VARIABILITY STUDIES IN OKRA
(*Abelmoschus esculentus L. Moench*)

A

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(VEGETABLE SCIENCE)

BY

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CERTIFICATE-I

This is to certify that the thesis entitled "**VARIABILITY STUDIES IN OKRA (*Abelmoschus esculentus* L. Moench)"** submitted by **ARCHANA MISHRA,** Adm. No.03VSc/12 to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** is a faithful record of *bona fide* research work under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma or published in any other form.

The assistance and help received during the course of investigation have been duly acknowledged.

Place: Bhubaneswar

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CERTIFICATE – II

This is to certify that the thesis entitled **"VARIABILITY STUDIES IN OKRA (*Abelmoschus esculentus L. Moench*)"** submitted by **ARCHANA MISHRA**to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE in** the discipline of **VEGETABLE SCIENCE** has been approved by the Student's Advisory Committee after an oral examination on the same in collaboration with the External Examiner.

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ABSTRACT

The genetic parameters for 13 quantitative characters were estimated in 33 genotypes (germplasm) of okra in All India Co-ordinated Research Project on Vegetable Crops, Odisha University of Agriculture and Technology, Bhubaneswar at Horticulture Research Station, following Randomized Block Design with 3 replications during 2013 (July - October).

The genotypes showed wide range of variation for eleven characters out of thirteen characters studied. Among the genotypes evaluated V_{24} (2013/OKHYB-5), V_{13} (2012/OKHYB-13), V_9 (2012/OKHYB-1), V_{19} (2012/OKHYB-15) and V_{15} (2012/OKHYB-7) are identified as ideal genotypes to be grown in Bhubaneswar (Odisha condition). High estimates of genotypic co-efficient of variation, heritability (broad sense) and genetic advance together were observed for the characters number of disease infected plants, yield per plant, fruit weight, days to 50% flowering and duration of fruiting suggesting additive gene action for expression of these characters. So, selection based on these characters will be more

effective in improvement of fruit yield of okra. Correlation studies among the traits indicated that there is a strong inherent association between fruit yield with number of fruits per plant, nodes per plant and plant height with nodes per plant, fruit length; nodes per plant with fruit length, number of fruits per plant; fruit length with fruit weight, duration of fruiting; first flowering node with days to first flowering, days to 50% flowering and days to first flowering with days to 50% flowering and days to first harvest; days to 50% flowering with days to first harvest both at phenotypic and genotypic level depicting that these are important correlated characters for fruit yield in okra. Path analysis study revealed that days to first flowering, duration of fruiting, fruit weight and nodes per plant have maximum direct positive effect on fruit yield. The genotypes are grouped into eight clusters using D^2 statistics in which cluster III and VI were the most divergent ones and hybridization involving parents from these two clusters would be result oriented. Among the characters number of disease infected plants contributed maximum towards divergence followed by duration of fruiting and days to first harvest.

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INTRODUCTION

Okra or Lady's finger (*Abelmoschus esculentus* [L.] Moench) belongs to family Malvaceae. Okra originated from tropical and sub-tropical Africa and is native to West Africa (Tindal, 1983). The crop was introduced to other parts of the world by the Portuguese (Sinnadurai, 1992). India is considered as the secondary centre of diversity with a possibility of polyphylectic origin. In India, okra is commercially grown in state of Gujarat, Maharashtra, Tamil Nadu, Haryana, Punjab, Uttar Pradesh, Odisha, Bihar, West Bengal, Andhra Pradesh and Karnataka as a kharif as well as summer season crop.

India had the credibility of producing 162.18 million tons of vegetables in 2012-13 (NHB, 2012-13) being the second among the vegetable producing country in the world. The per capita availability of vegetables in India is low i.e. 160 gm day^{-1} as against 285 g per day as per the recommendation of Food and Agriculture Organization (FAO). The prediction indicates that there is a further need of 27.2 million tons of vegetables other than potato and tubers to meet the nutritional requirements of the growing population i.e. 1200 million people by the year 2020-2021. In India, okra covers an area of 231 thousand hectares with productivity of 27.5 and production of 6350 thousand tons (NHB, 2012-13). In Odisha, vegetable covers an area of 688.1 thousand hectares with productivity of 13.8 MT/Ha and production of 9464.0 MT (NHB, 2012-13).

It is an annual herbaceous vegetable crop that is grown for its tender fruits often consumed as vegetable (Chattopadhyay *et al*., 2001) and other meal. The plant is a robust, erect, annual herb, ranging 1-2m in height, with simple leaves, which are alternate and palmately veined. It is generally amphidiploids in nature with 2n = 130 chromosomes. It is often cross-pollinated where the natural cross pollination occurs from 8.75 – 9.61%. Okra is highly susceptible to frost and requires warm climate for fruit production.

It has various uses as vegetables, soups, gravies stews in meat, seeds as a substitute for coffee and have nutritional and medicinal value. Okra is rich in vitamins, calcium, potassium and other minerals. Fresh okra fruit contains 2.1 g protein, 0.2 g fat, 8 g carbohydrate, 36 calories, 1.7 g fiber, 175.2 mg minerals and 88 ml of water per 100 g of edible portion (Tindal, 1983; Berry *et al*., 1988). Its edible leaf per 100 g contains about 81 ml water, 56 calories, 11 g carbohydrate and 4.4 g protein. Okra fruit is also useful in curing ulcers and suppressing the pains and effects of haemorrhoids. The mucilage has been used as a plasma replacement or blood volume expander (Siemonsma & Kouame, 2004). Reports from research in China revealed that an alcohol extract from *Abelmoschus* leaves can eliminate oxygen free radicals, alleviate renal tubular-interstitial diseases, improve renal function and reduce proteinuria (Siemonsma & Kouame, 2004). Okra is reported to have good alkaline pH which contributes to its relieving effect in gastrointestinal ulcer by neutralizing digestive acid (Wamanda, 2007). The mature fruits and stem contains more crude fiber and are used in paper industry. It is an excellent source of iodine besides other minerals and vitamins.

Because of its high nutritive value and prolonged shelf-life as compared to other vegetables, okra has captured a prominent position among the export oriented vegetable crops and exported to middle-east countries, Western Europe and USA. It has a vast potential as one of the foreign exchange earner crops. The improvement in genetic makeup i.e., growing habit of the plant increases the harvest index and improvement in resistance to insect-pest and diseases ultimately increases the yield.

Study of different varieties provides a strong basis for selection of desirable genotypes for augmentation of yield and other agronomical attributes. Such study estimates the feasibility of using available genetic resources for effective improvement. The fruit yield in Okra is the most important economic character which is dependent on many other attributes. In addition to yield, other yield attributing traits like plant height, number of nodes per plant, number of fruits per plant, fruit

length, fruit weight etc. are inherited quantitatively and their expression is governed by polygenes which are highly influenced by environment & lowly heritable. So selection based on yield components rather than yield itself is reliable & more dependable.

Further in quantitative characters, the measure of the phenotypic-expression is a combination of the genotype, environment and their interaction. It is the magnitude of variation which governs the progress in selection. Therefore it is necessary to formulate a biometrical approach to partition the observed variability into heritable and non-heritable components by studying genotypic co-efficient of variation, heritability and genetic advance. These parameters including correlation studies which give an idea regarding the genetic variability of the population are the pre-requisite to advocate an appropriate and successful breeding programme. Genotypic and phenotypic coefficients of variance suck out the association between yield and yield contributing traits in okra. If the association is positive and significant, simultaneous important and association is possible and significant. As the correlation measures the mutual relationships between different traits of a plant, it helps to determine the best yield contributing traits. Path analysis deals with a close system of variables that are linearly related. It specifies the causes and generally measures their relative importance. Path analysis split the correlation coefficient in to the measures of direct and indirect contribution of various characters towards the yield.

In addition to the above studies, it is also essential to make use of certain technique that could provide quantitative measures of genetic divergence with regard to multiple characters. Among these techniques, Mahalonobis' D^2 statistic is one of such multivariate measure of divergence which predicts classification of population into groups on the basis of genetic affinity/diversity with regards to several characters (Rao, 1952). Good amount of variability has been reported in okra for various characters. However, their utilization in breeding programme resulted in identification and release of good number of genotypes in okra. These released varieties cannot be

continued longer due to genetic drift and susceptibility to disease and pest. This demands replacement of old genotypes by many developed ones. Burton (1952) suggested that through genotypic coefficient of variation, the heritable variation couldn't be estimated, on other hand, genotypic coefficient of variation together with heritability would furnish most reliable information on the amount of genetic advance to be expected for selection.

The demand for Okra variety (as well as hybrids) than the existing ones is always desired for the attributes like higher yield, more number of fruits, high fruit weight, good size fruits, earliness & resistant to diseases and pests. This necessitates focus to evaluate the nature of genetic variability, heritability and character association of some quantitative traits in different varieties of okra for possible improvement in quality of yield and yield components so as to enhance productivity and subsequently improve income generation to the local producers. Hence, the present investigation entitled "Studies on Variability in Okra" has been designed with the following objective to be carried out with a set of genotypes including local ones with the following objectives**:**

1. To study the magnitude of genetic variation in the collection,
2. To assess the nature and extent of variability and heritability of character with their expected genetic gain by selection,
3. To investigate the amount and nature of association among different characters with yield through co-relation analysis,
4. To determine the direct and indirect association among yield components through path co-efficient analysis and
5. To compare and contrast the genotypes for component of yield and assess genetic divergence among them based on genetic distance.

REVIEW OF LITERATURE

Okra is considered as a popular and profiteering crop among the vegetables. In India, lot of variations has been observed in this crop leading to development of new varieties. As there is every possibility, that the established varieties may loose their importance in course of time, hence to search for new cultivars is a continuous process. Further for crop improvement programmes like selection and hybridization, a sound knowledge of nature of character association and genetic divergence in any crop is highly essential. Therefore, reviews relevant to okra on these aspects have been presented below for interpretation of results.

2.1 VARIABILITY AND HERITABILITY OF QUANTITIVE TRAITS

Selection of superior genotypes at one stage or the other is the most important aspect in any plant improvement programme and the effectiveness of the selection is dependent upon the existence of genetic variability within or among the population subjected to selection (Dixit *et al*., 1971; Swamy Rao, 1972; Tikka *et al*., 1974; Patnaik and Tak, 1974). Therefore, a quantitative measure of genetic variability would be extremely beneficial in breeding for improvement of quantitative traits.

Most of the economically important characters in crop plants are quantitative in nature which are controlled by polygenes and also influenced by the environment (Hirachand *et al*., 1975). The observable quantitative trait is only the phenotype which can be easily assessed but for purpose of selection, it is inadequate since plant is the resultant of the interaction of genotype and environment which creates difficulty to ascertain whether variability is heritable or non-heritable (environmental).This necessitates the partitioning of total variation or phenotypic variation into two groups such as heritable and non-heritable components as follows:

a) **Heritable or genotypic variation. It includes,**

   i. Additive genetic variance (V_A), which results from additive or average effect of genes and it is heritable.

   ii. Dominance variance (V_D), which arises from intra-allelic interaction (due to the deviation of the heterozygote Aa from the average of homozygotes AA and aa) and it is also heritable.

b) **Non-heritable variation or non-genetic variation**

   i. Epistatic variance (V_I) which results from the interaction of non-allelic and is referred as inter-allelic interaction.

   ii. Environmental variance (V_E) which results from non-genetic factor such as environmental fluctuations, sampling error and difference in cultural practices.

Beside this classification stated above statistical methods are now available for partitioning of phenotypic variation into genetic and environment components which permit a quantitative assessment of genetic variability and the relative importance of heredity and environment in the expression of quantitative traits.

2.2 COEFFICIENT OF VARIATION

Coefficient of variation is defined as the measure of variation and is independent of unit of measurement which is used for comparing different populations. It is provided by the standard deviation expressed as percentage of mean (Panse and Sukhatme, 1954).

Genotypic coefficient of variation is the genotypic standard deviation expressed as percentage of mean and phenotypic coefficient of variation is expressed as the phenotypic standard deviation expressed as the percentage of mean. A slight differences between phenotypic and genotypic standard deviation suggested negligible influence of environment on that character (Choudhary *et al*., 1973).

2.3 HERITABILITY

Heritability is an important parameter of great importance for the plant breeder as its magnitude indicates the accuracy with which a genotype can be recognized by its phenotypic expression. It is estimated as the ratio of genotypic variance to the total phenotypic variance that is due to genetic causes. The term heritability, is also used in more specific ways on consideration in response to selection e.g. narrow sense heritability measured as the ratio of additive genetic variance to the total phenotypic variance (Wright, 1921) and broad sense heritability is the ratio of total genotypic variance to the observed phenotypic variance (Lush, 1949) which are symbolically as follows:

h^2 (narrow sense) = $V_A/ (V_G + V_E) = V_A/ V_P$

h^2 (broad sense) = $V_G/ (V_G + V_E) = V_G/ V_P$

But Liang and Walter (1968) defined heritability as the transmission of character from parent to off-spring. Mohanty and Singh (1973) described the relative importance of genetic and a non-genetic factors on the expression of a quantitative character is commonly expressed by the term heritability.

Heritability is one of the major properties of a quantitative character. It should be noted that the heritability is a property not only of a character but also of a population and the environmental conditions to which the individuals are exposed. Further, variation in quantitative traits occurs due to their degree of heritability. Robinson (1966) grouped the heritability estimates in crop plants into three categories.

i. Low heritability – 5 to 10 percent.
ii. Moderate heritability – 10 to 30 percent.
iii. Higher heritability – 30 to 60 percent.

This classification represents average of heritability estimates over various crop plants, types of population, procedures of determination and environments encountered in different locations and years.

If heritability is 100% the phenotypic performance would be a perfect indication of genotypic value. However, in this hypothetical situation, the heritability values in itself provide no indication of the amount of genetic progress that would result from selecting the best individuals. Therefore, the utility of heritability is increased when they are used in conjugation with selection differential and the genetic advance is completely predicted as the product of heritability ratio and selection differential (Johnson *et al*., 1955). Randhawa *et al*., (1975) suggested that if the heritability of a character is high, better will be the opportunity for selecting a genetically good individual. Low value of heritability indicates high degree of non-heritable variability (Sharma *et al*., 1966). Further, difference in heritability values also differ greatly depending on the methods used to estimate the parameter (Robinson, 1963) the units for which the variance is considered (Johnson *et al*., 1955) and also the amount of genetic variation in population and environmental condition under which the population is evaluated (Allard, 1960).

Therefore the most important use of heritability lies in its predictive role, expressing the reliability of the phenotypic value as a guide to the breeding value. It also serves as a useful parameter in predicting genetic advance or response to selection.

2.4 GENETIC ADVANCE

The heritability alone conveys no indication of the amount of genetic progress that will result from selecting the best individual. But when they are used together with the selection differential, the utility is increased (Tikka *et al*., 1974).

Genetic advance indicates the potentiality of selection at a particular level of selection intensity. The expected genetic advance from selection when expressed as a percent of mean is the product of

i. the selection differential in terms of phenotypic standard deviation
ii. genotypic co-efficient of variation and
iii. the square root of heritability ratio.

Heritability in narrow sense is the most important tool to estimate expected improvement due to selection or response to selection of genetic advance. Robinson (1963) and Johnson *et al*., (1955) suggested that heritability estimates along with genetic advance were more valuable than the heritability value alone in predicting the response to selection. High heritability does not necessarily mean that the character will show high genetic advance. But the case where the above association exists, additive genes comes into prominence. It is because no genetic advance was due to non-additive genes, whereas additive genes are responsible for high genetic advance.

Genetic variability and heritability in Okra

Morakinyo and Makinde (1991) reported very high broad sense heritability in Okra in respect of characters like fresh fruit length, fresh fruit diameter, number of flowers per plant and number of fruits per plant but low heritability in characters like fresh fruit weight, fruit stalks length and number of flower buds per plant. They also reported significant genetic variance in okra in respect of characters like number of flower buds per plant, number of fruits per plant, height of plant at maturity and number of days to flowering.

In a variability study, Patil *et al.* (1996) at Dharwad evaluated 171 lines of Okra genotypes for two season of diverse origin for genotypic and phenotypic variances, genotypic and phenotypic coefficient of variation and heritability. They reported that characters like number of pods per plant, weight of good pods per plant, number of borer infested pods and weight of borer infested pods per plant showed

seasonal variation during kharif than rabi. The estimates of PCV and GCV values ranged from 14.7% for days to flowering (kharif) to 71.6% for weight of borer infested pods (kharif). They also observed relatively high genetic advance for plant height, number of good pods per plant and weight of good pods per plant.

Dhankhar and Dhankhar (2002) evaluated 62 inbred lines of Okra at Hissar and found broader range of variation and high mean values in rainy season for number of fruits per plant, days to 50% flowering and number of branches per plant and in spring-summer season for fruit yield and plant height. They also reported high genetic variability for number of branches per plant, fruit yield, number of fruits per plant and plant height in both the seasons. The magnitude of PCV was almost similar to the corresponding GCV in both seasons for fruit yield and plant height.

In a heritability study on Okra, Dhankhar and Dhankar (2002) evaluated high heritability for all the traits in both rainy and spring-summer seasons except for days to 50% flowering in spring summer season that showed low heritability (32.63%). They also reported high genetic advance coupled with high heritability for all the characters during both the seasons except for days to 50% flowering during spring-summer season.

