod yield was positively and significantly associated with plant height, number of branches, inter nodal length, pod weight and number of pods per plant both at genotypic and phenotypic levels. The traits such as pod number, pod weight, inter nodal length, number of branches per plant and days to 50% flowering had high direct effects on pod yield. Hence, it would be rewarding to lay emphasis on these characters in selection programmes for increasing yield in okra.

Saifulla and Rabbani (2010) evaluated 121 okra genotypes collected from different parts of Bangladesh and revealed path analysis showed that plant height showed medium direct positive effect on pod yield per plant. This trait had also indirect positive effect with number of pods per plant and number of seeds per plant. Primary branches per plant had negative direct effect on yield and indirect positive effect with plant height, length of pod, diameter of pod, number of pods per plant, pod weight, number of seeds per pod and pod yield per plant. Number of inter nodes per plant also showed direct negative effect on pod yield. The study indicated that number of inter nodes per plant, length and diameter of pod, number of pods per plant, average weight of pod and seeds per pod showed significant positive correlation with pod yield both genotypically and phenotypically. Number of pods per plant, average weight of pod, plant height, length of pod, days to first flowering, number of seeds per pod and diameter of pod showed positive direct effect on pod yield per plant. Emphasis should be given for selection of these characters for improvement of yield in okra.

Ramanjinappa *et al.* (2011) evaluated 17 genotypes of okra and indicated the path coefficient analysis revealed that number of pods per plant had highest direct influence towards pod yield per plant followed by number of seeds per pod, average pod weight, harvest index and number of nodes per plant. Hence, these important traits may be viewed in selection program for the further improvement of okra.

Senapati *et al.* (2011) conducted path coefficient studies in twelve genotypes of okra and revealed that the number of pods per plant (0.242), pod girth (0.218) and pod length (0.058) exhibited maximum direct effects on pod yield as phenotypic level. On the basis of their findings, it was concluded that the number of pods per plant and pod length would be considered for improvement of pod yield of okra hybrid and among the genotypes, JOH 05-9 was found the most promising hybrid followed by HOK 152 and AOH-23.

## **MATERIALS AND METHODS**

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The present experiment “Evaluation and genetic variability in advanced breeding lines of okra [*Abelmoschus esculentus* (L.) Moench] under Varanasi conditions” was undertaken to study the behavior of economic traits in respect of component of variances. The details of the experimental material used and methods applied during course of investigation were as follows:

### **3.1 EXPERIMENTAL MATERIALS**

The experimental materials used were narrated as below-

#### **3.1.1 Experimental site**

The experiment was carried out at the Vegetable Research Farm of the Horticulture Department, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during summer season 2012. The experimental site is situated at 129.23 meters above the mean sea level. The latitude and longitude of this place is 25°18’N, 83°03’E, respectively.

#### **3.1.2 Climatic conditions**

Varanasi has a semi arid sub tropical climatic with hot dry summer and cold winter. The average rainfall is recorded to be 1100mm per annum. The detailed climatic conditions during crop growth are presented in table 3.1.

#### **3.1.3 Soil properties**

The alluvial soils of this geographical region in general are reported to be flat, well drained and moderately fertile being less in available nitrogen and medium in available phosphorous and potash. The normal soil pH varies from 7.2-8.4.

### 3.1.4 Preparation of land and manuring

The experimental plot was ploughed twice with disc plough to achieve pulverized and compact transplanting beds and leveled with heavy plank. The Farm Yard Manure (FYM) was applied just after the first ploughing in the main field. Half of the recommended dose of nitrogen fertilizer and full dose of phosphorous and potash fertilizers were applied at the time of last ploughing and just before sowing. The rest of the nitrogen fertilizer was applied through top-dressing at the time of flowering and pod formation.

### 3.1.5 Experimental material used

Experimental material for the present investigation received from Indian Institute of Vegetable Research, Varanasi. This comprises of 32 genotypes of okra belonging to different morphological and productive attributes and presented in table 3.2.

## 3.2 Experimental design and layout

### 3.2.1 Experimental design

The experiment was laid out in Randomized Block Design with three replications. The experiment was conducted at Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi.

### 3.2.2 Details of layout plan

1) Experimental design	RBD
2) Number of genotypes	32
3) Number of replications	3
4) Total number of plots	$3 \times 32 = 96$
5) Size of plot	$3 \times 3\text{sqm}$
6) Field border	1m
7) Block border	1m

8) Main channel	1m
9) Sub-channel	1m
10) Date of sowing	15 March, 2012.
11) Spacing	Row to row      45 cm
	Plant to plant    30 cm
12) Fertilizers	Nitrogen          100 kg/ ha
	Phosphorus       60 kg/ ha
	Potassium        60 kg/ha

### **3.3 Observations recorded**

The technique of random sampling was adopted for recording the observations of various quantitative characters of okra. Five plants of each treatment from each replication were selected at random at the time of recording the data on various characters. Data of five plants were averaged replication wise and mean data was used for statistical analysis. Recommended package of practices were applied to raise a healthy crop.

#### **3.3.1 Days to 1<sup>st</sup> flowering**

Number of days were counted from the date of sowing to the date of 1<sup>st</sup> flowering in the plants of a plot of each treatment in each of the replication and averaged.

#### **3.3.2 Days to 50% flowering**

Number of days were counted from the date of sowing to the date of 50% flowering in a plot of each treatment in each of the replication and averaged.

### **3.3.3 Plant height (cm)**

At the time of last picking of pods, height of the plants in centimeters (cm) was measured from the base of the plant to the tip of the stem.

### **3.3.4 Number of branches per plant**

Number of braches produced by each plant was recorded at the time of last picking of the pods.

### **3.3.5 Inter nodal distance (cm)**

The distance between two nodes of randomly selected five plants was measured at five different places and average was calculated.

### **3.3.6 Number of nodes per plant**

Number of nodes on each plant was recorded at the time of last picking of the pods.

### **3.3.7 Pod length (cm)**

The length in centimeters (cm) of randomly selected five pods in each genotype per replication was taken and divided by the number of pod to obtain average pod length.

### **3.3.8 Pod width (cm)**

The width in centimeters (cm) was measured in terms of pod diameter from randomly selected five pods of each genotype in each replication and divided by number of pod to obtain average pod width.

### **3.3.9 Average pod weight (g)**

The pod weight in grams (g) of randomly selected five pods of each genotype in each replication was taken and divided by number of pods to obtain average pod weight.

### **3.3.10 Number of pods per plant**

Total number of pods of randomly selected five plants was counted from each picking and average was calculated.

### **3.3.11 Number of seeds per pod**

Number of seeds from five ripe pods in each genotype in each replication was extracted and average was worked out.

### **3.3.12 100 Seed weight (g)**

The 100 seed weight in grams (g) of each genotype in each replication was taken after seed extraction from dried pod.

### **3.3.13 Pod yield per plant (g)**

Total number of pods of randomly selected five plants was multiplied from average pod weight from each genotype in each replication and yield per plant was worked out.

### **3.3.14 Pod yield per hectare (q)**

The yield per plant was multiplied by total number of plants per hectare to obtain yield per hectare.

### 3.4 STATISTICAL ANALYSIS

The mean values of five randomly selected plants used for recording observations were computed for each of fourteen traits for each genotype in each replication and were subjected to statistical analysis.

#### 3.4.1 Analysis of variance

The analysis of variance for different characters was carried out using mean data in order to assess the genetic variability among genotypes as given by Cochran and Cox (1957). The level of significance was tested at 5% and 1% using F test. The model of ANOVA used is presented in table 3.3.

**Table 3.3 Analysis of variance (ANOVA)**

Sources of variation	Degrees of freedom (df)	Mean sum of squares (MSS)	Expected MSS
Replication	(r-1)	$M_r$	$g\sigma_r^2 + \sigma_e^2$
Between genotypes	(g-1)	$M_g$	$r\sigma_g^2 + \sigma_e^2$
Within genotypes (Error)	(g-1)(r-1)	$M_e$	$\sigma_e^2$
Total	(rg-1)		

Where,

r = number of replications

g = number of treatments (genotypes)

$\sigma_r^2$  = variance due to replications.

$\sigma_g^2$  = variance due to treatments (genotypes)

$\sigma_e^2$  = variance due to error

### 3.4.2 Study of variability parameters in okra genotypes

The variability among the genotypes for traits related to pod yield in okra were estimated as mentioned below.

#### 3.4.2.1 Genotypic variance and phenotypic variance

Phenotypic and genotypic components of variance were estimated by using the formula given by Cochran and Cox (1957).

$$\text{Genotypic variance } (\sigma_g^2) = \frac{\text{MSS due to genotypes} - \text{MSS due to error}}{R}$$

$$\text{Phenotypic variance} = \text{Genotypic variance } (\sigma_g^2) + \text{Error variance } (\sigma_e^2)$$

#### 3.4.2.2 Co-efficient of variability

Both phenotypic and genotypic co-efficient of variability for all characters were estimated using the formula of Burton (1952).

$$\text{Phenotypic Co-efficient of Variability (PCV\%)} = \frac{\sqrt{\text{Phenotypic variance}}}{\text{Grand mean}} \times 100$$

$$\text{Genotypic Co-efficient of Variability (GCV\%)} = \frac{\sqrt{\text{Genotypic variance}}}{\text{Grand mean}} \times 100$$

PCV and GCV were classified into three following categories as suggested by Sivasubramanian and Madhamenon (1973).

Low: Less than 10%

Moderate: 10-20%

High: More than 20%

#### 3.4.2.3 Heritability in broad sense ( $h^2$ )

The broad sense heritability ( $h^2_{bs}$ ) was estimated for all characters as the ratio of genotypic variance to the total of phenotypic variance as suggested by Lush (1949) and Hanson *et al.* (1956).

$$h^2 = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

Heritability estimates in cultivated plants could be placed in the following categories as suggested by Robinson *et al.* (1966).

Low: 0-30%;      Moderate: 30-60%;      High: >60%

#### **3.4.2.4 Genetic advance (GA):**

The expected genetic gain or advance for each character was estimated by using the following method suggested by Johnson *et al.* (1955).

$$GA = h^2_{bs} \times \sigma_p \times K$$

Where,

$h^2_{bs}$  = Heritability estimate in broad sense

$\sigma_p$  = Phenotypic standard deviation of the trait

K = Standard selection differential which is 2.06 at 5 per cent selection intensity.