Adeniji and Kehinde (2003) evaluated 7 accessions of West African Okra for heritability, genetic advance and genetic variability. The dominant gene effects were low in magnitude, unidirectional (positive increasing alleles) for hundred seed weight, pod length and seed per pod and ambi-directional (positive increasing and negative decreasing alleles) for ridges per pod, seeds per ridge, pod width and seed weight.

From an experiment using 41 genotypes of Okra, Kiran Patro and Ravisankar (2004) studied genetic variability for 17 characters. They reported high genotypic co-efficient of variation and phenotypic co-efficient of variation in characters like number of branches per plant, disease incidence (Cercospora leaf spot, Powdery mildew, YVMV), ascorbic acid content, yield per plant and fruit weight. They also

found high heritability for number of branches per plant and yield per plant and high genetic advance for yield per plant, plant height, germination percentage and number of branches per plant.

Khan *et al.* (2005) reported high phenotypic and genotypic variances in okra for characters like fruit yield, seed number, fruit number and node number and high phenotypic and genotypic coefficient of variation for number of fruits per plant, number of seeds per fruit, node number and yield per plant. They also recorded high heritability and genetic advance as percent of mean for number of nodes, number of seeds, fruit number, plant height and yield.

While studying genetic variability, heritability and genetic advance on okra genotypes, Singh *et al*. (2006) observed high phenotypic coefficient of variation and genotypic coefficient of variation for internodal length, number of branches/plant, number of fruits/plant, number of seeds/pod and fruit yield/plant. They also observed high heritability along with high genetic advance for characters like number of seeds/pod, internodal length, number of branches/plant, fruit yield/plant, number of fruits/plant, plant height and 100 seed weight.

According to Mehta *et al*. (2006), high genotypic coefficient of variance, heritability and genetic advance as percentage of mean in okra for fruit yield, average fruit weight, plant height and fruit length was visualized in the variability study.

In a genetic variability and correlation studies in okra, Dakahe *et al*. (2007) found that the estimates of heritability were of high magnitude for green fruit yield/plant, plant height at harvest, days to maturity and number of internodes/plant. They also found that phenotypic coefficient of variance and genotypic coefficient of variance estimate was maximum for fruit length, number of fruits/plant and fruit girth.

Alam and Hossain (2008) evaluated 50 accessions of okra and observed wide range of variation for spread of plant (43.73 cm), height of plant (80.90 cm), length of

petiole (12.31 cm), moderate variation for number of nodes/plant (14.58), number of leaves per plant (24.51 at 80 DAS), length of leaf (12.20 cm), breadth of leaf (13.05 cm), and lesser variation for number of primary branches/plant (1.57). They also observed highest genotypic coefficient of variation (26.56%) and phenotypic coefficient of variation (32.37%) for number of primary branches/plant, moderate for length of petiole (GCV = 14.24% and PCV = 15.95%), spread of plant (GCV = 12.00% AND PCV = 13.06%), breadth of leaf (GCV = 9.81% and PCV = 12.41%) and length of leaf (GCV = 9.53% and PCV = 13.35%).

In an investigation on genetic variance with 44 okra genotypes Prakash Kerure (2010), observed high genotypic coefficient of variation and phenotypic coefficient of variation for characters like plant height, inter-nodal length, first flowering node, first fruit producing node, average fruit weight and number o seeds per fruit.

While evaluating the genetic variability of okra genotypes Akotkar *et al*. (2010), reported high genotypic coefficient of variation, phenotypic coefficient of variation, heritability and genetic advance (% mean) for number o fruiting nodes, number of ridges per fruit, plant height and number of fruiting nodes.

Shanthakumar and Salimath (2010), observed moderate to high phenotypic and genotypic coefficient of variation for all the characters except days to first flowering, stem diameter (in double cross), fruit length and 100 seed weight in okra. They also observed high heritability and genetic advance for all the characters. High heritability coupled with high genetic advance over mean were observed for all the characters, studied, except for days to 50% flowering and days to 80% maturity showed high heritability with low genetic advance over mean.

In an study genetic variability of okra Gangashetty *et al*. (2010)observed high GCV and PCV for characters like number of branches per plant, number of fruits per plant, fruit yield per plant and moderate GCV and PCV for inter-nodal length,

fruit length, fruit diameter and fruit weight in both single and double cross F_4 and F_5 progenies. High heritability coupled with high genetic advance was observed for number of branches per plant, number of fruits per plant and fruit yield per plant. They also indicated that the amount of variability was more in double cross derived progenies as compared to single cross derived progenies for most of the characters.

Prakash and Pitchaimuthu (2010), estimated high genotypic coefficient of variation and phenotypic coefficient of variation in okra for the characters like plant height, inter-nodal length, first flowering node, first fruit producing node, height of first flowering node, average fruit weight and number of seeds per fruit.

High genotypic and phenotypic coefficients of variation in okra were noticed by Jindal *et al*. (2010), for characters like number of primary branches per plant. They also noticed high heritability coupled with genetic advance for number of branches per plant, total yield per plant and marketable yield per plant and high heritability coupled with low genetic advance for days to first picking, average fruit weight, plant height, inter-nodal length, number of fruits per plant, fruit diameter and average fruit length.

High heritability in okra were recorded for plant height, fruit width, fruit length, number of fruits per plant and weight of fruit per plant by Kumar *et al*. (2011). They also recorded varied genetic advance and genetic gain from 0.13 to 79.62 and 3.03 to 37.14 respectively.

Prakash *et al*. (2011), observed high PCV and GCV in okra for plant height, inter-nodal length, first flowering node, average fruit weight, number of seeds per fruit, first fruit producing node and height of first flowering node. They also observed high genetic advance for plant height, average fruit weight, number of seeds per fruit and total yield per plant.

From a variability study, Sateesh *et al*. (2011) observed that PCV were higher than GCV for all characters in okra. They also recorded high GCV, heritability and genetic advance as percentage of mean for plant height, fruit yield per plant, fruit weight and days to 50% flowering.

In a genetic variability study on 100 genotypes of okra Thirupathi Reddy *et al.* (2012), reported high magnitude of genotypic coefficient of variation (>20.00 %) for number of branches per plant, total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g) and yellow vein mosaic virus infestation on plants (%). They also reported that the characters plant height (cm), number of branches per plant, internodal length(cm), days to fifty per cent flowering, first flowering node, first fruiting node, fruit length (cm),fruit weight (g), total number of fruits per plant, number of marketable fruits per plant, total yield per plant (g), marketable yield per plant (g), yellow vein mosaic virus infestation on fruits and plants (%) have high heritability (>60.00 %) coupled with high expected genetic advance (>20.00 %).

Goswami *et al*. (2012), carried out a study on genetic variability, heritability and genetic advance of 13 quantitative characters in 17 okra genotypes. They recorded high phenotypic coefficient and genotypic coefficient of variation for plant height and number of branches per plant. They also recorded high heritability for all characters studied except days to 50% flowering which exhibited moderate heritability. The characters like plant height, number of branches per plant, inter-nodal length, number of fruits per plant, number of seeds per fruit, harvest index and total yield per plant exhibited high heritability coupled with genetic advance over mean (GAM).

In an investigation on genetic variability, heritability and genetic advance in Okra, Kumar *et al*. (2012) observed highest phenotypic and genotypic coefficient of variation for number of branches per plant and length of first fruiting node, closely

followed by number of seeds per fruit. They also reported 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 for plant height, length of first fruiting node and fruit diameter. The genetic advance as percentage of mean was high for number of branches per plant and days flowering to maturity and high heritability coupled with high genetic advance for days flowering to maturity and number of branches per plant.

From a field experiment with twenty diverse genotypes of Okra Annapurna *et al*. (2012) reported that among all the genotypes, Pusa Makhamali, Perkins Long Green, Parbhani Kranti, VRO-6, VRO-5 and Selection-10 gave promising results. Further great variation among the genotypes of crop characters were also observed under study.

The genetic variability, heritability and genetic advance in okra was studied by Nwangburuka *et al*. (2012). They reported high genotypic coefficient of variability, % broad-sense heritability and genetic advance in traits such as plant height (26.2, 90.7, 51.5), fresh pod length (23.9, 98.5, 48.8), fresh pod width (23.9, 98.5, 48.8), mature pod length (28.6, 98.5, 52.3), branching per plant (29.3, 82.3, 54.8) and pod weight per plant (33.9, 90.0, 63.3).

In an experiment for local Okra cultivar to evaluate the extend of variability and character association in some selected quantitative traits, Simon *et al*. (2013), observed wide variability in some yield traits, with growth contributing factors. They also observed a strong genotype-environment interaction affecting the yield performance of the local cultivar.

Jagan *et al*. (2013), observed highest phenotypic and genotypic coefficient of variation in okra for node at which mosaic disease appears, days at first mosaic symptom appears and number of branches per plant. The heritability estimates in broad sense were high for number of branches per plant, days to maturity, length of

the fruit, days to 50% flowering and node at which mosaic disease appears, while low for number of fruits per plant and node at which first flower appears. They also observed high genetic advance as percentage of mean for node at which mosaic disease appear, days at first mosaic symptom appear and number of branches per plant and high heritability coupled with high genetic advance for number of branches per plant and days to maturity.

According to Shaikh Md. *et al*. (2013), high genotypic and phenotypic coefficient of variation in okra was observed for characters like plant height, number of fruits per plant and number of seeds per fruit. They also reported high heritability coupled with high GCV and high genetic advance as percent of mean for plant height, number of seeds per fruit and number of fruits per plant.

Gendy and Aziz (2013), observed higher phenotypic coefficient of variation than genotypic coefficient of variation for all traits in okra. They also observed high or moderately high GCV, PCV, heritability and expected genetic advance GA% of mean in most crosses.

Analysis of variance and other genetic analyses such as genotypic and phenotypic coefficient of variation were performed by Simon *et al*. (2013) and they found highly significant variation in all the genotype except days to 50%flowering, and characters measured such as number of pods per plant(54.365**), number of branches per plant (8.2063**), number of leaves per plant (45.891**), days to pod formation, pod length (6.6526**), pod width(54.306**), seed index (20.787**), number of seeds per pod (2.4373**),plant height at 50% flowering (2543.5**), pod yield (45.395**), seed yield(427.73**), seed size (0.0144**) and internodes distance (0.6602**).

In a heritability study, Yonas *et al*. (2014), reported high heritability (96.76 and 96.50 %) coupled with high genetic advance as percent of mean (106.32 and 97.25%) for internodes length and plant height, respectively.

2.5 CHARACTER ASSOCIATION (CORRELATION)

The most important economic character in crop plants is yield, which is complex one and is dependent on a number of directly or indirectly associated traits. Therefore knowledge on the nature of association of different attributes with yield is essential. The nature of association between two components may be positive or negative. When any two attributes are positively associated then selection for one will indirectly result in selection of the other. When any two attributes are negatively correlated, selection for one will have adverse effect for the selection of the other character. The association between two attributes directly evaluated from the phenotypic correlation which may be due to genetic, environment or both. Thus the utility of correlation studies is enhanced further when phenotypic association is partitioned into genetic and environmental correlation. Pleiotropy and linkage are the genetic causes of association between two characters. The quantitative traits are controlled by polygenes, whose linkage is the cause of genetic correlation. However, genetic correlation resulting from linkage are transient and can be modified by recombination. Pleiotropy refers to the property of certain genes influencing two or more characters. So genetic correlation may be positive or negative depending on pleiotropic effects on the correlated characters and cannot be modified by recombination.

Selection for one character would result in progress for all positively correlated characters. This relation suggests the advantage of a scheme for more than one character at a time (Baha Eldin *et al*. 1958). If negative correlation exists between components of yield, then selection is to be done for intermediate combination for improvement of yield.

Characters association in okra

Morakinyo and Makinde (1991), found significant positive and negative correlation among the characters in each cultivar of okra. They also found that

seasonal effect on yield was more pronounced at the development of flower buds into flowers than at the level of the development of flowers into fruits.

In a study conducted on 62 inbreds line of okra Dhankhar and Dhankhar (2002), suggested significant negative genotypic and phenotypic correlation of days to 50% flowering with fruit number per plant and fruit yield.

Correlation studies carried out by Kiran Patro and Ravisankar (2004) in Okra, revealed that fruit yield per plant have significant positive correlation with germination percentage, number of branches per plant, number of ridges per fruit, fruit length, fruit weight and ascorbic acid content. They also revealed significant negative correlation of fruit yield per plant with plant height, number of days taken for first pod setting, fruit volume, shape index and longevity of tenderness.

Khan *et al*. (2005), conducted studies on correlation for ten quantitative characters on okra. They indicated that the yield was closely and positively correlated with its component characters like plant height, fruit length, node number and number of fruits per plant both at phenotypic and genotypic levels.

According to Singh *et al*. (2006), the fruit yield per plant of okra was positively and significantly correlated with fruit length, fruit diameter, fruit weight and number of fruits per plant.

From a correlation study, Mehta *et al*. (2006), suggested that the fruit yield was significant and positively correlated with fruit length and average fruit weight.

In a genetic variability and correlation studies in okra, Dakahe *et al*. (2007), observed that days to 50% flowering and days to maturity are the most important traits for exploring earliness, which are significantly associated. They also suggested that characters like number of fruits, number of internodes, plant height and fruit length had high heritability and highly significant positive association with fruit yield.

Alam and Hossain (2008), indicated that in okra, the yield of green pod had highly significant positive association with the number of nodes per plant.

In a correlation study utilizing ten genetically diverse okra genotypes of Okra, Kumar *et al*. (2011), observed that fruit yield was negatively correlated with fruit length (-0.792) and positively correlated with weight of fruits per plant (0.662), fruit length was positively correlated with weight of fruit per plant (0.703).

Guddadamath *et al*. (2011), reported that the genotypic coefficient of correlation showed more significant relationship between the pairs of characters such as average fruit weight (0.859), number of fruits per plant (0.929), 100 seed weight (0.871), and number of branches per plant (0.916), during selection process in segregating populations, as these characters exhibited positive significant association with fruit yield per plant.

Adiger *et al*. (2011) undertaken a study on 163 genotypes of okra to determine genetic variability and nature of association among different yield attributes. They found that the fruit yield has significant positive correlation with plant height, number of branches per plant, inter-nodal length, fruit length, fruit weight and number of fruits per plant at both genotypic and phenotypic level.

Guddadamath *et al*. (2012) taken up character association studies in okra and reported that the characters like fruit length, average fruit weight, number of fruits per plant (0.929^{**}), number of branches per plant and plant height showed significant positive association with fruit yield per plant and also showed significant positive association among themselves. The study also revealed intermating in early segregating generations of different individuals lead to release of additional variability.

From a correlation study Nwangburuka *et al*. (2012) recorded the positive and significant phenotypic and genotypic correlation in okra 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.

In a character association study for thirteen quantitative characters in Okra Thirupathi Reddy *et al*. (2013) observed significant positive phenotypic and genotypic correlation for plant height, fruit length, fruit width, fruit weight, total number of fruits per plant, number of marketable fruits per plant and total yield per plant and significant negative correlation of number of branches per plant, inter-nodal length, days to 50% flowering, first flowering node and first fruiting node with marketable yield per plant.

Simon *et al*. (2013) observed that genotypic coefficient of correlation showed more significant relationship between the pair of characters, meaning that, these characters are more related genotypically in Okra.

An investigation was conducted to find out the correlation and path coefficient effects in okra by Jagan *et al*. (2013). They reported that fruit yield per plant showed highly significant positive association with a number of branches per plant and number of fruits per plant at phenotypic and genotypic levels.

Yonas *et al*. (2014), studied correlation between various quantitative characters in okra and reported that fruit yield had positive and highly significant genotypic correlation with fruit length (r = 0.74), average fruit weight (r = 0.62), fruit diameter (r = 0.61), seed per pod (r = 0.56), hundred seed weight (r = 0.68) and number of pod per plant (r = 0.66).

2.6 PATH ANALYSIS

Yield is a complex trait resulting from direct and indirect effects of several traits operating either in combination or individually. Selection for a trait in one direction may influence another trait by a direct or indirect effect via a third variable. The study of correlation gives only the extent of association among various characters

taken in pairs. This extent of association does not imply the cause and effect relationship. Therefore the path coefficient analysis is used to determine the direct and indirect effects of various plant characters on crop yield.

According to Wright (1921), path coefficient analysis provides a better knowledge of direct and indirect causes of associations and it permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each causal factor. This method was first used by Dewey and Lu (1959) in their analysis of seed yield in crested wheat grass. Since then several workers have applied this method for analysis of character association in various crops.

Path analysis in okra

According to Dhankhar and Dhankhar (2002) in Okra, highest direct effect of number of branches per plant contributed indirectly to fruit yield having high indirect effects during both rainy and summer seasons. They also found that plant height while in rainy season contributed indirectly towards yield but during the summer seasons the direct and indirect effects in genetic association between plant height and fruit yield were almost similar may be due to response of genotypes to the similar environments.