Genetic advance was classified as high (>20%), moderate (10-20%) and low (<10%).

Further the Genetic advance as per cent of mean was computed by using the following formula

$$GA \text{ as per cent of mean} = \frac{GA}{\text{Grand mean}} \times 100$$

Genetic advance as per cent mean was categorized into following groups as suggested by Johnson *et al.* (1955).

Low - Less than 10%

Moderate -10-20%

High - More than 20%

### 3.4.3 Correlation coefficient analysis

To determine the degree of association of characters with yield and also among the yield components, the correlation coefficients were calculated.

Both genotypic and phenotypic coefficients of correlation between two characters were determined by using the variance and covariance components as suggested by Al-Jibouri *et al.* (1958).

$$r_g(xy) = \frac{\text{Cov}_g(xy)}{\sqrt{\sigma_g^2(x) \cdot \sigma_g^2(y)}}$$

$$r_p(xy) = \frac{\text{Cov}_p(xy)}{\sqrt{\sigma_p^2(x) \cdot \sigma_p^2(y)}}$$

Where,

$r_g(xy)$ ,  $r_p(xy)$  are the genotypic and phenotypic correlation coefficients respectively.

$\text{Cov}_g$ ,  $\text{Cov}_p$  are the genotypic and phenotypic covariance of  $xy$ , respectively.

$\sigma_g^2$  and  $\sigma_p^2$  are the genotypic and phenotypic variance of  $x$  and  $y$ , respectively.

The calculated value of 'r' was compared with table 'r' value with  $n-2$  degrees of freedom at 5% and 1% level of significance, where,  $n$  refers to number of pairs of observation.

Thus, the data obtained from various experimental objectives were subjected to pertinent statistical analysis to draw meaningful inference towards the genetic divergence of various okra genotypes.

### 3.4.4 Path coefficient analysis

Path coefficient analysis was carried out using phenotypic correlation values of yield components on yield as suggested by Wright (1921) and illustrated by Dewey and Lu (1959). Standard path coefficients which are the standardized partial regression coefficients were obtained using statistical software packages called GENRES. These values were obtained by solving the following set of 'p' simultaneous equation using above package.

$$P_{01} + P_{02} r_{12} + \dots + P_{0p} r_{1p} = r_{01}$$

$$P_{01} + P_{12} r_{02} + \dots + P_{0p} r_{2p} = r_{02}$$

$$P_{01} + r_{1p} + P_{02} r_{2p} + \dots + P_{0p} = r_{0p}$$

Where,  $P_{01}, P_{02}, \dots, P_{0p}$  are the direct effects of variables 1, 2, ..., p on the dependent variable 0 and  $r_{12}, r_{13}, \dots, r_{1p}, \dots, r_{p(p+1)}$  are the possible correlation coefficient between various independent variables and  $r_{01}, r_{02}, r_{03}, \dots, r_{0p}$  are the correlation between dependent and independent variables.

The indirect effects of the  $i^{th}$  variable via  $j^{th}$  variable is attained as  $(P_{0j} * r_{ij})$ . The contribution of remaining unknown factor is measured as the residual factor, which is calculated and given below.

$$P^2_{ox} = 1 - (P^2_{01} + 2P_{01}P_{02}r_{12} + 2P_{01}P_{03}r_{13} + \dots + P^2_{02} + 2P_{02}P_{03}r_{13} + \dots + P^2_{0p})$$

$$\text{Residual factor} = \sqrt{P^2_{ox}}$$

Negligible - 0.00 to 0.09;      Low- 0.10 to 0.19;      Moderate 0.20 to 0.29;

High - 0.30 to 1.0;      Very High- >1.00

**Table 3.1 Weekly Meteorological observations during experimental period  
(March, 2012 – July, 2012)**

Month & Date	Rainfall (mm)	Temperature °C		Relative humidity %		Wind Speed (km/hr)	Sunshine hours	Evaporation (mm)
		Max	Min	Max	Min			
March 05-11	0.0	29.7	14.5	74	36	2.7	8.6	4.0
12-18	6.4	28.1	14.5	75	62	3.9	7.7	3.8
19-25	0.0	33.1	16.2	68	37	4.2	9.4	4.5
26-01	0.0	36.6	18.1	59	20	3.5	9.4	5.5
April 02-08	1.3	37.9	21.3	66	24	2.8	8.8	4.6
09-15	10.3	37.0	21.7	67	27	4.8	9.3	5.9
16-22	0.0	38.1	22.4	48	24	5.1	9.6	7.2
23-29	0.0	39.8	23.3	44	17	4.8	10.5	8.9
30-06	0.0	39.0	22.1	48	16	4.2	9.6	7.0
May 07-13	0.0	40.6	26.5	48	23	3.6	9.3	6.8
14-20	0.0	41.6	26.1	42	17	5.9	9.8	8.9
21-27	0.0	43.0	25.9	40	28	4.2	9.6	8.8
28-03	0.0	43.3	25.9	39	20	3.2	8.3	7.6
June 04-10	0.0	41.3	29.7	42	21	5.2	8.2	8.7
11-17	0.0	42.6	30.6	42	22	6.4	8.5	9.7
18-24	69.3	34.3	27.1	79	62	3.1	1.8	5.0
25-01	14.0	40.8	29.5	54	33	7.5	5.0	7.3
July 02-08	83.3	33.4	27.9	81	66	5.8	4.5	5.9
09-15	70.0	33.7	27.4	85	68	4.6	3.3	3.7
16-22	105.2	32.3	26.2	87	73	5.4	2.6	4.4
23-29	43.4	32.1	26.9	89	81	3.8	4.4	3.1
30-05	57.8	32.2	26.5	89	74	3.9	3.5	3.6

**Table 3.2 Name of the genotypes of okra evaluated in the study and their source**

S. No.	Name of the genotype	Source
1	L-9	IIVR- VARANASI
2	L-27	IIVR- VARANASI
3	L-32	IIVR- VARANASI
4	L-73-B	IIVR- VARANASI
5	L-145	IIVR- VARANASI
6	L-146	IIVR- VARANASI
7	L-167	IIVR- VARANASI
8	L-168	IIVR- VARANASI
9	L-193	IIVR- VARANASI
10	L-198	IIVR- VARANASI
11	L-202	IIVR- VARANASI
12	L-210	IIVR- VARANASI
13	L-223	IIVR- VARANASI
14	L-238	IIVR- VARANASI
15	L-326	IIVR- VARANASI
16	L-332	IIVR- VARANASI
17	L-335	IIVR- VARANASI
18	L-337	IIVR- VARANASI
19	L-391	IIVR- VARANASI
20	L-409	IIVR- VARANASI
21	L-435	IIVR- VARANASI
22	L-437	IIVR- VARANASI
23	L-467	IIVR- VARANASI
24	L-1668	IIVR- VARANASI
25	L-1753	IIVR- VARANASI
26	L-1754	IIVR- VARANASI
27	L-93	IIVR- VARANASI
28	Kashi Pragati	IIVR- VARANASI
29	L-1956	IIVR- VARANASI
30	L-1963	IIVR- VARANASI
31	L-1998	IIVR- VARANASI
32	L-1999	IIVR- VARANASI

## **EXPERIMENTAL RESULTS**

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In the present study the data was collected from 32 genotypes of okra on fourteen characters related to vegetative and reproductive parameters emphasizing growth, pod and yield. The data were subjected to biometrical analysis and results obtained are presented below under the following headings:

- 4.1 Analysis of variance
- 4.2 Mean performance of genotypes
- 4.3 Variability, heritability ( $h^2$ ) and genetic advance
- 4.4 Correlation studies
- 4.5 Path coefficient analysis

### **4.1 Analysis of variance**

The results of analysis of variance for 32 genotypes in okra were presented in Table 4.1. Highly significant differences among the genotypes were observed for all the characters indicating presence of sufficient amount of variability in all the characters studied.

Analysis of variance of the 32 genotypes of okra for the fourteen characters *viz.*, days to 1<sup>st</sup> flowering, days to 50% flowering, plant height (cm), number of branches per plant, inter nodal distance (cm), number of nodes per plant, pod length (cm), pod width (cm), average pod weight (g), number of pods per plant, number of seeds per pod, 100 seed weight (g), pod yield per plant (g), pod yield per hectare (q) were carried out.

Mean sum of squares for treatments and error along with degree of freedom were presented in Table 4.1. The 'F' test indicted that the variance due to treatments were highly significant for almost all the characters under study.

## **4.2 Mean performance of genotypes**

The mean values of 14 characters of 32 genotypes of okra have been presented in table 4.2

### **4.2.1 Days to 1<sup>st</sup> flowering**

Earliness in flowering is always considered to be a favourable character with respect to yield and also avoid different biotic and abiotic stresses during crop growth period. Days to 1<sup>st</sup> flowering in different genotypes ranged from 38.00 to 45.00 days. The genotypes L-9 and L-1956 recorded earliest in 1<sup>st</sup> flower production (38.00 days) followed by genotypes L-435, L-1754, L-1963 and L-1999 (39.00 days). Longest days for 1<sup>st</sup> flower production were recorded in genotypes L-193, L-238 and L-1754 (45.00 days). The grand mean recorded for this trait was 42.21 days.

### **4.2.2 Days to 50% flowering**

A general observation is that if less time is taken for 50% flowering, it would be economical such as days to taken for 50% flowering is directly proportional to the pod yield. Early flowering genotypes are presumed to have high yield. Hence, days to taken from sowing to 50% flowering are taken into account for early pod producing genotypes. Days to 50% flowering in different genotypes ranged from 42.00 to 47.00 days. The genotypes L-9 and L-1956 recorded earliest in 50% flower production (42.00 days) followed by genotypes L-167, L-435, L-1668 and L-1999 (43.00 days). Longest days for 50% flower production were recorded in genotypes L-168, L-193, L-202, L-223, L-409, L-467 and L-93 (47.00 days). The grand mean recorded for this trait was 45.25 days.

### **4.2.3 Plant height (cm)**

Plant height of different genotypes ranged from 42.53 cm to 118.27 cm. The genotype L-332 recorded maximum plant heights (118.27 cm) followed by genotype L-326 (107.56 cm). The minimum plant height was recorded in genotype L-335 (42.53 cm) immediately followed by genotype L-223 (43.70 cm). The grand mean recorded for this trait was 72.94 cm.