From a path analysis study for 17 characters in 41 genotypes of Okra, Kiran Patro and Ravisankar (2004), observed high positive direct effect for fruit weight followed by fruit length, germination percentage, number of ridges, plant height, number of branches per plant, number of nodes per plant, fruit volume, ascorbic acid content. They also reported that a maximum positive indirect effect was recorded between fruit weight (via) number of ridges whereas a maximum negative direct effect was recorded in fruit weight (via) fruit length.

Mehta *et al*. (2006), reported that path coefficients for fruit girth had the maximum direct effect followed by fruit length towards fruit yield. Thus, the fruit

yield in okra can be improved by selecting for higher fruit length, fruit girth and average fruit weight simultaneously.

From a path analysis study Alam and Hossain (2008), observed that number of nodes per plant directly contribute towards the yield of green pod.

Adiger *et al*. (2011) undertaken association studies on 163 genotypes of Okra and observed that path analysis for fruit weight had maximum direct contribution (0.884) towards fruit yield followed by number of fruits per plant (0.852), plant height (0.024) and number of branches per plant (0.020). They also reported that days to 50% flowering exhibited highest negative direct effect (-0.013) followed by test weight (-0.009) and fruit diameter (-0.003).

While studying the correlation and path analysis of quantitative characters in Okra Reddy *et al*. (2013) observed that fruit weight, total number of fruits per plant and number of marketable fruits per plant had positively direct effect on marketable pod yield per plant. They also observed that the fruit weight, total number of fruits per plant and number of marketable fruits per plant not only had positively significant association with marketable pod yield per plant, but also had positively high direct effect on marketable pod yield per plant and are regarded as the main determinants of marketable pod yield per plant.

Simon *et al*. (2013) suggested that the seed size has high positive direct effect on seed yield (0.703). They also suggested that the number of seeds per pod had the highest significant correlation effect on seed yield (0.846^{**}) as well as highest negative direct effect with seed yield (-1.00) indicating that selection of number of seeds per pod will increase seed yield.

Path analysis study in Okra conducted by Yonas *et al*. (2014), at genotypic level revealed that internodes number had highly positive direct effect on fruit yield (p = 6.90) followed by average fruit weight (p = 6.89) which had positively genotypic correlation with yield.

2.7 GENETIC DIVERGENCE

Selection of genetically divergent varieties is important in the exploitation of heterosis and in the development of transgressive segregates for an efficient breeding programme. The information regarding the nature and magnitude of genetic distance among the genotypes will help the breeder choosing the suitable diverse combinations.

Genetic divergence in okra

According to Kiran Patro and Ravisankar (2004), cluster analysis in Okra revealed a considerable variation among the genotypes. Forty one genotypes were grouped into 8 clusters. They reported that among all the clusters, cluster IV had a maximum number (8) of genotypes, D^2 values ranged from 205.03 to 32666.9. The cluster means revealed that plant height, yield per plant and germination percentage contributed towards divergence.

In an evaluation of 50 genotypes of Okra Pradip *et al*. (2010), grouped it into 5 clusters. They observed that plant height had the highest contribution towards the total genetic divergence.

Prakash and Pitchaimuthu (2010), studied 44 genotypes in okra. They reported that the characters namely days to 50% flowering (35.62%), 100 seed weight (28.44%), number of seeds per fruit (17.23%) and average fruit weight (8.14%) directly contributed towards maximum divergence and therefore, selection of divergent parents based on this character is recommended for getting good hybrids or segregants in okra.

In a genetic divergence study in 44 Okra genotypes, Prakash Kerure (2010) grouped the genotypes into 12 clusters based on D^2 analysis and reported that the characters like days to 50% flowering (35.62%), 100 seed weight (28.44%), number of seeds per fruit (17.23%) and average fruit weight (8.14%) were directly contributed towards maximum divergence.

Garg *et al*. (2011), evaluated 53 germplasm lines of okra to assess the genetic diversity. They reported that no parallelism between genetic and geographic divergence was observed. They also reported substantial variation in cluster mean.

Saifullah and Rabbani (2013), conducted an experiment with 116 okra genotypes. They observed eight different electrophoretic zymotypes, all the zymotypes were polymorphic means presence of more than one band in each genotype. The genotypes were grouped in different polymorphic zymotypes, indicating considerable genetic diversity among the studied okra genotypes.

MATERIALS AND METHODS

The present investigation entitled "Variability Studies in Okra [*Abelmoschus esculentus* (L.) Moench]" was carried out during Kharif, 2013 at All India Co-ordinated Research Project on Vegetable Crops, HRS, Orissa University of Agriculture and Technology, Bhubaneswar. The investigation was carried to study the genetic variability, correlation, path analysis and D^2 analysis of 33genotypes/germplasm of okra. The seeds of the genotypes of okra hybrids have been supplied by Project Co-ordinator, Indian Institute of Vegetable Research, Varanasi.

3.1 CROPPING HISTORY OF THE PLOT

Prior to the present investigation, detail information on cropping history of the experimental plot was collected & presented in Table-1, for two successive years.

Table 1. Cropping history of the experimental plot

Year	Kharif	Rabi	Summer
2010	Brinjal	Broccoli	Bittergourd
2011	Cowpea	Tomato	Bittergourd
2012	Cowpea	Brinjal	Bittergourd

3.2 SOIL

A composite soil sample was taken from a depth of 15 cm surface from the experimental field before raising the crop for investigation. The sample was subjected to laboratory analysis to determine the physical and chemical compositions by following various standard methods. It is observed that the soils of experimental plot comes under sandy loam (Sand-75.24%, Silt-14.76%, Clay-10.76%) having pH 6.5. the chemical analysis of soil indicated low phosphorous content (125 Kg/ha). The organic carbon content of soil was 0.62% with 0.067 of total nitrogen having 10:2 (C: N) on oven dry basis.

3.3 GEOGRAPHICAL LOCATION OF THE EXPERIMENTAL SITE

Bhubaneswar is located at latitude of 20^0 15' N & 85^0 52' East longitude. It is about 60kms away from Bay of Bengal at an altitude of 25.5 meter above mean sea level (MSL).

3.4 CLIMATE

The experimental site comes under the eighteenth agro-climatic region of the country i.e. Eastern Coastal Plain and is termed as sub-humid characterized by warm moist climate with mild winter.

The average annual rainfall of Bhubaneswar is 1552mm (Based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September. The rainfall code of the place is D_1 E_3 ($B_1A_2B_1$) $C_1D_1E_2$. The average temperature varies from 14^0c in winter to 40^0c in summer & relative humidity varies between 49 or 90% from June to December.

Monthly average meteorological data during cropping season was recorded at meteorological Observatory of Orissa University of Agriculture and Technology Bhubaneswar in Table-2.

Table 2. Meteorological data collected during the experimental period (July13-Oct 13)

Month	Temperature(^{0}C)			Rainfall (mm)		Relative Humidity (%)			Wind Velocity	Bright Sunshine Hour
	Max	Min	Mean	Rainfall in (mm)	No. of rainy days	Morning	Afternoon	Mean		
July. 13	32.2	25.3	28.75	268.5	21	93	82	87.5	4.4	2.3
Aug. 13	32.2	25.2	28.7	156.1	18	94	77	85.5	3.6	3.0
Sept. 13	32.6	24.4	28.5	345.6	16	95	77	86	3.0	3.0
Oct. 13	30.5	22.9	26.7	720.1	20	96	78	87	5.0	2.9

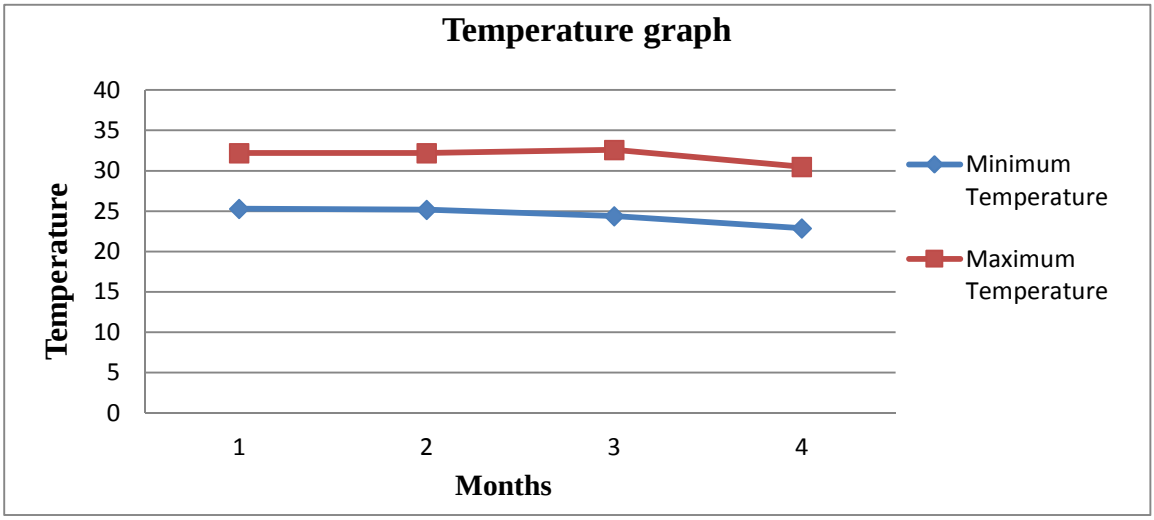


Fig. 1 Maximum and Minimum Temperature Graph

3.5.1 Experimental details:

(i) Design of Layout : Randomized Block Design (RBD) [Plan Layout Fig. 2]

(ii) Number of Treatments : 33

(iii) Number of Replication : 3

(iv) Total no. of plots :99

(v) Plot size

a) Length : 3.0m

b) Width : 3.0m

c) Area : 9.0m

(vi) Spacing

a) Row to Row : 60cm

b) Plant to Plant : 30cm

(vii) Number of rows per plot : 5

(viii) Number of plants per : 10

(ix) Number of plants per plot : 50

(x) Width of the bond separating Blocks : 40 cm

(xi) Width of irrigation channel : 90 cm

(xii) Length of experimental :36.6 m

(xiii) Width of experimental field : 32.7 m

(xiv) Total area under experiment :1196.82 m^2

Design – R.B.D, **Plot size** – 3.0m X 3.0m, **Treatments** – 33

Rep-I			Rep-II			Rep-III		
V_{20}	V_3	V_{25}	V_{18}	V_{16}	V_3	V_{25}	V_{11}	V_{26}
V_{29}	V_{28}	V_{17}	V_4	V_{23}	V_{21}	V_{20}	V_7	V_9
V_8	V_{22}	V_{10}	V_{31}	V_{19}	V_{14}	V_{32}	V_4	V_{23}
V_{27}	V_{11}	V_{31}	V_{24}	V_8	V_2	V_{15}	V_{21}	V_{31}
V_{12}	V_{19}	V_{24}	V_1	V_{15}	V_{28}	V_{28}	V_3	V_{33}
V_6	V_7	V_{13}	V_9	V_{12}	V_{20}	V_{14}	V_{24}	V_{27}
V_{26}	V_{21}	V_{14}	V_5	V_{32}	V_{30}	V_{30}	V_{18}	V_{13}
V_1	V_4	V_{16}	V_{26}	V_{22}	V_7	V_{22}	V_{16}	V_6
V_{23}	V_5	V_{18}	V_{33}	V_{27}	V_{13}	V_{10}	V_{29}	V_2
V_{30}	V_{32}	V_9	V_{25}	V_{10}	V_6	V_8	V_{17}	V_1
V_{15}	V_{33}	V_2	V_{29}	V_{11}	V_{17}	V_{12}	V_{19}	V_5

Fig.2 Plan of Layout

3.5.2 Field operation and Crop raising

The field was ploughed three times after incorporation of FYM during final land preparation @ 15 tons/ha and leveled properly. Then the individual plots are laid out of scheduled size as per the plan of layout (Fig.2) with required irrigation channel. Seeds are soaked in water over night to obtain better germination. The seed sowing was done on 17th July 2013.Five rows were made and ten plants were planted in each row, thus accommodating fifty plants/plot. Light irrigation was given with rose cane for the first time in main field.

A fertilizer dose of 100 kg N, 50kg P_2O_5 and 50 kg K_2O per ha were applied. The total amount of phosphorous with 20 kg of nitrogen and 10 kg of potash was applied to the soil before sowing. Remaining 80 kg of nitrogen and 40 kg of potash was applied in two-splits, as 40kg of nitrogen along with 20 kg of potash after first weeding, and remaining 20 kg of potash was applied after second weeding and 40kg of nitrogen was applied in 3 consecutive foliar sprays (1% urea) at 10 days interval during fruiting. Subsequently irrigation was provided in the irrigation channel at an interval of 8-10 days during the cropping season.

Thinning was carried out for the closely germinated plants at one true-leaf stage. Hoeing, weeding and earthing up were done at periodic interval. Manually hoeing followed by weeding, top dressing and earthing up were done followed by irrigation at 25 and 45 days after sowing. Adequate plant protection measures were taken by spraying insecticides and fungicides at periodical intervals to raise the crop successfully. Okra fruits were harvested when they were at tender stage and attained marketable size i.e. edible maturity stage. Picking of fruits were done at every alternate day till the last marketable produce.

3.6 BIOMETRIC OBSERVATIONS

3.6.1 Sampling Technique

Observations on various biometric characters were recorded by selecting randomly five competitive plants of each cultivar in a replication which were tagged

properly. The border plants were excluded while selecting the sample plants. The observations of these tagged plants were taken time to time starting from initiation of first flowering to final harvesting of fruits.

3.6.2 Characters studied

1. **Days to first flowering- (DFFL)**

   This was recorded by counting the number of days taken from sowing to initiation of first flower in each genotype.

2. **Node at which first flower appeared (NFF)**

   The node at which first flower appeared counted from the base and expressed in number.

3. **Days to 50% flowering (DF)**

   This was recorded by counting the number of days taken from sowing to the flowering in 50% plants in each genotype.

4. **Number of fruits per plant(NF)**

   This character was recorded by counting the total number of fruits harvested at different pickings in the sample plant till the final marketable harvest.

5. **Fruit length(FL)**

   The length of 10 fruits randomly selected from selected plants in observational plot of each genotype in each replication were measured and expressed in centimeter from the attachment end to the tip using a venier caliper and the mean value was calculated as fruit length.

6. **Fruit girth(FG)**

   Ten fruits selected randomly from each plot in a replication for recording of length were also used for noting their girth at the point of maximum thickness which were averaged and expressed in centimeter (cm).

7. **Fruit weight(FW)**

Fruits selected for length and girth were also used for recording the weight of fruit. Fruits were weighed individually and average weight of ten fruits was calculated as weight of fruit and was expressed in grams.

8. **Plant height(PH)**

The height of ten sample plants was recorded in cm from the base of the plant to the tip of the plant after final harvest and their mean value were taken for analysis of this character.

9. **Nodes per plant (NP)**

The ten sample plants selected for plant height were also used for recording node per plant. Nodes of each sample plants were counted and their mean values were taken for analysis of this character.

10. **Duration of fruiting(DOF)**

This was recorded by counting the number of days taken from sowing to the final harvest in each genotype.

11. **Days to first harvest(DFH)**

This was recorded by counting the number of days taken from sowing to the first harvest in each genotype.

12. **Fruit yield/plant(g)**

Observation for this character was recorded by taking the fresh weight of total number of fruits harvested at different pickings till marketable harvest in each replication and the total yield was expressed in terms of grams per plant.

13. **Number of disease(YVMV) infected plants at 90 days**

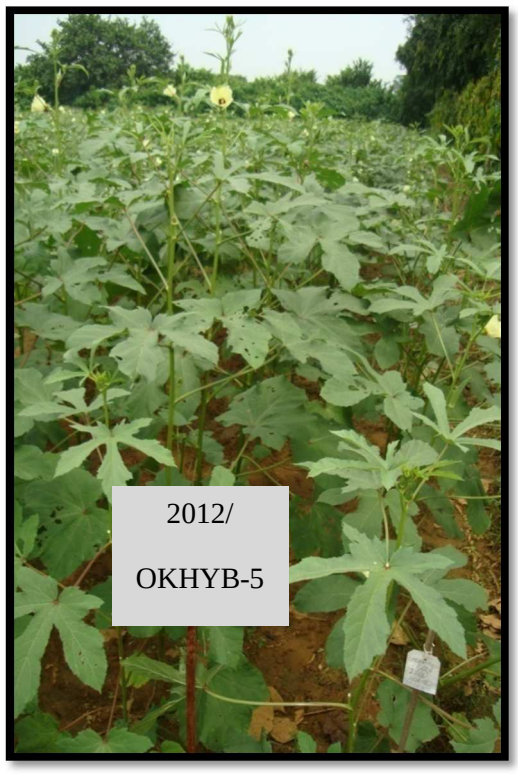
Observations for this character was recorded by counting the number of plants infected with disease (YVMV) at 90 days in each replication and were expressed in percentage.

Fig.3 Overall view of experimental field

Fig.4. Field view

Fig. 5.PROMISING GENOTYPES


2012/
OKHYB- 7


2012/
OKHYB-5


2012/
OKHYB-2


2013/
OKHYB-8

3.7 STATISTICAL ANALYSIS

The data recorded for various characters were subjected to statistical analysis based on their sample means (Gomez and Gomez, 1983). Observations of all the 13 characters were analyzed for variability and other genetic parameters related to fruit yield were taken for character association, path analysis, and genetic divergence study. In case of YVMV incidence the angular value after transformation is taken for analysis.

3.7.1 Analysis of variances

The analysis of variances for each of the characters stated was done to find out varietals differences. The analysis was carried out separately for each trait following the procedure of randomized block design analysis (Panse and Sukhatme, 1954).

Analysis of variance was done on basis of following model.

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

Where,

Y_{ij} = Phenotypic observation in the i^{th} genotype and the j^{th} replication

m = General mean

g_i = Effect of the i^{th} genotype/treatment

r_j = Effect of j^{th} replication

e_{ij} = random error associated with i^{th} genotype inj^{th} replication

Table 3. Analysis of variance and expected mean sum of square

Source	Df	Mss	Expected mean sum of square
Replication	(r-1)	M_R	$\sigma^2_e + g\sigma^2_r$
Genotype	(g-1)	M_G	$\sigma^2_e + r\sigma^2_g$
Error	(r-1)(g-1)	M_E	σ^2_e

3.7.2 Mean, range, standard error and critical differences

Sample mean values were calculated for each character by dividing the total by corresponding number of observations, while the highest and lowest values for each character were taken as the range. The S.E. and C.D. values were calculated by using the following formula.

Standard error mean (SEM) = $\sqrt{\frac{EMS}{r}}$

Critical difference (C.D.)

$= \sqrt{\frac{EMS}{r}} \times t$ value at error d.f. at 5 % and 10 level of significance

Where,

r = number of replications

EMS = Error mean sum of square

3.7.3 Co-efficient of variation

For comparing the variability of two or more than two characters, co-efficient of variation were calculated by using the formula given below:

C.V. = $\frac{SD}{X} \times 100 = \sqrt{\frac{EMS}{X}} \times 100$

Where,

S.D. =standard deviation which is the square root of mean square due to error (EMS)

X = Experimental mean

From the structure of the analysis of variance

Error variance = $\sigma e^2 = M_E$

Genotypic variance = $\sigma^2_g = \frac{M_G - M_E}{r}$

Phenotypic variance = $\sigma_p^2 = \frac{M_G}{r} = \frac{\sigma_g^2 + \sigma_e^2}{r}$

The genotypic co-efficient of variation (GCV) and the phenotypic co-efficient of variation (PCV) were calculated by the formula given by Burton (1952).

$$GCV = \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \times 100$$

$$PCV = \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \times 100$$

Heritability (broad sense)

The heritability estimates were used to measure the degree of correspondence between phenotypic value and breeding value. It is worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953) and expressed in percentage according to Weber and Moorty (1952).

$$h^2 \text{ (broad sense)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}}$$

$$h^2 \text{ (broad sense in percentage)} = \frac{\text{Genotypic variance}}{\text{Phenotypic variance}} \times 100$$

3.7.4 Expected genetic advance

Genetic advance was estimated as per the formula suggested by Johnson *et al* (1995).

$GA = K. h^2\sigma_p$

Where,

K = Selection differential in standard units (which is 2.06 per 5% selection intensity).

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

$$\text{GA expressed as percentage of mean} = \frac{GA}{\text{Mean}} \times 100$$

3.7.5 Estimation of correlation co-efficient

Simple correlation co-efficient were computed at phenotypic and genotypic levels between pairs of 14 important characters that contribute to fruit yield (number of fruits per plant) using the following formula.

$$\text{Genotypic correlation } (r_g) = \frac{\sigma_g(xy)}{\sigma_g(x)} \times \sigma_g(y)$$

$$\text{Phenotypic correlation } (r_p) = \frac{\sigma_p(xy)}{\sigma_p(x)} \times \sigma_p(y)$$

Where,

$\sigma_g(xy)$ = Genotypic co-variance between the two traits x and y.

$\sigma_p(xy)$ = Phenotypic co-variance between the two traits x and y.

$\sigma_g(x)$ and $\sigma_g(y)$ = Genotypic standard deviation for x and y respectively.

$\sigma_p(x)$ and $\sigma_p(y)$ = Phenotypic standard deviation for x and y respectively.

The estimated values were compared with the table value at (n - 2) and at 5% and 1% levels of significance in order of test the significance of correlation co-efficients at phenotypic and genotypic level.

3.7.6 Path co-efficient analysis

The cause and effect relationship among the various correlated characters are determined by path co-efficient analysis. Path co-efficient were standardized by partial regression coefficients which individually provide a measure of direct effect of the casual factors on the effect variable. These permit partitioning of the correlation between casual factors and the effect of variables into components of direct and indirect effect and thus give a better picture of the association of the casual factors with the effect variable.

In the present investigation fruit yield per plant was taken as the effect with other characters like plant height, days to first flowering, node at which first flower appeared, days to 50% flowering, days to first fruiting, number of fruits per plant, fruit length, fruit girth, fruit weight and YVMV incidence related to this as the casual factor.

The path coefficients were obtained by solving the following the simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes. (Dewey and Lu, 1959).

$$r_{112} = r_{11}p_{112} + r_{12}p_{112} + r_{13}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{111}p_{1112}$$

$$r_{212} = r_{21}p_{112} + r_{22}p_{112} + r_{23}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{211}p_{1112}$$

$$r_{312} = r_{31}p_{112} + r_{32}p_{112} + r_{33}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{311}p_{1112}$$

$$r_{1112} = r_{111}p_{112} + r_{112}p_{212} + r_{113}p_{312} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + p_{1112}$$

Where, r_{ij} is the coefficient of correlation between i^{th} and j^{th} characters and p_{qi} is the path coefficient (direct effect of i^{th} character on number of fruits per plant (1, 2)).

The solutions for path coefficients, direct and indirect effects of the casual factors were estimated as the values of the individual terms of the above equations in R.H.S.

The coefficient of determination (R^2) and the residual effect ($p_{12.R}$) were calculated as follows:

$$I = p^2_{12.R} + \sum p_{iy}r_{iy}$$

$$R^2 = \sum p_{iy}r_{iy}$$

$$= p_{112}r_{112} + p_{212}r_{212} + p_{312}r_{312} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + p_{1112}r_{1112}$$

$$P_{12.R} = \sqrt{I - R^2}$$

The path analysis at the phenotypic level with the same cause and effect relationship was computed using the phenotypic correlations as stated earlier.

Genetic divergence

Mahalanobis' (1928) generalized distance, D^2statistics was used for computing genetic divergence as described by (Rao, 1952). The original measurements were transformed to standardized uncorrelated variables by pivotal condensation (Rao, 1952). The divergence between any two varieties was obtained as the sum of squares of the difference in the values of the corresponding transformed values (V_{ij})

$$D^2_{jk} = \sum^{n}_{i=1} Y_ij - Y_ik$$

Gives the D^2 between J^{th} and K^{th} germplasm for 'n' characters. The all possible 528 pairs of D^2 were calculated from the 33 varieties using the formula n (n - 1) / 2.

Following Tocher's method as described by Rao (1952), the genotypes were grouped into clusters. The criterion of grouping was that any two genotypes belonging to the same cluster should have a smaller D^2 value than those between genotypes belong to different clusters. Inter and intra-cluster distances were determined and represented.

EXPERIMENTAL FINDINGS

During the course of research on the project entitled "**Variability Studies in Okra (*Abelmoschus esculentus* L. Moench)",** observation on fruit yield per plant and its component characters were recorded. The mean values of the traits studied were statistically analyzed to study the variability, heritability and genetic gain for selection and their association with yield as well as among themselves. The direct and indirect effect of these traits on fruit yield, the nature and the extend of genetic divergence among 33 genotypes were also studied. The salient findings as revealed from the investigation are present below:

4.1 Analysis of variance

The variance (mean square values) between genotypes for 13 characters such as plant height, nodes per plant, fruit length, fruit girth, fruit weight, number of fruits per plant, first flowering node, duration of fruiting, days to first flowering, days to 50% flowering, days to first harvest, number of disease infected plants and yield per plant are presented in Table 4. The data revealed the existence of significant difference among the genotypes for the characters studied, except for first flowering node and fruit girth.

4.1.1 Mean performance and co-efficient of variation

The mean performance, standard error of variance (S. E.) and critical difference (C. D.) values are presented in Table 5.

Plant height

A moderate variability ranging from 117.583 cm to 188.200 cm was noticed with respect to plant height. The plant height was maximum for germplasm V_4 which is followed by V_{19} (182.333 cm) and the minimum height was observed in V_{26}. The germplasm like V_{15} (150.533), Pusa Sawani (150.600), Arka Anamika (153.400), V_2 (154.067), V_{25} (154.667) and V_1 (155.067) was of medium type.

Table 4. Analysis of variance for 13 quantitative characters studied in okra germplasm

Sl. No.	Characters	Mean Sum of Square		
		Replication (2)	Genotypes (32)	Error (64)
1.	Plant height (cm)	982.590**	633.046**	338.016
2.	Nodes per plant	33.685**	14.046**	8.672
3.	Fruit length (cm)	0.739	5.798**	1.815
4.	Fruit girth (cm)	0.106	0.205	0.076
5.	Fruit weight (g)	2.358	19.468**	1.971
6.	Number of fruits per plant	3.658	9.109**	3.461
7.	First flowering node	0.942	1.763	0.753
8.	Duration of fruiting	2.133	31.082**	5.019
9.	Days to first flowering	1.064	12.306**	4.066
10.	Days to 50% flowering	6.444**	21.411**	2.962
11.	Days to first harvest	1.407	16.637**	3.979
12.	Number of disease infected plant	86.357**	1216.514**	84.466
13.	Yield per plant (g)	4900.886**	7066.161**	2228.008

** Significant at 1% level

Figure in the parenthesis indicate degree of freedom of respective sources of variation

Number of nodes per plant

V_3 produced highest number of nodes per plant (29.867) followed by V_8 (29.133). Lowest number of nodes were recorded in V_{26} (21.400). However V_{23} (25.133), V_{16} and V_{22} (25.267), V_7 (25.533), V_{17} (25.600), HOK-152 (25.777) and V_6 (25.800) exhibited intermediate value for this trait.

Fruit length

A significantly medium range of variation was obtained in case of fruit length among the germplasm. The highest value 17.627cm was recorded in case of V_{13} which was followed by V_9 (17.597cm). The lowest value 11.797cm was recorded in V_{26}. Some of the lines showing medium value for this trait were V_{24} (14.807cm), V_{29} (14.663cm), V_{31} (14.407cm), V_{30} (14.310cm) and V_{28} (14.290cm) in order.

Fruit girth

A narrow range of variation was observed among the thirty-three germplasm with respect to girth of the fruit. Maximum girth 6.783cm was recorded in V_{32} (Arka Anamika) which was followed by V_7 (6.637cm). However the lowest fruit girth 5.780cm was recorded in V_{33} (BO-2) followed by V_{16} (5.783) and V_{26} (5.787) in ascending order.

Fruit weight

A significantly moderate range of variation 12.233g to 23.397g was observed in case of fruit weight. The germplasm V_{23} recorded the highest fruit weight 23.397g closely followed by V_{27}(23.333g) and V_9(23.067g). The lowest fruit weight 12.233g was recorded in V_{26}, followed by V_{11} (14.827). The germplasm like V_{18} (17.667), V_{10} and V_2 (17.867) and V_{21} (17.950) have shown medium value for the character.

Number of fruits per plant

A significant variation was visualized in the number of fruits per plant among the genotypes ranging from 16.267to 23.550. The highest number of fruit (23.550) was recorded in V_{28}followed by (22.800) in V_{19} and the lowest number of fruits (16.267) was observed in V_{32} (Arka Anamika). V_5 (19.600), V_{11} (19.667) and V_{29} (19.867), showed medium value for this character.

Node at which first flower appeared

Significant range was observed for this trait among the genotypes evaluated. The highest value under this character was recorded in V_{14} (7.767) where as V_5 (4.900) recorded the lowest value. Genotypes like V_{24} (6.333), V_1 (6.400) and V_3 (6.467) exhibited medium value for this trait.

Duration of fruiting

A wide variability ranging from 35.547 to 46.263 was noticed with respect to duration of fruiting. It was maximum for germplasm V_9 (46.263) and the minimum of 35.547 in V_{32} (Arka Anamika). The germplasm V_3 (40.027) and BO-2 (40.060) were of medium type.

Days to first flower

A wide range of variation from 30.357 (V_{33}) to 40.100 (V_{14}) were observed for days to first flowering. However genotypes V_7 showed moderate value (35.600) followed by V_{15} (35.527) for this character.

Days to 50% flowering

A range of 34.877 to 47.270 days were recorded for days taken to 50% flowering among the genotypes evaluated. The lowest value was observed in V_8 (34.877) whereas the highest value estimated 47.270 in V_{11}. Germplasm like V_{10} (40.950), HOK-152 (40.980) and V_{20} (41.060) of intermediate type.

Table 5. Mean of performance of 33 okra germplasm for 13 characters

	Germplasm	Plant height (PH) (cm)	Number of nodes per plant (NP)	Fruit length (FL) (cm)	Fruit girth (FG) (cm)	Fruit weight (FW) (g)	Number of fruits per plant (NF)	Node at which first flower appeared (NFF)	Duration of fruiting (DOF)	Days to first flowering (DFFL)	Days to 50% flowering (DF)	Days to first harvest (DFH)	Number of disease infected plants	Fruit yield per plant (g)
V_1	2011/OKHYB-1	155.067	24.333	16.223	6.583	20.283	19.067	6.400	42.333	35.183	44.007	42.150	48.860	280.180
V_2	2011/OKHYB-2	161.067	24.267	17.460	6.330	17.867	20.367	5.133	42.290	33.033	37.067	40.550	40.393	278.513
V_3	2011/OKHYB-5	174.200	**29.867**	16.737	5.973	21.910	21.133	6.467	40.027	37.547	43.803	44.407	55.610	290.913
V_4	2011/OKHYB-6	**188.200**	24.933	16.810	6.277	19.380	17.400	5.533	42.220	33.583	37.737	40.690	25.220	256.160
V_5	2011/OKHYB-7	147.733	24.467	14.073	6.433	19.500	19.600	**4.900**	43.030	31.853	36.207	39.963	62.843	280.560
V_6	2011/OKHYB-8	166.800	25.800	13.827	6.530	20.437	20.667	5.667	43.590	33.027	37.427	**39.367**	63.123	304.367
V_7	2011/OKHYB-10	144.133	25.533	15.407	6.637	23.018	18.267	5.933	43.217	35.600	42.073	40.777	65.423	255.960
V_8	2011/OKHYB-11	179.733	29.133	15.657	6.443	19.880	21.000	5.200	44.587	32.920	**34.877**	40.467	60.763	318.667
V_9	2012/OKHYB-1	160.400	28.600	17.597	5.993	23.067	22.333	6.200	**46.263**	37.453	42.327	44.550	40.963	349.180
V_{10}	2012/OKHYB-2	176.000	26.000	15.000	6.263	17.867	21.600	5.133	44.383	36.590	40.950	45.360	23.457	326.320
V_{11}	2012/OKHYB-4	145.100	27.133	13.193	6.150	14.827	19.667	7.333	42.097	35.370	**47.270**	46.287	45.810	242.370
V_{12}	2012/OKHYB-5	176.667	28.933	16.473	6.303	20.467	21.267	6.733	4.180	35.387	42.667	47.463	19.910	330.930
V_{13}	2012/OKHYB-13	177.000	26.733	**17.627**	6.320	21.667	21.467	6.933	43.847	37.813	42.437	45.697	16.647	375.440
V_{14}	2012/OKHYB-6	145.000	26.400	15.437	6.097	16.117	20.400	**7.767**	47.287	**40.100**	44.393	44.790	13.170	321.687
V_{15}	2012/OKHYB-7	150.533	26.000	15.180	6.173	20.267	20.133	5.300	43.963	35.527	41.627	**47.717**	15.553	338.313
V_{16}	2012/OKHYB-8	158.667	25.267	15.747	5.783	18.067	18.667	6.633	46.030	37.447	45.190	45.067	40.987	273.500
V_{17}	2012/OKHYB-10	167.267	25.600	16.043	5.830	18.400	19.133	5.400	45.813	33.887	41.320	45.097	24.170	266.130
V_{18}	2012/OKHYB-12	162.733	26.733	15.893	5.940	17.667	20.200	5.833	46.667	38.583	43.103	46.197	33.947	305.090

Contd….