#### **4.2.4 Number of branches per plant**

Number of branches per plant of different genotypes ranged from 1.26 to 3.60. The genotype L-198 recorded maximum number of branches per plant (3.60) followed by genotype L-193 (3.46). The minimum number of branches per plant was recorded in genotypes L-9, L-238 and L-1753 (1.26) immediately followed by genotype L-391 (1.33). The grand mean recorded for this trait was 2.13.

#### **4.2.5 Inter nodal distance (cm)**

Inter nodal distance of different genotypes ranged from 3.56 to 8.23 cm. The minimum inter nodal distance was recorded in genotype L-335 (3.56 cm) immediately followed by genotype L-73-B (3.60 cm). The genotype L-210 recorded maximum intermodal distances (8.23 cm) followed by genotype L-332 (8.06 cm). The grand mean recorded for this trait was 5.22 cm.

#### **4.2.6 Number of nodes per plant**

Number of nodes per plant of different genotypes ranged from 10.00 to 18.00. The genotype L-1999 recorded maximum number of nodes per plant (18.00) followed by genotype L-1998 (17.00). The minimum number of nodes per plant was recorded in genotype L-223 (10.00). The grand mean recorded for this trait was 13.91.

#### **4.2.7 Pod length (cm)**

The variability for pod length among various genotypes ranged from 11.63 to 19.13 cm. The genotype L-193 recorded minimum pod length of 11.63 cm followed by genotype L-335 (11.90 cm). The genotype L-210 recorded maximum pod length of 19.13 cm immediately followed by genotype L-145 (18.63 cm). The grand mean recorded for this trait was 14.42 cm.

#### **4.2.8 Pod width (cm)**

Pod width of different genotypes ranged from 1.30 to 1.90 cm. The genotype L-1754 recorded minimum pod width of 1.30 cm among other genotypes. The

genotypes L-1963 and L-1999 were recorded maximum pod width of 1.90 cm among other genotypes. The grand mean recorded for this trait was 1.59 cm.

#### **4.2.9 Average pod weight (g)**

Average pod weight of different genotypes ranged from 12.33 g to 21.67 g. The genotype L-198 was recorded maximum pod weight of 21.67 g followed by genotype L-223 (20.53 g). The genotype L-337 was recorded minimum pod weight of 12.33 g immediately followed by genotype L-409 (12.63 g). The grand mean recorded for this trait was 17.17 g.

#### **4.2.10 Number of pods per plant**

Number of pods per plant ranged from 5.00 to 13.00 in different genotypes. The genotype L-1999 recorded maximum number of pods per plant (13.00) followed by genotype L-1998 (11.66). The minimum number of pods per plant was recorded in genotype L-223 (5.00) followed by genotype L-335 and L-391 (7.00). The grand mean recorded for this trait was 9.05.

#### **4.2.11 Number of seeds per pod**

Number of seeds per pod ranged from 46.00 to 78.00 in different genotypes. The genotype Kashi Pragati recorded maximum number of seeds per pod (78.00) followed by genotype L-27 (76.66). The minimum number of seeds per pod was recorded in genotype L-1753 (46.00) followed by genotype L-337 (48.66). The grand mean recorded for this trait was 64.62.

#### **4.2.12 100 Seed weight (g)**

100 seed weight of different genotypes ranged from 3.71 g to 4.32 g. The genotype L-198 recorded maximum 100 seed weight (4.32 g) followed by genotype L-1963 (4.27 g). The lowest 100 seed weight was recorded in genotypes L-1956 (3.71 g) immediately followed by genotype L-146 (3.79 g). The grand mean recorded for this trait was 4.01 g.

#### 4.2.13 Pod yield per plant (g)

Pod yield per plant of different genotypes ranged from 94.20 g to 255.60 g. The genotype L-1999 recorded maximum pod yield per plant (255.60 g) followed by genotype L-1998 (228.06 g). The minimum pod yield per plant was recorded in genotype L-335 (94.20 g) immediately followed by genotype L-1753 (96.66 g). The grand mean recorded for this trait was 154.99 g.

#### 4.2.14 Pod yield per hectare (q)

Pod yield per hectare of different genotypes ranged from 47.10 q to 127.80 q. The genotype L-1999 recorded maximum pod yield per hectare (127.80 q) followed by genotype L-1998 (114.03 q). The minimum pod yield per hectare was recorded in genotype L-335 (47.10 q) followed by genotype L-1753 (48.33 q). The grand mean recorded for this trait was 77.49 q.

### 4.3 Variability, heritability ( $h^2$ ) and genetic advance

The results pertaining to grand mean, range, phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability in broad sense ( $h^2$ ) and expected genetic advance as per cent of mean (GA) for all the fourteen characters are furnished in Table 4.3 . The character wise details of these variability parameters are presented below

#### 4.3.1 Days to 1<sup>st</sup> flowering

Days to 1<sup>st</sup> flowering in different genotypes ranged from 38.00 to 45.00 days. The grand mean recorded for this trait was 42.21 days. It showed low PCV and GCV of 5.32 and 4.81 per cent, respectively. High estimates of heritability (81.57%), low genetic advance (3.77) and low GA as per cent of mean (8.95) were observed for this character.

#### **4.3.2 Days to 50% flowering**

Days to 50% flowering in different genotypes ranged from 42.00 to 47.00 days. The grand mean recorded for this trait was 45.25 days. It also recorded low estimates of PCV (3.82%), GCV (3.11%) and high heritability (66.20%), low genetic advance (2.36) and low GA as per cent of mean (5.21) were observed for this character.

#### **4.3.3 Plant height (cm)**

Plant height of different genotypes ranged from 42.53 cm to 118.27 cm. The grand mean recorded for this trait was 72.94 cm. It also recorded high PCV (26.26%), GCV (27.64%), heritability (90.21%), genetic advance (37.48) and high GA as per cent of mean (51.37%) was recorded.

#### **4.3.4 Number of branches per plant**

Number of branches per plant of different genotypes ranged from 1.26 to 3.60. The grand mean recorded for this trait was 2.13. It also showed high PCV (34.05%), GCV (30.53%) and high heritability (80.38%), low genetic advance (1.20) and high GA as per cent of mean (56.38) were recorded for this character.

#### **4.3.5 Inter nodal distance (cm)**

Inter nodal distance of different genotypes ranged from 3.56 to 8.23 cm. The grand mean recorded for this trait was 5.22 cm. It also showed high PCV (23.98%), GCV (23.00%) and high heritability (92.02%), low genetic advance (2.34) and high GA as per cent of means (45.46) was observed for this character

#### **4.3.6 Number of nodes per plant**

Number of nodes per plant of different genotypes ranged from 10.00 to 18.00. The grand mean recorded for this trait was 13.91. It also had moderate PCV (12.71%) and low GCV (9.98%), high heritability (61.61%), low genetic advance (2.24%) and moderate GA as percent of mean (16.13) were observed for this character.

#### **4.3.7 Pod length (cm)**

The variability for pod length among various genotypes ranged from 11.63 to 19.13 cm. The grand mean recorded for this trait was 14.42 cm. It also showed moderate PCV (11.77%), GCV (11.31%) and high heritability (92.27%), low genetic advance (3.22) and high GA as per cent of mean (22.39) recorded for this trait.

#### **4.3.8 Pod width (cm)**

Pod width of different genotypes ranged from 1.30 to 1.90 cm. The grand mean recorded for this trait was 1.59 cm. It also showed moderate PCV (10.62%) and low GCV (8.01%), moderate heritability (56.92%), low genetic advance (0.19) and moderate GA as per cent of mean (12.45) were recorded for this character.

#### **4.3.9 Average pod weight (g)**

Average pod weight of different genotypes ranged from 12.33 g to 21.67 g. The grand mean recorded for this trait was 17.17 g. It also recorded moderate PCV (17.54%), GCV (14.57%) and high heritability (69.07%), low genetic advance (4.28) and high GA as per cent of means (24.95) was recorded for this trait.

#### **4.3.10 Number of pods per plant**

Number of pods per plant ranged from 5.00 to 13.00 in different genotypes. The grand mean recorded for this trait was 9.05. It also recorded high PCV (20.55%), moderate GCV (15.29%) and moderate heritability (55.36%), low genetic advance (2.12) and high GA as per cent of mean (23.43).

#### **4.3.11 Number of seeds per pod**

Number of seeds per pod ranged from 46.00 to 78.00 in different genotypes. The grand mean recorded for this trait was 64.62. It also showed moderate PCV (13.17%), GCV (12.77%) and high heritability (94.09%), moderate genetic advance (16.50) and high GA as per cent of mean (25.53).

#### **4.3.12 100 Seed weight (g)**

100 seed weight of different genotypes ranged from 3.71 g to 4.32 g. The grand mean recorded for this trait was 4.01 g. It also recorded low PCV (5.03%), GCV (3.18%) and moderate heritability (39.95%), low genetic advance (0.16) and low GA as per cent of mean (4.14).

#### **4.3.13 Pod yield per plant (g)**

Pod yield per plant of different genotypes ranged from 94.20 g to 255.60 g. The grand mean recorded for this trait was 154.99 g. It also recorded high estimates of PCV (26.55%), GCV (26.06%), heritability (96.37%), genetic advance (81.70) and GA as per cent of mean (52.71).

#### **4.3.14 Pod yield per hectare (q)**

Pod yield per hectare of different genotypes ranged from 47.10 q to 127.80 q. The grand mean recorded for this trait was 77.49 q. It also recorded high estimates of PCV (26.55%), GCV (26.06%), heritability (96.37%), genetic advance (40.83) and GA as per cent of mean (52.71).

### **4.4 Correlation studies**

Genotypic (G) and phenotypic (P) correlation coefficients were worked out for fourteen characters in 32 okra genotypes and the data have been presented in Table 4.4 and 4.5 respectively. It was observed that genotypic correlation coefficients were higher than that of phenotypic correlation coefficients. Analysis of phenotypic and genotypic coefficient of correlation studies for various characters was given below.