	Germplasm	Plant height (PH) (cm)	Number of nodes per plant (NP)	Fruit length (FL) (cm)	Fruit girth (FG) (cm)	Fruit weight (FW) (g)	Number of fruits per plant (NF)	Node at which first flower appeared (NFF)	Duration of fruiting (DOF)	Days to first flowering (DFFL)	Days to 50% flowering (DF)	Days to first harvest (DFH)	Number of disease infected plants	Fruit yield per plant (g)
V_{19}	2012/OKHYB-15	182.333	28.933	16.813	6.097	20.400	22.800	5.167	43.953	34.583	42.060	45.747	14.450	340.363
V_{20}	2013/OKHYB-1	140.733	23.067	15.960	5.910	21.333	17.833	6.000	39.040	35.287	41.060	41.997	41.547	258.027
V_{21}	2013/OKHYB-2	154.067	23.467	16.233	6.000	17.950	17.533	6.267	40.373	35.423	42.107	39.493	16.750	255.863
V_{22}	2013/OKHYB-3	160.800	25.267	15.590	6.007	21.600	19.200	6.933	37.863	36.890	43.543	45.607	35.887	313.117
V_{23}	2013/OKHYB-4	179.783	25.133	15.043	6.007	**23.397**	20.033	5.667	37.883	34.807	38.693	42.437	**0.000**	214.220
V_{24}	2013/OKHYB-5	174.467	28.200	14.807	6.047	22.157	22.667	6.333	37.730	34.813	41.747	44.603	15.330	**433.337**
V_{25}	2013/OKHYB-6	154.667	23.533	13.527	6.263	17.310	19.100	5.833	38.350	33.690	38.953	44.377	39.910	271.910
V_{26}	2013/OKHYB-7	**117.583**	**21.400**	**11.797**	5.787	**12.233**	18.133	7.100	38.377	35.967	41.780	42.440	56.550	221.987
V_{27}	2013/OKHYB-8	159.333	27.000	15.070	6.247	23.333	20.400	7.767	41.653	36.003	43.157	41.463	12.177	326.113
V_{28}	2013/OKHYB-9	159.533	27.733	14.290	5.953	18.783	**23.550**	5.333	37.757	38.113	40.247	44.370	13.787	321.443
V_{29}	2013/OKHYB-10	161.600	24.400	14.663	6.467	20.200	19.867	6.633	38.610	35.403	39.650	42.317	21.167	275.333
V_{30}	HOK-152 (c)	158.683	25.777	14.310	6.057	19.003	18.467	6.233	41.197	35.913	40.980	42.147	56.913	263.903
V_{31}	Pusa Sawani (c)	150.600	21.600	14.407	6.383	23.043	17.000	6.133	36.313	36.673	42.140	44.293	63.003	252.317
V_{32}	Arka Anamika (c)	153.400	22.267	12.867	**6.783**	17.333	**16.267**	5.800	**35.547**	36.653	40.047	44.097	**69.847**	**192.263**
V_{33}	BO-2 (lc)	156.533	24.200	13.923	**5.780**	19.063	20.800	5.500	40.060	**30.357**	39.070	40.960	63.240	265.217
	SE(±)	15.011	2.404	1.100	0.226	1.146	1.519	0.709	1.829	1.647	1.405	1.629	7.504	38.540
	C. D. (0.05)	29.989	4.803	2.198	0.452	2.290	3.035	1.416	3.655	3.289	2.808	3.254	14.991	76.993

Days to first harvest

Days to first harvest was minimum (39.367 days) in V_6 whereas it is maximum (47.717) in V_{15}. A moderate value was exhibited by Arka Anamika (44.097), Pusa Sawani (44.293) and V_{28} (44.370) for this trait.

Number of disease infected plants

A wider variation was observed for disease incidence among the genotypes ranging from 0.00% (V_{23}) to 69.847% in V_{32} (Arka Anamika) followed by 65.423% (V_7). However, V_{18} (33.947), V_{22} (35.887) and V_{25} (39.910) showed the incidence to lower magnitude.

Fruit yield per plant (g)

A significant wide range of variation for this character was recorded ranging from 192.263 to 433.337 g per plant among the genotype. The maximum value 433.337g was recorded in V_{24} which was followed by V_{13}(375.440g), V_9 (349.180) and V_{19} (340.363) in decreasing order. The lowest yield (192.263g/plant) was obtained from V_{32} (Arka Anamika) followed by V_{23} and V_{26}.

Co-efficient of variance (C. V)

The co-efficient of variation with respect to different characters are presented in Table 6, which ranged from 4.177% to 24.913%. The highest variation (24.913%) was noticed in number of disease infected plants followed by yield per plant (16.226%) and first flowering node (14.238%). The lowest variation 4.177% was recorded in days to 50% flowering followed by days to first harvest (4.594%) and duration of fruiting (5.371%) in ascending order. Therefore, basing on the C.V value, the characters can be grouped into three classes such as:

i. Low variability (C.V. = 5% or less)
ii. Moderate variability (C.V. = 5-10%)
iii. High variability (C.V. = >10%)

Table 6. General mean, range, co-efficient of variation (C. V), genotypic variance, phenotypic variance for 13 quantitative characters in okra germplasm

Sl. No.	Characters	General Mean	Range	C.V (%)	Genotypic Variance	Phenotypic Variance
1.	Plant height (cm)	160.619	117.583-188.200	11.446	98.343	436.360
2.	Nodes per plant	25.688	21.400-29.867	11.464	1.791	10.463
3.	Fruit length (cm)	15.263	11.797-17.627	8.828	1.327	3.143
4.	Fruit girth (cm)	6.177	5.780-6.783	4.486	0.043	0.120
5.	Fruit weight (g)	19.631	12.233-23.397	7.152	5.823	7.804
6.	Number of fruits per plant	19.879	16.267-23.550	9.360	1.883	5.344
7.	First flowering node	6.097	4.900-7.767	14.238	0.336	1.090
8.	Duration of fruiting	41.713	35.547-46.263	5.371	8.688	13.707
9.	Days to first flowering	35.499	30.357-40.100	5.681	2.747	6.813
10.	Days to 50% flowering	41.203	34.877-47.270	4.177	6.150	9.112
11.	Days to first harvest	43.422	39.367-47.717	4.594	4.219	8.199
12.	Number of disease infected plant	36.891	0.000-69.847	24.913	377.349	461.816
13.	Yield per plant (g)	290.900	192.263-433.337	16.226	1612.718	3840.727

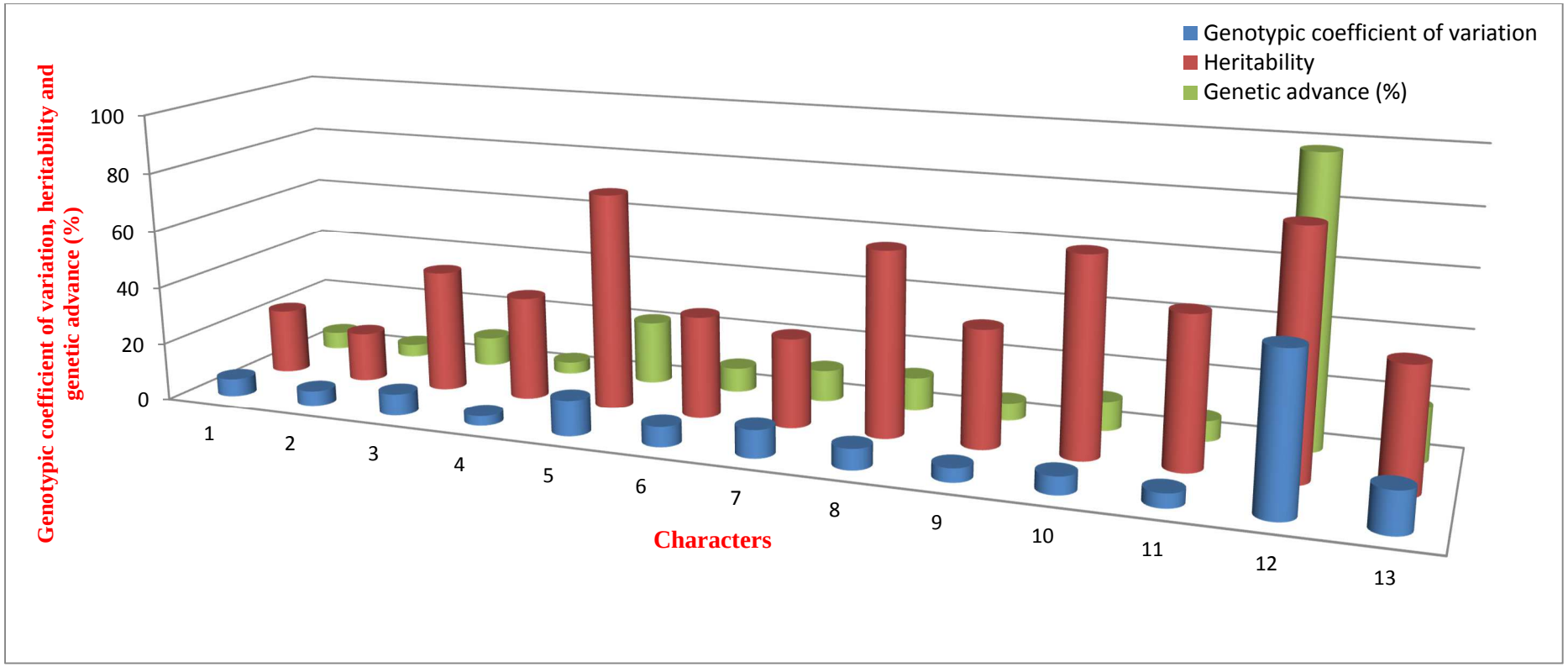
The traits like fruit girth, days to 50% flowering and days to first harvest exhibited low variability. On the contrary, the traits like fruit length, fruit weight, number of fruits per plant, duration of fruiting and days to first flowering recorded moderate variability. Plant height, nodes per plant, first flowering node, number of disease infected plants and yield per plant exhibited high variability.

Estimation of genetic parameters

The estimates of genetic parameters such as genotypic variance and phenotypic variance are presented in Table-6, and their respective co-efficient of variation, broad sense heritability and genetic gain for selection are presented in Table 7.

Table 7. Genotypic co-efficient of variance (GCV), Phenotypic co-efficient of variance (PCV), Heritability (in broad sense) and Genetic advance for 13 quantitative characters studied in okra

Sl. No.	Characters	Phenotypic co-efficient of variance (PCV)	Genotypic co-efficient of variance (GCV)	Heritability (in broad sense) (%)	Genetic advance (at 5% level)	GA Expressed in % of mean
1.	Plant height (cm)	13.005	6.174	22.54	9.698	6.038
2.	Nodes per plant	12.592	5.210	17.12	1.141	4.440
3.	Fruit length (cm)	11.615	7.548	42.23	1.542	10.105
4.	Fruit girth (cm)	5.602	3.355	35.88	0.256	4.140
5.	Fruit weight (g)	14.230	12.302	74.74	4.301	21.908
6.	Number of fruits per plant	11.629	6.901	35.23	1.677	8.438
7.	First flowering node	17.124	9.514	30.87	0.664	10.889
8.	Duration of fruiting	8.875	7.066	63.38	4.834	11.588
9.	Days to first flowering	7.352	4.668	40.31	2.168	6.106
10.	Days to 50% flowering	7.326	6.018	67.49	4.197	10.185
11.	Days to first harvest	6.594	4.730	51.46	3.035	6.990
12.	Number of disease infected plant	58.252	52.656	81.71	36.172	98.051
13.	Yield per plant (g)	21.304	13.805	41.99	53.607	18.427



1. Plant height (cm)
2. Nodes per plant
3. Fruit length (cm)
4. Fruit girth (cm)
5. Fruit weight (g)
6. Number of fruits per plant
7. First flowering node
8. Duration of fruiting
9. Days to first flowering
10. Days to 50% flowering
11. Days to first harvest
12. Number of disease infected plants
13. Yield per plant (g)

Fig. 6 Genotypic co-efficient of variation (GCV), heritability and genetic advance (%) of 13 quantitative characters in okra

The genotypic variance ranged from 0.336 for first flowering node to 1612.718 for yield per plant. Phenotypic variance ranged from 0.120 for fruit yield to 3840.727for yield per plant. In general all the traits exhibited parallel values between those two variance showing lower value in the former than later.

The perusal of data in Table 7, revealed that the phenotypic co-efficient of variation (PCV) was higher than genotypic co-efficient variance (GCV) for all traits studied. The PCV was highest (58.252) in number of disease infected plant followed by yield per plant (21.304). The traits like first flowering node (17.124), fruit weight (14.230), plant height (13.005), nodes per plant (12.592), number of fruits per plant (11.629) and fruit length (11.615) exhibited moderate value. The other traits like duration of fruiting (8.875), days to first flowering (7.352), days to 50% flowering (7.326) and days to first harvest (6.594) showed lower value having the lowest value of (5.602) for the trait.

More or less similar trend was observed in the estimates of GCV for all the traits with number of disease infected plant having the highest value (52.656) followed by yield per plant (13.805). Moderate values were obtained for fruit weight (12.302), first flowering node (9.514), fruit length (7.548), duration of fruiting (7.066), number of fruits per plant (6.901), plant height (6.174), days to 50% flowering (6.018) and nodes per plant (5.210). Fruit girth exhibited the lowest value (3.355) which was closely followed by (4.668) in days to first flowering and (4.730) in days to first harvest in ascending order for this parameter.

Heritability

Heritability (broad sense) estimates (Table 7) ranged from 17.12% to 81.71%. High heritability above, 60% were observed in traits like number of disease infected plant (81.71), fruit weight (74.74), days to 50% flowering (67.49) and duration of fruiting (63.38). Moderate heritability was observed in days to first harvest (51.46), fruit length (42.23), yield per plant (41.99) and days to first flowering

(40.31), fruit girth (35.88), number of fruits per plant (35.23), first flowering node (30.87). The traits like plant height (22.54) showed lower heritability being lowest in nodes per plant (17.12).

Genetic advance

The genetic advance varied from 0.256 (fruit girth) to 53.607 (yield per plant). High genetic advance (36.172) was also observed in number of disease infected plant. All other remaining characters like plant height (9.698), nodes per plant (1.141), fruit length (1.542), fruit weight (4.301), number of fruits per plant (1.677), duration of fruiting (4.834), days to first flowering (2.168), days to 50% flowering (4.197) and days to first harvest (3.035) showed low genetic advance (less than 10). The lowest value was recorded in fruit girth (0.256) followed by (0.664) in first flowering node in ascending order.

The predicted genetic advance expressed as percent of population mean ranged from 98.051% for number of disease infected plant to 4.140% for fruit girth. Highest expected genetic gain by selection was observed in the trait number of disease infected plant (98.051%). Other characters showing genetic gain of higher magnitude were fruit weight (21.908%) followed by yield per plant (18.427%), while rest of the character showed moderate to low value being lowest in fruit girth (4.140%).

Character association

Estimates of Phenotypic and Genotypic correlation co-efficient of all pairs of thirteen characters related to fruit yield are presented in Table-8 and Table-9 respectively.

Phenotypic correlation

Fruit yield per plant was positively and significantly correlated with plant height (0.340), nodes per plant (0.504) and number of fruits per plant (0.657). Other characters like fruit length (0.277), fruit girth (0.005), fruit weight (0.242), first

flowering node (0.015), duration of fruiting (0.240), days to first flowering (0.056), days to 50% flowering (0.047), days to first harvest (0.177) are positively associated with fruit yield per plant with insignificant values. But number of disease infected plant (-0.287) was negatively associated with fruit yield per plant having insignificant value.

Plant height was significantly and positively correlated with nodes per plant (0.539), fruit length (0.386), number of fruits per plant (0.394) and fruit yield per plant (0.340) whereas it is positively associated with fruit girth (0.091), fruit weight (0.284), duration of fruiting (0.092) and days to first harvest (0.102) having insignificant values. On the contrary, it was negatively and significantly correlated with first flowering node (-0.300). Further this trait exhibited negative association with days to first flowering (-0.158), days to 50% flowering (-0.199) and number of disease infected plants (-0.283) having insignificant values.

Nodes per plant was positively and significantly correlated with fruit length (0.322), number of fruits per plant (0.703) and fruit yield per plant (0.504). Rest of the characters like fruit girth (0.021), fruit weight (0.152), first flowering node (0.018), duration of fruiting (0.271), days to first flowering (0.011), days to 50% flowering (0.076), days to first harvest (0.123) were positively correlated and number of disease infected plants (-0.179) was negatively correlated having insignificant values.

Fruit length was positively and significantly correlated with fruit weight (0.442) and duration of fruiting (0.351) while it was positively correlated with fruit girth (0.106), number of fruits per plant (0.287), days to first flowering (0.075), days to 50% flowering (0.051), days to first harvest (0.084) and fruit yield per plant (0.277) with insignificant values. Fruit length was negatively correlated with number of disease infected plant (-0.297) and with first flowering node (-0.052) having significant value in the former.

Fruit girth was positively correlated with fruit weight (0.175), duration of fruiting (0.031), number of disease infected plant (0.233), fruit yield per plant (0.005) and negatively correlated with number of fruits per plant (-0.060), first flowering node (-0.014), days to first flowering (-0.093), days to 50% flowering (-0.221) and days to first harvest (-0.180) with insignificant values.

Fruit weight was positively correlated with number of fruits per plant (0.167), fruit yield per plant (0.242) and negatively correlated with first flowering node (-0.063), duration of fruiting (-0.056), days to first flowering (-0.017), days to 50% flowering (-0.084), days to first harvest (-0.047) and number of disease infected plant (-0.108) with insignificant values.

Number of fruits per plant was significantly and positively correlated with fruit yield per plant (0.657) and was positively correlated with duration of fruiting (0.227) and days to first harvest (0.075). Characters like first flowering node (-0.107), days to first flowering (-0.050), days to 50% flowering (-0.068) and number of disease infected plants (-0.252) were negatively and insignificantly associated with this parameter.