#### **4.4.1 Genotypic correlation coefficient**

The genotypic correlation coefficient was significant and positive for days to 1<sup>st</sup> flowering with days to 50% flowering (0.906). Whereas, it showed negative significant genotypic correlation with pod width (-0.463), average pod weight (-0.502), number of pods per plant (-0.367), pod yield per plant (-0.490) and pod yield

per hectare (-0.499). Days to 50% flowering recorded negative and significant genotypic correlation with number of nodes per plant (-0.430), pod width (-0.443), number of pods per plant (-0.551), pod yield per plant (-0.521) and pod yield per hectare (-0.521). Plant height showed significant and positive genotypic correlation with inter nodal distance (0.944), number of nodes per plant (0.539), pod length (0.618), average pod weight (0.413), number of pods per plant (0.500), pod yield per plant (0.523) and pod yield per hectare (0.523). Inter nodal distance recorded positive significant genotypic correlation with pod length (0.688). Number of nodes per plant recorded significant and positive genotypic correlation with average pod weight (0.380), number of pods per plant (0.999), pod yield per plant (0.849) and pod yield per hectare (0.849). Pod length showed positive and significant genotypic correlation with average pod weight (0.677), 100 seed weight (0.469), pod yield per plant (0.376) and pod yield per hectare (0.376). Pod width recorded positive and significant genotypic correlation with average pod weight (0.590), number of pods per plant (0.435), pod yield per plant (0.598) and pod yield per hectare (0.598). Average pod weight showed significant and positive genotypic correlation with number of pods per plant (0.467), 100 seed weight (0.420), pod yield per plant (0.808) and pod yield per hectare (0.808). Number of pods per plant recorded positive significant genotypic correlation with pod yield per plant (0.896) and pod yield per hectare (0.896).

#### 4.4.2 Phenotypic correlation coefficient

Days to 1<sup>st</sup> flowering showed significant and positive phenotypic correlation with days 50% flowering (0.638). Whereas, it showed negative significant phenotypic correlation with pod yield per plant (-0.441) and pod yield per hectare (-0.441). Days 50% flowering recorded negative significant phenotypic correlation with pod yield per plant (-0.412) and pod yield per hectare (-0.412). Plant height recorded significant and positive phenotypic correlation with inter nodal distance (0.902), pod length (0.577), number of nodes per plant (0.530), pod yield per plant (0.506), pod yield per hectare (0.506) and number of pods per plant (0.444). Inter nodal distance recorded positive significant phenotypic correlation with pod length (0.627). Number of nodes per plant showed positive and significant phenotypic correlation with number of pods per plant (0.866), pod yield per plant (0.727) and pod yield per hectare (0.727). Pod

length showed positive and significant phenotypic correlation with average pod weight (0.482), pod yield per plant (0.370) and pod yield per hectare (0.370). Pod width showed significant and positive phenotypic correlation coefficient with average pod weight (0.473), pod yield per plant (0.416) and pod yield per hectare (0.416). Average pod weight recorded positive significant phenotypic correlation with pod yield per plant (0.588) and pod yield per hectare (0.588). Number of pods per plant recorded positive significant phenotypic correlation with pod yield per plant (0.761) and pod yield per hectare (0.761).

#### **4.5 Path Coefficient Analysis**

##### **Path coefficient analysis for pod yield and its associated traits**

Genotypic and phenotypic path was worked out considering pod yield per plant as dependent character and its attributes as independent characters *viz*, days to 1<sup>st</sup> flowering, days to 50% flowering, plant height (cm), number of branches per plant, inter nodal distance (cm), number of nodes per plant, pod length (cm), pod width (cm), average pod weight (g), number of pods per plant, number of seeds per pod, 100 seed weight (g), pod yield per plant (g), pod yield per hectare (q) Each component has two path actions *viz*, direct effect on yield and indirect effect through components which are not revealed by correlation studies.

##### **4.5.1 Genotypic path analysis**

Genotypic path was worked out for fourteen characters in 32 okra genotypes and the results has been presented in Table 4.6

##### **4.5.1.1 Days to 1<sup>st</sup> flowering**

Days to 1<sup>st</sup> flowering showed negative direct effect (-0.180) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, number of nodes per plant (0.132), days to 50% flowering (0.068), number of pods per plant (0.042) inter nodal distance (0.014) and number of branches per plant (0.010). However, it was recorded negative indirect effect towards pod yield per plant

*via*, plant height (-0.368), pod width (-0.099), pod length (-0.044) and number of seeds per pod (-0.041).

#### **4.5.1.2 Days to 50% flowering**

Days to 50% flowering recorded positive direct effect (0.075) towards pod yield per plant. Further, it recorded positive indirect effect towards pod yield per plant *via*, number of nodes per plant (0.175), number of pods per plant (0.063) and number of branches per plant (0.021). However, it was recorded negative indirect effect towards pod yield per plant *via*, plant height (-0.495), days to 1<sup>st</sup> flowering (-0.163), pod width (-0.095), number of seeds per pod (-0.048), inter nodal distance (-0.026) and average pod weight (-0.021).

#### **4.5.1.3 Plant Height (cm)**

Plant height recorded positive direct effect (3.766) towards pod yield per plant. Further, it exhibited positive indirect effect towards pod yield per plant *via*, pod length (0.221), number of seeds per pod (0.035), average pod weight (0.026), days to 1<sup>st</sup> flowering (0.017), number of branches per plant (0.015) and 100 seed weight (0.011). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-3.278), number of nodes per plant (-0.220), number of pods per plant (-0.058) and days to 50% flowering (-0.010).

#### **4.5.1.4 Number of branches per plant**

Number of branches per plant recorded positive direct effects (0.117) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (0.493), pod width (0.018), average pod weight (0.013), days to 50% flowering (0.013) and pod length (0.013). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.365), number of nodes per plant (-0.060), number of pods per plant (-0.019), days to 1<sup>st</sup> flowering (-0.016) and number of seeds per pod (-0.014).

#### 4.5.1.5 Inter nodal distance (cm)

Inter nodal distance recorded negative direct effect (-3.472) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (3.555), pod length (0.246), number of seeds per pod (0.045), average pod weight (0.021), number of branches per plant (0.012) and 100 seed weight (0.010). However, it was recorded negative indirect effect towards pod yield per plant *via*, number of nodes per plant (-0.095), pod width (-0.028) and number of pods per plant (-0.022).

#### 4.5.1.6 Number of nodes per plant

Number of nodes per plant recorded negative direct effect (-0.408) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (2.029), days to 1<sup>st</sup> flowering (0.058), pod width (0.055), pod length (0.033), average pod weight (0.024) and number of branches per plant (0.017). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.810), number of pods per plant (-0.115) and days to 50% flowering (-0.032).

#### 4.5.1.7 Pod length (cm)

Pod length recorded positive direct effect (0.358) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (2.326), average pod weight (0.043), number of seeds per pod (0.029), days to 1<sup>st</sup> flowering (0.022), pod width (0.014) and 100 seed weight (0.014). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-2.391) and number of nodes per plant (-0.038).

#### 4.5.1.8 Pod width (cm)

Pod width recorded positive direct effect (0.213) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, inter nodal distance (0.452), days to 1<sup>st</sup> flowering (0.083), number of seeds per pod

(0.039), average pod weight (0.038), pod length (0.024) and number of branches per plant (0.010). However, it was recorded negative indirect effect towards pod yield per plant *via*, number of nodes per plant (-0.105), plant height (-0.075), number of pods per plant (-0.050) and days to 50% flowering (-0.033).

#### **4.5.1.9 Average pod weight (g)**

Average pod weight recorded positive direct effect (0.064) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (1.557), pod length (0.242), pod width (0.126), days to 1<sup>st</sup> flowering (0.090), number of seeds per pod (0.066), number of branches per plant (0.024) and 100 seed weight (0.013). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-1.142), number of nodes per plant (-0.155), number of pods per plant (-0.054) and days to 50% flowering (-0.024).

#### **4.5.1.10 Number of pods per plant**

Number of pods per plant recorded negative direct effect (-0.115) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (1.884), pod width (0.093), days to 1<sup>st</sup> flowering (0.066), average pod weight (0.030), number of branches per plant (0.019), pod length (0.017) and number of seeds per pod (0.017). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.672), number of nodes per plant (-0.407) and days to 50% flowering (-0.041).

#### **4.5.1.11 Number of seeds per pod**

Number of seeds per pod recorded positive direct effect (0.207) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (0.634), pod length (0.050), pod width (0.041), days to 1<sup>st</sup> flowering (0.035), average pod weight (0.020) and number of nodes per plant (0.017). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.756) and days to 50% flowering (-0.017).

#### **4.5.1.12 100 Seed weight (g)**

100 seed weight recorded positive direct effect (0.032) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (1.312), pod length (0.168), average pod weight (0.027) and number of branches per plant (0.022). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-1.132) and number of nodes per plant (-0.082)

#### **4.5.2 Phenotypic path analysis**

Phenotypic path was worked out for fourteen characters in 32 okra genotypes and the results has been presented in Table 4.7

##### **4.5.2.1 Days to 1<sup>st</sup> flowering**

Days to 1<sup>st</sup> flowering recorded positive direct effect (0.001) towards pod yield per plant. Further, it was recorded negative indirect effect towards pod yield per plant *via*, average pod weight (-0.204), number of pods per plant (-0.193), days to 50% flowering (-0.015) and plant height (-0.011).

##### **4.5.2.2 Days to 50% flowering**

Days to 50% flowering recorded negative direct effect (-0.024) towards pod yield per plant. Further, it was recorded negative indirect effect towards pod yield per plant *via*, number of pods per plant (-0.211) and average pod weight (-0.148).

##### **4.5.2.3 Plant height (cm)**

Plant height recorded positive direct effect (0.128) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, number of pods per plant (0.317), number of nodes per plant (0.017) and average pod weight (0.160). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.119).

#### 4.5.2.4 Number of branches per plant

Number of branches per plant recorded negative direct effect (-0.014) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, number of pods per plant (0.107), average pod weight (0.075) and plant height (0.015). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.012).

#### 4.5.2.5 Inter nodal distance (cm):

Inter nodal distance recorded negative direct effect (-0.132) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, average pod weight (0.190), plant height (0.115) and no. pods per plant (0.061).

#### 4.5.2.6 Number of nodes per plant

Number of nodes per plant recorded positive direct effect (0.032) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, no. pods per plant (0.618), plant height (0.068) and average pod weight (0.018). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.016).

#### 4.5.2.7 Pod length (cm)

Pod length recorded negative direct effect (-0.001) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, average pod weight (0.297), plant height (0.074), number of pods per plant (0.072) and 100 seed weight (0.010). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.083).

#### 4.5.2.8 Pod width (cm)

Pod width recorded positive direct effect (0.026) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, average pod weight (0.291) and number of pods per plant (0.088).

#### **4.5.2.9 Average pod weight (g)**

Average pod weight recorded positive direct effect (0.615) on pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (0.033) and pod width (0.012). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.041) and number of pods per plant (-0.042).

#### **4.5.2.10 Number of pods per plant**

Number of pods per plant recorded positive direct effect (0.713) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, plant height (0.057) and number of nodes per plant (0.028). However, it was recorded negative indirect effect towards pod yield per plant *via*, average pod weight (-0.036) and inter nodal distance (-0.011).

#### **4.5.2.11 Number of seeds per pod**

Number of seeds per pod recorded negative direct effect (-0.001) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, average pod weight (0.133), number of pods per plant (0.074) and plant height (0.021). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.026).

#### **4.5.2.12 100 Seed weight (g)**

100 seed weight recorded positive direct effect (0.031) towards pod yield per plant. Further, it was recorded positive indirect effect towards pod yield per plant *via*, average pod weight (0.133), number of pods per plant (0.053) and plant height (0.018). However, it was recorded negative indirect effect towards pod yield per plant *via*, inter nodal distance (-0.021).

**Table 4.1 Analysis of variance for 14 characters of 32 genotypes of okra**

Parameter	d.f.	MSS													
		Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	No. of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Pod yield per plant (g)	Pod yield per hectare (q)
<b>Replication</b>	2	3.12	0.59	72.39	0.13	0.39	0.07	0.05	0.00	15.73	5.44	9.59	1.86	119.00	29.75
<b>Genotype</b>	31	13.30**	6.96**	1140.7**	1.38**	4.45**	6.98**	8.20**	0.06**	21.59**	7.29**	208.89**	0.07**	4958.3**	1239.59**
<b>Error</b>	62	0.93	1.01	39.81	0.10	0.12	1.20	0.22	0.01	2.80	1.54	4.28	0.02	61.38	15.34
<b>CV (%)</b>	-	2.28	2.22	8.65	15.08	6.77	7.87	3.27	6.97	9.75	13.73	3.20	3.90	5.05	5.05

\*and \*\* Significant at 5% and 1% levels, respectively.

**Table 4.2 Mean performance for 14 characters of 32 genotypes of okra.**

S. No.	Genotype	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	No. of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Pod yield per plant (g)	Pod yield per hectare (q)
1	L-9	38.00	42.00	61.73	1.26	4.13	15.00	12.73	1.70	19.46	10.00	67.00	4.09	193.63	96.81
2	L-27	41.00	45.00	77.70	1.80	5.56	14.00	14.43	1.60	18.36	9.33	76.66	4.03	169.70	84.85
3	L-32	40.00	45.00	89.93	2.06	6.00	15.00	15.00	1.60	19.56	9.00	57.67	4.07	175.10	87.55
4	L-73-B	42.00	46.00	50.26	1.73	3.60	14.00	13.76	1.70	18.40	10.00	77.00	3.98	182.66	91.33
5	L-145	42.00	46.00	80.73	1.86	5.40	15.00	18.63	1.50	19.20	10.00	63.33	4.19	191.36	95.68
6	L-146	42.00	45.00	88.43	1.53	5.90	15.00	14.36	1.60	19.00	10.67	72.67	3.79	199.00	99.50
7	L-167	43.00	43.00	91.33	2.53	6.10	15.00	15.30	1.70	18.50	10.67	76.33	4.20	195.16	97.58
8	L-168	44.00	47.00	69.00	2.53	5.30	13.00	14.06	1.40	13.10	8.00	66.33	4.11	104.16	52.08
9	L-193	45.00	47.00	76.46	3.46	5.46	14.00	11.63	1.60	15.73	9.33	67.00	3.80	147.93	73.96
10	L-198	43.00	46.00	64.86	3.60	5.00	13.00	15.83	1.60	21.67	8.66	68.66	4.32	184.66	92.33
11	L-202	44.00	47.00	92.50	3.33	6.63	14.00	15.66	1.70	18.96	9.33	52.00	4.01	174.96	87.48
12	L-210	41.00	45.00	106.86	1.60	8.23	13.00	19.13	1.60	19.83	8.00	65.00	4.03	157.33	78.66
13	L-223	44.00	47.00	43.70	1.86	4.36	10.00	15.40	1.80	20.53	5.00	67.33	3.81	101.16	50.58
14	L-238	45.00	45.00	64.53	1.26	4.96	13.00	13.66	1.40	14.13	8.00	56.33	4.05	112.36	56.18
15	L-326	42.00	46.00	107.56	2.00	7.70	14.00	15.63	1.50	18.40	8.33	65.33	4.17	151.13	75.56
16	L-332	43.00	46.00	118.26	1.80	8.06	14.66	16.03	1.46	15.73	10.00	75.33	4.04	156.26	78.13
17	L-335	44.00	46.00	42.53	1.73	3.56	12.00	11.90	1.66	13.53	7.00	56.66	3.81	94.20	47.10
18	L-337	43.00	46.00	58.73	2.20	3.90	15.00	12.26	1.50	12.33	10.67	48.67	4.03	130.06	65.03
19	L-391	41.00	45.00	44.90	1.33	3.73	12.00	12.53	1.63	14.86	7.00	70.00	3.87	103.63	51.81

Contd...

S. No.	Genotype	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	No. of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Pod yield per plant (g)	Pod yield per hectare (q)
20	L-409	43.00	47.00	57.36	2.00	4.40	13.00	12.70	1.60	12.63	8.33	66.00	3.89	103.83	51.91
21	L-435	39.00	43.00	76.86	2.73	5.46	14.00	14.76	1.50	16.96	8.66	55.33	3.97	143.40	71.70
22	L-437	40.00	44.00	61.33	1.40	5.13	12.00	13.93	1.50	18.33	7.66	68.00	4.25	137.93	68.96
23	L-467	44.00	47.00	70.66	3.06	5.20	13.66	15.13	1.40	18.26	8.00	63.33	3.90	145.10	72.55
24	L-1668	41.00	43.00	81.60	2.53	5.83	14.00	13.66	1.60	14.66	10.00	68.00	3.81	145.96	72.98
25	L-1753	44.00	46.00	44.36	1.26	3.70	12.00	13.73	1.53	13.40	7.33	46.00	3.94	96.66	48.33
26	L-1754	45.00	46.00	61.66	2.33	4.40	14.00	13.66	1.30	14.16	9.00	64.67	4.15	127.00	63.50
27	L-93	44.00	47.00	59.06	2.33	4.10	14.33	12.80	1.40	14.23	8.00	60.33	3.90	112.76	56.38
28	Kashi Pragati	44.00	45.00	82.66	1.40	5.93	14.00	14.93	1.70	17.20	9.00	78.00	4.00	153.96	76.98
29	L-1956	38.00	42.00	66.13	2.06	4.23	15.66	13.96	1.70	18.86	11.00	66.33	3.71	206.86	103.43
30	L-1963	39.00	44.00	62.33	3.33	4.76	13.00	14.56	1.90	19.90	9.00	67.00	4.27	178.13	89.06
31	L-1998	44.00	46.00	93.73	1.80	5.53	17.00	14.60	1.76	19.73	11.67	50.00	4.19	228.06	114.03
32	L-1999	39.00	43.00	86.50	2.60	4.80	18.00	14.96	1.90	19.73	13.00	65.66	4.00	255.6	127.8
*	<b>Grand Mean</b>	42.21	45.25	72.94	2.13	5.22	13.91	14.42	1.59	17.17	9.05	64.62	4.01	154.99	77.49
*	<b>SE. m ±</b>	0.55	0.58	3.64	0.18	0.20	0.63	0.27	0.06	0.96	0.71	1.19	0.09	4.52	2.26
*	<b>CD (P=0.05)</b>	1.27	1.34	8.42	0.42	0.46	1.46	0.62	0.14	2.22	1.64	2.75	0.21	10.46	5.23
*	<b>CD (P=0.01)</b>	1.57	1.64	10.32	0.52	0.57	1.79	0.77	0.18	2.70	2.03	3.38	0.25	12.82	6.41

**Table 4.3** Range, grand mean, phenotypic and genotypic coefficient of variation (PCV and GCV), heritability ( $h^2$ ), genetic advance (GA) and GA as per cent of mean for 14 characters of 32 genotypes of okra.

Character	Range	Grand mean	PCV	GCV	Heritability (%)	Genetic Advance	GA as % of mean
Days to 1 <sup>st</sup> flowering	38.00-45.00	42.21	5.32	4.81	81.57	3.77	8.95
Days to 50% flowering	42.00-47.00	45.25	3.82	3.11	66.20	2.36	5.21
Plant height (cm)	42.53-118.27	72.94	27.64	26.26	90.21	37.48	51.37
Number of branches per plant	1.26-3.60	2.13	34.05	30.53	80.38	1.20	56.38
Inter nodal distance (cm)	3.56-8.23	5.22	23.98	23.00	92.02	2.37	45.46
No. of nodes per plant	10.00-18.00	13.91	12.71	9.98	61.61	2.24	16.13
Pod length (cm)	11.63-19.13	14.42	11.77	11.31	92.27	3.22	22.39
Pod width (cm)	1.30-1.90	1.59	10.62	8.01	56.92	0.19	12.45
Average Pod weight (g)	12.33-21.67	17.17	17.54	14.57	69.07	4.28	24.95
Number of pods per plant	5.00-13.00	9.05	20.55	15.29	55.36	2.12	23.43
Number of seeds per pod	46.00-78.00	64.62	13.17	12.77	94.09	16.50	25.53
100 seed weight (g)	3.71-4.32	4.01	5.03	3.18	39.95	0.16	4.14
Pod yield per plant (g)	94.20-255.60	154.99	26.55	26.06	96.37	81.70	52.71
Pod yield per hectare (q)	47.10-127.80	77.49	26.55	26.06	96.37	40.85	52.71