First flowering node was significantly and positively associated with days to first flowering (0.371), days to 50% flowering (0.516). It was positively associated with characters like duration of fruiting (0.045), days to first harvest (0.082), fruit yield per plant (0.015) and negatively associated with number of disease infected plant (-0.136) having insignificant values.

Duration of fruiting was positively correlated with days to first flowering (0.123), days to 50% flowering (0.053), days to first harvest (0.006), fruit yield per plant (0.240) and negatively correlated with number of disease infected plant (-0.112) with insignificant value.

Days to first flowering was significantly and positively correlated to days to 50% flowering (0.533) and days to first harvest (0.364). Further this trait was positively correlated with fruit yield per plant (0.056) but negatively correlated with number of disease infected plant (-0.244) with insignificant values.

Days to 50% flowering was significantly and positively associated with days to first harvest (0.483).Further this trait was positively associated with fruit yield per plant (0.047) and negatively associated with number of disease infected plant (-0.206) having insignificant values.

Days to first harvest showed a positive correlation with fruit yield per plant (0.177) This trait was significantly and negatively correlated with number of disease infected plant (-0.295).

Genotypic correlation

The genotypic correlation co-efficient for all the thirteen characters related to fruit yield per plant are presented in Table 9. Perusal of the data in the above cited table indicated that, fruit yield per plant was significantly and positively correlated to plant height (0.550), nodes per plant (1.044), fruit length (0.602), fruit weight (0.453), number of fruits per plant (0.914), duration of fruiting (0.472), days to first flowering (0.345) and days to first harvest (0.558) while negatively but significantly associated to number of disease infected plant (-0.576). The characters like first flowering node (0.142), days to 50% flowering (0.180) were positively associated and fruit girth (-0.188) was negatively associated. But the association was found to be non-significant.

Plant height was significantly and positively correlated to nodes per plant (0.718), fruit length (0.834), fruit weight (0.679), number of fruits per plant (0.557), duration of fruiting (0.349), fruit yield per plant (0.550) while negatively and significantly correlated with first flowering node (-0.338), days to 50% flowering (-

0.344) and number of disease infected plant (-0.571). Rest of the characters like days to first flowering (-0.079) was negatively and fruit girth (0.100), days to first harvest (0.138) were positively associated with insignificant values.

Nodes per plant exhibited significant positive association with days to 50% flowering (0.328), fruit length (0.751), fruit weight (0.580), number of fruits per plant (0.974), duration of fruiting (0.844), days to first flowering (0.522), days to first harvest (0.767), fruit yield per plant (1.044). Significant negative association was exhibited by this trait with fruit girth (-0.403) and number of disease infected plant (-0.570).

Fruit length was significantly and negatively correlated only to number of disease infected plant (-0.456) whereas negatively correlated to fruit girth (-0.290) and first flowering node (-0.107). Fruit weight (0.495), duration of fruiting (0.635), fruit yield per plant (0.602) exhibited significant and positive correlation while number of fruits per plant (0.287), days to first flowering (0.265), days to 50% flowering (0.137) and days to first harvest (0.137) exhibit positive correlation only with this character.

Fruit girth was negatively and significantly associated with number of fruits per plant (-0.405), first flowering node (-0.313), days to 50% flowering (-0.414), days to first harvest (-0.341) while duration of fruiting (-0.193), days to first flowering (-0.244), fruit yield per plant (-0.188) were negatively correlated. Rest of the characters like fruit weight (0.234) was positively and number of disease infected plant (0.384) was significantly and positively correlated to this trait.

Fruit weight was positively correlated to number of fruits per plant (0.265) and fruit yield per plant (0.453) being significant at the later. Remaining characters like first flowering node (-0.093), duration of fruiting (-0.114), days to first flowering (-0.031), days to 50% flowering (-0.070), days to first harvest (-0.088) and number of disease infected plant (-0.157) were negatively correlated with this trait having insignificant values.

Table 8. Phenotypic correlation co-efficient (r_p) between all pairs of 13 quantitative characters in okra germplasm

Characters		Nodes per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	No. of fruits/ plant	First flowering node	Duration of fruiting	Days to first flowering	Days to 50% flowering	Days to first harvest	No. of disease infected plants	Yield/ plant (g)
Plant height (cm)	r_p	0.539**	0.386*	0.091	0.284	0.394*	-0.300*	0.092	-0.158	-0.199	0.102	-0.283	0.340*
Nodes/plant	r_p		0.322*	0.021	0.152	0.703**	0.018	0.271	0.011	0.076	0.123	-0.179	0.504**
Fruit length (cm)	r_p			0.106	0.442**	0.287	-0.052	0.351*	0.075	0.051	0.084	-0.297*	0.277
Fruit girth (cm)	r_p				0.175	-0.060	-0.014	0.031	-0.093	-0.221	-0.180	0.233	0.005
Fruit weight (g)	r_p					0.167	-0.063	-0.056	-0.017	-0.084	-0.047	-0.108	0.242
No. of fruits/plant	r_p						-0.107	0.227	-0.050	-0.068	0.075	-0.252	0.657**
First flowering node	r_p							0.045	0.371*	0.516**	0.082	-0.136	0.015
Duration of fruiting	r_p								0.123	0.053	0.006	-0.112	0.240
Days to first flowering	r_p									0.533**	0.364*	-0.244	0.056
Days to 50% flowering	r_p										0.483**	-0.206	0.047
Days to first harvest	r_p											-0.295*	0.177
No. of disease infected plants	r_p												-0.287

***and ** indicates significant at 5% and 1% level respectively.**

Table 9. Genotypic correlation co-efficient (r_g) between all pairs of 13 quantitative characters in okra germplasm

Characters		Nodes per plant	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	No. of fruits/ plant	First flowering node	Duration of fruiting	Days to first flowering	Days to 50% flowering	Days to first harvest	No. of disease infected plants	Yield/ plant (g)
Plant height (cm)	r_g	0.718**	0.834**	0.100	0.679**	0.557**	-0.338	0.349*	-0.079	-0.344*	0.138	-0.571**	0.550**
Nodes/plant	r_g		0.751**	-0.403**	0.580**	0.974**	0.070	0.844**	0.522**	0.328*	0.767**	-0.570**	1.044**
Fruit length (cm)	r_g			-0.290	0.495**	0.287	-0.107	0.635**	0.265	0.137	0.137	-0.456**	0.602**
Fruit girth (cm)	r_g				0.234	-0.405**	-0.313*	-0.193	-0.244	-0.414**	-0.341	0.384*	-0.188
Fruit weight (g)	r_g					0.265	-0.093	-0.114	-0.031	-0.070	-0.088	-0.157	0.453**
No. of fruits/plant	r_g						-0.118	0.392*	0.218	0.046	0.564**	-0.594**	0.914**
First flowering node	r_g							-0.114	0.763**	0.925**	0.389*	-0.184	0.142
Duration of fruiting	r_g								0.113	0.222	0.319*	-0.167	0.472**
Days to first flowering	r_g									0.796**	0.753**	-0.339*	0.345*
Days to 50% flowering	r_g										0.704**	-0.193	0.180
Days to first harvest	r_g											-0.435**	0.558**
No. of disease infected plants	r_g												-0.576**

***and ** indicates significant at 5% and 1% level respectively.**

Number of fruits per plant was positively and significantly associated with duration of fruiting (0.392), days to first harvest (0.564), fruit yield per plant (0.914) while days to first flowering (0.218), days to 50% flowering (0.046) were positively correlated. It was significantly and negatively associated with number of disease infected plant (-0.594) while with first flowering node (-0.118) the association was negative but insignificant.

First flowering node was positively and significantly correlated with days to first flowering (0.763), days to 50% flowering (0.925), days to first harvest (0.389) and only positively correlated with yield per plant (0.142).Rest of the characters has negative insignificant association with this trait.

Duration of fruiting was positively associated with days to first flowering (0.113), days to 50% flowering (0.222) while days to first harvest (0.319), fruit yield per plant (0.472) were positively associated with significant values. Number of disease infected plant (-0.167) was negatively and insignificantly associated with this trait.

Days to first flowering was positively and significantly associated to characters like days to 505 flowering (0.796), days to first harvest (0.753) and fruit yield per plant (0.345) while negatively and significantly correlated only with number of disease infected plant (-0.339).

Days to 50% flowering exhibited positive association with days to first harvest (0.704) and fruit yield per plant (0.180) with significant value in the former. Further this trait was negatively associated with number of disease infected plant (-0.193) having insignificant values.

Days to first harvest was positively correlated to fruit yield per plant (0.558) and negatively correlated with number of disease infected plant (-0.435), having significant values in both the cases. Number of disease infected plant was negatively and significantly associated with fruit yield per plant (-0.576).

Path co-efficient analysis

In order to find out the cause and effect relationship on yield per plant, path co-efficient analysis was carried out taking 13 quantitative traits in Okra. The correlation of fruit yield per plant with other characters were partitionised into component of direct and indirect effects that would reflect on the nature of these association and relative importance of the components in determining fruit yield. The phenotypic correlation co-efficient was used in path analysis and the results (phenotypic path) are presented in Table 10.

Phenotypic path analysis Table 10, revealed that days to first flowering had the highest positive direct effect (0.624) on fruit yield per plant followed by duration of fruiting (0.611). Positive direct effect were also observed for fruit weight (0.483), nodes per plant (0.412), plant height (0.290), number of fruits per plant (0.059) and node at which first flower appeared (0.028). Rest of characters showed negative direct effect being highest in fruit length (-0.852) followed by days to first harvest (-0.348), days to 50% flowering (-0.269), fruit girth (-0.243) and number of disease infected plant (-0.242).

Days to first flowering had the highest positive direct effect (0.624) on fruit yield per plant. This indirect highest effect were mainly resulted by positive indirect effect via nodes per plant (0.215), fruit girth (0.059), number of fruits per plant (0.013), nodes at which first flower appeared (0.021), duration of fruiting (0.068) and number of disease infected plant (0.082). The indirect effect of days to first flowering via plant height (-0.022), fruit length (-0.225), fruit weight (-0.015), days to 50% flowering (-0.214) and days to first harvest (-0.262) were in negative direction.

Fruit length showed the highest negative direct effect (-0.852). The indirect effect of fruit length via node at which first flower appeared (-0.003), days to 50% flowering (-0.036) and days to first harvest (-0.047) were in negative direction while rest of the characters like plant height (0.242), nodes per plant (0.309), fruit girth

(0.070), fruit weight (0.239), number of fruits per plant (0.017), duration of fruiting (0.387), days to first flowering (0.165), number of disease infected plants (0.110) were found to exert positive indirect effect.

Duration of fruiting showed high positive direct effect (0.611) which was mainly contributed by indirect positive via plant height (0.101), nodes per plant (0.348), fruit girth (0.047), number of fruits per plant (0.023), days to first flowering (0.070) and number of disease infected plant (0.040). The indirect effect of duration of fruiting was in negative direction via fruit length (-0.541), fruit weight (-0.054), node at which first flower appeared (-0.003), days to 50% flowering (-0.059) and days to first harvest (-0.110).

Fruit weight showing positive direct effect (0.483) exhibited indirect positive effect via plant height (0.197), nodes per plant (0.239), number of fruits per plant (0.015), days to 50% flowering (0.018), days to first harvest (0.030) and number of disease infected plant (0.038) while for rest of the characters like fruit length (-0.421), fruit girth (-0.056), node at which first flower appeared (-0.002), duration of fruiting (-0.069) and days to first flowering (-0.019), the effect was on negative direction.

Other characters such as nodes per plant (0.412), plant height (0.290) and number of fruits per plant (0.059) showed positive direct effect being lowest in node at which first flower appeared (0.028). The lowest positive direct effect for node at which first flower appeared was due to negative indirect effect via plant height (-0.098), fruit weight (-0.044), number of fruits per plant (-0.007), duration of fruiting (-0.069), days to 50% flowering (-0.249) and days to first harvest (-0.135), in spite of positive indirect effect via other traits for this character.

The negative direct effect of fruit girth (-0.243) was via the negative indirect effect of nodes per plant, number of fruits per plant, node at which first flower appeared, duration of fruiting, days to first flowering and number of disease infected plant, in spite of positive indirect effect by rest of the characters among which fruit length (0.237) was higher magnitude.

Table 10. Estimate of direct (diagonal) and indirect effect of component characters on yield in okra germplasm

Characters	PH	NP	FL	FG	FW	NF	NFF	DOF	DFFL	DF	DFH	No. of disease infected plants	Phenotypic correlation with yield
PH	0.290	0.296	-0.711	-0.024	0.328	0.033	-0.009	0.213	-0.049	0.092	-0.048	0.138	0.340
NP	0.208	0.412	-0.640	0.098	0.280	0.058	0.002	0.515	0.326	-0.088	-0.267	0.138	0.504
FL	0.242	0.309	-0.852	0.070	0.239	0.017	-0.003	0.387	0.165	-0.036	-0.047	0.110	0.277
FG	0.028	-0.166	0.237	-0.243	0.113	-0.024	-0.008	-0.118	-0.153	0.111	0.118	-0.093	0.005
FW	0.197	0.239	-0.421	-0.056	0.483	0.015	-0.002	-0.069	-0.019	0.018	0.030	0.038	0.242
NF	0.161	0.401	-0.245	0.098	0.128	0.059	-0.003	0.239	0.136	-0.012	-0.196	0.144	0.657
NFF	-0.098	0.028	0.091	0.076	-0.044	-0.007	0.028	-0.069	0.476	-0.249	-0.135	0.044	0.015
DOF	0.101	0.348	-0.541	0.047	-0.054	0.023	-0.003	0.611	0.070	-0.059	-0.110	0.040	0.240
DFFL	-0.022	0.215	-0.225	0.059	-0.015	0.013	0.021	0.068	0.624	-0.214	-0.262	0.082	0.056
DF	-0.099	0.135	-0.116	0.100	-0.033	0.002	0.026	0.135	0.497	-0.269	-0.245	0.046	0.047
DFH	0.040	0.316	-0.117	0.083	-0.042	0.033	0.011	0.194	0.470	-0.189	-0.348	0.105	0.177
No. of disease infected plants	-0.165	-0.235	0.388	-0.093	-0.076	-0.035	-0.005	-0.101	-0.211	0.052	0.151	-0.242	-0.287

Residual effect = 0.4452013

Figures underlined denoted the Direct Effect

PH = Plant height FW = Fruit weight DFFL = Days to first flowering DFH = Days to first harvest

NP = nodes per plant NF = No. of fruits/plant DF = Days to 50% flowering DOF = Duration of fruiting

FL = Fruit length NFF = Node at which first flower appeared FG = Fruit girth

1. Plant height (cm)
2. Nodes per plant
3. Fruit length (cm)
4. Fruit girth (cm)
5. Fruit weight (g)
6. Number of fruits per plant
7. First flowering node
8. Duration of fruiting
9. Days to first flowering
10. Days to 50% flowering
11. Days to first harvest
12. Number of disease infected plants
13. Yield per plant (g)

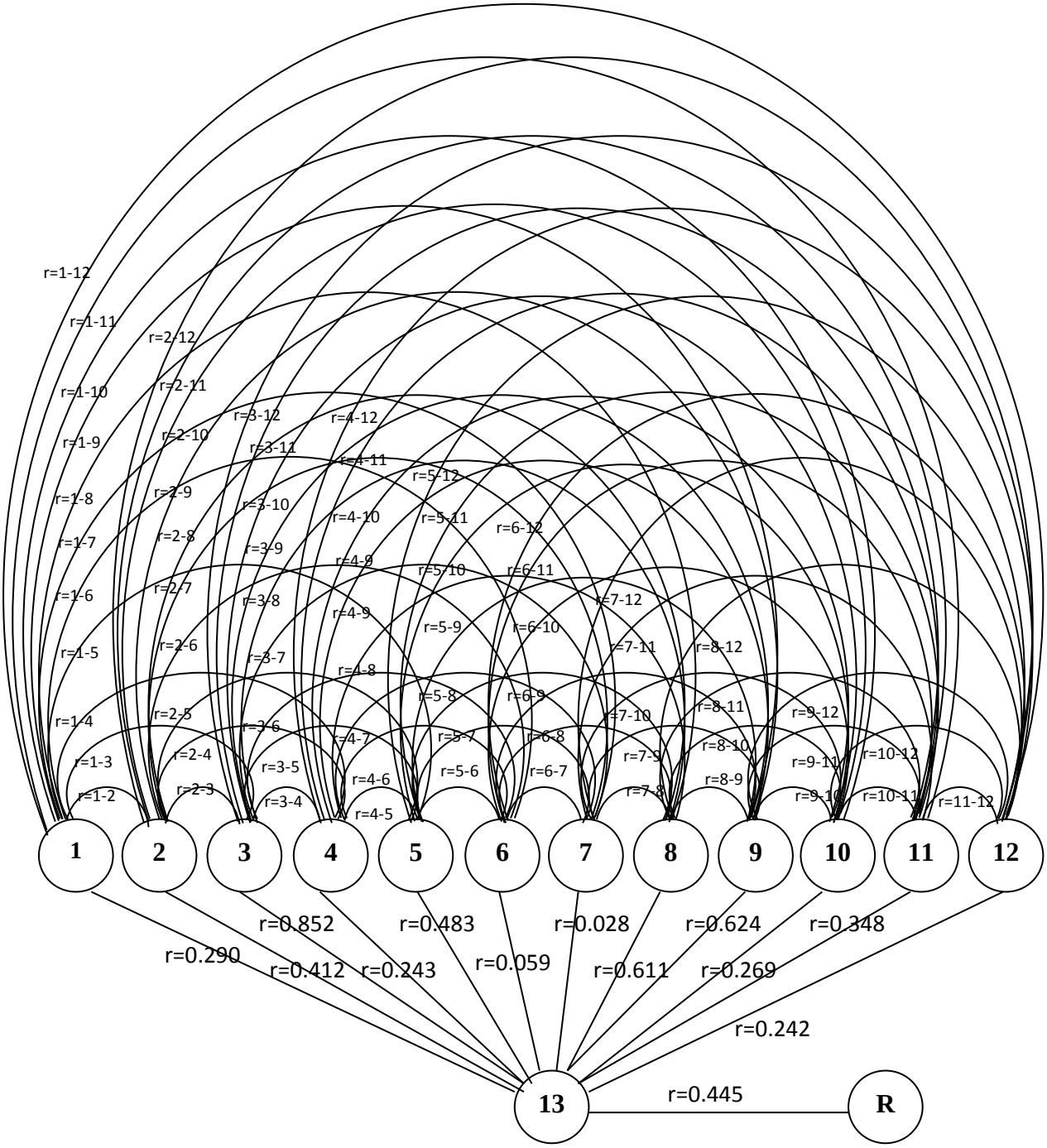


Fig. 7 Path diagram of factors influencing yield in okra

Days to 50% flowering showed negative direct effect (-0.269), mainly via the negative effect of days to first harvest, in spite of high positive indirect effect via days to first flowering (0.497).

From the path analysis, it appeared that days to first flowering, duration of fruiting, fruit weight, nodes per plant and plant height showed high direct effect on fruit yield per plant in Okra. High indirect effect through these characters were also visualized.

This clearly indicated that days to first flowering and duration of fruiting are two important yield contributing components in Okra. Further the correlation co-efficient (0.056) between days to first flowering, duration of fruiting (0.240) (both causal factor) and fruit yield per plant (The effect) being positive and having a little difference with its direct effect (0.624) and (0.611) respectively explain the true relationship and thus the direct selection through days to first flowering and duration of fruiting in okra improvement programme could be effective.

Clustering pattern

Thirty-three germplasm were grouped in eight different genetic clusters on the basis of genetic affinity/diversity as measured by D^2 using Tocher's method, Table 11. Cluster I, the largest group included 8 germplasm such as 2011/OKHYB-1, 2011/OKHYB-2, 2011/OKHYB-5, 2011/OKHYB-6, 2011/OKHYB-7, 2011/OKHYB-8, 2011/OKHYB-10 and 2011/OKHYB-11.

Cluster III was the second largest cluster comprising 7 germplasm named 2012/OKHYB-4, 2012/OKHYB-13, 2012/OKHYB-6, 2012/OKHYB-7, 2012/OKHYB-8, 2012/OKHYB-10 and 2012/OKHYB-12.

Cluster II, IV and V were comprised of 4 germplasm each. 2012/OKHYB-1, 2012/OKHYB-2, 2012/OKHYB-5 and 2012/OKHYB-15 were included in Cluster II. 2013/OKHYB-1, 2013/OKHYB-2, 2013/OKHYB-3 and HOK-152 were under Cluster IV. And Cluster V includes 2013/OKHYB-4, 2013/OKHYB-5, 2013/OKHYB-6 and 2013/OKHYB-10.

Table 11. Clustering Pattern of 33 okra germplasm

Cluster No.	Number of Okra	Name of germplasm (with Entry number)
I	8	2011/OKHYB-1 (V_1), 2011/okhyb-2 (V_2), 2011/OKHYB-5 (V_3), 2011/OKHYB-6 (V_4), 2011/OKHYB-7 (V_5), 2011/OKHYB-8 (V_6), 2011/OKHYB-10 (V_7), 2011/OKHYB-11 (V_8)
II	4	2012/OKHYB-1 (V_9), 2012/OKHYB-2 (V_{10}), 2012/OKHYB-5 (V_{12}), 2012/OKHYB-15 (V_{19})
III	7	2012/OKHYB-4 (V_{11}), 2012/OKHYB-13 (V_{13}), 2012/OKHYB-6 (V_{14}), 2012/OKHYB-7 (V_{15}), 2012/OKHYB-8 (V_{16}), 2012/OKHYB-10 (V_{17}), 2012/OKHYB-12 (V_{18})
IV	4	2013/OKHYB-1 (V_{20}), 2013/OKHYB-2 (V_{21}), 2013/OKHYB-3 (V_{22}), HOK-152 (V_{30})
V	4	2013/OKHYB-4 (V_{23}), 2013/OKHYB-5 (V_{24}), 2013/OKHYB-6 (V_{25}), 2013/OKHYB-10 (V_{29})
VI	2	Pusa Sawani (V_{31}), Arka Anamika (V_{32})
VII	2	2013/OKHYB-7 (V_{26}), BO-2 (V_{33})
VIII	2	2013/OKHYB-8 (V_{27}), 2013/OKHYB-9 (V_{28})

Table 12. Intra Diagonal and Inter cluster average (D^2) corresponding D ($\sqrt{D^2}$) Values (in parenthesis) among groups

Cluster	I	II	III	IV	V	VI	VII	VIII
I	28.932 (5.379)	52.658 (7.257)	59.392 (7.707)	27.732 (5.266)	52.682 (7.258)	45.438 (6.741)	45.931 (6.777)	61.938 (7.870)
II		17.097 (4.135)	24.349 (4.934)	42.435 (6.514)	50.505 (7.107)	100.539 (10.027)	80.452 (8.970)	39.598 (6.293)
III			28.739 (5.361)	46.604 (6.827)	68.382 (8.269)	104.103 (10.203)	72.653 (8.524)	57.904 (7.609)
IV				19.569 (4.424)	38.858 (6.234)	44.985 (6.707)	41.271 (6.424)	42.682 (6.533)
V					32.419 (5.694)	67.917 (8.241)	71.931 (8.481)	28.604 (5.348)
VI						30.074 (5.484)	52.223 (7.227)	87.048 (9.330)
VII							38.421 (6.199)	84.808 (9.209)
VIII								41.146 (6.415)

Cluster VI, VII and VIII each having two germplasm namely Pusa Sawani and Arka Anamika, 2013/OKHYB-7 and BO-2, 2013/OKHYB-8 and 2013/OKHYB-9 respectively.

Intra and inter-cluster distances

From the average intra and inter cluster distance presented in Table-12 and Fig.5 it is evident that among the two multivariate Cluster, Cluster II had the minimum intra-cluster distance (D^2 = 17.097) whereas maximum intra-cluster distance (D^2 = 41.146) was observed in Cluster VIII.

The average inter-cluster distance revealed that the most divergent clusters were Cluster III and VI (D^2 = 104.103), followed by Cluster II and VI (D^2 = 100.539), Cluster VI and VIII (D^2 = 87.048).

Characteristics features of eight clusters

The cluster means of 13 quantitative characters for groups of okra germplasm are presented in Table 13.

Cluster I consisting of 8 okra germplasm shows the lowest value in first flowering node(5.654), days to 50% flowering (39.150) and days to first harvest (41.046). For rest of the characters moderate expressions were observed.

Cluster II having 4 germplasm shows the maximum values for characters like yield per plant (336.698), plant height (173.850), nodes per plant (28.117), number of fruits per plant (22.000) and fruit length (16.471). Rest characters have moderate expressions.

Seven germplasm were grouped in Cluster III which were giving highest values for days to first harvest (45.836), duration of fruiting (45.100), days to 50% flowering (43.620) and first flowering node (6.457).

Table 13. Mean of 13 characters in different clusters of okra germplasm

Sl. No.	Characters \ Clusters	I (8)	II (4)	III (7)	IV (4)	V (4)	VI (2)	VII (2)	VIII (2)
1.	Plant height (cm)	164.617	173.850**	158.043	153.571	167.629	152.000	137.058*	159.433
2.	Nodes per plant	26.042	28.117**	26.267	24.394	25.317	21.933*	22.800	27.367
3.	Fruit length (cm)	15.774	16.471**	15.589	15.523	14.510	13.637	12.860*	14.680
4.	Fruit girth (cm)	6.401	6.164	6.042	5.993	6.196	6.583**	5.783*	6.100
5.	Fruit weight (g)	20.284	20.450	18.144	19.972	20.766	20.188	15.648*	21.058**
6.	Number of fruits per plant	19.688	22.000**	19.952	18.258	20.417	16.633*	19.467	21.975
7.	First flowering node	5.654*	5.808	6.457**	6.358	6.117	5.967	6.300	6.550
8.	Duration of fruiting	42.662	44.695	45.100**	39.618	38.143	35.930*	39.218	39.705
9.	Days to first flowering	34.093	36.003	36.961	35.878	34.678	36.663	33.162*	37.058**
10.	Days to 50% flowering	39.150*	42.001	43.620**	41.922	39.761	41.093	40.425	41.702
11.	Days to first harvest	41.046*	45.780	45.836**	42.311	43.433	44.195	41.700	42.917
12.	Number of disease infected plant	52.780	24.695	27.183	37.774	19.102	66.425**	59.895	12.982*
13.	Yield per plant (g)	283.165	336.698**	303.219	272.728	298.700	222.290*	243.602	323.778

- and ** indicate lowest and highest values
- figures in the parenthesis indicate number of cultivars in a cluster.

Cluster IV consisted of four germplasm which were having moderate value for various characters under study.

Cluster V having four germplasm which were characterized by its moderate value with respect to all traits.

Cluster VI having two germplasm exhibited maximum diversity as it shows the lowest values in number of fruits per plant (16.633), nodes per plant (21.933), duration of fruiting (35.930) and yield per plant (222.290). In contrary highest value was observed in number of disease infected plant (66.425) and fruit girth (6.583) in this cluster.

Cluster VII consisting of two germplasm was having lowest value for fruit girth (5.783), fruit length (12.860), fruit weight (15.648), days to first flowering (33.162) and plant height (137.058).

Cluster VIII with two germplasm having highest value for days to first flowering (37.058), fruit weight (21.058) and lowest value in number of disease infected plant (12.982).

Relative contribution of characters to divergence:

The relative contribution of 13 quantitative traits to genetic divergence among the 33 germplasm of okra was accessed (Table-14) by rank average of individual character over all 528 paired combinations.

The character contributing maximum divergence needs greater emphasis for deciding on the cluster for the purpose of selection of parents in respective cluster for hybridization. The number of times, each of the component character appeared first in rank and its respective percent of contribute on towards genetic divergence was analyzed.

Table 14. Relative contribution to different characters to genetic divergence in okra germplasm

Sl. No.	Characters	No. of first rank	% Contribution
1.	Plant height (cm)	1	0.189
2.	Nodes per plant	0	0.000
3.	Fruit length (cm)	4	0.757
4.	Fruit girth (cm)	15	2.840
5.	Fruit weight (g)	43	8.143
6.	Number of fruits per plant	4	0.757
7.	First flowering node	6	1.136
8.	Duration of fruiting	71	13.447
9.	Days to first flowering	10	1.893
10.	Days to 50% flowering	32	6.060
11.	Days to first harvest	42	7.954
12.	Number of disease infected plant	158	29.924
13.	Yield per plant (g)	142	26.893
Total		528	100

Among the yield contributing characters, the maximum contribution towards divergence was made by number of disease infected plant (29.9242%) followed by yield per plant (26.8939%). Rest of the characters contributing to the divergence in order were duration of fruiting (13.4470%), fruit weight (8.1439%), days to first harvest (7.9545%), days to 50% flowering (6.0606%), fruit girth (2.8409%), first flowering node (1.1364%), fruit length and number of fruits per plant (0.7576%), plant height (0.1894%).

DISCUSSION

An assessment of nature and magnitude of variability is one of the basic principles towards the successful breeding programme, because the success of any crop improvement programme involving selection and hybridization depends on existence of genetic variability among the tested material and extend to which it is heritable. Further information on association of various components for the desirable character for selection is of immense importance. In addition to this, the cause and effect relationship among the various correlated characters plays an important role for selecting the material subjected to improvement programme. Moreover, computation of the genetic divergence among the selected materials (germplasm) for the character proposed to be improved also having significant importance.

Taking the above factors into consideration for improvement in okra, the present investigation "VARIABILITY STUDIES IN OKRA (*Abelmoschus esculentus* L. Moench)" was conducted during the year 2013 (July 3013-October 2013) at AICRP on Vegetable Crops, Bhubaneswar, to select the superior genotypes, in order to improve their productivity (yield and adoptability), under Bhubaneswar condition (Odisha). The investigation yielded some interesting findings which are presented in the foregoing chapter and are being discussed hereafter.

Pattern of variation in plant attributes

The most important economic trait in okra is the green fruit yield. According to Hayes, Immer and Smith (1955), other supporting characters influencing yield and yield itself are governed by polygenes are quantitatively inherited. Since the selection is based on phenotypic observations, their reflection on genotypic value may not hold good unless observations on the quantitative trait are subjected and interpreted

according to statistical procedures as yield in okra is much influenced by environmental factors. Therefore, the parameters like mean, range and variation etc. for different attributes in okra have been calculated to draw valid inferences from the setup germplasm evaluated in the present investigation.

On examining the ANOVA (Table-4), the nature and magnitude of variability for 13different quantitative characters are clearly visualized in okra. The value indicates high significant differences for most of the characters (except two characters i.e. fruit girth and first flowering node) under study, thereby suggesting existence of large amount of variations among the germplasm for rest 11 characters. So the present study suggested that there is a scope for considerably improvement in okra through characters studied such as plant height, nodes per plant, fruit length, fruit weight, number of fruits per plant, duration of fruiting, days to first flowering, days to 50% flowering, days to first harvest, number of disease infected plant and yield per plant. Similar to the present findings wide variation for various characters were also reported by Dhankhar and Dhankhar (2002), Alam and Hossain (2008) and Simon *et al*. (2013) in okra.

It may be inferred from the statistics of range and general mean values of the characters that there is a great deal of variability for such characters under study. Further, this statistics quite hopefully provides a strong background of selecting genotypes for specific goals, because of the magnitude and wide spectrum of variation observed in each character among the genotypes under study.

In okra, yield per plant, days to 50% flowering, number of fruits per plant, duration of fruiting, fruit weight and resistance to diseases are importance characters for selecting ideal genotype of okra. Among the genotypes evaluated high to moderate values for these characters are observed in V_{24} (2013/OKHYB-5), V_{13} (2012/OKHYB-13), V_9 (2012/OKHYB-1) and V_{19} (2012/OKHYB-15) suggesting the suitability of these genotypes for cultivation at Bhubaneswar in Odisha condition. The compatible association of other characters, the above mentioned genotypes may be

quite acceptable. Further the coefficient of variation being less than 20% for most of the characters except number of disease infected plants among the genotypes indicates that good precision is maintained in conducting the experiment.

It is well establish that for understanding a breeding principle in any crop improvement programme two aspects are most important i.e. (i) selection cannot create variability but act only on that which is already in existence, (ii) selection can act effectively only on heritable differences (Allard, 1960). Thus it is a prime requisite for selection is to ascertain whether the genetic variability for these characters are present in population at significant level or not. Further, the phenotypic mean values are the basis of comparison may fall far short of requirement and may even be misleading as the phenotypic effect sometimes influenced by environment, thereby may not necessarily represent the genotypic values. Therefore, estimation of phenotypic and genotypic coefficient of variance alongwith its coefficient of variation as suggested by Burton and Devance (1953) provides a sound basis to evaluate the variability components so also to know the relative amount of heritable and non-heritable variation for such characters.

The perusal of data (Table-6) indicated wide range of phenotypic as well as genotypic variance for all the 13 characters studied. The occurrence of minimum variation between these two parameters indicated that environment has a little effect in expression of these characters in okra and phenotype truly represents to the genotype. The existence of large genotypic variability for the characters like yield per plant, number of disease infected plant, plant height etc. indicated that major part is attributed through its additive interaction instead of dominance and epistatic component and usually favours an effective selection. Morakinyo and Makinde (1991) and Khan *et al*. (2005) observed similar trend for various characters studied which are in conformity to the present findings.

In comparing the phenotypic coefficient of variation with genotypic coefficient of variation (Table-7) it is observed that in general the former values are greater than the later in respect of all the quantitative characters studies and the differences between the two is quite less in some of the characters suggesting a negligible influence of environment on such character. This is in agreement with findings of Sateesh *et al*. (2011) and Gendy and Aziz (2013) in okra. Further phenotypic coefficient of variation exhibiting parallelism effect with genotypic coefficient of variation indicating the phenotypes truly representing the genotypes. In present study presence of high to moderate genotypic coefficient of variation for number of disease infected plants, yield per plant, fruit weight, first flowering node, fruit length, duration of fruiting and number of fruits per plant indicating the presence of good amount the variability among the materials evaluated, so selection for these characters may be useful in okra crop improvement. The present findings are in agreement with Dhankhar and Dhankhar (2002), Kiran Patro and Ravisankar (2004), Khan *et al*. (2005), Singh *et al*. (2006), Dakahe *et al*. (2007), Alam and Hossain (2008), Prakash Kerure (2010), Shanthakumar and Salimath (2010), Gangashetty *et al*. (2010), Prakash and Pitchaimuthu (2010), Jindal *et al*. (2010), Prakask *et al*. (2011), Reddy *et al*. (2012), Goswami *et al*. (2012), Kumar *et al*. (2012) and Shaikh Md. *et al*. (2013) in okra.