**Table 4.4 Genotypic (G) correlation among yield and yield attributes for 14 characters in 32 genotypes of okra.**

Character	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	Number of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Pod yield per plant (g)	Pod yield per hectare (q)
Days to 1 <sup>st</sup> flowering	—	0.906**	-0.098	0.087	-0.004	-0.324	-0.125	-0.463**	-0.502**	-0.367*	-0.198	-0.040	-0.499**	-0.499**
Days to 50% flowering		—	-0.132	0.180	0.008	-0.430*	-0.015	-0.443*	-0.328	-0.551**	-0.232	-0.050	-0.521**	-0.521**
Plant height (cm)			—	0.131	0.944**	0.539**	0.618**	-0.020	0.413*	0.500**	0.168	0.348	0.523**	0.523**
Number of branches per plant				—	0.105	0.147	0.036	0.086	0.211	0.162	-0.069	0.190	0.201	0.201
Inter nodal distance (cm)					—	0.233	0.688**	-0.130	0.329	0.194	0.218	0.326	0.274	0.274
No. of nodes per plant						—	0.093	0.258	0.380*	0.999**	-0.042	0.200	0.849**	0.849**
Pod length (cm)							—	0.068	0.677**	0.048	0.140	0.469**	0.376*	0.376*
Pod width (cm)								—	0.590**	0.435*	0.190	0.021	0.598**	0.598**
Average pod weight (g)									—	0.467**	0.318	0.420*	0.808**	0.808**
Number of pods per plant										—	0.081	0.202	0.896**	0.896**
Number of seeds per pod											—	-0.006	0.214	0.214
100 seed weight (g)												—	0.331	0.331
Pod yield per plant (g)													—	1.000**

\*and \*\* Significant at 5% and 1% levels, respectively.

**Table 4.5 Phenotypic (P) correlation among yield and yield attributes for 14 characters in 32 genotypes of okra.**

Character	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	Number of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Pod yield per plant (g)	Pod yield per hectare (q)
Days to 1 <sup>st</sup> flowering	—	0.638**	-0.084	0.066	0.003	-0.232	-0.108	-0.335	-0.332	-0.271	-0.168	-0.063	-0.441*	-0.441*
Days to 50% flowering		—	-0.083	0.114	0.016	-0.261	0.008	-0.258	-0.240	-0.296	-0.175	-0.024	-0.412*	-0.412*
Plant height (cm)			—	0.118	0.902**	0.530**	0.577**	0.004	0.259	0.444*	0.166	0.141	0.506**	0.506**
Number of branches per plant				—	0.090	0.101	0.056	0.078	0.122	0.150	-0.033	0.085	0.177	0.177
Inter nodal distance (cm)					—	0.121	0.627**	-0.052	0.309	0.085	0.196	0.158	0.239	0.239
No. of nodes per plant						—	0.112	0.082	0.029	0.866**	0.002	0.035	0.727**	0.727**
Pod length (cm)							—	0.014	0.482**	0.100	0.126	0.316	0.370*	0.370*
Pod width (cm)								—	0.473**	0.124	0.134	-0.138	0.416*	0.416*
Average pod weight (g)									—	-0.059	0.217	0.216	0.588**	0.588**
Number of pods per plant										—	0.104	0.074	0.761**	0.761**
Number of seeds per pod											—	0.012	0.209	0.209
100 seed weight (g)												—	0.210	0.210
Pod yield per plant (g)													—	1.000**

\*and \*\* Significant at 5% and 1% levels, respectively.

**Table 4.6 Direct and indirect effects of genotypic (G) path coefficient for 14 characters of 32 genotypes of okra.**

Character	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	Number of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Correlation values for pod yield (g per plant)
Days to 1 <sup>st</sup> flowering	<b>-0.180</b>	0.068	-0.368	0.010	0.014	0.132	-0.044	-0.099	-0.032	0.042	-0.041	-0.001	-0.499**
Days to 50% flowering	-0.163	<b>0.075</b>	-0.495	0.021	-0.026	0.175	-0.005	-0.095	-0.021	0.063	-0.048	-0.001	-0.521**
Plant height (cm)	0.017	-0.010	<b>3.766</b>	0.015	-3.278	-0.220	0.220	-0.004	0.026	-0.058	0.035	0.011	0.523**
Number of branches per plant	-0.016	0.013	0.493	<b>0.117</b>	-0.365	-0.060	0.013	0.019	0.013	-0.019	-0.014	0.006	0.201
Inter nodal distance (cm)	0.001	0.000	3.555	0.012	<b>-3.472</b>	-0.095	0.246	-0.028	0.021	-0.022	0.045	0.010	0.274
No. of nodes per plant	0.05	-0.032	2.029	0.017	-0.810	<b>-0.408</b>	0.033	0.055	0.024	-0.115	-0.008	0.006	0.849**
Pod length (cm)	0.022	-0.001	2.326	0.004	-2.391	-0.038	<b>0.358</b>	0.014	0.043	-0.005	0.029	0.015	0.376*
Pod width (cm)	0.083	-0.033	-0.075	0.010	0.452	-0.105	0.024	<b>0.213</b>	0.038	-0.050	0.039	0.001	0.598**
Average pod weight (g)	0.090	-0.024	1.557	0.024	-1.142	-0.155	0.242	0.126	<b>0.064</b>	-0.054	0.066	0.013	0.808**
Number of pods per plant	0.066	-0.041	1.884	0.019	-0.672	-0.407	0.017	0.093	0.030	<b>-0.115</b>	0.017	0.006	0.896**
Number of seeds per pod	0.035	-0.017	0.634	-0.008	-0.756	0.017	0.045	0.041	0.020	-0.009	<b>0.207</b>	-0.000	0.214
100 seed weight (g)	0.007	-0.004	1.312	0.022	-1.132	-0.081	0.168	0.004	0.027	-0.023	-0.001	<b>0.031</b>	0.331

**Residual Effect: 0.01118;** diagonal values indicates direct effects; values above and below diagonal indicates indirect effects.

**Table 4.7 Direct and indirect effects of phenotypic (P) path coefficient for 14 characters of 32 genotypes of okra.**

Character	Days to 1 <sup>st</sup> flowering	Days to 50% flowering	Plant height (cm)	Number of branches per plant	Inter nodal distance (cm)	Number of nodes per plant	Pod length (cm)	Pod width (cm)	Average pod weight (g)	Number of pods per plant	Number of seeds per pod	100 seed weight (g)	Correlation values for pod yield (g per plant)
Days to 1 <sup>st</sup> flowering	<b>0.001</b>	-0.015	-0.011	-0.001	-0.000	-0.007	0.000	-0.009	-0.204	-0.193	0.000	-0.002	-0.441*
Days to 50% flowering	0.001	<b>-0.024</b>	-0.010	-0.002	-0.002	-0.008	-0.000	-0.007	-0.148	-0.211	0.000	-0.001	-0.412*
Plant height (cm)	-0.000	0.002	<b>0.128</b>	-0.002	-0.119	0.017	-0.001	0.000	0.160	0.317	-0.000	0.004	0.506**
Number of branches per plant	0.000	-0.002	0.015	<b>-0.014</b>	-0.012	0.003	-0.000	0.002	0.075	0.107	0.000	0.003	0.177
Inter nodal distance (cm)	0.000	-0.000	0.115	-0.001	<b>-0.132</b>	0.004	-0.000	-0.001	0.190	0.061	-0.000	0.005	0.239
No. of nodes per plant	-0.000	0.006	0.068	-0.001	-0.016	<b>0.032</b>	-0.000	0.002	0.018	0.618	0.000	0.001	0.727**
Pod length (cm)	-0.000	-0.000	0.074	-0.001	-0.083	0.004	<b>-0.001</b>	0.000	0.297	0.072	-0.000	0.010	0.370*
Pod width (cm)	-0.000	0.006	0.000	-0.001	0.007	0.003	-0.000	<b>0.026</b>	0.291	0.089	-0.000	-0.004	0.416*
Average pod weight (g)	-0.000	0.006	0.033	-0.002	-0.041	0.001	-0.001	0.012	<b>0.615</b>	-0.042	-0.000	0.007	0.588**
Number of pods per plant	-0.000	0.007	0.057	-0.002	-0.011	0.028	-0.000	0.003	-0.036	<b>0.713</b>	-0.000	0.002	0.761**
Number of seeds per pod	-0.000	0.004	0.021	0.000	-0.026	0.000	-0.000	0.003	0.133	0.074	<b>-0.001</b>	0.000	0.209
100 seed weight (g)	-0.000	0.000	0.018	-0.001	-0.021	0.001	-0.000	-0.003	0.132	0.053	-0.000	<b>0.031</b>	0.210

**Residual Effect: 0.01501**; diagonal values indicates direct effects; values above and below diagonal indicates indirect effects.

## DISCUSSION

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Okra [*Abelmoschus esculentus* (L.) Moench,] is an annual vegetable crop grown extensively throughout India. Due to its high adaptability it can be cultivated under a wide range of environmental conditions. Further, it is also a crop of significant nutritional as well as medicinal value. Germplasm collection, maintenance and evaluation for economically important traits are a prerequisite for genetic improvement of any crop. Since okra occupies a unique position among vegetable growers due to higher yield per plant and maximum net returns, it is necessary to carrying the investigation on genetic variability present in germplasm for further improvement.

Yield being an important and complex character, is a function of several component characters and their interaction with environment. In the integrated structure of a plant, most of the characters are inter-related and often change in one character will influence the other. Hence, direct selection based on yield alone will not be very effective.

Grafius (1964) pointed out that it would be more meaningful if the structure of yield is probed through its components rather than *per se* yield. For improving yield through breeding, it is necessary to study these components and their inter relationships with yield. The phenotypic and genotypic correlations reveal the extent of association between different characters. Thus, it helps to base selection procedure to a required balance, when two opposite desirable characters affecting the principal characters are being selected. It also helps to improve different characters simultaneously (Falconer, 1981). As a preliminary step of heterosis breeding, it is desirable to investigate nature and degree of genetic variance in a population of different crops.

## 5.1 MEAN PERFORMANCE

The range of mean values could present a rough estimate about the variation in magnitude of variability present among genotypes. The characters showing high range of variation have more scope for improvement. All the fourteen characters under study exhibited high variability as evident from the ranges of mean values. Out of the fourteen characters under study, plant height, number of branches per plant and number of nodes per plant are considered as growth attributing characters. Days to 1<sup>st</sup> flowering and days to 50% flowering is regarded as earliness attributes. Pods per plant, pod length, pod width and average pod weight, number of seeds per pod and 100 seed weight are considered as reproductive traits. Yield per plant and yield per hectare are the economic traits.