The heritability is of interest to a plant breeder primarily as a major of selection for a particular character in various types of progenies and are index of transmissibility. According to Poehlman and Borthakur (1972) character not influenced by environment will have high heritability. Higher the heritability value of a character less will be the environmental influence, thereby suggesting better opportunity for selecting a genetically good individual (Randhawa *et al*. 1975). In the present study high heritability value (above 60%) have been obtained for 4 characters such as number of disease infected plants, fruit weight, days to 50% flowering and duration of fruiting. Further recording of moderate heritability values for days to first

harvest, fruit length, yield per plant, days to first flowering, fruit girth, number of fruits per plant and first flowering node suggesting that these characters might be highly heritable and less influenced by environment and selecting genotypes on basis of such characters would be beneficial in okra improvement. The results obtained here are in agreement with Morakinyo and Makinde (1991), Dhankhar and Dhankhar (2002), Kiran Patro and Ravisankar (2004), Dakahe *et al*. (2007), Kumar *et al*. (2011), Goswami *et al*. (2012), Kumar *et al*. (2012) and Jagan *et al*. (2013).

It is true that information concerning heritability of quantitative characters, genetic environmental variances when considered together will be useful for improving efficiency of selection (Weber and Moorty, 1952). Considering the heritability estimate with genotypic coefficient of variation values together (Table-7) Fig.2, high values are obtained for both the parameters for number of disease infected plants, yield per plant, fruit weight, duration of fruiting. So selection based on these characters may be quite effective. High heritability and high genotypic coefficient of variation was reported for disease incidence, yield per plant and fruit weight by Kiran Patro and Ravisankar (2004), fruit yield per plant by Singh *et al*. (2006), Gangashetty *et al.* (2010) for fruit yield and fruit weight which are in accordance with our present findings. On the contrary, deviations noticed from the findings of previous workers in present investigation is due to difference in genetic stock subjected to evaluation and environmental variation.

In spite of importance of heritability estimate in selection, the scope is limited due to its broad sense estimation as well as they are prone to change with change in environment and testing material. Further, the heritability estimate by itself may not be solely an useful index of genetic potentialities of a character. According to Eswro *et al.,* (1963) genetic advance indicate the potentiality of selection at a particular level of selection intensity. Thus, heritability estimate along with its genetic advance are more liable then heritability alone in predicting the response to selection (Johnson *et al*., 1955; Robinson, 1963). High heritability does not necessarily mean that the

character will show high genetic advance but the case where the above association exists (high heritability and high genetic advance), additive genes comes into prominence because no genetic advance is due to non-additive genes. The selection based on character showing high genetic gain (GA) may be desirable particularly in case of directional selection when the primary aim of selection is to change the mean value of a character to have better standard. On the other hand, high heritability accompanied with low genetic advance indicate the prominence of non-additive gene effect, warranting heterosis (hybridization breeding) instead of direct selection. In the present study, high estimate of heritability coupled with high genetic advance for characters such as number of disease infected plants, yield per plant, fruit weight, days to 50% flowering and duration of fruiting may be ascribed due to effect of additive genes (Panse and Sukhatme, 1954; Liang and Walter, 1968) may be amenable for selection. The present findings are in conformity with the work of Dhankhar and Dhankhar (2002) for most of the characters, Singh *et al*.(2006) for yield per plant, Shanthakumar and Salimath(2010) for most of the characters except 50% flowering, Gangashetty *et al*. and Jindal *et al*.(2010) for fruit yield per plant, Reddy *et al*.(2012) for fruit yield, fruit weight, days to 50% flowering, percentage of disease incidence, Goswami *et al*.(2012) for yield per plant in okra.

Considering the three important genetic parameters together such as genetic coefficient of variation, heritability and predicted genetic gain at a glance, (Fig.2) it is observed that characters like number of disease infected plants, yield per plant, fruit weight, days to 50% flowering and duration of fruiting showing higher values for the above three important genetic parameters suggested that additive gene action is responsible for expression of these character. So, direct selection through these characters will be effective in improvement programme of okra. Similar to our present findings, Mehta *et al*.(2006) reported high values for these three parameters for fruit yield, Sateesh *et al*.(2011)for fruit yield and days to 50% flowering and Gendy and Aziz (2013) for most of the traits in okra.

Characters association

In okra the green (fresh) fruit yield is the most economic character. The fruit yield is the ultimate effect of interaction of several quantitative characters that are highly susceptible to environmental change. Thus, selection based on fruit yield alone may not be sound preposition for effecting selection. Among various component characters which directly and positively correlated with fruit yield often act as an useful indicator in selection. Hence a sound knowledge of such association among fruit yield and its components is primary requisite in planning a successful and effective breeding programme. Robinson (1966) opined that correlation studies are useful in choosing superior genotypes from their phenotypic expression. Thus, after getting information on variation in the genetic parameters in the present set of genotypes (germplasm) taken for study, attempt has been made to examine the inter-relationship of these quantitative characters both at phenotypic and genotypic level.

The perusal of results (Table 8 and Table 9) showed that the genotypic correlation coefficient showed higher values for most of the variable pairs than the phenotypic correlation coefficient, suggesting that there is a strong inherent association between the various characters studied. Further, exhibition of parallelism effect with value of genotypic correlation coefficient to the phenotypic correlation coefficient may be assumed that there is not much influence of environment in determining the association of these yield attributing characters with fruit yield of okra which is probably due to a strong genetical makeup of the evaluated materials (germplasm).

According to Wiang and Mather (1942) and Sparque (1966), a strong positive association of character with yield may be attributed to linkage and pleiotropy. In the present study significant positive correlation was observed both at phenotypic and genotypic level for fruit yield with plant height, nodes per plant and number of fruits per plant. Further, plant height is positively and significantly correlated with nodes per plant, fruit length, number of fruits per plant; nodes per plant is significantly and

positively correlated with fruit length, number of fruits per plant; fruit length is significantly and positively correlated with fruit weight, duration of fruiting; first flowering node is significantly and positively correlated with days to first flowering, days to 50% flowering; days to first flowering with days to 50% flowering, days to first harvest and days to 50% flowering with days to first harvest. Further, yield per plant was also significantly and positively correlated with fruit length, fruit weight, duration of fruiting, days to first flowering and days to first harvest under the present study. These correlations suggested that selection for these component traits simultaneously will be effective in improving fruit yield per plant. In case of other pairs of characters showing significantly negative correlation value and insignificant value either positive or negative at phenotypic and genotypic level have least importance for effective selection based on these characters. In conformity to present findings Khan et al. (2005), Adiger*et al.* (2011), Jagan *et al.* (2013) and Reddy *et al.* (2013) obtained significant positive correlation for yield per plant with plant height, nodes per plant number of fruits per plant. Further, number of disease infected plants showing negative correlation with all the traits suggested that disease incidence significantly reduce the fruit yield of okra.

Plant height showed significant positive correlation with nodes per plant, fruit length, number of fruits per plant, yield per plant suggesting that taller plants in okra will have more number of nodes per plant resulting more number of fruits per plant and more total yield. Similarly nodes pr plant significantly and positively correlated with fruit length, number of fruits per plant and yield per plant suggesting more number of nodes in okra plant in produced more number of fruits per plant having higher fruit length resulting higher total yield. From the above discussion on characters association it may be suggested that plant height, nodes per plant, number of fruits per plant and fruit weight are the important correlated characters contributing towards fruit yield in okra and simultaneous increase in these traits also will be helpful in okra improvement programme.

Direct and indirect effect of characters

Correlation coefficient which measures the association between any two characters mat not give true comprehensive picture of a rather complex situation. The association between any two characters which are measure do not exist by themselves alone but are part of complicated pathway in which other traits are also interwoven. The indirect association become complex and important due to number of variables in correlation study. Further, the mutual relationship among different characters which may be positive or negative make the situation complicated. In such situation, path coefficient analysis deviced by Wright (1921) provides a better knowledge as it reveals direct and indirect causes of association and permits a critical examination of specific forces acting to produce a given correlation and measure the relative importance of each causal factor. The cause and effect relationships with values of correlation and path coefficient for the components of fruit yield at phenotypic level are presented in Table-10 of the present investigation are discussed below.

The phenotypic path coefficient analysis revealed that days to first flowering, duration of fruiting, fruit weight and nodes per plant had maximum direct effect on fruit yield of okra. Further, plant height, number of fruits per plant and node at which first flower appeared also produced positive direct effect of lower magnitude. On the other hand, fruit girth, days to first harvest, days to 50% flowering and number of disease infected plant had negative direct effect on yield being highest in fruit length. The low positive or negative direct effect resulted due to cancellation by the respective indirect effects via days to first flowering, duration of fruiting fruit weight and nodes per plant.

The indirect effect of days to first flowering via nodes per plant, fruit length, days to 50% flowering and days to first harvest thus producing high positive direct effect for these characters. Similarly duration of fruiting, fruit weight and number of nodes per plant has the highest direct effect which is mainly contributed by the

positive indirect effect via nodes per plant and plant height, nodes per plant and plant height, duration of fruiting and plant height respectively. The findings are in agreement with Dhankhar and Dhankhar (2002) who reported indirect contribution of plant height towards yield. Kiran Patro and Ravisankar (2004) reported high positive direct effect for fruit weight, nodes per plant and plant height towards okra similar to present findings. Further, Alam and Hossain (2008), Adiger *et al*.(2011), Reddy *et al*.(2013), Yonas *et al*.(2014) also reported direct and indirect effect of various characters like nodes per plant, fruit weight, plant height, days to 50% flowering on fruit yield of okra similar to present findings.

On the basis of foregoing discussion it may be inferred that days to first flowering, duration of fruiting, fruit weight and nodes per plant had considerable direct contribution to fruit yield in okra. High indirect effect to these traits are also observed. This clearly indicates that direct selection for these characters would be beneficial for improvement in fruit yield of okra since all these characters also show positive correlation with fruit yield. Other characters which had shown significant correlation with fruit yield per plant are mainly due to indirect effect via these characters.

Genetic divergence

The multivariate analysis based on Mahalonbis D^2 statistics is being employed as a powerful tool for measuring genetic divergence among the test genotypes (Peter and Rai, 1976; Singh and Singh, 1976; Nair and Gupta, 1976). Further, published reports of Murty and Arunachalam (1966), Anand and Murty (1968), Ramanujam *et al*. (1974) have emphasized the merits of D^2 statistics for genetic grouping of germplasm. In the present study the grouping by multivariate techniques have shown good results (Table-11).

Being a numerical estimate the multivariate technique had the added advantage over other criteria of permitting precise comparison among all possible

pairs of population in any given group. Since the estimates are obtained from study of potential parents themselves, the required information is available before deciding parents for future recombination breeding thus, can be used with advantage.

It is an established phenomenon that hybrid derivatives from divergent parents are found to be promising probably because of complimentary interaction of divergent genes in the parents. From the present investigation Cluster III comprising of seven germplasm and Cluster VI consisting of two germplasm showing highest inter-cluster distance. So, promising hybrid derivatives can be obtained by crossing parents of these two divergent groups probably because of complimentary interaction of divergent gene parents.

It was also observed that characters like number of disease infected plants, yield per plant, duration of fruiting, fruit weight, days to first harvest and days to 50% flowering had contributed predominantly towards genetic divergence. So, selection of parents differencing in these quantitative traits proved useful for heterosis breeding programme in okra. Prakash and Pitchaimuthu (2010), Prakash Kerure (2010), reported role of days to 50% flowering, fruit weight towards divergence of okra, similar to our present findings.

SUMMARY AND CONCLUSION

SUMMARY

The present investigation "VARIABILITY STUDIES IN OKRA (*Abelmoschus esculentus* L. Moench)" was under taken to assess the comparative performance genetic variability, character association and the cause and effect relationship to determine the direct and indirect contribution of various characters to meet the most economic character fruit yield through path analysis. Further, attempt was made to assess the genetic divergence among the genotypes by D^2 statistics to formulate a suitable breeding programme for improvement in yield of okra. Thirty-three germplasm (genotypes) collected from Indian Institute of Vegetable Research through All India Co-ordinated Research Project on Vegetable Crops, Odisha University of Agriculture and Technology, Bhubaneswar were subjected to evaluation for 13 different quantitative characters such as plant height, nodes per plant, fruit length, fruit girth, fruit weight, number of fruits per plant, first flowering node, duration of fruiting, days to first flowering, days to 50% flowering, days to first harvest, number of disease infected plants, yield per plant. The results of this investigation are summarized below.

a) Analysis of variance indicated that 33 genotypes of okra under study differ significantly among themselves for 13 quantitative characters except fruit girth and first flowering node studied. Further, a wide range of variation was noticed for all the characters as revealed through statistics of mean, range and co-efficient of variation.

b) Closeness of phenotypic co-efficient of variation and genotypic co-efficient of variation for all the character studied indicated that the phenotype represents true to the genotype. Expression of high to moderate genotypic co-efficient of variation in characters like number of disease infected plants, yield per plant,

fruit weight, first flowering node, fruit length, duration of fruiting, number of fruits per plant, plant height, days to 50% flowering and nodes per plant indicated a good amount of genetic variability among the test genotypes, so selection for such characters will be useful in okra. High heritability (above 60%) were observed in 4 characters such as number of disease infected plants, fruit weight, days to 50% flowering and duration of fruiting. Moderate heritability (30-60%) was observed in seven characters like days to first harvest, fruit length, yield per plant, days to first flowering, fruit girth, number of fruits per plant and first flowering node. Rest two characters such as nodes per plant and plant height showed lower heritability being lowest in former one.

c) Highest genetic advance in percentage of mean was observed in number of disease infected plants followed by fruit weight, yield per plant, duration of fruiting, first flowering node and days to 50% flowering. Rest of the characters showed low to very low value for this genetic parameter.

d) Taking a simultaneous study of the three important genetic parameters together such as genotypic co-efficient of variation, heritability and predicted genetic advance at a glance at phenotypic and genotypic level, traits like number of disease infected plants, yield per plant and fruit weight showed higher values for these parameters. So, direct selection through these characters will be effective in improvement of fruit yield of okra. Other characters like duration of fruiting and days to 50% flowering showing high heritability and low genetic advance warrant heterosis breeding for improvement.

e) Genotypic correlation co-efficient showing higher values than phenotypic correlation co-efficient for most important valuable pair of characters influencing fruit yield suggested that there is a strong inherent association

between the various characters studied. The existence of significant positive correlation both at phenotypic and genotypic level for yield per plant with number of fruits per plant, nodes per plant and plant height, suggested that selection for these component traits simultaneously will be effective in improving the fruit yield in okra. Rest of the character combinations having negative (significant or insignificant) and insignificant positive value at both the levels offer least importance for effecting selection.

f) Path co-efficient (phenotypic path) analysis of various quantitative traits indicated that days to first flowering followed by fruit yield, fruit weight, nodes per plant, plant height, number of fruits per plant and node at which first flower appeared have positive direct effect on fruit yield whereas number of disease infected plants, fruit girth, days to 50% flowering, days to first harvest and fruit length have direct negative effect on fruit yield per plant.

g) By using D^2 statistics and Tocher's method, the 33 genotypes were grouped into 8 clusters. Cluster-I, the largest group comprising of 8 germplasm (genotypes). Cluster-III was the second largest cluster comprising of seven genotypes. Cluster-II, IV and V comprised of four genotypes each whereas Cluster-VI, VII and VIII each having two genotypes. The germplasm in Cluster-III and Cluster-VI are the most divergent followed by Cluster-II and Cluster-VI. The characters like number of disease infected plants contribute maximum towards genetic divergence. Other characters such as duration of fruiting, fruit weight, days to first harvest, days to 50% flowering, fruit girth, first flowering node, fruit length, number of fruits per plant and plant height contribute towards genetic divergence in descending order.

CONCLUSION

From the present investigation it may be concluded that besides direct selection for fruit yield indirect selection through days to first flowering, duration of fruiting, fruit weight and number of nodes per plant should be considered for further improvement in fruit yield of okra. Further, number of fruits per plant, nodes per plant and plant height, being significant correlated within improvements in okra simultaneously based on these characters will be beneficial. The genotypes such as V_{24} (2013/OKHYB-5), V_{13} (2012/OKHYB-13), V_{9} (2012/OKHYB-1), V_{19} (2012/OKHYB-15) and V_{15} (2012/OKHYB-7) are suitable for growing in Odisha condition. The most divergent Cluster-III and VI consisting of seven and two genotypes in each and as expected hybridization between germplasm of these two groups might result in highly heterotic hybrid and thus, produced wide spectrum variation in segregating generation. Number of disease infected plant is contributing maximum towards divergence suggested that special attention should given to this character while designing any crop improvement programme in okra.

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