On the basis of mean performance, the genotypes L-9, L-1956 and L-435 has considered as early flowering varieties. Regarding growth attributing characters genotypes L-332, L-326 and L-210 has well for plant height and genotypes L-198, L-193 and L-1963 best for number of branches per plant. With respect of reproductive traits genotypes L-210, L-145 and L-332 are best for pod length. For better pod width L-1999, L-1963 and L-223 genotypes are best suited. For maximum average pod weight genotypes L-198, L-223 and L-1963 are good. For high number of pods per plant L-1999, L-1998 and L-146 genotypes are best suited. The genotypes Kashi Pragati, L-27 and L-167 were found promising for number of seeds per pod. For high seed yield L-198, L-1963 and L-167 are best suited. Regarding economic traits the genotypes L-1999, L-1998 and Kashi Pragati are best suited for high pod yield per plant as well as pod yield per hectare.

Since no genotype could be identified to have superior performance for all the characters, the genotypes with diverse characteristics could be involved in a well planned hybridization programme to select superior performing lines in the successive segregating generation.

## 5.2 GENETIC VARIABILITY

Evaluation of the genotypes for important agronomic traits is an important aspect for any crop improvement programme. A breeder is always concerned with the selection of superior genotypes. Therefore, the assessment of genetic variability in okra is of paramount importance in selecting the best genotypes for making rapid improvement in yield and related characters as well as to select most potential parent for making the hybridization programme successful.

The success of a breeding programme for the genetic improvement of quantitative characters depends on the magnitude of genetic variability available in the germplasm. Which is however, not directly measurable by itself, but has to be inferred with the phenotypic expression. The phenotype may therefore be defined as a function of genotype (G), environment (E) and genotype  $\times$  environment (G  $\times$  E) interaction effect. A wide spectrum of variability will provide an insight to the local conditions. In the present study, the most divergent genotypes are expected to manifest maximum heterosis and generate wide variability in genetic architecture.

The extent of genetic variation observed in the present studies for most of the traits in okra was quite high and the same can be exploited by the breeders for increasing the productivity. In the present study, genotypes of okra exhibited significant differences for all the fourteen characters studied and a wide range of variability was observed for plant height, number of branches per plant, Inter nodal distance, number of pods per plant, yield per plant and pod yield per hectare indicating the scope for selection of suitable initial breeding material for further improvement.

From the analysis of variance, it was observed that mean squares due to genotypes were significant for all the traits, indicating thereby the presence of genetic variability in the experimental material. The high magnitude of genotypic and phenotypic coefficient of variation (GCV and PCV) was observed for traits namely plant height, number of branches per plant, intermodal distance, pod yield per plant and pod yield per hectare. Where, as number of pods per plant recorded high PCV and moderate GCV. The moderate GCV and PCV estimates were observed for pod

length, average pod weight and number of seeds per pod. Where, as number of nodes per plant and pod width recorded moderate PCV and low GCV. The traits like days to 1<sup>st</sup> flowering, days to 50% flowering and 100 seed weight recorded low GCV and PCV. In general it was observed that the phenotypic coefficient of variation is higher than genotypic coefficient of variation. The traits having high GCV and PCV values indicating that a high degree of genetic variability is present in these traits which provide greater scope for selection. Similar observations were reported by Padda *et al.* (1970), Rao (1972), Reddy *et al.* (1985), Patel and Dalal (1992), Mahto (1996), Yassin and Anbu (1997), Dash and Mishra (1998), Singh and Singh (2006), Singh *et al.* (2006), Jaiprakashnarayan *et al.* (2006) and Magar and Madrap (2009), Patel and Dalal (1992), Mahto (1996), Yassin and Anbu (1997), Bindhu *et al.* (1997), Gandhi *et al.* (2001), Singh and Singh (2006), and Jaiprakashnarayan *et al.* (2006), Gandhi *et al.* (2001), Singh and Singh (2006), Jaiprakashnarayan *et al.* (2006), Chaurasiya *et al.* (2010) and Vani *et al.* (2012).

### 5.3 HERITABILITY AND GENETIC ADVANCE

In crop improvement programme, genetic variation is important. Heritability is the only component which is transmitted to the next generation. The ratio of genetic variance to the total variance i.e., phenotypic variance is known as heritability. Heritability estimates gives a measure of transmission of characters from one generation to the next and the consistency in the performance of progeny in succeeding generations depends mainly on the magnitude of heritable portion of variation.

The heritable variability and more particularly its genetic component, is clearly the most important aspect of the genetic constitution of the breeding material, which has a close bearing on its response to selection. However, a measure of heritability alone does not give an idea about the expected gain in the next generation, but it has to be considered in conjunction with genetic advance. Thus high yield can be achieved by selection of those characters that have high heritability coupled with high genetic advance.

In the present experiment heritability in broad sense ranged from 39.95% for 100 seed weight to 96.37% for pod yield per plant and pod yield per hectare. The high heritability was observed for traits namely pod yield per hectare, pod yield per plant, number of seeds per pod, pod length, internodal distance, plant height, days to 1<sup>st</sup> flowering, number of branches per plant, average pod weight, days to 50% flowering and number of nodes per plant. Such high values of heritability for all these traits clarified that they were least affected by environmental modification and selection based on phenotype performance would be reliable. Where, as traits like pod width, number of pods per plant and 100 seed weight recorded moderate heritability. The genetic advance as per cent of mean (genetic gain) ranged from 4.14% for 100 seed weight to 56.38% for number of branches per plant. High estimates of genetic gain were obtained for number of branches per plant, pod yield per hectare, pod yield per plant, plant height, internodal distance, number of seeds per pod, average pod weight, number of pods per plant and pod width. Whereas, moderate genetic gain were observed for number of nodes per plant and pod width. Low genetic gain recorded for days to 1<sup>st</sup> flowering, days to 50% flowering and 100 seed weight, which elucidated that they could be uplifted to a large extent.

High heritability does not mean a high genetic advance for a particular quantitative character. Johnson *et al.* (1955) reported that heritability estimated along with genetic advance would be more rewarding than heritability alone in predicting the consequential effect of selection to choose the best individual. High values of heritability coupled with high genetic gain were noticed for pod yield per hectare, pod yield per plant, number of seeds per pod, pod length, internodal distance, plant height, number of branches per plant and average pod weight, which might be assigned to additive gene effect governing their inheritance and these traits are good responsive for selection. On other hand high heritability along with moderate genetic gain were recorded for number of nodes per plant. Whereas, days to 1<sup>st</sup> flowering and days to 50% flowering recorded high heritability along with low genetic gain, which indicates these traits are under the influence of non additive gene action and are less reliable for direct selection in crop improvement. Similar results were also observed by Padda *et al.* (1970), Randhawa and Sharma (1988), Mahto (1996), Yassin and Anbu (1997),

Panda and Singh (1997), Dash and Mishra (1998), Dhall *et al.* (2000) Gandhi *et al.* (2001), Dhall *et al.* (2003), Patro and Sankar (2004), Khan *et al.* (2005), Dakahe *et al.* (2007), Manivannan *et al.* (2007), Kumar (2007), Singh and Singh (2006), Pal *et al.* (2010), Prakash *et al.* (2011) and Reddy *et al.* (2012).

Hence, the breeder should adopt suitable breeding methodology to utilize both additive and non-additive gene effects simultaneously since varietal and hybrid development will go a long way in the breeding programmes, especially in case of okra.

#### 5.4 CORRELATION COEFFICIENT ANALYSIS

Yield is the resultant of combined effect of several component characters and environment. Genotypic and phenotypic correlation studies provide information on the nature and extent of association between two pairs of metric characters. From this it would be possible to bring about genetic up gradation in one character by selection of the other pair of the character. A positive correlation occurs due to coupling phase of linkage and negative correlation arises due to repulsion phase of linkage of genes controlling different traits. No correlation indicates that genes concerned are located far apart on the same chromosome or they are located on different chromosomes.

Knowledge of correlation is required when selection is to be made on several characters at a time through some simultaneous selection model. Even if, the objective is to make selection on a single trait, the knowledge of correlation is essential to avoid the undesirable correlated changes in other characters.

Yield being a complex character, is governed by a large number of genes. The influence of each character on yield could be known through correlation studies with a view to determine the extent and nature of relationships prevailing among yield and yield attributing characters. The present investigation was carried out to study the association of different characters on yield and yield attributing traits in okra both at phenotypic and genotypic levels. In general, it is evident from the data recorded that genotypic correlation was higher than phenotypic correlation indicating that genotype

is superior but its expression is lessened under the influence of environment.

At both genotypic and phenotypic level pod yield per plant recorded significant positive correlation with number of pods per plant, number of nodes per plant, average pod weight, pod width, plant height and pod length. It shows that fruit yield in okra can be improved by making direct selection based on these traits. The traits like days to 1<sup>st</sup> flowering showed positive significant correlation with days to 50% flowering. Whereas, plant height recorded positive significant correlation with inter nodal distance, number of nodes per plant, pod length, number of pods per plant and pod yield per plant. Inter nodal distance showed significant positive correlation with pod length. Further, the trait number of nodes per plant recorded significant positive correlation with number of pods per plant and pod yield per plant. Pod length showed significant positive correlation with average pod weight, 100 seed weight and pod yield per plant. Whereas, pod width recorded significant positive correlation with average pod weight, number of pods per plant and pod yield per plant. Average pod weight recorded significant positive correlation with number of pods per plant, 100 seed weight and pod yield per plant. Since, there is a positive association among these component characters, the selection aimed for improvement of any characters shall automatically influence other character in desirable direction. Significant negative correlation was recorded for pod yield per plant with days to 50% flowering and days to 1<sup>st</sup> flowering. Significant negative correlation also existed between days to 1<sup>st</sup> flowering with pod width, average pod weight and number of pods per plant, days to 50% flowering with number of nodes per plant and number of pods per plant suggesting that such type of negative correlation among components will not be helpful as selection for particular traits shall have adverse effect on the other trait. Similar results in okra were reported by Padda *et al.* (1970), Thamburaj and Kamalanathan (1973), Rao and Ramu (1975), Mishra and Singh (1985), Ariyo *et al.* (1987), Balakrishnan (1988), Randhawa and Sharma (1988), Dhall *et al.* (2000), Gandhi *et al.* (2002), Bendale *et al.* (2003), Patro and Sankar (2006), Mehta *et al.* (2006), Yadav *et al.* (2007), Pal *et al.* (2008), Ali *et al.* (2008), Magar and Madrap (2009) and Ramya and Kumar (2009), Chaurasiya *et al.* (2010) and Vani *et al.* (2012). Thus, the results indicated that adequate knowledge of interrelationship

between pod yield per plant and its components themselves is useful for selection and simultaneous improvement in these characters.

### 5.5 PATH COEFFICIENT ANALYSIS

Path coefficient analysis is a simple standardized partial regression coefficient which splits the correlation coefficient into the measure of direct and indirect effects. In other words, it measures the direct and indirect contribution of various independent characters on a dependent character. As such, it measures the direct influence of one variable on other, such information would be of great value in enabling the breeder to specifically identify the important component traits of yield and utilize the genetic stock for improvement in a planned way.

Genotypic path coefficient analysis for pod yield per plant revealed that the characters namely plant height and pod length recorded maximum positive direct effect on pod yield per plant followed by pod width, number of seeds per pod, number of branches per plant, days to 50% flowering, average pod weight and 100 seed weight indicating direct selection based on these traits will be rewarding for crop improvement. Whereas, characters like inter nodal distance, number of nodes per plant, days to 1<sup>st</sup> flowering, number of pods per plant, showed negative direct effect on pod yield per plant. Number of nodes per plant and number of pods per plant had significant positive correlation on pod yield per plant, but its direct effects on pod yield per plant was recorded negative mainly because of high negative indirect effect *via* inter nodal distance. Hence direct selection based on these characters is not effective. These results are in accordance with findings of Dhall *et al.* (2000), Dhankhar and Dhankhar (2002), Mehta *et al.* (2006), Adeniji and Aremu (2007), Saifulla and rabbani (2010) and Ramanjinappa *et al.* (2011).

Regarding indirect effects, it was observed that days to 1<sup>st</sup> flowering and days to 50% flowering exhibited positive indirect effects towards yield *via* number of nodes per plant; plant height *via* pod length; number of branches per plant *via* plant height; inter nodal distance *via* plant height and pod length; number of nodes per plant, pod length, number of nodes per plant, average pod weight and number of seeds per pod *via* plant height; pod width *via* inter nodal distance; 100 seed weight

*via* plant height and pod length. It suggested that for selecting genotypes with higher yield the indirect influence of different traits should be given due weightage along which exerted direct effects.

Phenotypic path coefficient analysis for pod yield per plant revealed that the characters namely number of pods per plant, average pod weight and plant height recorded maximum positive direct effect on pod yield per plant followed by pod width, number of nodes per plant, 100 seed weight and days to 1<sup>st</sup> flowering indicating direct selection based on these traits will be rewarding for crop improvement. Whereas, characters like inter nodal distance, days to 50% flowering, number of branches per plant, pod length and number of seeds per pod showed negative direct effect on pod yield per plant. Pod length had significant positive correlation on pod yield per plant, but its direct effects on pod yield per plant was recorded negative mainly because of high negative indirect effect *via* inter nodal distance. Hence direct selection based on these characters is not effective. These results are in accordance with findings of Gandhi *et al.* (2002), Subrata Sarkar Hazra and Chattopadhyay (2004) , Patro and Sankar (2006), Mahaveer Koujalagi Gangappa and Satish (2010) and Senapati *et al.* (2011).

Regarding indirect effects, it was observed that plant height exhibited positive indirect effects towards yield *via* number of pods per plant and average pod weight; number of branches per plant and number of nodes per plant *via* number of pods per plant; inter nodal distance *via* average pod weight and plant height; pod length and pod width *via* average pod weight; number of seeds per pod and 100 seed weight *via* average pod weight. It suggested that for selecting genotypes with higher yield the indirect influence of different traits should be given due weightage along which exerted direct effects.

## **FUTURE LINE OF WORK**

The crosses involving parents belonging to the maximum variability genotypes were expected to manifest heterosis and also wide variability in genetic architecture. Considering the magnitude of genetic variability, contribution of characters towards the total variability and magnitude of genotypes means for

different characters performance, the following genotypes were considered to perform better if used in hybridization programme. From the present investigation it may be concluded that characters like pod yield per hectare, pod yield per plant, number of seeds per pod, pod length, internodal distance, plant height, number of branches per plant and average pod weight recorded high estimates of heritability coupled with high genetic gain and selection based on these characters may result in development of high yielding genotypes. Based on selection indices the genotypes L-1999, L-1998, L-1956 and L-167 were found to be superior with respect to pod yield per plant. The genotype L-198 was also dominating in majority of the yield components like average pod weight and number of branches per plant and 100 seed weight coupled with good pod quality which can be used as a parent in future breeding programmes following direct selection. The superiority of other genotypes like L-9 in days to 1<sup>st</sup> flowering and days to 50% flowering, L-210 in pod length, L-332 in plant height, L-1999 in number of pods per plant, Kashi Pragati in number of seeds per pod could also be considered for creating variability and improving the yield.

## **SUMMARY AND CONCLUSION**

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Nutritional security is likely to be considered as an important aspect of profitable agriculture. Vegetables are one of the most important components for balanced diet of predominantly vegetarian population of India. However, the productivity of vegetables is relatively low in our country compared to many of the developed countries. Among the various reasons attributed for low vegetable production in the country, the practices like cultivation of low heterogeneous planting materials, low yielding varieties, multiplication of genotypes of unknown pedigree, use of poor quality seeds and problematic crop pests are the predominant ones. Okra has many varieties and hybrids to its credit suitable for various agro-ecological conditions. It is often grown as a perennial in many tropical areas. It has several good features which help the breeders and geneticists to have quick genetic results. Among these features, its growing habits, short life span and adaptability to wide range of soil and climatic conditions are highly desirable for developing a high yielding variety.

The genetic variability is the raw material of vegetable breeding industry on which selection acts to evolve superior genotypes. The wide genetic variability that exists in the available genotypes provides ample scope for further improvement. Yield being a complex quantitative character, direct selection for yield may not result in successful improvement. Information on character association and direct and indirect effects of component traits on yield would greatly help in formulating the selection criteria and using them effectively in crop improvement programme. Therefore, it is necessary to partition the observed variability into heritable and non-heritable components by calculating genetic parameters such as genotypic and phenotypic coefficient of variation, heritability and genetic gain. In view of the above, there is a constant need to evaluate the germplasms to identify the genetically diverse lines with desirable character combination. Hence, the present investigation is under taken to study, 1) the nature and magnitude of genetic variability available in the selected genotypes of okra, 2) the degree of heritability and genetic advance of

yield and yield components among the selected genotypes, 3) the degree and direction of relationship between yield and its component characters.

The present investigation entitled, “Evaluation and genetic variability in advanced breeding lines of okra, [*Abelmoschus esculentus* (L.) Moench] under Varanasi conditions” was carried out in thirty two genotypes of okra at the Vegetable Research Farm, Department of Horticulture, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during summer season 2012. The experimental design laid out in Randomized Block Design and each treatment was replicated three times.

Observations were recorded on five randomly selected plants in each replication for fourteen traits *viz.*, days to 1<sup>st</sup> flowering, days to 50% flowering, plant height (cm), number of branches per plant, inter nodal distance (cm), number of nodes per plant, pod length (cm), pod width (cm), average pod weight (g), number of pods per plant, number of seeds per pod, 100 seed weight (g), pod yield per plant (g), pod yield per hectare (q).

Analysis of variance revealed significant differences among genotypes of all the characters under study, which indicate that there is ample scope for selection from present gene pool for improvement of quality and yield attributing characters. On the basis of mean performance, genotypes L-9 and L-1956 took minimum number of days to 1<sup>st</sup> flowering and days to 50% flower appear. Whereas L-210 recorded maximum pod length and maximum pod width was recorded in L-1963 and L-1999. The genotype L-1999 also recorded maximum number of pods per plant, pod yield per plant and pod yield per hectare. Maximum number of nodes per plant was recorded in L-1999 and maximum number of branches, 100 seed weight was recorded in L-198. Whereas, Kashi Pragati showed maximum number of seeds per pod. So, these lines can be used for future breeding programme.

The high magnitude of genotypic and phenotypic coefficient of variation (GCV and PCV) was observed for traits namely plant height, number of branches per plant, intermodal distance, pod yield per plant and pod yield per hectare, indicating

that selection for these traits will be effective. From the present investigation it may be concluded that characters like pod yield per hectare, pod yield per plant, number of seeds per pod, pod length, internodal distance, plant height, number of branches per plant and average pod weight recorded high estimates of heritability coupled with high genetic gain and selection based on these characters may result in development of high yielding genotypes.

In the present investigation at both genotypic and phenotypic level pod yield per plant recorded significant positive correlation with number of pods per plant, number of nodes per plant, average pod weight, pod width, plant height and pod length. It shows that fruit yield in okra can be improved by making direct selection based on these traits.

Genotypic path coefficient analysis for pod yield per plant revealed that the characters namely plant height and pod length recorded maximum positive direct effect on pod yield per plant followed by pod width, number of seeds per pod, number of branches per plant, days to 50% flowering, average pod weight and 100 seed weight indicating direct selection based on these traits will be rewarding for crop improvement. Whereas, Phenotypic path coefficient analysis for pod yield per plant revealed that the characters namely number of pods per plant, average pod weight and plant height recorded maximum positive direct effect on pod yield per plant followed by pod width, number of nodes per plant, 100 seed weight and days to 1<sup>st</sup> flowering indicating direct selection based on these traits will be rewarding for crop improvement.

Since no genotype could be identified to have superior performance for all the characters, the genotypes with diverse characteristics could be involved in a well planned hybridization programme to select superior performing genotypes in the successive segregating generation. On the basis of performance the lines *viz.* L-1999, L-1998, L-1963, L-1956, L-198, L-9 and Kashi Pragati were found to be the best genotypes for multiple traits and so these can be used as parent for future breeding programme.

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